Chemical Equations

Chemical equations are the shorthand notations for chemical reactions. *Chemical reaction is the process of transforming a substance into one or more new substances* during which bonds are broken and new bonds are formed. Such situations are indicated by the chemical equations. Chemical equations, just like mathematical equations, concisely display the chemical reactions. Here you will learn how to write chemical equations and balance them.

Writing the Chemical Equation

Consider the reaction between hydrogen gas and oxygen gas to form water. The starting substances are hydrogen gas and oxygen gas, which are known as **reactants**. The end product (the new substance formed after the reaction) is water, which is known as a **product.** To write the chemical equation, first you write the symbols for reactants, then arrow, followed by the symbols for products:

$H_2 + O_2$ → H_2O
Reactants   →   products

where the "plus" (+) indicates combination or reacting with. The arrow (→) indicates the direction of the reaction or "to yield". This equation is **unbalanced equation** because the number of atoms of each kind on both sides is not the same. However, the *law of conservation mass s*ays that the mass is conserved, meaning, the mass of the recants must be equal to the mass of the products. Therefore, making the unbalanced equation to obey the law of conservation of mass is known as **balancing.** However, the balancing is **trial and error** method, meaning, if something does not work out, go back and try again. If that does not work out, go back and try again, and so on, until you get it right!
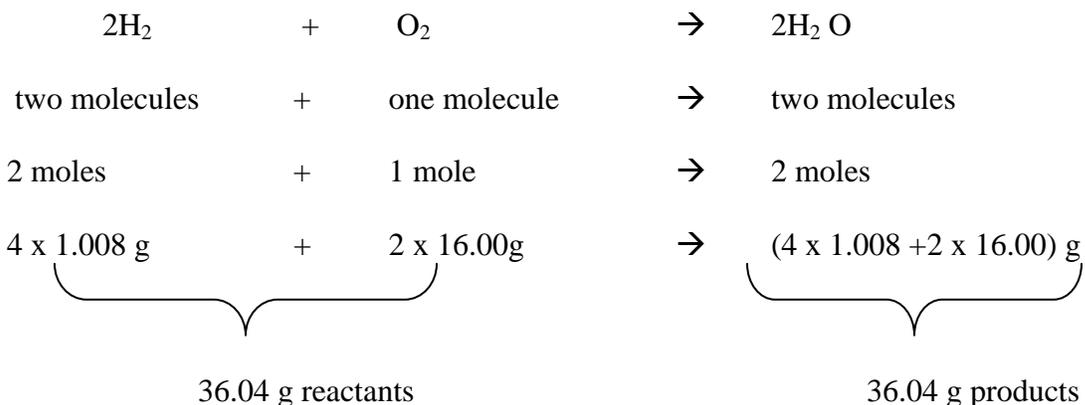
Balancing the Chemical Equation

Balancing the chemical equation also means making the total number of atoms of each kind equal to one another on both sides (reactants-side and products-side) of the equation. Examining the above equation reveals that there two H atoms on the left side and two H atoms on the right side. In terms of H atoms, the equation is balanced. However, there are two O atoms on the left side and there is only one on the right side, which needs to be balanced. To make two O atoms on the right side, you need to add 2 in front of H_2O as a prefix.

$H_2 +$ O_2 → $2H_2O$

Now the O atoms are balanced but the H atoms are not (2 H atoms on the left side and 4 H atoms on the right side). To balance the H atoms, add 2 in front of H_2.

$2H_2 +$ O_2 → $2H_2O$
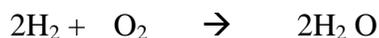
This is known as the **balanced chemical equation** that states that 2 hydrogen gas molecules combine with one oxygen gas molecule to produce two water molecules. It also means that 2 moles of hydrogen gas are combined with 1 mole of oxygen gas to produce 2 moles of water. Yet, there is another way of interpreting this equation in terms of masses; 4.04 g of hydrogen combines with 32.00 g of oxygen to produce 36.04 g of water. These three ways of interpreting the balanced chemical equation is shown below:

$2H_2$	$+$	O_2	$\rightarrow$	$2H_2O$
two molecules	$+$	one molecule	$\rightarrow$	two molecules
2 moles	$+$	1 mole	$\rightarrow$	2 moles
4 x 1.008 g	$+$	2 x 16.00g	$\rightarrow$	(4 x 1.008 +2 x 16.00) g

36.04 g reactants   36.04 g products

As you can see that 36.04 g reactants are converted into 36.04 g of products is in accordance with the law of conservation of mass.

Check:

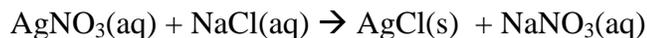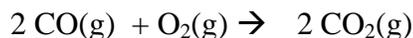Atoms of each kind must be equal to one another on both sides.

Reactants		Products	
H	4	H	4
O	2	O	2

When writing the chemical equation, it is also necessary to indicate the physical states of reactants and products using the abbreviations shown below.

g   gas
l   liquid
s   solid
aq   aqueous (water solution)

The following few examples are written incorporating these abbreviations.

$$2\,CO(g) + O_2(g) \rightarrow 2\,CO_2(g)$$

$$2\,HgO(s) \rightarrow 2Hg(l) + O_2(g)$$

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

Let us consider few more examples. One of the ways of preparing the oxygen gas in the laboratory is by heating the potassium chlorate ($KClO_3$). The products are solid potassium chloride (KCl) and the oxygen gas (O_2). Now we can write the chemical equation based on this information noting that $KClO_3$ is the reactant and KCl and O_2 are the products. Thus,

$$KClO_3(s) \rightarrow KCl(s) + O_2(g)$$

You can see that this equation is not balanced. To balance this equation, first we examine each atom on both sides:

1 K is on left side and 1 K on the right side
1 Cl is on the left side and 1 Cl is on right side
3 O on the left side and 2 O on the right side

As you can see the equation is not balanced in terms of O atoms. To make the O atoms equal on both sides, you need to put 2 in front of $KClO_3$ and 3 in front of O_2,

$$2KClO_3(s) \rightarrow KCl(s) + 3 O_2(g)$$

Now the equation is balanced in terms of O atoms but not in terms of K and Cl atoms. To balance these atoms, put 2 in front of KCl,

$$2KClO_3(s) \rightarrow 2 KCl(s) + 3O_2(g)$$

Now the equation is balanced in terms of all atoms.

Check:

Reactants		Products	
K	2	K	2
Cl	2	Cl	2
O	6	O	6

The second example would be the combustion (combustion means rapid burning) of octane (C_8H_{18}) in your car engine. When you burn the octane in your engine, it combines with oxygen from the air and yields carbon dioxide gas (CO_2) and water (H_2O), which are discharged in the air through exhaust system. The unbalanced chemical equation for this chemical process is,

$$C_8H_{18} + O_2 \rightarrow CO_2 + H_2O$$
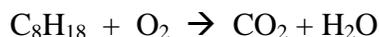
Examination of the equation on both sides reveals that the number of atoms of each kind is not the same:

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8 C on the left side and 1 C on the right side
18 H on the left side and 2 H on the right side
2 O on the left side and 3 O (2 from CO_2 and 1 from H_2O) on the right side

The most important thing to remember is that when you start balancing, always start with more complex molecule and leave the simple molecules at the end. In this equation, the more complex molecule is $C_8H_{18.}$ So, you start balancing C and H on the other side by placing 8 in front of CO_2 and 9 in front of H_2O.

$$C_8H_{18} + O_2 \rightarrow 8\ CO_2 + 9\ H_2O$$

Now the C and H are balanced, but the O atoms are not balanced. The O atoms on the left side come from only one source, i.e., O_2 while they come from two different sources (CO_2 and H_2O) on the right side. There are 2 O atoms on the left side and 25 O (16 O from $8CO_2$ and 9 O from $9H_2O$) on the left side. The easiest way to balance the O atoms is to place 25/2 in front of O_2 on the left side because 25/2 O_2 molecules is equivalent to 25 O atoms due to the fact that O_2 is diatomic molecule and produces two O atoms upon dissociation($O_2 \rightarrow 2O$). Now the equation looks like,

$$C_8H_{18} + 25/2\ O_2 \rightarrow 8\ CO_2 + 9\ H_2O$$
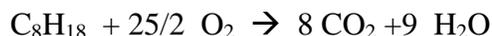
This is the balanced equation, nothing wrong with that except the fraction front of O_2. It is a common practice to express the coefficients (prefixes) in whole numbers rather than fractions. Therefore, the entire equation is multiplied by 2 to eliminate the fraction in front of O_2.

$$2\ (C_8H_{18} + 25/2\ O_2 \rightarrow 8\ CO_2 + 9\ H_2O)$$

or $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$
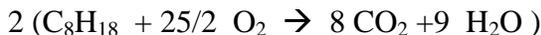
Check:

Reactants		Products	
C	16	C	16
H	36	H	36
O	50	O	50 (32 from CO_2 + 18 from H_2O)

Now the last equation is perfectly balanced with coefficients in smallest set of whole numbers as they should be.