# Activity 9 - Nomenclature

Every compound has its own chemical formula and its own name. The nomenclature (naming system) for ionic and molecular compounds is different. Molecular compounds contain only nonmetals and ionic compounds contain **ions (charged particles)** comprised of metals and nonmetals.

**Ionic compounds:** These consist of any positive ion (**a cation**) except $H^+$ with any negative ion (**an anion**). If $H^+$ is the positive ion, it's an acid.

The **cation** may be a metal ion (e.g., $Na^+$) or a polyatomic ion (e.g., $NH_4^+$).

The **anion** may be a nonmetal ion (e.g., $Cl^-$) or a polyatomic ion (e.g., $SO_4^{2-}$).

## A. Representative Metal + Nonmetal Compounds

| | | |
|---|---|---|
| Examples: | KBr | potassium bromide |
| | $AlCl_3$ | aluminum chloride |

- The metal cation always comes first (name unchanged).
- The nonmetal anion is second in the formula (name given *–ide* ending).
- The compound is electrically neutral without any charges in the formula.

## B. Transition Metal + Nonmetal Compounds

In general, the ions formed by the transition metals are not predictable. **Memorize** those ions assigned by your instructor (flash cards can help you).

- If the transition metal forms only one ion, name the compound as in Case 1.

| | | |
|---|---|---|
| Examples: | $ZnCl_2$ | zinc chloride |
| | $Ag_2S$ | silver sulfide |

- If the metal can form more than one type of ion, name the compounds according to one or both of the possible naming systems (each has two names!).

| | | | |
|---|---|---|---|
| Examples: | FeO | ferrous oxide or iron (II) oxide | formed from $Fe^{2+}$ and $O^{2-}$ |
| | $Fe_2O_3$ | ferric oxide or iron (III) oxide | formed from $Fe^{3+}$ and $O^{2-}$ |

**Lead** and **tin** form 2+ and 4+ ions. Even though they are **not** transition metals, they are named as such.

*Archaic system:*

The **–ous** ending refers to the ion with the lower charge state (e.g., $Fe^{2+}$ or $Cu^+$, cu**prous**).

The **–ic** ending refers to the ion with the higher charge state (e.g., $Fe^{3+}$ or $Cu^{2+}$, cu**pric**).

*Modern (IUPAC) system:*

The modern names for $Cu^+$ and $Cu^{2+}$ would be copper (I) ion and copper (II) ion.

Cases 1 and 2 involve ionic compounds that consist of only a metal cation and a nonmetal anion – two elements only. They are called binary compounds and consist of two monatomic ions. Ionic compounds can also be formed from more complex ions (polyatomic ions).

## C. Ionic Compounds with Polyatomic Ions

The list of polyatomic ions (names and formulas) to be memorized is assigned by your instructor (again, index cards can be helpful). Don't worry – you will become more comfortable with these as you gain more experience. For all ionic compounds, the cation is named first, followed by the anion.

| Examples: | $(NH_4)_2SO_4$ | ammonium sulfate |
|---|---|---|
| | $K_3PO_4$ | potassium phosphate |
| | $Fe_2(SO_4)_3$ | iron(III) sulfate or ferric sulfate (how do we know it's $Fe^{3+}$?) |

**Parentheses, ( ),** are used only when **two or more** polyatomic ions comprise the positive portion or the negative portion of the compound (or both). In other words, when you need two or more of the cation species to balance the charge on the anion, e.g., $(NH_4)_2SO_4$, or vice versa, balancing the charge of the cation, as in the example of $Fe_2(SO_4)_3$. Sometimes, you don't need ( ) at all (as in $K_3PO_4$).

## D. Molecular compounds

These are compounds formed when two nonmetal atoms share electrons with other nonmetal atoms. Binary molecular compounds consist of two different atoms and should be named according to the rules below. Like ionic compounds, the more positive "ion" is first and the more negative "ion" is second, with the negative "ion's" name including an **–ide** ending. To determine which is the most positive or negative compare relative electronegativities.

Unlike ionic compounds, **the number of each type of atom is specified with a prefix.**

| | | | | |
|---|---|---|---|---|
| 1: mono | 3: tri | 5: penta | 7: hepta | 9: nona |
| 2: di | 4: tetra | 6: hexa | 8: octa | 10: deca |

**If there is only one of the first atom, the mono prefix is not used.**

| Examples: | NO | nitrogen monoxide | $N_2O$ | dinitrogen monoxide |
|---|---|---|---|---|
| | $NO_2$ | nitrogen dioxide | $IF_7$ | iodine heptafluoride |
| | $O_2$ | oxygen | $N_2$ | nitrogen |

## E. Acids:

Acids (from the Latin word *acidus*, meaning "sour") are an important class of compounds. One way to define these compounds is as a substance whose molecules each yield one or more hydrogen ions ($H^+$) when dissolved in water.

The formula for an acid is formed by adding sufficient $H^+$ ions to balance the anion's charge. The name of the acid is related to the name of the anion and includes the label **acid**.

- Binary acids are an important class of acids. These follow the general formula HX. The anions whose names end in **–ide** have associated acids that have the **hydro–** prefix and an **–ic** ending.

  Example: anion = $Cl^-$ corresponding acid = HCl (**hydro**chlor**ic acid**)

- Many of the most important acids are derived from oxyanions (polyatomic ions which contain oxygen). Oxyanions whose names end in **–ite** (sulfite, nitrite, chlorite, etc.) have associated acids whose names end in **–ous**.

| Examples: | $SO_3^{2-}$ | sulfite | $H_2SO_3$ | sulfur**ous acid** |
|---|---|---|---|---|
| | $ClO_2^-$ | chlorite | $HClO_2$ | chlor**ous acid** |

- Oxyanions whose names end in **–ate** (sulfate, phosphate, nitrate, chlorate, etc.) have corresponding acids whose names are given an **–ic** ending.

| | | | | |
|---|---|---|---|---|
| Examples: | $SO_4^{2-}$ | sulfate | $H_2SO_4$ | sulfur**ic acid** |
| | $ClO_3^-$ | chlorate | $HClO_3$ | chlor**ic acid** |

- *Note that the sulfur containing acids use the root name of "sulfur-" rather than the shorter version "sulf-" used in the anions.* This is exceptional and must be memorized. Phosphoric acid has three hydrogens attached to a phosphate ion and is like sulfur in that two syllables of the element name are used to name this acid.

Table 1. Common Ions

| Positive Ions (Cations) | Negative Ions (Anions) |
|---|---|
| ***+1 Charge*** | ***-1 Charge*** |
| Group 1A cations | Group 7A anions |
| ammonium ($NH_4^+$) | acetate ($C_2H_3O_2^-$) |
| copper (I) or cuprous ($Cu^+$) | cyanide $CN^-$ |
| hydrogen ($H^+$) "proton" | dihydrogen phosphate ($H_2PO_4^-$) |
| silver ($Ag^+$) | hydrogen carbonate or bicarbonate ($HCO_3^-$) |
| hydronium ion ($H_3O^+$) | hydrogen sulfate of bisulfate ($HSO_4^-$) |
| | hydroxide ($OH^-$) |
| | nitrate ($NO_3^-$), nitrite ($NO_2^-$) |
| | perchlorate ($ClO_4^-$), chlorate ($ClO_3^-$), chlorite ($ClO_2^-$), hypochlorite ($ClO^-$) |
| | permanganate ($MnO_4^-$) |
| | thiocyanate ($SCN^-$) |
| | |
| ***+2 Charge*** | ***-2 Charge*** |
| Group 2A cations | Group 6A anions |
| cadmium ($Cd^{2+}$) | carbonate ($CO_3^{2-}$) |
| chromium (II) or chromous ($Cr^{2+}$) | chromate ($CrO_4^{2-}$), dichromate($Cr_2O_7^{2-}$) |
| cobalt(II) or cobaltous ($Co^{2+}$) | hydrogen phosphate ($HPO_4^{2-}$) |
| copper(II) or cupric ($Cu^{2+}$) | oxalate ($C_2O_4^{2-}$) |
| iron(II) or ferrous ($Fe^{2+}$) | peroxide ($O_2^{2-}$) |
| lead(II) or plumbous ($Pb^{2+}$) | sulfate ($SO_4^{2-}$), sulfite ($SO_3^{2-}$) |
| manganese(II) or manganous ($Mn^{2+}$) | |
| mercury(I) or mercurous ($Hg_2^{2+}$) | |
| mercury(II) or mercuric ($Hg^{2+}$) | |
| nickel ($Ni^{2+}$) | |
| tin(II) or stannous ($Sn^{2+}$) | |
| zinc ($Zn^{2+}$) | |
| | |
| ***+3 Charge*** | ***-3 Charge*** |
| aluminum ($Al^{3+}$) | Group 5A anions |
| chromium(III) or chromic ($Cr^{3+}$) | phosphate ($PO_4^{3-}$), phosphite ($PO_3^{3-}$) |
| iron(III) or ferric ($Fe^{3+}$) | phosphide ($P^{3-}$) |
| titanium (III) ($Ti^{3+}$) | |
| | |
| ***+4 Charge*** | |
| lead(IV) or plumbic ($Pb^{4+}$) | |
| tin(IV) or stannic ($Sn^{4+}$) | |

Summary of metal cations with more than one possible charge state:
$Cu^+$, $Cu^{2+}$; $Hg_2^{2+}$, $Hg^{2+}$; $Co^{2+}$, $Co^{3+}$; $Cr^{2+}$, $Cr^{3+}$; $Fe^{2+}$, $Fe^{3+}$; $Mn^{2+}$, $Mn^{3+}$; $Pb^{2+}$, $Pb^{4+}$; $Sn^{2+}$, $Sn^{4+}$

# Activity 9 - Nomenclature

Name A Key

Section _____ Date _____

## Exercise A. Representative Metal + Nonmetal Compounds

1. Name the following:

NaF Sodium Fluoride

CaS Calcium Sulfide

$SrI_2$ Strontium Iodide

$K_2O$ Potassium Oxide

$Al_2O_3$ Aluminum Oxide

AlN Aluminum Nitride

2. Give the formulas for the following (refer to the periodic table only):

cesium phosphide $Cs_3P$

calcium iodide $CaI_2$

barium fluoride $BaF_2$

magnesium nitride $Mg_3N_2$

lithium oxide $Li_2O$

potassium sulfide $K_2S$

chloride ion $Cl^-$

aluminum ion $Al^{3+}$

## Exercise B. Transition Metal + Nonmetal Compounds

1. Name the following using both naming systems:

$Pb^{2+}$ lead (II) Plumbous

$Sn^{4+}$ Tin (IV) Stannic

$Fe^{2+}$ Iron (II) Ferrous

$Cu^{2+}$ Copper (II) Cupric

2. Name the following:

only one charge state →

AgCl Silver Chloride

$FeBr_3$ Iron (III) Bromide Ferric Bromide

$Cu_3N$ Copper (I) Nitride Cuprous Nitride

3. Referring to question 2 above, what is the charge on the Ag? + Fe? 3+ Cu? +

4. Give formulas for the following:

chromium (III) oxide $Cr_2O_3$

stannous fluoride $SnF_2$

ferrous iodide $FeI_2$

ferric oxide $Fe_2O_3$

cuprous sulfide $Cu_2S$

plumbic chloride $PbCl_4$

## Exercise C. Ionic Compounds with Polyatomic Ions

1. Name the following:

$(NH_4)_2O$ Ammonium Oxide

$CuC_2H_3O_2$ Copper (I) Acetate Cuprous Acetate

$Na_2SO_3$ Sodium Sulfide

$Fe(NO_3)_2$ Iron (II) nitrate Ferrous Nitrate

LiSCN Lithium thiocyanate

$NaHCO_3$ Sodium hydrogen Carbonate Sodium bicarbonate

2. Give the formulas for the following:

cupric nitrate $Cu(NO_3)_2$

zinc phosphate $Zn_3(PO_4)_2$

silver carbonate $Ag_2CO_3$

titanium (III) nitride TiN

mercury (II) cyanide $Hg(CN)_2$

lead(IV) acetate $Pb(C_2H_3O_2)_4$

potassium dichromate $K_2Cr_2O_7$

barium permanganate $Ba(MnO_4)_2$

cadmium sulfate $CdS$

sodium chlorate $NaClO_3$

cobalt (II) nitrite $Co(NO_2)_2$

ammonium phosphide $(NH_4)_3P$

This part on Exam #2 | Not on Exam 1

**Exercise D. Molecular compounds**

3. Name the following:

$SO_3$ Sulfur trioxide
$N_2O_4$ dinitrogen tetroxide
$CO_2$ Carbon dioxide
$P_2O_5$ dipotassium pentoxide
$N_2O_5$ dinitrogen pentoxide
CO Carbon monoxide
$Cl_2O$ dichlorine monoxide
$N_2$ Nitrogen

4. Give the formulas:

bromine trichloride $BrCl_3$
oxygen difluoride $OF_2$
sulfur hexafluoride $SF_6$
iodine pentabromide $IBr_5$
hydrogen $H_2$
gallium nitride GaN
carbon tetrachloride $CCl_4$
silicon dioxide $SiO_2$
chlorine trifluoride $ClF_3$
dibromine monoxide $Br_2O$

5. Circle any of the common names that require memorization. The compounds marked in bold are those most commonly memorized, ask your instructor to specify the ones you will be tested on.

| | | |
|---|---|---|
| **methane, $CH_4$** | **water, $H_2O$** | **baking soda (sodium bicarbonate), $NaHCO_3$** |
| ethane, $C_2H_6$ | **ammonia, $NH_3$** | lye (sodium hydroxide), NaOH |
| propane, $C_3H_8$ | acetylene, $C_2H_2$ | table salt (sodium chloride), NaCl |
| butane, $C_4H_{10}$ | **hydrogen peroxide, $H_2O_2$** | **methanol (wood alcohol), $CH_3OH$** |
| benzene, $C_6H_6$ | **ethanol (grain alcohol), $C_2H_5OH$** | |

**molecular elements: $P_4$, $S_8$, $H_2$, $O_2$, $F_2$, $Br_2$, $I_2$, $N_2$, $Cl_2$**

**Exercise E. Acids**

6. Give the formula and name for the corresponding acids of the following anions.

| Anion | Formula of anion | # of $H^+$ required to neutralize charge | Formula of Acid | Name of acid |
|---|---|---|---|---|
| Sulfide | $S^{2-}$ | $2H^+$ | $H_2S$ | hydrosulfic acid |
| Carbonate | $CO_3^{2-}$ | $2H^+$ | $H_2CO_3$ | Carbonic acid |
| Oxalate | $C_2O_2^{2-}$ | $2H^+$ | $H_2C_2O_2$ | Oxalic acid |
| Phosphate | $PO_4^{3-}$ | $3H^+$ | $H_3PO_4$ | Phosphoric acid |
| Acetate | $C_2H_3O_2^-$ | $H^+$ | $HC_2H_3O_2$ | Acetic acid |
| Nitrite | $NO_2^-$ | $H^+$ | $HNO_2$ | Nitrous acid |

7. List of common acids (*ask your instructor to specify the ones you will be tested on*). Acids in boldface are STRONG acids/STRONG electrolytes.

| | | | | | |
|---|---|---|---|---|---|
| **$HCl_{(aq)}$** | **hydrochloric acid** | $HF_{(aq)}$ | hydrofluoric acid | $H_3PO_4$ | phosphoric acid |
| **$HBr_{(aq)}$** | **hydrobromic acid** | **$HNO_3$** | **nitric acid** | $H_2SO_3$ | sulfurous acid |
| **$HI_{(aq)}$** | **hydroiodic acid** | **$H_2SO_4$** | **sulfuric acid** | $HC_2H_3O_2$ | acetic acid |