Name:

Skill Sheet 19-B Chemical Formulas

Compounds have unique names that identify them for us when we study chemical properties and changes. Chemists have devised a shorthand way of representing chemical names that provides important information about the substance. This shorthand representation for a compound's name is called a chemical formula. You will practice writing chemical formulas in the following activity.

1. What is a chemical formula?

Chemical formulas have two important parts: **chemical symbols** for the elements in the compound and **subscripts** that tell how many atoms of each element are needed to form the compound. The chemical formula for water, H_2O, tells us that a water molecule is made of the elements hydrogen (H) and oxygen (O) and that it takes 2 atoms of hydrogen and one atom of oxygen to build the molecule. For sodium nitrate, $NaNO_3$, the chemical formula tells us there are three elements in the compound: sodium (Na), nitrogen (N), and oxygen (O).To make a molecule of this compound, you need one atom of sodium, one atom of nitrogen, and 3 atoms of oxygen.

2. How to write chemical formulas

How do chemists know how many atoms of each element are needed to build a molecule? For ionic compounds, oxidation numbers are the key. An element's oxidation number is the number of electrons it will gain or lose in a chemical reaction. We can use the periodic table to find the oxidation number for an element. When we add up the oxidation numbers of the elements in an ionic compound, the sum must be zero. Therefore, we need to find a balance of negative and positive ions in the compound for the molecule to form.

Example 1:

A compound is formed by the reaction between magnesium and chlorine. What is the chemical formula for this compound?

- From the periodic table, we find that the oxidation number of magnesium is 2+. Magnesium loses 2 electrons in chemical reactions. The oxidation number for chlorine is 1-. Chlorine tends to gain one electron in a chemical reaction.
- Remember that the sum of the oxidation numbers of the elements in a molecule will equal zero. This compound requires one atom of magnesium with an oxidation number of 2+ to combine with two atoms of chlorine, each with an oxidation number of 1-, for the sum of the oxidation numbers to be zero.

$$(2+) + 2(1-) = 0$$

To write the chemical formula for this compound, first write the chemical symbol for the positive ion (Mg) and then the chemical symbol for the negative ion (Cl). Next, use subscripts to show how many atoms of each element are required to form the molecule. When one atom of an element is required, no subscript is used. Therefore, the correct chemical formula for magnesium chloride is $MgCl_2$.

Example 2:

Aluminum and bromine combine to form a compound. What is the chemical formula for the compound they form?

From the periodic table, we find that the oxidation number for aluminum (Al) is 3+. The oxidation number for bromine (Br) is 1-. In order for the oxidation numbers of this compound add up to zero, one atom of aluminum must combine with three atoms of bromine:

$$(3+) + 3(1-) = 0$$

The correct chemical formula for this compound, aluminum bromide, is $AlBr_3$.

3. Practice writing chemical formulas for ionic compounds

Use the periodic table to find the oxidation numbers of each element. Then write the correct chemical formula for the compound formed by the following elements:

Element	Oxidation Number	Element	Oxidation Number	Chemical Formula for Compound
Potassium (K)		**Chlorine (Cl)**		
Calcium (Ca)		**Chlorine (Cl)**		
Sodium (Na)		**Oxygen (O)**		
Boron (B)		**Phosphorus (P)**		
Lithium (Li)		**Sulfur (S)**		
Aluminum (Al)		**Oxygen (O)**		
Beryllium (Be)		**Iodine (I)**		
Calcium (Ca)		**Nitrogen (N)**		
Sodium (Na)		**Bromine (Br)**		

4. Polyatomic ions

Have you ever heard of sodium nitrate? It's a preservative used in foods like hot dogs. The chemical formula for sodium nitrate is $NaNO_3$. How many types of atoms does this compound contain? You are right if you said three: sodium, nitrogen, and oxygen. The nitrogen and oxygen atoms have a shared-electron bond. They act as one unit (called nitrate) with an oxidation number of 1-. Ions that have more than one type of atom (like nitrate) are called *polyatomic ions*.

To write the chemical formula for a compound containing one or more polyatomic ions, consult a reference table or guide to determine the ion's oxidation number. Then, use the same procedure for writing chemical formulas that you practiced in section 3. The oxidation numbers for the polyatomic ions you will need for the problems in the skill sheet are shown in the following table:

Polyatomic Ion	Oxidation Number	Polyatomic Ion	Oxidation Number
Phosphate (PO_4)	3-	Nitrate (NO_3)	1-
Carbonate (CO_3)	2-	Sulfate (SO_4)	2-
Ammonium (NH_4)	1+	Acetate ($C_2H_3O_2$)	1-
Hydroxide (OH)	1-	Hydronium (H_3O)	1+

Example 3:

Calcium and the hydroxide ion (-OH) combine to form a compound. Write the chemical formula for this compound.

From the periodic table, we see that the oxidation number for calcium is 2+. From the table above, you will see that the oxidation number for the hydroxide ion is 1-. To make a molecule of calcium hydroxide, therefore, we need one calcium atom and two hydroxide ions:

$$(2+) + 2(1-) = 0$$

The correct chemical formula for this compound would be $Ca(OH)_2$. Note that we enclose the members of the polyatomic ion in parentheses. The subscript for this ion is placed outside of the parentheses. This shows that we need two complete polyatomic hydroxide ions to form the compound.

5. Writing chemical formulas for compound containing polyatomic ions

Use the table on the previous page and the periodic table to find the oxidation numbers of each ion. Then write the correct chemical formula for the compounds formed by these ions.

Element	Oxidation Number	Polyatomic Ion	Oxidation Number	Chemical Formula for Compound
Sodium (Na)		**Phosphate (PO_4)**		
Calcium (Ca)		**Nitrate (NO_3)**		
Fluorine (F)		**Ammonium (NH_4)**		
Boron (B)		**Sulfate (SO_4)**		
Lithium (Li)		**Hydroxide (OH)**		
Beryllium (Be)		**Carbonate (CO_3)**		
Nitrogen (N)		**Hydronium (H_3O)**		