Unit 5 - Nomenclature
Covalent Naming

Writing chemical formulas is a fundamental skill in chemistry. Mastery of this unit is REQUIRED as it will be used in EVERY subsequent unit. Chemists have agreed in every nation on rules to name and write the chemical formulas of compounds. Chemists are able to communicate in a common language based on these rules and it is an important step in becoming a chemist.

Chemical nomenclature is a set of rules to generate **systematic names** for **chemical compounds**. The nomenclature used most frequently worldwide is the one created and developed by the **International Union of Pure and Applied Chemistry (IUPAC)**.

The IUPAC's rules for naming **organic and inorganic compounds** are contained in two publications, known as the Blue Book and the Red Book, respectively.

The primary function of chemical nomenclature is to ensure that a spoken or written chemical name leaves no ambiguity concerning which chemical compound the name refers to: each chemical name **should refer to a single substance.**

There are **two** types of nomenclature. The IUPAC has a set of rules for naming organic chemicals and inorganic chemicals.

Covalent Naming

- Binary covalent compounds are characterized by having two nonmetals. Naming these compounds involves the use of numerical prefixes:

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

- If there is only ONE atom of the first element, you DON'T need a prefix. The FIRST element is named as a normal element.
- The SECOND element **has an *–IDE* ending**.

o N_2O_4 **dinitrogen tetraoxide** o XeF_4 **xenon tetrafloride** o N_2O_5 **dinitrogen pentaoxide** o CO **carbon monoxide** o CBr_4 **carbon tetrabromide**	o Diarsenic pentoxide **As_2O_5** o Phosphorous pentabromide **PBr_5** o Carbon tetraiodide **CI_4** o Trisilicon tetranitride **Si_3N_4** o Tetraphosphorous decoxide **P_4O_{10}**

Naming Polyatomic Ions

You have memorized several polyatomic ions, but there are some you don't know, but can figure out:

- ***Use chlorate (ClO_3^-) as an example***
- If the ion has 1 more oxygen atom than the base ion (**ClO_3^-**), it is named by a prefix ***per***- and a suffix –***ate***.
  - **ClO_4^- is perchlorate**
- If the ion has 1 less oxygen atom then the base ion (**ClO_3^-**), then it is named by the suffix –***ite*****.**
  - **ClO_2^- is chlorite**
- If the ion has 2 less oxygen atoms than the base ion (**ClO_3^-**), then it is named by the prefix ***hypo***- and a suffix ***–ite***.
  - **ClO^- is hypochlorite**

Name the following:

1. SO_3^{2-} **Sulfite**
2. PO_3^{3-} **Phosphite**
3. SO_2^{2-} **Hyposulfite**
4. CO_2^{2-} **Carbonite**
5. PO_5^{3-} **Perphosphate**
6. CrO_3^{2-} **Chromite**

Balancing Charges

Overall

1. Balance charge with **+ and – ions**
2. Write the positive ion of metal **first**, and the negative ion **second**

   Ba^{2+} Cl^-

   Cl^-
3. Write the number of ions needed as subscripts

   $BaCl_2$

Naming Binary Ionic Formulas

1. The Cation is named and written first, then anion and the Monatomic cation = name of the element

   Ca^{2+} = calcium ion
2. The monatomic anion = root and the ending is changed to -ide

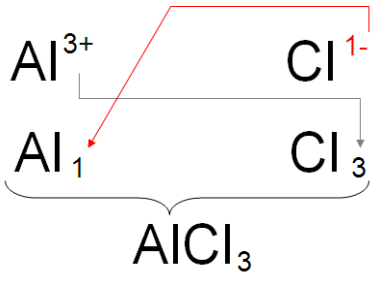
   Cl^- = chloride

   So **$CaCl_2$** = Calcium Chlo**ride**

Criss-Cross rule

1. Write out symbols and charge of elements
2. **Criss-Cross** charges as subscripts

   (Swap and Drop)
3. Combine as a formula unit



Equation For Balancing Charges

(Number of Cations)x(Cation Charge) + (Number of Anions)x(Anion Charge) = 0

(1)(+3) + (X)(-1) = 0, x = 3

- EX: Aluminum and Oxygen

  $Al^{+3}O^{-2} \rightarrow Al_2O_3$
- EX: Barium and Oxygen

  $Ba^{+2}\ O^{-2} \rightarrow BaO$

- Balancing Charges Practice:
  - Lithium Iodide **Li I**
  - Strontium Chloride **$SrCl_2$**
  - Aluminum Nitride **Al N**
  - Sodium Sulfide **Na_2S**

Ionic Compound Naming Notes

- To name ionic compounds:
  - Name the **Metal (cation)** first.
  - Name the **Non-Metal (anion)** second- change the ending to ***ide***.
  - Al_2O_3 **Aluminum Oxide**
  - $BaCl_2$ **Barium Chloride**
  - Ca_3N_2 **Calcium Nitride**
  - KF **Potassium Fluoride**

- Ionic Compounds with transition metals:
  - Transition metals and p-block metals can have multiple oxidation states.
    - **Silver (Ag) is always +1**
    - **Zinc (Zn) is always +2**
    - **Cadmium (Cd) is always +2**
  - Roman numerals are used in naming transition metals with more than one charge, we have to specify which charge is involved.

Roman numeral	Charge
I	+1
II	+2
III	+3
IV	+4

  - Some elements, such as iron, form two or more cations with different charges. We use **Roman numerals** to indicate the ion's

charge. For example, Fe^{+2} would be named **Iron (II)** and Fe^{+3} would be named **Iron (III)**. If an element does *not* form more than one charge, then you do not use a Roman numeral in its name.

- Iron (III) Oxide **Fe_2O_3**
- PbO_2 **Lead (IV) Oxide**
- Fe_2S_3 **Iron (III) Sulfide**

- The one you are responsible for are as follows:

Name	Symbol	Name	Symbol
lead (II)	**Pb^{+2}**	**mercury (II)**	**Hg^{+2}**
lead (IV)	**Pb^{+4}**	**tin (II)**	**Sn^{+2}**
mercury (I)	**Hg^{+1}**	**tin (IV)**	**Sn^{+4}**
copper (I)	**Cu^{+1}**	**iron (II)**	**Fe^{+2}**
copper (II)	**Cu^{+2}**	**iron (III)**	**Fe^{+3}**
chromium (II)	**Cr^{+2}**	**chromium (III)**	**Cr^{+3}**

Naming Acids

- If the compound begins with Hydrogen, it is an acid. If the acid does not contain a polyatomic ion, write the prefix ***hydro***-, then name the second element and change the ending to ***–ic***.'
  - HCl
    Hydrochloric acid
  - HBr
    Hydrobromic acid
  - H_2S
    Hydrosulfuric acid

Naming Acids with Polyatomic Ions

The polyatomic ions you have memorized have *–ate* as the ending, so you name the polyatomic ion and change the ending to *–ic*.

Use sulfate (SO_4^{2-}) as the example

- H_2SO_4 is sulfur*ic* acid

- If the ion has one more oxygen atom than the base (SO_4^{2-}), then the ion is named by adding the prefix *per-* and the suffix *–ic*
  - H_2SO_5 **is** **persulfuric acid**

- If the ion has one less oxygen atom than the base (SO_4^{2-}), then the ion is named with the suffix *–ous*.
  - H_2SO_3 **is** **sulfurous acid**

- If the ion has two less oxygen atoms than the base (SO_4^{2-}), then the ion is named with the prefix *hypo-* and the suffix *–ous*.
  - H_2SO_2 **is** **hyposulfurous acid**

Name the following:

1. H_2CO_3 **Carbonic acid**
2. H_3PO_2 **Hypophosphorious acid**
3. $HClO_4$ **Perchloric acid**
4. H_3PO_3 **Phosphorous acid**

Hydrated Compounds

- These are Ionic compounds that produce water when decomposed by heating.
- The compounded is named using the ionic compound, a dot ●, H_2O, and the ending hydrate.
- The number of water molecules are indicate using previous prefixes of "di", "tri", etc.

Practice Name Formula

1. $CuSO_4 \bullet 5H_2O$ **Copper (II) sulfate pentahydrate**
2. $ZnCl_2 \bullet 6H_2O$ **Zinc chloride hexahydrate**

Naming Summary Sheet:

Naming Ionic Compounds: Metal and Nonmetal

Rules:

- 1. The first element (the cation) is named first, using the elements name.
- 2. Second element (the anion) is named change the ending of the anion to –ide (unless a polyatomic ion) (suffix "-ide")
- Example: CaF_2 – calcium fluoride
- If a metal has more than one possible charge, use roman numerals to describe the charge of the metal.
  - Fe_2S_3 – iron (III) sulfide

Transition Metals with Single Charges:
-Ag^{+1} -Cd^{+2} -Zn^{+2}
Transition Metals with Multiple Charges:

- Cu^{+1} or Cu^{+2}
- Cr^{+2} or Cr^{+3}
- Co^{+2} or Cr^{+3}
- Fe^{+2} or Fe^{+3}
- Pb^{+2} or Pb^{+4}
- Sn^{+2} or Sn^{+4}

Naming a Covalent Compounds: 2 Nonmetals

Rules:

- 1. Prefixes are used to denote the number of atoms
- 2. "Mono" is not used to name the first element
  Note: *when the addition of the Greek prefix places two vowels adjacent to one another, the "a" (or the "o") at the end of the Greek prefix is usually dropped; e.g., "nonaoxide" would be written as "nonoxide", and "monooxide" would be written as "monoxide". The "i" at the end of the prefixes "di-" and "tri-" are never dropped*

Prefix	Number	Prefix	Number
Mono	1	Hex(a)	6
Di	2	Hept(a)	7
Tri	3	Oct(a)	8
Tetr(a)	4	Non(a)	9
Pent(a)	5	Dec(a)	10

- If there is only ONE atom of the first element, you DON'T need a prefix. The FIRST element is named as a normal element. The SECOND element has an –IDE ending.
- Example: CBr_4 – carbon tetrabromide

Naming Polyatomics and Acids: Only Nonmetals

Base Polyatomics:

ClO_3^{-1}	Chlorate	IO_3^{-1}	Iodate
NO_3^{-1}	Nitrate	SO_4^{-2}	Sulfate
CO_3^{-2}	Carbonate	PO_4^{-3}	Phosphate
BrO_3^{-1}	Bromate	CrO_4^{-2}	Chromate

To determine name, look at how the compound compares to the base, with an –ate ending.

Number of Oxygen:	Polyatomics	Example	Acids	Example
1 more than base	Per –ate	$-SO_5$ - persulfate	Per –ic acid	$HClO_4$ – perchloric acid
Base	-ate	$-SO_4$ - sulfate	-ic acid	$HClO_3$ - chloric acid
1 less than base	-ite	$-SO_3$ - sulfite	-ous acid	$HClO_2$ - chlorous acid
2 less than base	Hypo-ite	$-SO_2$ - hyposulfite	Hypo-ous acid	HClO – hypochlorous acid
Binary (no oxygen present	-ide	-S - sulfide	Hydro-ic acid	HCl – hydrochloric acid

Note: When Group is used, it is referring to all of the elements in the groups on the periodic table.

Condensed List of Common Ions and their charges

1. Cations:

+1 charge		**+2 charge**		**+3 charge**		**+4 charge**	
Group 1 Ex: sodium	**Ex: Na^{+1}**	**Group 2 Ex: calcium**	**Ex: Ca^{+2}**	**aluminum**	**Al^{+3}**		
hydrogen	**H^{+1}**	**cadmium**	**Cd^{+2}**				
silver	**Ag^{+1}**	**zinc**	**Zn^{+2}**				
hydronium	**H_3O^{+1}**	copper (II)	Cu^{+2}				
ammonium	NH_4^{+1}	chromium (II)	Cr^{+2}	chromium (III)	Cr^{+3}		
copper (I)	Cu^{+1}	cobalt (II)	Co^{+2}	cobalt (III)	Co^{+3}		
gold(I)	Au^{+1}	iron (II)	Fe^{+2}	iron (III)	Fe^{+3}		
		lead (II)	Pb^{+2}			lead (IV)	Pb^{+4}
		mercury (I)	Hg_2^{+2}				
		mercury (II)	Hg^{+2}				
		tin (II)	Sn^{+2}			tin (IV)	Sn^{+4}

2. Anions

Required Ions							
-1				**-2**		**-3**	
Name	**Symbol**	**Name**	**Symbol**	**Name**	**Symbol**	**Name**	**Symbol**
Group 17 Ex: Chloride	**Ex: Cl^-**	**Cyanide**	**CN^{-1}**	**Group 16 Ex: Oxide**	**Ex: O^{-2}**	***Group 15 Ex: nitride**	**Ex: N^{-3}**
*perchlorate	ClO_4^{-1}	**hydroxide**	**OH^{-1}**	**carbonate**	**CO_3^{-2}**	**phosphate**	**PO_4^{-3}**
chlorate	**ClO_3^{-1}**	*bicarbonate	HCO_3^{-1}	**sulfate**	**SO_4^{-2}**	phosphite	PO_3^{-3}
*chlorite	ClO_2^{-1}	hydride	H^{-1}	*sulfite	SO_3^{-2}		
*hypochlorite	ClO^{-1}	**acetate**	**$C_2H_3O_2^{-1}$**				
nitrate	**NO_3^{-1}**						
*nitrite	NO_2^{-1}						
Optional Ions (May appear in extra credit or in AP Chemistry)							
-1				**-2**		**-3**	
Name	**Symbol**	**Name**	**Symbol**	**Name**	**Symbol**	**Name**	**Symbol**
hypochlorite	ClO^{-1}	perbromate	BrO_4^{-1}	oxalate	$C_2O_4^{-2}$	arsenate	AsO_4^{-3}
permanganate	MnO_4^{-1}	bromate	BrO_3^{-1}	peroxide	O_2^{-2}		
Periodate	IO_4^{-1}	bromite	BrO_2^{-1}	silicate	SiO_3^{-2}		
iodate	IO_3^{-1}	hypobromite	BrO^{-1}	telluriate	TeO_4^{-2}		
iodite	IO_2^{-1}			seleniate	SeO_4^{-2}		
hypoiodite	IO^{-1}			chromate	CrO_4^{-2}		
				dichromate	$Cr_2O_7^{-2}$		

* -indicates ion can be determined by using additional information (see below).

Bolded Ions- Indicates the most important of the required ions for students to know

3. Additional Information
   a. All cations not listed will use Roman numerals to indicate charges
   b. Anions with different numbers of oxygens other than the "ate" form"
      i. 1 more O "per"-------"ate" Ex: FO_4^{-1} = perfluorate
      ii. 1 less O ----------"ite" Ex: FO_2^{-1} = fluorite
      iii. 2 less O "hypo"-----"ite" Ex: FO^{-1} = hypofluorite

c. Anions which have a hydrogen added to them take a “bi-“ or “hydrogen” prefix AND the charges increases by +1
    i. Ex. HCO_3^{-1} = bicarbonate or hydrogen carbonate

d. Some transition metals can be named in another ways, using their Latin name as a root.
    i. An “ous” ending has the lower possible oxidation state
    ii. An “ic” ending indicates the higher possible oxidation state
    iii. This naming system is no longer commonly used and can be found on older bottles of compounds.

FYI only

Name	Symbol	Latin Name
lead (II)	Pb^{+2}	plumbous
lead (IV)	Pb^{+4}	plumbic
mercury (I)	Hg^{+1}	mercurous
mercury (II)	Hg^{+2}	mercuric
tin (II)	Sn^{+2}	stannous
tin (IV)	Sn^{+4}	stannic
copper (I)	Cu^{+1}	cuprous
copper (II)	Cu^{+2}	cupric
iron (II)	Fe^{+2}	ferrous
iron (III)	Fe^{+3}	ferric
chromium (II)	Cr^{+2}	chromous
chromium (III)	Cr^{+3}	chromic