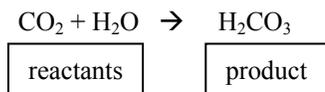
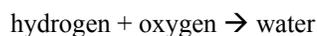


Writing, Balancing and Predicting Products of Chemical Reactions.

A chemical equation is a concise shorthand expression which represents the relative amount of reactants and products involved in a chemical reaction.



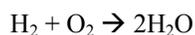
The first step in writing a chemical equation is the word equation. It is composed of the names of the materials that enter into chemical reaction, the reactants, and the names of the materials that result from the reaction, the products. The second step in writing a chemical equation is a skeleton equation. This equation includes the chemical formulas and symbols for all the reactants and products. The third step is a balanced equation. This equation is similar to a skeleton equation, but it also includes coefficients placed directly in front of the chemical formulas and symbols. The coefficients of a balanced equation indicate the number of units of each substance involved. Hydrogen burns in oxygen to form water. The reactants are hydrogen and oxygen. The product is water. The word equation for this reaction is



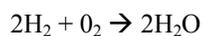
It is read, "hydrogen plus oxygen yield water." Since hydrogen and oxygen are diatomic gases, the H_2 and O_2 represent one molecule of hydrogen and one molecule of oxygen. The compound, water, is represented by the formula H_2O . The skeleton equation is $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$

The Balanced Equation

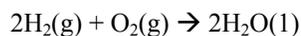
The skeleton equation indicates that two hydrogen atoms react with two oxygen atoms on the reactant side of the equation. On the product side, two hydrogen atoms are bonded to one oxygen atom. The equation is deficient by one oxygen atom on the product side. Balance the equation by putting coefficients directly in front of any of the reactants or products. A coefficient should be a whole number. *Never change the subscripts.* Changing the subscript changes the chemical formula of the compound. Place a 2 in front of the H_2O so that there are two oxygen atoms on each side of the equation.



The 2 placed in front of the H_2O changes the balance of the hydrogen atoms. Correct this imbalance by placing another 2 in front of the H_2 . The equation is now balanced.



Symbols are used in an equation to indicate the physical state of each substance. The symbols used (placed in parenthesis) are (g) for gas, (l) for liquid, (s) for solid, and (aq) for aqueous (water) solution.



What can we infer from a balanced equation? An equation indicates:

- (1) two parts of hydrogen react with one part of oxygen to yield two parts of water.
- (2) two molecules of hydrogen react with one molecule of oxygen to give two molecules of water
- (3) a quantitative relationship between the reactants and products. This relationship is the basis for working all quantitative problems.

Steps in Writing a Balanced Equation

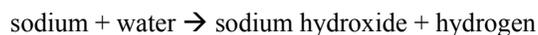
- Step 1. In writing a chemical reaction, the reactants and the products are written down. If the products are not known, they can be predicted in many cases.
- Step 2. The formulas of each substance must be correct. The diatomic gases are hydrogen, H₂, nitrogen, N₂, oxygen, O₂, fluorine, F₂; chlorine, Cl₂, bromine, Br₂; and iodine, I₂.
- Step 3. The equation is then balanced. The balancing is done by putting a coefficient before compounds until the atoms of each element on one side of the equation equal the number of atoms of that element on the other side of the equation.

Example 1

Sodium reacts with water to produce a metallic hydroxide and hydrogen gas. Write a balanced equation for the reaction.

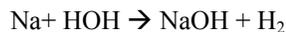
Solving Process:

Step 1. Write the word equation:



Step 2. Write a skeleton equation.

Since hydrogen is a diatomic gas, its formula is H₂. The formula for water may be written as HOH if this makes it easier to balance the equation.

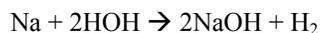


Step 3. Balance the equation.

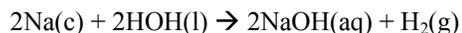
The metallic element sodium is balanced. One atom of sodium is on each side of the equation. There is one hydrogen atom on the reactant side (the H in OH has been accounted for) and 2 hydrogen atoms on the product side. Place a 2 in front of the HOH to balance the hydrogen atoms.



There are now 2OH on the left and 1 on the right. Place a 2 in front of the NaOH to give the same number of OH on each side.



Put a 2 in front of the sodium metal. The balanced equation reads



Check visually to see if the equation is balanced, or list all the atoms (the hydroxide can be listed as OH or can be separated into H and O).

Example 2

Iron(III) oxide reacts with carbon monoxide to give iron and carbon dioxide. What is the balanced equation?

Solving Process:

Step 1. Write the word equation.

iron(III) oxide + carbon monoxide \rightarrow iron + carbon dioxide

Step 2. Write the formulas and symbols of all reactants and products.

$\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow \text{Fe} + \text{CO}_2$

Step 3. Balance the iron atoms.

$\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow 2\text{Fe} + \text{CO}_2$

The carbon atoms are already balanced. Visual inspection indicates that a 2 in front of the CO, to balance the oxygen atoms changes the carbon atom balance. A 2 in front of carbon monoxide results in an odd number of oxygen atoms on the reactant side. This change will not work because any number placed in front of carbon dioxide will always give an even number of oxygen atoms on the product side. A 3 in front of CO will give an even number of oxygen atoms on the reactant side. A 3 as a coefficient for CO, will balance the oxygen atoms and the carbon atoms. The balanced equation is

$\text{Fe}_2\text{O}_3(\text{s}) + 3\text{CO}(\text{g}) \rightarrow 2\text{Fe}(\text{s}) + 3\text{CO}_2(\text{g})$

Check the equation.

Example 3

Calcium hydroxide reacts with phosphoric acid to yield calcium phosphate and water. Determine the balanced equation.

Solving Process:

Step 1.

calcium hydroxide + phosphoric acid \rightarrow calcium phosphate + water

Step 2.

$\text{Ca}(\text{OH})_2 + \text{H}_3\text{PO}_4 \rightarrow \text{Ca}_3(\text{PO}_4)_3 + \text{HOH}$

Step 3. Balance the calcium atoms by placing a 3 in front of the $\text{Ca}(\text{OH})_2$.

$3\text{Ca}(\text{OH})_2 + \text{H}_3\text{PO}_4 \rightarrow \text{Ca}_3(\text{PO}_4)_2 + \text{HOH}$

Since the phosphate and hydroxide ions are on both sides of the equation they can be balanced as units. Place a 2 in front of the phosphoric acid to balance the PO_4 group. Place a 6 in front of the HOH to balance the OH group.

$3\text{Ca}(\text{OH})_2(\text{s}) + 2\text{H}_3\text{PO}_4(\text{l}) \rightarrow \text{Ca}_3(\text{PO}_4)_2(\text{s}) + 6\text{HOH}(\text{l})$

Visual inspection shows that the hydrogen in H_3PO_4 and HOH is balanced. The hydrogen in the OH ion was balanced in Step 3. Check the balanced equation.

We have used only the smallest whole number coefficients. In balancing equations, you may sometimes obtain multiples of the smallest coefficients. If so, reduce the coefficients to the smallest whole numbers

possible.

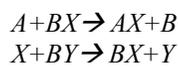
Prediction of Products

The products of a chemical reaction may often be predicted by applying known facts about common reaction types. While there are hundreds of different "kinds" of chemical reactions, only four general types of reactions will be considered; single displacement, double displacement, decomposition, and synthesis. The following sections give examples of these general types.

Single Displacement

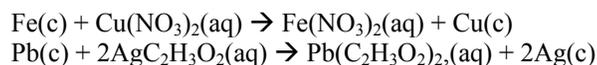
One metallic element displaces another metallic element in a compound, or a nonmetallic element displaces another nonmetallic element in a compound. A single displacement has the general form

element + compound \rightarrow element + compound

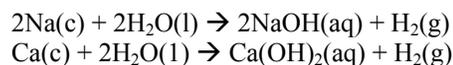


The following are some general types of single displacement reactions.

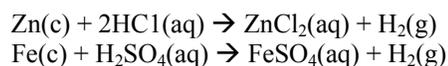
1. An active metal will displace the metallic ion in a compound of a less active metal.



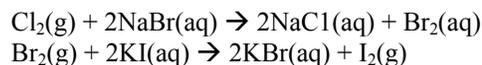
2. Some active metals such as sodium and calcium will react with water to give a metallic hydroxide and hydrogen gas.



3. Active metals such as zinc, iron, and aluminum will displace the hydrogen in acids to give a salt and hydrogen gas.



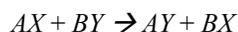
4. Halogens (which are active nonmetals) will displace less active halogens.



Double Displacement

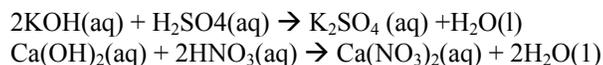
The positive and negative ions of two compounds are interchanged. The form of these reactions is easy to recognize,

compound + compound \rightarrow compound + compound

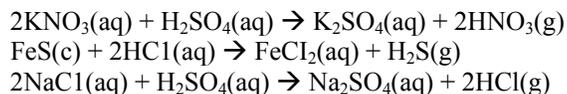


The following are some general types of double displacement reactions.

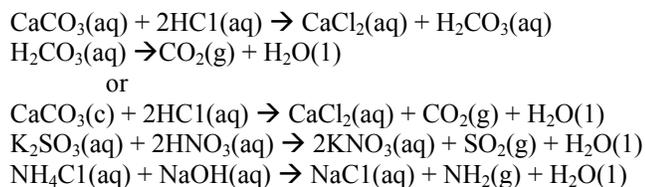
1. A reaction between an acid and a base yields a salt and water. Such a reaction is a neutralization reaction.



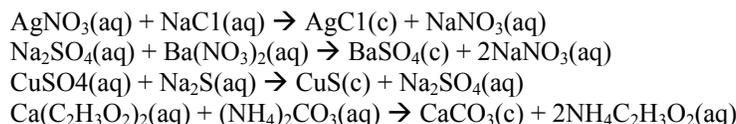
2. Reaction of a salt with an acid forms a salt of the acid and a second acid which is volatile.



2a. This same reaction of a salt with an acid or base may yield a compound which can be decomposed.



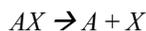
3. Reaction of some soluble salts produces an insoluble salt and a soluble salt.



Decomposition

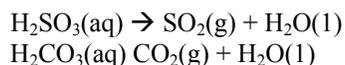
When energy in the form of heat, electricity, light, or mechanical shock is supplied, a compound may decompose to form simpler compounds and/or elements. The general form for this type of reaction is

compound \rightarrow two or more substances

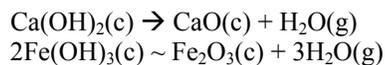


The following are some general types of decomposition reactions.

1. If some acids are heated, they decompose to form water and an acidic oxide.



2. When some metallic hydroxides are heated, they decompose to form a metallic oxide and water.



3. Some metallic carbonates decompose to form a metallic oxide and carbon dioxide when heated.



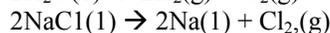
4. Metallic chlorates decompose to form metallic chlorides and oxygen when heated.



5. Most metallic oxides are stable, but a few decompose when heated.



6. Some compounds cannot be decomposed by heat, but can be decomposed into their elements by electricity.



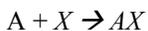
Synthesis

In a synthesis reaction two or more simple substances (compounds and/or elements) are combined to form one new and more complex substance. Here the general form is

Element + element \rightarrow compound

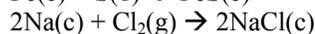
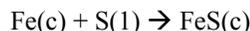
or

compound + compound \rightarrow compound

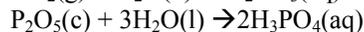
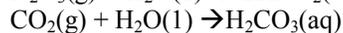
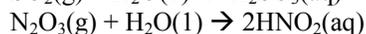
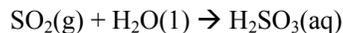


The following are some general types of synthesis reactions.

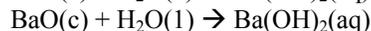
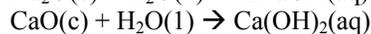
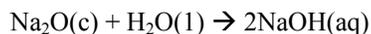
1. Combination of elements.



2. Combination of an acid anhydride with water to give an acid.



3. Combination of a basic anhydride or a metallic oxide with water to form a base.



4. Combination of the metal of a basic oxide with the nonmetal of an acidic oxide to form a salt.

