CHEMICAL NOMENCLATURE

I. Ionic vs. Covalent Compounds

Ionic compounds: usually form between a **metal** and **nonmetal** *or* a **metal** and a **polyatomic** ion. They consist of cations and anions held together by electrostatic attraction.

Covalent (molecular) compounds: usually form between **nonmetal** atoms held together by shared electrons.

II. Naming Ions

Naming ionic compounds requires knowledge of how to name the individual ions that make up the ionic compound.

A. Monatomic Cations:

Metal atoms lose electrons to form positively charged ions, called **cations**. A cation formed from a single atom is called a *monatomic* cation. Some metals form one ion, while others can form multiple ions.

One ion: Some metals form only one ion. Metals of groups 1, 2, 3, 13 & Zn form only one ion each. These ions are named as follows:

element name + ion

e.g. Na^+ = sodium ion Sr^{2+} = strontium ion Zn^{2+} = zinc ion

Multiple ions: Transition metals often form more than one ion. Since these atoms form more than one ion, the *charge* on the ion must be specified in the name to tell the ions apart. The Stock system is used to name transition metal cations as follows:

element name (charge as Roman numeral) + **ion**

e.g. Fe^{2+} = iron(II) ion Pb^{4+} = lead(IV) ion Cu^+ = copper(I) ion

B. Monatomic Anions:

Nonmetal atoms gain electrons to form negatively charged ions, called **anions**. An anion formed from one individual atom is a *monatomic* anion. Nonmetals form only one ion, so Roman numerals are never used to name anions.

When a nonmetal atom forms an ion, it is named as follows:

element stem name + *"ide"* + ion

e.g. O^{2-} = ox*ide* ion N^{3-} = nitr*ide* ion Cl^{-} = chlor*ide* ion

C. Polyatomic ions:

Groups of atoms that gain or lose electrons are called **polyatomic ions**. Polyatomic ions are groups of covalently bonded atoms that must *gain* or *lose* electrons to be more stable.

Nearly all polyatomic ions are anions; there is only one common polyatomic cation, NH_4^+. Polyatomic ions do not follow a predictable naming pattern – their names must be ***memorized***.

III. <u>Nomenclature for Ionic Compounds</u>

A. Writing Formulas for Ionic Compounds << write the ions, do the criss-cross >>

The sum of the oxidation numbers (charges) of the ions in any ionic compound = 0 . The "criss-cross" method is a tool for balancing positive and negative charges in an ionic compound.

e.g. Na^{+} S^{2-} → Na_2S Ca^{2+} NO_3^{-} → $Ca(NO_3)_2$ Ti^{4+} O^{2-} → Ti_2O_4 → TiO_2 (*simplify* subscripts)

Essentially, the charge from the cation becomes the subscript for the anion and the charge from the anion becomes the subscript for the cation. Put ( ) around polyatomic ions if there is more than one in the formula. If necessary, *simplify subscripts* to get the lowest whole number ratio of ions in the formula.

<u>Practice A</u>. Write the formula for the compound formed by the *combination of the ions* given. Use the criss-cross method.

Example: Na^{+} Cl^{-} 1 1 NaCl

1. Li^{+} NO_3^{-} _____
2. Ca^{2+} Cl^{-} _____
3. Al^{3+} O^{2-} _____
4. Ca^{2+} SO_4^{2-} _____
5. Fe^{2+} O^{2-} _____
6. Fe^{3+} O^{2-} _____

7. NH_4^+ OH^- _____

8. NH_4^+ PO_4^{3-} _____

9. Ag^+ S^{2-} _____

10. Mg^{2+} CO_3^{2-} _____

11. Cu^{2+} NO_3^- _____

12. Sn^{4+} SO_4^{2-} _____

13. Ni^{2+} PO_4^{3-} _____

14. Al^{3+} OH^- _____

15. Fe^{3+} N^{3-} _____

<u>Practice B</u>. Write the formula for the compound given the *formula name*. Write the ions first, then create the formula using the criss-cross method.

Example: Sodium Chloride Na^+ Cl^- (1, 1) NaCl

1. Lithium fluoride _____ _____

2. Calcium iodide _____ _____

3. Iron(II) chloride _____ _____

4. Iron(III) phosphide _____ _____

5. Titanium(III) oxide _____ _____

6. Lead(IV) bromide _____ _____

7. Strontium carbonate _____ _____

8. Copper(II) sulfate _____ _____

9. Tin(IV) nitrate _____ _____

10. Copper(II) bromate _____ _____

B. Naming Ionic Compounds from Formulas << name the cation, name the anion >>

The rule for naming an ionic compound from its formula is easy: name the cation, and then name the anion.

If the metal forms one ion (Gp 1, 2, 3, 13 & Zn)**:** Simply name the cation, and then name the anion.

e.g. $NaCl$ Na^{+} sodium ion and Cl^{-} chloride ion = <u>Sodium chloride</u>

BaI_2 Ba^{2+} barium ion and I^{-} iodide ion = <u>Barium iodide</u>

$Al(OH)_3$ Al^{3+} aluminum ion and OH^{-} hydroxide ion = <u>Aluminum hydroxide</u>

If the metal forms *more than one* ion (transition metals): The rule is the same - name the cation, and then name the anion. *However*, to name the cation, you must *first* determine the *charge* of the cation.

-Use the charge on the *anion* to determine the overall negative charge in the compound.

-Since an ionic compound is neutral (the sum of the charges is zero), the overall positive charge must equal the overall negative charge.

-If there is more than one of the cations present, divide the overall positive charge by the number of cations present to get the charge for each cation.

-Name the cation using the charge as Roman numeral, the name the anion.

e.g. $NiBr_2$ Br has a 1– charge, so 2 Br^{-} ions means the overall negative charge is –2

The overall positive charge must be +2

There is one Ni ion, so its charge must be 2+

Ni^{2+} nickel**(II)** ion and Br^{-} bromide ion = <u>Nickel(II) bromide</u>

e.g. $Fe_2(SO_4)_3$ SO_4 has a 2– charge, so 3 SO_4^{2-} ions means the overall negative charge is –6

The overall positive charge must be +6

There are 2 Fe ions, so each Fe ion charge must be **3+** (6+ ÷ 2 = 3+)

Fe^{3+} iron**(III)** ion and SO_4^{2-} sulfate ion = <u>Iron(III) sulfate</u>

<u>Practice C</u>. Given the formula, write the ions present, and then name the ionic compound.

1. $MgCl_2$ _____ _____

2. KCl _____ _____

3. AgF _____ _____

4. FeO _____ _____

5. PbI_4 _____ _____

6. $Sn(NO_3)_2$ _____ _____

7. FeN _____ _____

8. MnF_3 _____ _____

9. Cr_2O_3 _____ _____

10. $AlBr_3$ _____ _____

11. $BaSO_4$ _____ _____

12. Al_2S_3 _____ _____

13. Li_2O _____ _____

14. AuF_3 _____ _____

15. $Cd(NO_3)_2$ _____ _____

Practice D. Given the formula, name the ionic compound. Remember to determine the charge on the cation (if necessary).

1. $(NH_4)_2S$ _____

2. $ZnCO_3$ _____

3. K_2SO_3 _____

4. NaOH _____

5. $Ca(IO_3)_2$ _____

6. Na_2SO_4 _____

7. $Cu(NO_2)_2$ _____

8. $Al(OH)_3$ _____

9. PbS _____

10. $Sn(ClO_3)_2$ _____

IV. Nomenclature for Covalent Compounds

Covalent compounds are named using the Prefix system. In the Prefix system, the number of atoms present in the compound is indicated by Greek prefixes, as follows:

# of atoms	Greek prefix	# of atoms	Greek prefix
1	mono *	6	hexa
2	di	7	hepta
3	tri	8	octa
4	tetra	9	nona
5	penta	10	deca

* often omitted – see below

A. Writing Formulas for Covalent Compounds << use prefixes >>

Use the Greek prefixes in the compound name to determine the subscripts in the formula of the covalent compound, as follows:

e.g. Dichlorine pentaoxide — 2 Cl 5 O — Cl_2O_5

Tetraphosphorus heptasulfide — 4 P 7 S — P_4S_7

Carbon dioxide — 1 C 2 O — CO_2

Practice E. Write the formula for the covalent compound given the name.

1. Sulfur dioxide _____
2. Chlorine trifluoride _____
3. Dinitrogen pentachloride _____
4. Dibromine heptaoxide _____
5. Tetraphosphorus decasulfide _____

B. Naming Covalent Compounds from Formulas << use prefixes >>

Use the subscripts in the formula to determine the Greek prefixes in the compound name. The first element

in the compound uses the element name; the second element uses the element name with the ending changed to "ide", as below. The prefix *mono* is *omitted* if associated with the first element.

Greek prefix + first element name , Greek prefix + second element stem name + "*ide*"

e.g.	P_2O_5	SF_6	CO
	di penta	mono* hexa	mono* mono
	Diphosphorus pentaoxide	Sulfur hexafluoride	Carbon monoxide

<u>Practice F</u>. Given the formula, name the covalent compound.

1. P_2I_5 _____

2. CS_2 _____

3. PCl_5 _____

4. Cl_2O_7 _____

5. $SiBr_4$ _____

V. <u>Nomenclature for Hydrates – a Special Case of Ionic Compounds</u>

Hydrates: hydrates are ionic compounds that have a specific number of water molecules 'attached' to the crystalline structure of the compound. The ionic compound without the attached water molecules is called the *anhydrous salt*; the ionic compound with water attached is called the *hydrate*, or hydrated form of the compound. The attached water is called the *water of hydration*.

Cu^{2+}

The water molecules get into the three-dimensional structure of the ionic compound in one of two ways. If the compound is prepared in a solution of water, and the water is evaporated slowly, some of the water is trapped in the structure of the compound. It is also possible for an anhydrous ionic compound without water to "pick up" water from the air and become hydrated.

During the process of hydration, the structure of the compound changes to include the water molecules. Often the physical appearance of the ionic compound changes, too. For example, $CuSO_4$ anhydrous is a white crystalline solid, while $CuSO_4 \bullet 5H_2O$ hydrate, which has 5 H_2O molecules for every $CuSO_4$, is aqua blue.

A. Writing Formulas for Hydrates

The general formula of a hydrate is $A \bullet n\ H_2O$ where A is the anhydrous salt, and $n\ H_2O$ represents the number, *n*, of water molecules loosely bound to the ionic compound.

To write the formula for a hydrate, first write the correct formula for the anhydrous compound, followed by a dot • . Use the Greek prefix in the name to indicated the number of attached water molecules.

The correct method for writing the formula for a hydrate is shown below.

anhydrous formula + • + **number of water molecules** + H_2O

e.g. aluminum chloride *di*hydrate $AlCl_3$ + • + 2 + H_2O = $AlCl_3 \bullet 2\ H_2O$

e.g. magnesium sulfate *hexa*hydrate $MgSO_4$ + • + 6 + H_2O = $MgSO_4 \bullet 6\ H_2O$

B. Naming Hydrates from Formulas

To name a hydrate from its formula, write the correct name of the anhydrous ionic compound first. Use Greek prefixes to indicate the number of water molecules present; the prefix is added to the word *hydrate*.

The naming of a hydrate from its formula is illustrated below.

anhydrous compound name + **Greek prefix** + **hydrate**

e.g. $CaCl_2 \bullet 2\ H_2O$ calcium chloride + *di* + hydrate = calcium chloride *di*hydrate

e.g. $CuSO_4 \bullet 5\ H_2O$ copper(II) sulfate + *penta* + hydrate = copper(II) sulfate *penta*hydrate

Practice G. Write the formula or name of the hydrate.

1. magnesium chloride heptahydrate _____
2. sodium carbonate trihydrate _____
3. $BaCl_2 \bullet 2\ H_2O$ _____
4. $FeF_3 \bullet 10\ H_2O$ _____
5. $Li_2SO_4 \bullet 4\ H_2O$ _____

VI. Put it All Together - Mixed Ionic and Covalent Naming

Practice H. First determine if the following compounds are Ionic or Covalent. If ionic, use the Stock system to name the compound. If covalent, use the Prefix system.

1. $BaCl_2$ _____
2. SO_2 _____
3. $NaClO_3$ _____

4. $Al_2(CO_3)_3$ _____

5. PF_5 _____

6. $NiBr_2$ _____

7. NCl_5 _____

8. Cu_2O _____

9. FeP _____

10. sodium nitrate _____

11. silver(I) hydroxide _____

12. zinc phosphate _____

13. lead(IV) carbonate _____

14. bromine monoiodide _____

15. copper(I) sulfate octahydrate _____

16. triphosphorus pentoxide _____