A Summary of Inorganic Nomenclature

Ionic Compounds:

Ionic compounds contain both positive ions (cations) and negative ions (anions). The ions in these compounds are held together by strong electrical attractions between ions of opposite charge (ionic bonds). At the molecular level discrete molecules do not exist in ionic compounds, rather they consist of three-dimensional arrays of cations and anions arranged in a regular pattern that we call a lattice. **The formula of an ionic compound represents the smallest whole number ratio of ions that results in a net charge of zero for the compound.** The ionic charges do not appear in the formula of an ionic compound.

1. **Names and Formulas of Monatomic Ions:** These are single atom ions. Metals lose electrons to form cations whereas nonmetals gain electrons to form anions. **It is essentially that you be able to determine if an element is a metal or a nonmetal by its position in the Periodic Table.**

   a. **Fixed-Charge Metal Ions (cations):** These are metals that form stable cations of only one charge. They are named by using the elemental name.

   Na^{+} Sodium Ion
   Ca^{2+} Calcium Ion
   Al^{3+} Aluminum Ion

   You do not need to memorize the charges for most of the fixed-charge metal ions, since the position of the metal in the Periodic Table can be used to determine the charge of its ion.

   Group 1A metal ions have a charge of +1.
   Group 2A metal ions have a charge of +2.
   Group 3A metal ions (aluminum and gallium) have a charge of +3.

   Four common transition elements that have a fixed-charge are silver, cadmium, nickel and zinc. You must memorize these!

   Zn^{2+} Zinc Ion Ag^{+} Silver Ion Cd^{2+} Cadmium ion Ni^{2+} Nickel ion

   b. **Variable-Charge Metal Ions (cations): Many transition metals as well as lead and tin** are able to form stable cations of more then one charge. The charge on the metal ion (oxidation number) is indicated in the name by using a Roman numeral, inside parentheses, after the name of the metal. The Roman numeral is considered to be part of the name of the ion and is required.

   Fe^{2+} Iron(II) Ion
   Fe^{3+} Iron(III) Ion

   In an alternative system, the metal ion with the higher charge is given the ending -ic; the one with the lower charge is given the ending -ous. (The Latin name for the metal is usually used in this system.)

   Fe^{2+} Ferrous Ion
   Fe^{3+} Ferric Ion

   You do not need to memorize the charges for the variable-charge metal ions, since the charge is given by the name or can be determined by the formula of the compound.

   c. **Ions of Nonmetals (anions):** These are named by taking the stem of the elemental name and changing the ending to -ide.

O^{2-} Oxide Ion
N^{3-} Nitride Ion
F^- Fluoride Ion

You do not need to memorize the charges for the monatomic anions, since the position of the nonmetal in the Periodic Table can be used to determine the charge of its ion.

Group 7A nonmetal ions have a charge of –1.
Group 6A nonmetal ions (oxygen, sulfur, selenium) have a charge of –2.
Group 5A nonmetal ions (nitrogen, phosphorus) have a charge of –3.

2. **Names and Formulas of Polyatomic Ions:** A polyatomic ion is an ion composed of two or more atoms covalently bound together. The atoms as a group carry a charge. Polyatomic ions are not compounds themselves, they are always found associated with ions of opposite charge to give a zero net charge. **Polyatomic ions are given special names that you must memorize** in order to name the compounds containing them. It is essential that you be able to recognize the presence of polyatomic ions in compounds by both their name and formula.

Most polyatomic ions are negatively charged. A common positively charged polyatomic ion is the ammonium ion (NH_4^+).

Many polyatomic ions contain oxygen. These ions are referred to as **oxoanions**. Several series of oxoanions that contain an atom of a given element and different numbers of oxygen atoms exist. When two such ions exist in a series, the name of the ion that contains the most oxygen atoms ends in -ate and the name of the ion containing the least oxygen atoms ends in -ite.

SO_4^{2-} is sulfate (contains more oxygen atoms than sulfite)
SO_3^{2-} is sulfite

When more than two ions exist in a series of oxoanions the prefixes per- and hypo- are used to indicate the ion with the greatest and the least number of oxygen atoms, respectively.

ClO_4^- is perchlorate (contains more oxygen atoms than chlorate)
ClO_3^- is chlorate
ClO_2^- is chlorite
ClO^- is hypochlorite (contains less oxygen atoms than chlorite)

While the names of most negatively charged polyatomic ions end with either –ate or –ite, there are three common negative polyatomic ions that have names which end in -ide: the hydroxide ion (OH^-), the cyanide ion (CN^-) and the peroxide ion (O_2^{2-}).

3. **Writing Formulas for and Naming Ionic Compounds:**

Formulas: The cation (positive ion) is always written first followed by the anion (negative ion). The subscripts used in the formula must indicate the smallest whole number ratio of ions that will give the compound a net charge of zero.

Naming: The cation is named first followed by the anion.

Examples:

a. **Binary ionic compounds containing a fixed-charge metal.** These are composed of two elements, one of which is a fixed-charge metal ion (cation) and the other a nonmetal ion (anion).

$CaCl_2$ is Calcium Chloride: composed of Ca^{2+} and Cl^- ions
Ag_2O is Silver Oxide: composed of Ag^+ and O^{2-} ions
Na_2S is sodium Sulfide: composed of Na^+ and S^{2-} ions

b. **Binary ionic compounds containing a variable-charge metal.** These are composed of two elements, one of which is a variable-charge metal ion (cation) and the other a nonmetal ion (anion).

$CuCl_2$ is Copper(II) Chloride: composed of Cu^{2+} and Cl^- ions
CuCl is Copper(I) Chloride: composed of Cu^+ and Cl^- ions

Remenber, there is no need to memorize charges for the variable-charge cations since the charge is given by the name or can be determined by the formula by knowing the anion charge.

In the alternative system

$CuCl_2$ is Cupric Chloride: composed of Cu^{2+} and Cl^- ions
CuCl is Cuprous Chloride: composed of Cu^+ and Cl^- ions

c. **Ionic Compounds that Contain Polyatomic Ions.** (Some text books call these ternary compounds). These compounds may be composed of a metal ion (cation) and a polyatomic anion, a polyatomic cation and a nonmetal ion (anion) or both a polyatomic cation and a polyatomic anion.

$(NH_4)_2CO_3$ is Ammonium Carbonate: composed of NH_4^+ and CO_3^{2-} ions
Na_3PO_4 is Sodium Phosphate: composed of Na^+ and PO_4^{3-} ions
$Fe_2(SO_4)_3$ is Iron(III) Sulfate: composed of Fe^{3+} and SO_4^{2-} ions
NH_4Cl is Ammonium Chloride: composed of NH_4^+ and Cl^- ions
$Mg(CN)_2$ is Magnesium Cyanide: composed of Mg^{2+} and CN^- ions

Binary Molecular Compounds:

Binary molecular compounds contain two nonmetallic elements. The atoms in these compounds are held together by sharing electrons (covalent bonds). At the molecular level these compounds consist of discrete molecules. The two nonmetals present are named in the order in which they appear in the formula. The least electronegative element is usually written first. The name of the first nonmetal is given in full. In naming the second nonmetal, the stem of the elemental name is used with the suffix -ide added. In addition, the number of atoms of each element present in a molecule of a compound is explicitly incorporated into the name of the compound by using Greek numerical prefixes. **You must memorize these prefixes.**

Name: prefix + name of first nonmetal prefix + stem of second nonmetal + ide

Prefix	Number of Atoms
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta	7
octa-	8
nona-	9
deca-	10

Examples:

NO is Nitrogen Monoxide.
NO_2 is Nitrogen Dioxide.
N_2O_4 is Dinitrogen Tetroxide.

Note: **The prefix mono- is usually omitted for the first element.** Also, when the element is oxygen and the prefix ends in a or o the, a or o of the prefix is dropped for ease of pronunciation.

mono-oxide becomes monoxide
tetra-oxide becomes tetroxide

Compounds with hydrogen listed as the first element in the formula are named without using prefixes. This is a standard exception to the use of numerical prefixes.

H_2S is Hydrogen Sulfide
HCl is Hydrogen Chloride

Two common names that are always used are water (H_2O) and ammonia (NH_3).

Acids:

In the Arrhenius definition, an acid is a substance that produces hydrogen (H^+) ions when dissolved in water. An example is hydrochloric acid:

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

However, not all compounds that contain hydrogen behave as acids (e.g. PH_3 and CH_4 are not acids). Acids generally have hydrogen written first in their formula.

1. **Binary Acids:** These acids are composed of hydrogen and another nonmetal. The name of the acid is derived from the name of the parent anhydrous compound by using the following general rules:
    a. The word hydrogen is replaced with the prefix hydro-.

b. The suffix -ide is replaced with -ic.

c. The word acid is added.

Anhydrous Form	Name in Water Solution
HCl is Hydrogen Chloride.	HCl(aq) is Hydrochloric Acid.
H_2S is Hydrogen Sulfide.	H_2S(aq) is Hydrosulfuric Acid.

2. **Oxo-acids:** These are acids that contain oxoanions. The name of the acid is derived from the name of the oxoanion by using the following general rules:

   a. When the name of the oxoanion ends in -ate, replace the -ate with -ic. When the name of the oxoanion ends in -ite, replace the -ite with -ous.

   b. The word acid is added.

   c. Prefixes hypo- and per- are retained.

Oxoanion	Formula and Name of Acid
Sulfate (SO_4^{2-})	H_2SO_4(aq) is Sulfuric Acid.
Sulfite (SO_3^{2-})	H_2SO_3(aq) is Sulfurous Acid.
Hypochlorite (ClO^-)	HClO(aq) is Hypochlorous Acid.

Bases:

In the Arrhenius definition, a base is a substance that produces hydroxide (OH^-) ions when dissolved in water. An example is sodium hydroxide:

$$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$$

The most common strong inorganic bases contain a metal ion along with the hydroxide ion.

Formulas: The metal is always written first followed by the hydroxide ion.

Naming: The metal is named first, followed by the hydroxide ion.

NaOH is Sodium Hydroxide.
$Ba(OH)_2$ is Barium Hydroxide.

Ammonia is a common weak base. It does not contain hydroxide ions, but reacts with water producing OH^- ions:

$$NH_3(aq) + H_2O(l) \leftrightarrow NH_4^+(aq) + OH^-(aq)$$

Bottles of aqueous ammonia are sometimes labeled as ammonium hydroxide or NH_4OH. This is misleading since ammonia is a weak base that produces only a small concentration of ions in water solution. The predominant form in solution is NH_3(aq).

Hydrates:

Some substances exist as hydrates. In a hydrate, each formula unit of the compound has associated with it a certain number of weakly bound water molecules. These weakly bound water molecules are called waters of hydration. This does not mean that these compounds are "wet" or liquid. The waters of hydration are incorporated into the solid structure of the compound. The waters of hydration may be driven off by heating to give the anhydrous form of the compound. Hydrates are named from the anhydrous compound, followed

by the word hydrate with a Greek numerical prefix used to indicate the number of water molecules per formula unit of the compound.

Name: name of anhydrous compound followed by prefix + hydrate

Formula	Name
$CuCl_2 \cdot 2H_2O$ or $CuCl_2(H_2O)_2$	Copper(II) Chloride Dihydrate

The formula can be written either way shown above.

Table of Cations

Ionic Charge: +1	Ionic Charge: +2	Ionic Charge: +3
Alkali Metals	**Alkaline Earth Metals**	**Group 3A:**
(Group 1A):	**(Group 2A:)**	Al^{3+} Aluminum
Li^{+} Lithium	Be^{2+} Beryllium	Ga^{3+} Gallium
Na^{+} Sodium	Mg^{2+} Magnesium	
K^{+} Potassium	Ca^{2+} Calcium	
Rb^{+} Rubidium	Sr^{2+} Strontium	
Cs^{+} Cesium	Ba^{2+} Barium	**Transition Elements:**
		Cr^{3+} Chromium(III)
Transition Elements:	**Transition Elements:**	Mn^{3+} Manganese(III)
Cu^{+} Copper(I)	Zn^{2+} Zinc	Fe^{3+} Iron(III)
Ag^{+} Silver	Cd^{2+} Cadmium	Co^{3+} Cobalt(III)
	Mn^{2+} Manganese(II)	Ti^{3+} Titanium(III)
Polyatomic Ions:	Fe^{2+} Iron(II)	
NH_4^{+} Ammonium	Co^{2+} Cobalt(II)	**Others:**
	Ni^{2+} Nickel	As^{3+} Arsenic(III)
	Cu^{2+} Copper(II)	
	Cr^{2+} Chromium(II)	
	Hg^{2+} Mercury(II)	
	Hg_2^{2+} Mercury(I)	
	Others:	
	Sn^{2+} Tin(II)	
	Pb^{2+} Lead(II)	

Other Charges:

Sn^{4+}	Tin(IV)
Pb^{4+}	Lead(IV)
Ti^{4+}	Titanium(IV)
As^{5+}	Arsenic(V)

Table of Anions

Ionic Charge: −1

Halogens (Group 7A):

- F^- Fluoride
- Cl^- Chloride
- Br^- Bromide
- I^- Iodide

Oxoanions that Contain Hydrogen:

- HCO_3^- Bicarbonate or Hydrogen Carbonate
- HSO_4^- Bisulfate or Hydrogen Sulfate
- HSO_3^- Bisulfite or Hydrogen Sulfite
- $H_2PO_4^-$ Dihydrogen Phosphate

Others:

- CN^- Cyanide
- SCN^- thiocyanate ion
- H^- Hydride (when combined with group 1A and 2A metals)

Oxoanions:

- ClO_4^- Perchlorate
- ClO_3^- Chlorate
- ClO_2^- Chlorite
- ClO^- Hypochlorite
- BrO_3^- Bromate
- BrO_2^- Bromite
- BrO^- Hypobromite
- IO_4^- Periodate
- IO_3^- Iodate
- NO_3^- Nitrate
- NO_2^- Nitrite
- OH^- Hydroxide
- $C_2H_3O_2^-$ Acetate (Often written as CH_3COO^-)
- MnO_4^- Permanganate

Ionic Charge: −2

Group 6A:

- O^{2-} Oxide
- S^{2-} Sulfide

Oxoanions:

- CO_3^{2-} Carbonate
- SO_4^{2-} Sulfate
- SO_3^{2-} Sulfite
- CrO_4^{2-} Chromate
- $Cr_2O_7^{2-}$ Dichromate
- $C_2O_4^{2-}$ Oxalate
- $S_2O_3^{2-}$ Thiosulfate
- O_2^{2-} Peroxide

Oxoanions that Contain Hydrogen:

- HPO_4^{2-} Hydrogen Phosphate

Ionic Charge: −3

Group 5A:

- N^{3-} Nitride
- P^{3-} Phosphide

Oxoanion:

- PO_4^{3-} Phosphate