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., NH₄⁺).

The anion may be a nonmetal ion (e.g., Cl⁻) or a polyatomic ion (e.g., SO₄²⁻).

A. Representative Metal + Nonmetal Compounds

Examples: KBr potassium bromide
           AlCl₃ 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: ZnCl₂ zinc chloride
             Ag₂S 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 Fe²⁺ and O²⁻
             Fe₂O₃ ferric oxide or iron (III) oxide formed from Fe³⁺ and O²⁻

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., Fe²⁺ or Cu⁺, cuprous).

The -ic ending refers to the ion with the higher charge state (e.g., Fe³⁺ or Cu²⁺, cupric).

Modern (IUPAC) system:

The modern names for Cu⁺ and Cu²⁺ 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:  
(NH₄)₂SO₄ ammonium sulfate  
K₃PO₄ potassium phosphate  
Fe₂(SO₄)₃ iron(III) sulfate or ferric sulfate (how do we know it’s Fe³⁺?)

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., (NH₄)₂SO₄ or vice versa, balancing the charge of the cation, as in the example of Fe₂(SO₄)₃. Sometimes, you don’t need () at all (as in K₃PO₄).

D. Molecular compounds

These are compounds formed when two nonmetals 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 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  
N₂O dinitrogen monoxide  
NO₃ nitrogen dioxide  
IF₇ iodine heptafluoride  
O₃ oxygen  
N₂ 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:  
  \[ \text{anion} = \text{Cl}^- \text{ corresponding acid} = \text{HCl (hydrochloric acid)} \]

- 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:  
  \[ \text{SO}_2^2- \text{ sulfate} \quad \text{H}_2\text{SO}_3 \text{ sulfurous acid} \]
  \[ \text{ClO}_2^- \text{ chlorite} \quad \text{HClO}_2 \text{ chlorous acid} \]
Oxanions whose names end in -ate (sulfate, phosphate, nitrate, chlorate, etc.) have corresponding acids whose names are given an -ic ending.

Examples: \(\text{SO}_4^{2-}\) sulfate \(\text{H}_2\text{SO}_4\) sulfuric acid
\(\text{ClO}_3^-\) chlorate \(\text{HClO}_3\) chloric 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 the acid.
<table>
<thead>
<tr>
<th>Positive Ions (Cations)</th>
<th>Negative Ions (Anions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1 Charge</td>
<td>-1 Charge</td>
</tr>
<tr>
<td>Group 1A cations</td>
<td>Group 7A anions</td>
</tr>
<tr>
<td>ammonium (NH₄⁺)</td>
<td>acetate (C₂H₃O₂⁻)</td>
</tr>
<tr>
<td>copper (I) or cuprous (Cu⁺)</td>
<td>cyanide CN⁻</td>
</tr>
<tr>
<td>hydrogen (H⁺) &quot;proton&quot;</td>
<td>dihydrogen phosphate (H₂PO₄⁻)</td>
</tr>
<tr>
<td>silver (Ag⁺)</td>
<td>hydrogen carbonate or bicarbonate (HCO₃⁻)</td>
</tr>
<tr>
<td>hydronium ion (H₃O⁺)</td>
<td>hydrogen sulfate of bisulfate (HSO₄⁻)</td>
</tr>
<tr>
<td></td>
<td>hydroxide (OH⁻)</td>
</tr>
<tr>
<td></td>
<td>nitrate (NO₃⁻), nitrite (NO₂⁻)</td>
</tr>
<tr>
<td></td>
<td>perchlorate (ClO₄⁻), chlorate (ClO₃⁻), chloride (Cl⁻), hypochlorite (ClO⁻)</td>
</tr>
<tr>
<td></td>
<td>permanganate (MnO₄⁻)</td>
</tr>
<tr>
<td></td>
<td>thiocyanate (SCN⁻)</td>
</tr>
<tr>
<td>+2 Charge</td>
<td>-2 Charge</td>
</tr>
<tr>
<td>Group 2A cations</td>
<td>Group 6A anions</td>
</tr>
<tr>
<td>cadmium (Cd²⁺)</td>
<td>carbonate (CO₃²⁻)</td>
</tr>
<tr>
<td>chromium (II) or chromous (Cr³⁺)</td>
<td>chromate (CrO₄²⁻), dichromate(Cr₂O₇²⁻)</td>
</tr>
<tr>
<td>cobalt(II) or cobaltous (Co³⁺)</td>
<td>hydrogen phosphate (H₂PO₄⁻)</td>
</tr>
<tr>
<td>copper(II) or cupric (Cu²⁺)</td>
<td>oxalate (C₂O₄²⁻)</td>
</tr>
<tr>
<td>iron(II) or ferrous (Fe²⁺)</td>
<td>peroxyde (O₂²⁻)</td>
</tr>
<tr>
<td>lead(II) or plumbous (Pb²⁺)</td>
<td>sulfate (SO₄²⁻), sulfite (SO₃²⁻)</td>
</tr>
<tr>
<td>manganese(II) or manganous (Mn²⁺)</td>
<td></td>
</tr>
<tr>
<td>mercury(I) or mercurous (Hg₂⁺)</td>
<td></td>
</tr>
<tr>
<td>mercury(II) or mercuric (Hg²⁺)</td>
<td></td>
</tr>
<tr>
<td>nickel (Ni²⁺)</td>
<td></td>
</tr>
<tr>
<td>tin(II) or stannous (Sn²⁺)</td>
<td></td>
</tr>
<tr>
<td>zinc (Zn²⁺)</td>
<td></td>
</tr>
<tr>
<td>+3 Charge</td>
<td>-3 Charge</td>
</tr>
<tr>
<td>aluminum (Al³⁺)</td>
<td>Group 5A anions</td>
</tr>
<tr>
<td>chromium(III) or chromic (Cr³⁺)</td>
<td>phosphate (PO₄³⁻), phosphite (PO₃⁻)</td>
</tr>
<tr>
<td>iron(III) or ferric (Fe³⁺)</td>
<td>phosphide (P⁻)</td>
</tr>
<tr>
<td>titanium (III) (Ti³⁺)</td>
<td></td>
</tr>
<tr>
<td>+4 Charge</td>
<td></td>
</tr>
<tr>
<td>lead(IV) or plumbic (Pb⁴⁺)</td>
<td></td>
</tr>
<tr>
<td>tin(IV) or stannic (Sn⁴⁺)</td>
<td></td>
</tr>
</tbody>
</table>

Summary of metal cations with more than one possible charge state:
Cu⁺, Cu²⁺; Hg₂⁺, Hg²⁺; Co²⁺, Co³⁺; Cr³⁺, Cr⁵⁺; Fe³⁺, Fe⁶⁺; Mn²⁺, Mn⁷⁺; Pb²⁺, Pb⁴⁺; Sn²⁺, Sn⁶⁺
Activity 9 - Nomenclature

Name _____________________________

Section __________________________

Date _____________________________

Exercise A. Representative Metal + Nonmetal Compounds

1. Name the following:
   Na: Sodium Fluoride
   SrI₂: Strontium Iodide
   Al₂O₃: Aluminum Oxide
   CaS: Calcium Sulfide
   K₂O: Potassium Oxide
   AlN: Aluminum Nitride

2. Give the formulas for the following (refer to the periodic table only):
   cesium phosphate: Cs₃P
   calcium iodide: CaI₂
   barium fluoride: BaF₂
   magnesium nitride: Mg₃N₂
   lithium oxide: Li₂O
   potassium sulfide: K₂S
   chloride ion: Cl⁻
   aluminum ion: Al³⁺

Exercise B. Transition Metal + Nonmetal Compounds

1. Name the following using both naming systems:
   Pb⁴⁺: Lead (IV)
   Sn²⁺: Tin (II)
   Fe²⁺: Iron (II)
   Fe⁷⁺: Ferric Iron
   Cu²⁺: Copper (II)

2. Name the following:
   AgCl: Silver Chloride
   FeBr₃: Ferric Bromide
   CuCN: Cuprous Nitride
   CuNO₃: Copper (II) Nitrate

3. Referring to question 2 above, what is the charge on the Ag? +₁⁺
   Fe? +₃⁺
   Cu? +₂⁺

4. Give formulas for the following:
   chromic oxide: Cr₂O₃
   stannous fluoride: SnF₂
   ferric oxide: Fe₂O₃
   cuprous sulfide: Cu₂S
   ferrous iodide: FeI₂
   plumbic chloride: PbCl₄

Exercise C. Ionic Compounds with Polyatomic Ions

1. Name the following:
   (NH₄)₂CO₃: Ammonium Carbonate
   CuCl₂: Copper (II) Chloride
   Fe(NO₃)₃: Ferric Nitrate
   Li₂SO₃: Lithium Sulfite
   Na₂SO₃: Sodium Sulfite
   NaHCO₃: Sodium Bicarbonate

2. Give the formulas for the following:
   cupric nitrate: Cu(NO₃)₂
   zinc phosphate: Zn₅(PO₄)₂
   titanium (III) nitride: Ti₃N
   mercury (II) cyanide: Hg(CN)₂
   potassium dichromate: K₂Cr₂O₇
   barium permanganate: Ba(MnO₄)₂
   cadmium sulfate: CdSO₄
   cobalt (II) nitrite: Co(NNO₃)₂
   ammonium phosphate: (NH₄)₃PO₄
Exercise D. Molecular compounds

3. Name the following:
   \[ \text{SO}_3 \quad \text{N}_2 \text{O}_5 \quad \text{N}_2 \quad \text{N}_2 \text{O}_5 \quad \text{CO}_2 \quad \text{Cl}_2 \text{O} \quad \text{Cl}_2 \text{O}_3 \quad \text{SiO}_2 \quad \text{C}_6 \text{H}_6 \]

4. Give the formulas:
   \[ \text{Br}_2 \text{Cl}_2 \quad \text{Ga}\text{N} \quad \text{OF}_2 \quad \text{CCl}_4 \quad \text{Si}\text{O}_2 \quad \text{Br}_2\text{O}_2 \]

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, CH₄  
   ethane, C₂H₆  
   propane, C₃H₈  
   butane, C₄H₁₀  
   benzene, C₆H₆  
   hydrogen peroxide, H₂O₂  
   methanol (wood alcohol), CH₃OH

   molecular elements: P, S, H₂, O₂, F₂, Br₂, I₂, N₂, Cl₂

Exercise E. Acids

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

<table>
<thead>
<tr>
<th>Anion</th>
<th>Formula of anion</th>
<th># of H⁺ required to neutralize charge</th>
<th>Formula of Acid</th>
<th>Name of acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfide</td>
<td>( \text{S}^{2–} )</td>
<td>2⁺</td>
<td>( \text{H}_2\text{S} )</td>
<td>Hydrosulfuric acid</td>
</tr>
<tr>
<td>Carbonate</td>
<td>( \text{CO}_3^{2–} )</td>
<td>2⁺</td>
<td>( \text{H}_2\text{CO}_3 )</td>
<td>Carbonic acid</td>
</tr>
<tr>
<td>Oxalate</td>
<td>( \text{C}_2\text{O}_4^{2–} )</td>
<td>2⁺</td>
<td>( \text{H}_2\text{C}_2\text{O}_4 )</td>
<td>Oxalic acid</td>
</tr>
<tr>
<td>Phosphate</td>
<td>( \text{PO}_4^{3–} )</td>
<td>3⁺</td>
<td>( \text{H}_3\text{PO}_4 )</td>
<td>Phosphoric acid</td>
</tr>
<tr>
<td>Acetate</td>
<td>( \text{CH}_3\text{CO}_2^{–} )</td>
<td>1⁺</td>
<td>( \text{H}_2\text{CH}_2\text{O}_2 )</td>
<td>Acetic acid</td>
</tr>
<tr>
<td>Nitrate</td>
<td>( \text{NO}_3^{–} )</td>
<td>1⁺</td>
<td>( \text{HNO}_3 )</td>
<td>Nitrato acid</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Acid</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>hydrochloric acid</td>
<td>( \text{HCl} )</td>
</tr>
<tr>
<td>hydrobromic acid</td>
<td>( \text{HBr} )</td>
</tr>
<tr>
<td>hydroiodic acid</td>
<td>( \text{HI} )</td>
</tr>
</tbody>
</table>