<u>Nomenclature Worksheet</u>

<u>Number of Lab Periods:</u> 1

<u>Objectives</u>

1. Be able to convert between chemical name and chemical formula for binary covalent compounds.
2. Be able to convert between chemical name and chemical formula for binary and polyatomic ionic compounds.
3. Be able to convert between chemical name and chemical formula for hydrates.
4. Be able to convert between chemical name and chemical formula for acids.
5. Be able to convert nonsystematic names for ionic compounds to chemical formulae.

<u>Reading Topics</u>

1. The periodic table (section 2.6)
2. Covalent and Ionic bond formation (section 2.7)
3. Nomenclature for ionic, covalent and organic compounds. (2.8)

<u>Introduction</u>

Would not (E)-1-(2,6,6-Trimethyl-1-cyclohexa-1,3-dienyl) but-2-en-1-one by any other name smell as sweet?

-(a reference to the main chemical component of rose scent)

My friend Willie was a chemist, my friend Willie is no more.
What Willie thought was H_2O was H_2SO_4.

-(a poem on the importance of chemical identification)

The ability to use nomenclature and chemical formulae to identify and discuss specific reagents is a key skill for a chemist. While molecules can be depicted in a variety of fashions, chemical nomenclature provides the shorthand vocabulary that chemists use to disseminate their findings and techniques. Without this ability to interconvert between chemical names and structure we would be seriously handicapped in our ability to communicate substantively about topics in the field. As such, it is vital that we take the time to learn and understand the rules for naming chemicals so that we can continue to build a foundation of knowledge that will support our future studies in chemistry.

Chemicals can be broken down into several broad categories for the purpose of organization. The first is the distinction between organic and inorganic molecules. Inorganic molecules are those that come from non-living sources, such as minerals or stone, while organic molecules were originally defined as those that came from living materials, such as living plants or decayed organic material. Today, we refer to organic molecules as those with carbon as a major constituent while inorganic chemicals are those without carbon. This lab focuses mainly on inorganic molecules. While some simple organic compounds are mentioned, the extent of the rules regarding organic nomenclature is beyond the scope of this class.

Inorganic molecules can be broken down further into two main groups: ionic and covalent compounds. In this lab we will examine the systematic process of converting the formulae for binary ionic compounds to the corresponding chemical name and vice versa. Binary covalent compounds, inorganic acids, and hydrates are also discussed. A brief discussion of organic nomenclature and non-systematic names for ionic compounds is also included.

Procedure

Reagents Needed: None

Equipment Needed: Worksheet and textbook

Lab Protocol:

1. Form groups of 3 or 4 and work through the first five sections of the worksheet.
2. Complete final review section as directed by instructor.
3. When finished, check work with instructor.
4. Complete additional worksheets as directed by instructor.

Section 1: Binary Ionic Compounds

Ionic compounds are comprised of positively charged cations (metals) and negatively charged anions (nonmetals) held together by electrostatic forces. As discussed previously, the charge on many ions can be predicted based on the chemical group the element belongs to. Table 1 summarizes the group trends.

Table 1: Group Trends for Ion Formation

Group	Trend	Notes
1A	+1 cations	
2A	+2 cations	
3A	+3 cations	Only Al. Others are variable or not ionic
4A	No overall trend	Mix of nonmetals and metals
5A	-3 anions	Only N. Others are variable.
6A	-2 anions	O, S, Se
7A	-1 anions	
8A	Does not form ions	Noble gases are generally non-reactive

There are three general rules for naming binary ionic compounds: 1) compounds must have an overall neutral charge, 2) the cation is named first, and 3) the nonmetal anion is named second and the suffix *–ide* is added to the root name of the element. Given this, complete the following problems:

Name the following chemicals	Give the molecular formula
$MgCl_2$ ______________________________	Strontium nitride ________________
Al_2S_3 ______________________________	Lithium bromide ________________
K_3N ______________________________	Calcium oxide ________________
NaF ______________________________	Cesium selenide ________________

Some cations, including most of the transition metals, have two charge states that they commonly adopt. To denote which ion is present, the charge in roman numerals is added following the cation in the chemical name. Ex: $FeCl_3$ is iron (III) chloride. An older non-systematic naming system is sometimes applied to these compounds as well. For example, $FeCl_3$ would be ferric chloride. First, note that the root name for the cation is used in the nonsystematic names. Second, for the higher of the two common charge states the suffix *–ic* is added to the root name for the cation, while *–ous* is added to the lower charge state. As older chemical containers may still be labeled with these names, it is useful to be able to recognize them. Table 2 summarizes a few common metals that have multiple charge states and lists both the systematic (IUPAC) and nonsystematic (common) names.

Table 2: Nomenclature for cations with multiple charge states

Cation	Systematic name	Non-systematic name
Fe^{2+}	iron (II)	ferrous
Fe^{3+}	iron (III)	ferric
Co^{2+}	cobalt (II)	cobaltous
Co^{3+}	cobalt (III)	cobaltic
Cu^{+}	copper(I)	cuprous
Cu^{2+}	copper (II)	cupric
Sn^{2+}	tin(II)	stannous
Sn^{4+}	tin(IV)	stannic
Hg^{+} (as Hg_2^{2+})	mercury(I)	mercurous
Hg^{2+}	mercury(II)	mercuric
Pb^{2+}	lead(II)	plumbous
Pb^{4+}	lead(IV)	plumbic

*Note that Ag, Zn, and Cd have only one possible charge each: Ag^{+}, Zn^{2+}, Cd^{2+}
As such, they are not written with roman numerals. Ex: AgCl is silver chloride

Using Table 2, complete the following problems:

Name the following using systematic names		Give the Molecular Formula	
$CoCl_3$	____________________	Ferric sulfide	__________
SnS_2	____________________	Chromium (II) iodide	__________
CuO	____________________	Manganese (IV) oxide	__________
Fe_2O_3	____________________	Stannic fluoride	__________
Pb_3N_4	____________________	Tin (II) nitride	__________
$ZnBr_2$	____________________	Cuprous oxide	__________

Section 2: Hydrates and Polyatomic Ions

Hydrates are ionic compounds that have a specific number of water molecules associated with each formula unit. The presence of associated water molecules is denoted by appending the word *hydrate* to the end of the ionic compound's name. The number of water molecules is specified by giving a numerical prefix to the "hydrate" portion of the name. These prefixes can be found below in Table 3. For example, $MgCl_2 \cdot 2H_2O$ is magnesium chloride dihydrate.

Table 3:Numerical Prefixes for Hydrates and Binary Covalent Compounds

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

Polyatomic ions consist of two or more atoms bonded covalently and carry a net positive or negative charge. These ions always stay together as a charged unit, and do not break up further into individual atoms. Most polyatomic ions are anions. The only two common polyatomic cations are ammonium (NH_4^+) and mercury (I) (Hg_2^{2+}). Polyatomic anions are broken up into two main groups: those that contain oxygen (often called oxoanions) and those that do not. While memorization is required for the polyatomic ions in general, there are two rules for oxoanions that help predict the appropriate name.

1. For oxoanions families with two members
   a. The ion with more O atoms takes the nonmetal root and the suffix *–ate*
   b. The ion with fewer O atoms takes the nonmetal root and the suffix *–ite*
2. For oxoanion familes with four members
   a. The ion with the most O atoms takes the nonmetal root, the prefix *per-* and the suffix *–ate*
   b. The ion with 1 fewer O atom takes the nonmetal root and the suffix *–ate*
   c. The ion with 2 fewer O atoms takes the nonmetal root and the suffix *–ite*
   d. The ion with the fewest O atoms (3 fewer) takes the nonmetal root, the prefix *hypo-* and the suffix *–ite*

Table 4: Common Polyatomic Anions

Ion	Name	Ion	Name
NO_2^-	Nitrite	CO_3^{2-}	carbonate
NO_3^-	Nitrate	HCO_3^-	hydrogen carbonate or bicarbonate
OH^-	Hydroxide	CN^-	cyanide
SO_3^{2-}	Sulfite	PO_4^{3-}	phosphate
SO_4^{2-}	Sulfate	HPO_4^{2-}	hydrogen phosphate
$H\ SO_4^-$	hydrogen sulfate	$H_2PO_4^-$	dihydrogen phosphate
CH_3COO^-	acetate	ClO_4^-	perchlorate
CrO_4^{2-}	chromate	ClO_3^-	chlorate
$Cr_2O_7^{2-}$	dichromate	ClO_2^-	chlorite
MnO_4^-	permanganate	ClO^-	hypochlorite
O_2^{2-}	peroxide	SCN^-	thiocyanate

Using Tables 3 and 4 on the previous page, complete the following:

Name the following

KCN ______________________________

$LiNO_3$ ______________________________

$Cd(CH_3COO)_2 \cdot 2H_2O$ ______________________________

$Pb(MnO_4)_4$ ______________________________

NH_4ClO_4 ______________________________

$SnSO_4$ ______________________________

$Al(H_2PO_4)_3$ ______________________________

$Mg(O_2)$ ______________________________

$NaSCN$ ______________________________

$Ca(NO_2)_2$ ______________________________

Give the formula for the following

tin (II) phosphate ____________________ potassium hydroxide________________

iron (II) chlorite ___________________ calcium acetate ___________________

lead (IV) nitrite ___________________ cesium perchlorate __________________

sodium carbonate____________________ aluminum cyanide ___________________

barium permanganate_______________ ammonium nitride ___________________

sodium chromate trihydrate __________________________

Section 3: Acids

Acids are an important class of chemical compounds that have been an integral part of the study of matter since alchemical times. In this type of compound, anions balance their negative charge via the addition of hydrogen atoms. There are two classes of acids: binary acids and oxoacids. Oxoacids are composed of oxoanions and hydrogen, while binary acids are composed of other anions and hydrogen. Each has their own rules for naming.

1. Binary Acids (no oxygen in anion)
    a. Prefix *hydro*- is added to nonmetal root plus suffix –*ic* plus "acid"
        i. H_2S is hydrosulfuric acid
2. Oxoacids (based on oxoanion name)
    a. –*ate* suffix becomes –*ic* plus "acid
        i. H_2SO_4 is sulfuric acid
    b. –*ite* suffix becomes –*ous* plus "acid"
        i. H_2SO_3 is sulfurous acid
    c. oxoanion prefixes are retained
        i. $HClO_4$ is perchloric acid

Use the rules above along with Table 4 to complete the following

Name the following		**Give the Molecular Formula**	
HBr	________________	nitrous acid	________________
HNO_3	________________	hydrocyanic acid	________________
H_3PO_4	________________	dichromic acid	________________
H_2CO_3	________________	hydrofluoric acid	________________
CH_3COOH	________________	perbromic acid	________________
HClO	________________	carbonic acid	________________
$HClO_3$	________________	hydroiodic acid	________________

Section 4: Binary Covalent Compounds

Covalently bound compounds involving two nonmetals require a more specific nomenclature than ionic compounds. While magnesium and oxygen can combine in only one ratio, nitrogen and oxygen can combine in a variety of ways, including NO, NO_2, N_2O, N_2O_4, and others. To differentiate between these compounds, the following guidelines are used.

1. Name the most metallic atom first with its full name. The most metallic element is the one farthest to the left and down on the periodic table.
2. The second element uses its root name plus the suffix –*ide*.
   a. Example: N_2S_5 is dinitrogen pentasulfide
3. Each element gets a number prefix from Table 3 to denote how many atoms of that element are in each molecule.
   a. For the first named element only, the "mono-" prefix is omitted.
      i. Ex: BF_3 is boron trifluoride (not monoboron trifluoride)
   b. If the second element is oxygen, the "a" at the end of the number prefix is elided with the "o" in oxide.
      i. Ex: N_2O_5 is dinitrogen pentoxide, (not dinitrogen pentaoxide)

Use the rules above along with Table 3 to answer the following

Name the following	**Give the Molecular Formula**
XeF_4 ______________________	sulfur hexafluoride__________
NO_2 ______________________	iodine tribromide__________
PCl_3 ______________________	sulfur trioxide __________
SiO_2 ______________________	carbon monoxide__________
S_2O_5 ______________________	diphosphorous pentoxide__________
CCl_4 ______________________	diboron hexachloride__________
As_2S_3 ______________________	iodine heptachloride__________

Section 5: Simple Organic Compounds

As mentioned previously, organic chemistry has its own detailed and complex system of nomenclature. Much of this is beyond the scope of general chemistry, but it is worthwhile to explore the simplest of the organic molecules: hydrocarbons. Hydrocarbons are compounds that contain only carbon and hydrogen. This class of compounds is known collectively as **alkanes.** When all the carbons are attached to each other in a straight line, the most basic of organic compounds, the straight chain alkanes, or n-alkanes, are formed. For these compounds, the number of hydrogens always equals the 2*C+2. For example if there are 3 carbons, there are 3*2+2 = 8 hydrogens. The names for each of these compounds end in the suffix –*ane* while the remainder of the name corresponds to the number of carbons. As can be seen in Table 5, the first four alkanes have common or historical prefixes, while chains with five carbons or more use similar prefixes as those in Table 3. Chains that are branched or have non-carbon substituents have their own rules and are not covered here.

Table 5: Organic Nomenclature for Straight Chain Alkanes

Number of carbons in chain	Number prefix
1	meth-
2	eth-
3	prop-
4	but-
5	pent-
6	hex-
7	hept-
8	oct-
9	non-
10	dec-

Using Table 5 complete the following

Fill in the appropriate name or formula

C_3H_8	________________	ethane	________________
C_5H_{12}	________________	butane	________________
C_9H_{20}	________________	heptane	________________
C_6H_{14}	________________	methane	________________

Final Review Section

Use what you have learned in the previous sections to complete the following by providing either the correct chemical name or the formula.

Name the following		Give the Molecular Formula	
$Hg_2(CH_3COO)_2$	________________	Bromine pentafluoride	__________
H_2CrO_4	________________	Copper (II) carbonate	__________
Na_2O	________________	Antimony triiodide	__________
C_4H_{10}	________________	Iron (III) nitride	__________
H_2S	________________	Propane	__________
C_2H_6	________________	Bromous acid	__________
$SrCl_2 \bullet 2H_2O$	________________	Octane	__________
$SeCl_6$	________________	Lithium sulfide	__________
$AgNO_3$	________________	Sulfuric acid	__________
P_2F_4	________________	Sodium hydrogen phosphate	__________