Name: ______________________________________ Date: ________________________

Guided Learning: Naming Compounds

[Note: You will need a copy of the periodic table handy as you do this activity.]

Learning goals
After completing this activity, you will be able to …

- Identify ionic compounds, covalent compounds, polyatomic ions, acids, and bases by their chemical formulas.
- Determine the chemical formulas of ionic compounds, covalent compounds, polyatomic ions, acids, and bases given their names.

Vocabulary: acid, alkali metal, alkaline earth metal, anion, base, cation, chemical formula, compound, covalent bond, halogen, ion, ionic bond, molecule, nomenclature, polyatomic ion, transitional metal

Warm-up questions

1. The **chemical formula** of a certain gas is CO_2. How many carbon and oxygen atoms do you think are in a molecule of this gas? ____

2. The chemical name for this gas is carbon dioxide. How does the name of this gas relate to its chemical formula? ____

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Activity A: Naming covalent compounds
A **compound** is a pure substance made of two or more elements that are chemically bonded together. The elements in a compound occur in fixed proportions. For example, in carbon dioxide there are always two oxygen atoms for every carbon atom. This ratio is expressed in the chemical formula for carbon dioxide, CO_2.

Compounds can be held together with **ionic** and/or **covalent bonds**. In an ionic bond, one or more electrons are transferred from a metal atom to a nonmetal atom. The metal becomes a positively-charged **ion** and bonds to the negatively-charged nonmetal ion. In a covalent bond, two nonmetals share one or more pairs of electrons.

Carbon dioxide is an example of a covalent compound because it consists of two nonmetals: carbon and oxygen. Many covalent compounds are gases because they tend to form **molecules**, or single units of a compound. Ionic compounds tend to be solids that form crystalline structures.

Chemists use a specific set of rules, or **nomenclature**, to name compounds. Here are some basic rules for naming simple covalent compounds:

- The elements are named in the same order as they appear in the formula. This is generally from left to right on the periodic table.
- The second element is given an "-ide" suffix: oxygen becomes "oxide," fluorine becomes "fluoride," nitrogen becomes "nitride."
- Prefixes are used to indicate the number of each element: mono = 1, di = 2, tri = 3, tetra = 4, penta = 5, hexa = 6, hepta = 7, and octa = 8.

If the first element in the name has only one atom, then no prefix is used. If the second element has one atom, then the prefix "mono"-can be used but is not always used.

Based on these rules, here are some examples of chemical names for covalent compounds.

CO_2 carbon dioxide CCl_4 carbon tetrachloride SO_2 sulfur dioxide

The rules for naming chemical compounds can be used in reverse to determine the formula of a covalent compound based on its name. For example, the name "diphosphorous pentoxide" indicates two phosphorous (P) atoms and five oxygen (O) atoms. Therefore, the formula of diphosphorous pentoxide is P_2O_5.

Some common covalent compounds have names that are not related to their chemical formula. These include water (H_2O), ammonia (NH_3), nitric oxide (NO), nitrous oxide (NO_2), and ozone (O_3).

1. Name the following covalent compounds based on the formulas:

   CO ____________________ NCl_3 ____________________

   SeF_6 ____________________ SiO_2 ____________________

2. Write the formulas of the following covalent compounds:

   Silicon dioxide ________   Dinitrogen pentoxide ________

   Disulfur dichloride ________   Nitrogen trifluoride ________

3. What information can you get from the name of a covalent compound? ________________

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Activity B: Naming polyatomic ions

Many compounds contain **polyatomic ions**. These are groups of atoms that are held together with covalent bonds and carry a net charge. Many ionic compounds consist of a metal bonded to a polyatomic ion.

The rules for naming polyatomic ions are more variable than the rules for naming covalent compounds. Some common polyatomic ions have irregular chemical names that cannot be derived from their chemical formulas. These include ammonium (NH_4^+), acetate (CH_3COO^-), cyanide (CN^-), oxalate ($C_2O_4^{2-}$), and hydroxide (OH^-).

Many polyatomic ions contain oxygen. If so, their name will end in "-ite" or "-ate." Examples include carbonate (CO_3^{2-}), silicate (SiO_3^{2-}), nitrite (NO_2^-), and nitrate (NO_3^-).

When there are two similar names, such as nitrite and nitrate, the ion with the name ending in "-ate" has the greater number of oxygen atoms. Here are some examples:

SO_3^{2-}	sulfite	NO_2^-	nitrite	PO_3^{3-}	phosphite	AsO_3^{3-}	arsenite
SO_4^{2-}	sulfate	NO_3^-	nitrate	PO_4^{3-}	phosphate	AsO_4^{3-}	arsenate

If there are three or more similar ions, the prefixes "hypo-" and "per-" are used to indicate fewest or most oxygen atoms, as in this example:

ClO^- → hypochlorite ClO_2^- → chlorite ClO_3^- → chlorate ClO_4^- → perchlorate

In this case, hypochlorite means "fewer oxygen atoms than chlorite." Perchlorate can be interpreted as "more oxygen atoms than chlorate." It is important to understand that these symbols do not specify the exact number of oxygen atoms, they just indicate more or fewer. Also notice that in these formulas, the oxygen always comes last.

If there is more than one of another element in a polyatomic ion, then prefixes are used to indicate how many. Here are some examples:

$H_2PO_3^-$	dihydrogen phosphite	$Cr_2O_7^{2-}$	dichromate
$H_2PO_4^-$	dihydrogen phosphate	S_2^{2-}	disulfide

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1. The polyatomic ion IO_2^- is called iodite. Based on this information, name the following polyatomic ions.

   IO^- ___________________________ IO_2^- ___________________________

   IO_3^- ___________________________ IO_4^- ___________________________

2. The polyatomic ion PO_4^{3-} is called phosphate. Based on this information, write the chemical formulas of phosphite and hypophosphite:

   Phosphite ___________   Hypophosphite ___________

Activity C: Naming ionic compounds

Ionic bonds occur between ions, or charged particles. They occur because positively charged particles are attracted to negatively charged particles. In an ionic bond, the positive ion is called a **cation**. The negative ion is the **anion**.

When naming an ionic compound, start with the name of the cation, followed by the name of the anion. As with covalent compounds, the second element in the formula ends in "-ide." Here are some examples:

NaCl	sodium chloride	CaO	calcium oxide	Al_2O_3	Aluminum oxide
LiF	lithium fluoride	$MgCl_2$	magnesium chloride	KI	Potassium iodide

Notice that there are no prefixes in the names of ionic compounds to indicate how many of each ion there are. The numbers of ions in the formula can be determined based on the charges of the ions. In any ionic compound, the total charge is zero. For example, consider the compound formed by magnesium (Mg^{2+}) and chlorine (Cl^-). Because magnesium has a charge of 2+, it takes two chloride ions to balance the charge. Therefore the formula is $MgCl_2$.

For metals, the charge of the ion can be determined by the position of the metal on the periodic table. Metals in group 1 are called **alkali metals**. These metals all have one valence electron and form ions with a charge of 1+. These include lithium, sodium, potassium, rubidium, cesium, and francium.

Metals in group 2 are called **alkaline earth metals**. They have two valence electrons, form ions with a charge of 2+, and include beryllium, magnesium, calcium, strontium, barium, and radium.

The metals in groups 3–12 are called **transitional metals**. The ionic charges of these metals do not follow a simple pattern. Many of the transition metals can form more than one ion. Iron can form Fe^{2+} and Fe^{3+} ions. If the cation can have more than one charge, chemists use Roman numerals to indicate its charge. For example, in iron(II) oxide, the iron ions have a charge of 2^+ and the formula is FeO. In iron(III) oxide the iron ions have a charge of 3+ and the chemical formula is Fe_2O_3.

Ionic charges for some of the common transition metals are given below:

Element symbol	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Atomic number	21	22	23	24	25	26	27	28	29	30
Ionic charges	3+	2+, 3+, 4+	2+, 3+, 4+, 5+	2+, 3+, 6+	2+, 4+, 7+	2+, 3+	2+, 3+	2+	1+, 2+	2+

The charge of many anions can also be determined from the periodic table. Elements in group 17, called the **halogens**, have seven valence electrons and form ions with a charge of 1-. This group includes fluorine, chlorine, bromine, iodine, and astatine. Elements in the oxygen family (group 16) contain six valence electrons and form ions with a charge of 2-. This group includes oxygen, sulfur, selenium, tellurium, and polonium. Elements in the Nitrogen family contain five valence electrons and form ions with a charge of 3-. This group includes nitrogen, phosphorus, arsenic, antimony, and bismuth.

Many ionic compounds contain polyatomic ions. In this case, the name of the compound is the name of the cation followed by the name of the anion. Here are some examples:

NH_4Cl ammonium chloride $CuSO_4$ copper(II) sulfate

Notice that in the first example, since the cation is a polyatomic ion (NH_4), the anion has the "-ide" ending.

1. Name the following ionic compounds based on their formulas. (For names of polyatomic ions, see page 3 of this worksheet.) For the last two, you will have to determine if copper(I) or copper(II) is used.

   NaCl ______________________ $CaCl_2$ ______________________

   KNO_3 ______________________ $Al_2(SO_4)_3$ ______________________

   CuO ______________________ Cu_2O ______________________

2. Challenge: Write the formulas for the following ionic compounds. (Note: You will have to determine the charge of each ion based its position in the periodic table. For polyatomic ions, use the information on page 3 of this worksheet.)

   Lithium oxide ______________   Rubidium iodide ______________

   Ammonium sulfate ______________   Sodium hydroxide ______________

   Manganese(II) carbonate ______________   Iron(III) chloride ______________

3. Consider the chemical names manganese carbonate and iron chloride. In each compound, how can you tell if the anion is a single element or a polyatomic ion?

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Activity D: Naming acids and bases

A **base** is a substance that serves as a proton acceptor in reactions with **acids**. Most bases are ionic compounds composed of a metal bonded to hydroxide (OH^-). Examples include NaOH, KOH, and $Ba(OH)_2$. The rules for naming these bases are the same as the rules for naming other ionic compounds. For example, NaOH is called sodium hydroxide.

Most acids consist of hydrogen bonded to an anion. The bonds that hydrogen forms with the anion are partly ionic and partly covalent— they are not purely one or the other. When acids react with bases, they serve as proton donors. This means they tend to give up their H^+ ions in these reactions.

Unlike bases, acids have special rules for their names. The naming convention used for an acid depends on whether it contains oxygen.

- When an acid does *not* contain oxygen, the word "hydrogen" is changed to the prefix "hydro-." The ending of the anion is changed to "-ic acid." *Example: HCl becomes hydrochloric acid*.
- When an acid contains oxygen, the word "hydrogen" is not used at all. All "ate" endings become "-ic acid." All "-ite" endings become "-ous acid." *Example:* HNO_3 *becomes nitric acid.*

The table below lists many of the polyatomic ions found in acids and describes how their names are altered in the acid name.

Formula	Ion name	In acids	Formula	Name	In acids
NO_2^-	nitrite	nitrous	CN^-	cyanide	cyanic
NO_3^-	nitrate	nitric	ClO_1^-	hypochlorite	hypochlorous
SO_3^{2-}	sulfite	sulfurous	ClO_3^-	chlorate	chloric
SO_4^{2-}	sulfate	sulfuric	ClO_4^-	perchlorate	perchloric
PO_3^{3-}	phosphite	phosphorous	CH_3COO^-	acetate	acetic
PO_4^{3-}	phosphate	phosphoric	$CHOO^-$	formate	formic
CrO_4^{2-}	chromate	chromic	BO_3^{3+}	borate	boric

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1. Give the names of the following bases:

   KOH ______________________ $Ba(OH)_2$ ______________________

   $Ca(OH)_2$ ______________________ LiOH ______________________

2. Give the formula of each base. (Hint: Use your periodic table to determine the ionic charge of each cation.)

   Cesium hydroxide ____________ Rubidium hydroxide ____________

   Strontium hydroxide ____________ Ammonium hydroxide ____________

3. Give the names of the following acids based on their formulas:

   HI ______________________ HBr ______________________

   HCOOH ______________________ CH_3COOH ______________________

   H_3PO_3 ______________________ HClO ______________________

4. Write the formula of each of the following acids. (Hint: To determine the charge of the cation, use the table on page 6 or your periodic table.)

Hydrofluoric acid _____________ Chromic acid _____________

Perchloric acid _____________ Hydrocyanic acid _____________

Sulfuric acid _____________ Hydrosulfuric acid _____________

5. Summarize: Consider the similar names "sulfuric acid" and "hydrosulfuric acid." How are these names different from one another, and what does this tell you about the composition of each acid?

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