EXPERIMENT 7: **Nomenclature** (Binary and Ternary Compounds)

**Names and Formulas in General Chemistry**

Mastering names and formulas takes *practice* – the more you do, the more you remember and the easier it gets! This is a skill that will help to open up the subject of chemistry to you, because after all, chemical names are an integral part of the language of chemistry. The following notes are really intended to be more of reminders, as your textbook should have this information in much better detail and organization. The rules below pertain to the English names, but even so, there are variations, such as "sulfate" (American spelling) and "sulphate" (British spelling), and "aluminum" (American spelling) and "aluminium" (British spelling).

Memorize (some things in chemistry simply *have* to be memorized!) the names and charges of common ions such as chloride, nitrate, sulfate, sulfite, etc. This will happen automatically with practice. Use the periodic table to determine the charges of common single atom (monatomic) cations and anions: Group(charge) 1A(1+), 2A(2+), 3A(3+), 7A(1–), 6A(2–), 5A(3– for N, P, and As). You can many times easily deduce the charge of an ion that you're not sure about from another formula with the same ion in it. For example, what was the sulfate ion's charge? Luckily, I remember the formula of sodium sulfate: Na₂SO₄. Since Na ion is +1 (Group 1A) and there are two of them in the formula, SO₄ ion must therefore be −2, SO₄²−. Easy! Incidentally, when you write the charge with the formula of an ion, the convention nowadays is like this: Na⁺, Ca²⁺, PO₄³⁻ rather than Na⁺¹, Ca⁺² or PO₄⁻³. *Oxidation numbers* of atoms (sometimes but not *necessarily* the actual charge of the atom), are normally written +1, +2, −3, etc.

**Ionic Compounds**

Formulas of ionic compounds are by their nature *empirical*, or *simplest*, formulas, which have the simplest whole numbers of positive and negative ions that give a charge-balanced formula. The formula of sodium chloride is always NaCl, never "Na₂Cl₂." If an equation has two sodium chlorides in it, we would use a *coefficient* of two: 2 NaCl. A case that looks like an exception, but is not, is mercurous chloride, or mercury(I) chloride, which has the formula Hg₂Cl₂ instead of HgCl. This is because the mercurous ion occurs as an unusual *diatomic* metal cation, Hg₂⁺ with a *covalent bond* between the two Hg⁺ ions. Remember that when naming ionic compounds (in English), the *positive ion* is always named first, and likewise with the formulas also. Sodium chloride, not "chloride sodium;" NaCl, not "ClNa." Note the "ide" ending of single atom negative ions: sodium chloride and not "sodium chlorine."

**Binary Molecular Compounds**

Names of *binary molecular* compounds (which contain only two different elements, normally nonmetals, and do not contain positive and negative ions) can contain the prefixes mono, di, tri, tetra, penta, etc. Normally, names of *ionic* compounds do *not* use these prefixes to indicate the number of positive or negative ions. CaCl₂ is calcium chloride, *not* "calcium dichloride". However, aluminum chloride, AlCl₃, is sometimes called aluminum trichloride which is not incorrect in this case because it actually *is* a molecular compound (it has very
polar aluminum-chlorine covalent bonds) even though it looks like it should be ionic since it contains metal and nonmetal elements typical of ionic compounds. MnO₂ is often called manganese dioxide rather than manganese(IV) oxide for the same reason. Usually, it is best to play it safe with compounds like these and use the ionic names: FeCl₃ is ferric chloride or iron(III) chloride rather than "iron trichloride." PCl₃, a molecular compound (expected since only nonmetallic elements are present), is commonly called phosphorus trichloride, but is sometimes called "phosphorus(III) chloride." The "(III)" in the latter name, called the Stock name, would indicate the oxidation state rather than an actual charge of the phosphorus atom.

**Acid Names**

Acid names should be used when specified or usually when the acid is dissolved in water. For example, hydrogen chloride, HCl (g), which is a gaseous molecular compound, becomes hydrochloric acid, HCl (aq) a strong acid which exists as completely separated H⁺ and Cl⁻ ions in aqueous solution. H₂SO₄ is normally always named by its acid name sulfuric acid, not "dihydrogen sulfate;" likewise HNO₃ is nitric acid and not "hydrogen nitrate." H₂S (g) is hydrogen sulfide or dihydrogen sulfide, a gaseous molecular compound. In aqueous solution, H₂S (aq), the acid name hydrogensulfuric acid (a weak acid) will normally be used, especially in the context of acid behavior. Another common weak acid is acetic acid, HC₂H₃O₂, which is found in vinegar. In this case, as with other common acids such as sulfuric acid, the acid name is always used; "hydrogen acetate" is not correct. (Acetic acid belongs to a class of organic compounds called carboxylic acids. These have their own special nomenclature rules as do the many other classes of organic compounds.)

**Handling Variable Charges**

Many positive ions can have more than one charge and in such cases the charge must be specified in the name. You can indicate the positive charge with a Roman numeral in parentheses (known as the Stock number after the German chemist Alfred Stock), or by using the common name endings ous (for the lower common charge) and ic (for the higher common charge). Since iron can form +2 or +3 ions commonly, the names of ionic iron compounds must be unambiguous in this regard. FeCl₂ is iron(II) chloride or ferrous chloride, not "iron chloride." On the other hand, since the calcium ion, for example, always has the same charge (+2), we call CaCl₂ simply calcium chloride and not "calcium(II) chloride" because we know automatically that the charge of calcium ion is +2.

**Oxyanions**

Remember, with the oxyanion (or "oxoanion") names that the "ite" ion simply has one less oxygen than the "ate" ion, but the charge is still the same. Na₂SO₄ = sodium sulfate, Na₂SO₃ = sodium sulfite. These translate into the acid names sulfuric acid, H₂SO₄, and sulfurous acid, H₂SO₃. Also, if the oxyanion has one more oxygen than the "ate" ion, add the prefix per to the ate ion name, and if there is one less oxygen than the "ite" ion, add the prefix hypo to the ite name.
You probably have the chlorate series in your textbook as an example:

\[ \text{ClO}_4^- = \text{perchlorate ion (one more oxygen than chlorate)} \]
\[ \text{ClO}_3^- = \text{chlorate ion} \]
\[ \text{ClO}_2^- = \text{chlorite ion} \]
\[ \text{ClO}^- = \text{hypochlorite ion (one less oxygen than chlorite)} \]

And the corresponding **acid names**:

\[ \text{HClO}_4 = \text{perchloric acid} \]
\[ \text{HClO}_3 = \text{chloric acid} \]
\[ \text{HClO}_2 = \text{chlorous acid} \]
\[ \text{HClO} = \text{hypochlorous acid} \]

**IUPAC Names**

Systematic names from the IUPAC rules (International Union of Pure and Applied Chemistry) are sometimes used to name complex inorganic compounds (the IUPAC rules are the standard for organic compounds). Here are some examples:

\[ \text{NaClO}_4 = \text{sodium tetraoxochlorate(VII)} \]
\[ \text{Na}_2\text{SO}_4 = \text{sodium tetraoxosulfate(VI)} \]
\[ \text{Na}_2\text{SO}_3 = \text{sodium trioxosulfate(IV)} \]
\[ \text{NaAlCl}_4 = \text{sodium tetrachloroaluminate(III)} \]

While the last name is in common use, the other three compounds (and most other inorganic compounds) are almost always named according to the common rules outlined above - sodium perchlorate, sodium sulfate, and sodium sulfite.

**Naming Hydrated salts**

Hydrates are crystalline solids that contain a fixed number of water molecules as an integral part of their crystalline structure. The number of water molecules bound per metal ion is often characteristic of that particular metal ion. One of the more common hydrates is copper(II) sulfate pentahydrate, which contains 5 moles of water per 1 mole of copper(II) sulfate, written as CuSO\(_4\cdot5\)H\(_2\)O. It is used as a catalytic precursor, fungicide, and as a source of copper in chemical manufacturing processes. Epsom salt is magnesium sulfate heptahydrate, MgSO\(_4\cdot7\)H\(_2\)O. Epsom salt is used to reduce inflammation when applied externally.
**REPORT FORM**

Name ___________________________
Instructor ________________________ Date __________________________

**Worksheet I - Binary Compounds**

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<tbody>
<tr>
<td>barium sulfide</td>
<td>phosphorus triiodide</td>
<td>sulfur trioxide</td>
<td>aluminum selenide</td>
<td>silicon disulfide</td>
<td>carbon dioxide</td>
<td>sodium oxide</td>
<td>carbon monoxide</td>
<td>lithium fluoride</td>
<td>boron trichloride</td>
<td>lithium phosphide</td>
<td>diarsenic pentoxide</td>
<td>aluminum oxide</td>
<td>strontium fluoride</td>
<td>potassium sulfide</td>
<td>sodium sulfide</td>
<td>cesium telluride</td>
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Worksheet II: Stock Nomenclature

1. Cu$_3$P$_2$ _______________________
2. Pb$_3$(PO$_4$)$_2$ ______________________
3. Fe$_2$(SO$_4$)$_3$ ______________________
4. PbO$_2$ ______________________
5. PbSO$_4$ ______________________
6. CuI ______________________
7. PbO ______________________
8. Fe(CN)$_2$ ______________________
9. Sn$_3$(PO$_4$)$_2$ ______________________
10. Cu(ClO$_3$)$_2$ ______________________
11. FePO$_4$ ______________________
12. HgBr$_2$ ______________________
13. Fe$_2$(SO$_4$)$_3$ ______________________
14. Sn(SO$_4$)$_2$ ______________________
15. Cu(OH)$_2$ ______________________

iron(II)sulfide _____________
tin(II)oxalate _____________
copper(II)oxide _____________
iron(II)hydroxide _____________
tin(IV)carbonate _____________
copper(I)sulfite _____________
copper(II)nitrate _____________
lead(II)nitrite _____________
lead(IV)iodide _____________
iron(II)sulfide _____________
copper(I)acetate _____________
lead(II)phosphate _____________
tin(II)phosphide _____________
iron(III)permanganate _____________
lead(II)fluoride _____________
copper(II)nitrate _____________
tin(IV)chloride _____________
Worksheet III: Polyatomic Salts Nomenclature

1. Mg(ClO$_3$)$_2$ ________________
2. Na$_2$SO$_4$ ________________
3. Mg(CN)$_2$ ________________
4. Na$_3$PO$_4$ ________________
5. NaClO ________________
6. Rb$_2$CO$_3$ ________________
7. Cs$_2$C$_2$O$_4$ ________________
8. BeCO$_3$ ________________
9. NaCH$_3$CO$_2$ ________________
10. BaSO$_3$ ________________
11. Mg(NO$_2$)$_2$ ________________
12. CaCO$_3$ ________________
13. Al(OH)$_3$ ________________
14. (NH$_4$)$_2$SO$_4$ ________________
15. Sr(ClO$_3$)$_2$ ________________
16. Na$_2$O ________________

sodium cyanide ________________
lithium chlorate ________________
rubidium sulfate ________________
beryllium cyanide ________________
calcium phosphate ________________
cesium carbonate ________________
potassium dichromate ________________
ammonium acetate ________________
strontium chromate ________________
sodium permanganate ________________
magnesium phosphate ________________
potassium nitrite ________________
barium hydroxide ________________
zinc hypochlorite ________________
Worksheet IV  Extra Nomenclature Exercises

Hydrates Salts

1. SnCl₂ • H₂O ______________________________
2. BaI₂ • H₂O ______________________________
3. NaCH₃CO₂ • 3H₂O _________________________
4. CuSO₄ • 5H₂O ______________________________
5. Ca(ClO₂)₂ • 3H₂O _________________________
6. Na₃PO₄ • 10H₂O __________________________

zinc acetate dihydrate ______________________________
ammonium phosphate trihydrate __________________
sodium hypochlorite pentahydrate _________________
barium nitrite monohydrate ________________________
calcium bromide hexahydrate ______________________
iron(III)bromide hexahydrate ______________________
lead(II)perchlorate trihydrate ______________________
magnesium iodide octahydrate ______________________
Worksheet V: Nomenclature Review

1. $K_2S$ ___________________
2. $Mg(NO_3)_2 \cdot 3H_2O$ ___________________
3. $P_4O_{10}$ ___________________
4. $K_2C_2O_4$ ___________________
5. $Ba_3(PO_4)_2$ ___________________
6. $LiHCO_3$ ___________________
7. $AgCl$ ___________________
8. $CuF_2 \cdot 2H_2O$ ___________________
9. $Al_2O_3$ ___________________
10. $FeSO_3$ ___________________
11. $KMnO_4$ ___________________
12. $SF_6$ ___________________
13. $NH_4CH_3CO_2$ ___________________
14. $Fe(HSO_4)_2$ ___________________
15. $NaOH$ ___________________

lead(IV)perchlorate ___________________ lead(IV)perchlorate ___________________

sodium hypochlorite _________________ sodium oxalate ___________________
silicon tetraiodide __________________ barium chloride ___________________

barium nitrite tetrahydrate ____________
calcium chromate ____________________
copper(II)acetate monhydrate __________
potassium iodide ____________________ phosphorus pentafluoride ___________________
aluminum chlorate _________________ ammonium sulfide ___________________
aluminum dichromate _______________ magnesium hydroxide ___________________
lead(IV)bicarbonate _________________ zinc sulfide ___________________________
strontium telluride _______________         sodium sulfate _______________

sodium hypochlorite _____________         sodium oxalate _______________

silicon tetraiodide _______________         barium chloride _______________

barium nitrite tetrahydrate _______________

 copper(II)acetate monohydrate _______________

calcium chromate _______________

potassium iodide _______________         phosphorus pentafluoride _______

aluminum chlorate _______________         ammonium sulfide _______________

aluminum dichromate _____________         magnesium hydroxide _______________

lead(IV)bicarbonate _______________         zinc sulfide _______________

strontium telluride _______________         sodium sulfate _______________
EXPERIMENT 7: Nomenclature (Binary and Ternary Compounds)

Name:_____________________________________

Pre-Laboratory Questions and Exercises
Due before lab begins. Answer in the space provided.

1. Define **Hydroacids** and **Oxyacids**. Give two examples of each.

2. Identify the following as **acidic** or **basic** oxides.
   - CaO
   - CO₂
   - K₂O
   - SO₃
   - MgO

3. Write the **formula** for the following acids.
   - Hydrosulfuric acid
   - nitric acid
   - hydroiodic acid
   - perbromic acid

4. **Complete** and **balance** the following reactions.
   a) K + O₂ ➞
   b) CaO + H₂O ➞
   c) Zn + HCl ➞
   d) Cl₂ + KI ➞

5. Write the **charges** for the following.
   - SO₄
   - HCO₃
   - NO₃
   - C₂H₅O₂
   - PO₃
   - OH
EXPERIMENT 7: Nomenclature (Binary and Ternary Compounds)

Name:____________________________

Post-Laboratory Questions and Exercises
Due after completing the lab. Answer in the space provided.

1. Which of the following reactions is not balanced? (write Yes or No)
   a) Zn + H₂SO₄ $\rightarrow$ ZnSO₄ + H₂
   b) 4NH₃ + 5O₂ $\rightarrow$ 4 NO + 6H₂O
   c) (NH₄)₂CO₃ $\rightarrow$ NH₃ + CO₂ + 4H₂O

2. What are the correct names for the following ions?
   NH₄⁺   NO₂⁻   H₂PO₃⁻   Cr₂O₇⁻²   HSO₄⁻

3. Which of the following reactions will not occur? (Write Yes or No)
   a) Br₂ + KI $\rightarrow$
   b) Mg + Zn(NO₃)₂ $\rightarrow$
   c) Cu + HCl $\rightarrow$
   d) I₂ + NaBr $\rightarrow$

4. Write the correct formula for the following compounds.
   Dinitrogen trioxide    Oxygen difluoride    Carbon disulfide    Phosphorous pentoxide