5.3: Balancing Chemical Equations

In another example of a chemical reaction, sodium metal reacts with chlorine gas to form solid sodium chloride. An equation describing this process is shown below.

$$\mathbf{Na}\ (s) + \mathbf{Cl_2}\ (g) \rightarrow \mathbf{NaCl}\ (s)$$

Inspection of this equation, however, shows that, while there is one sodium atom on each side of the arrow, there are two chlorine atoms in the reactants and only one in the products. This equation is **not balanced**, and is therefore *not* a valid chemical equation. In order to balance this equation, we must insert **coefficients** (not *subscripts*) in front of the appropriate reactants or products so that *the same number and types of atoms appear on both sides of the equation.* Because chlorine is diatomic, there are two chlorines in the reactants and there must also be two chlorines in the products. In order to accomplish this, we place the coefficient "2" in front of the product, NaCl. Now we are balanced for chlorine, but there are two atoms of sodium in the products and only one shown in the reactants. To resolve this, we need to place the coefficient "2" in front of the sodium in the reactant, to give the equation shown below.

$$\mathbf{2\ Na}\ (s) + \mathbf{Cl_2}(g) \rightarrow \mathbf{2\ NaCl}\ (s)$$

In this equation, there are two sodiums in the reactants, two sodiums in the products, two chlorines in the reactants and two chlorines in the products; **the equation is now balanced**.

There are many different strategies that people use in order to balance chemical equations. The simplest methods, where you examine and modify coefficients in some systematic order, is generally called "balancing by inspection". These methods are generally useful for most simple chemical equations, although mathematical algorithms are often necessary for highly complex reactions. One version of the "inspection" method that we will use in this section can be called the "**odd-even**" approach. Looking at the first equation that we wrote for the sodium-chlorine reaction, we note that there are an **odd** number of chlorines in the products and an **even** number of chlorines in the reactants. The first thing we did in balancing this equation was to insert the multiplier "2" in front of the product (NaCl) so that there were now an *even* number of chlorines on both sides of the equation. Once we did that, we simply had to balance the other element (Na) which was "odd" on both sides, and the equation was easily balanced. When you are using this approach with more complicated equations, it is often useful to begin by balancing the **most complex molecule** in the equation first (the one with the most atoms), and focus on the element in this compound that is present in the **greatest amount**.

Another example where the "odd-even" approach works well is the decomposition of hydrogen peroxide to yield water and oxygen gas, as shown below.

$$\mathbf{H_2O_2}\ (aq) \rightarrow \mathbf{O_2}\ (g) + \mathbf{H_2O}\ (l)$$

As we inspect this equation, we note that there are an even number of oxygen atoms in the reactants and an odd number of oxygens in the products. Specifically, water has only one oxygen (in the products) and the number of oxygen atoms in the products can be made "even" by inserting the coefficient "2" in front of H_2O. Doing this (shown below) we note that we now have four hydrogens in the products and only two in the reactants.

$$\mathbf{H_2O_2}\ (aq) \rightarrow \mathbf{O_2}\ (g) + \mathbf{2\ H_2O}\ (l)$$

Balancing the hydrogens by inserting "2" in front of H_2O_2 in the reactants gives us an equation with four hydrogens on both sides on four oxygens on both sides; **the equation is now balanced**.

$$\mathbf{2\ H_2O_2}\ (aq) \rightarrow \mathbf{O_2}\ (g) + \mathbf{2\ H_2O}\ (l)$$

? Exercise 5.3.1

Write a **balanced chemical equation** for the reactions given below:

a. When hydrogen gas reacts is combined with oxygen gas and the mixture ignited with a spark, water is formed in a violent reaction.
b. Lead (IV) oxide reacts with HCl to give lead (II) chloride, chlorine gas and water.
c. Solid potassium chlorate decomposes on heating to form solid KCl and oxygen gas.
d. An aqueous solution of barium chloride reacts with an aqueous solution of sodium sulfate to form solid barium sulfate and a solution of sodium chloride.

e. Hydrogen reacts with nitrogen to give ammonia, according to the equation shown below; **balance this equation**.
_____H_2 *(g)* + _____N_2 *(g)* → _____NH_3 *(g)*
f. Zinc metal reacts with aqueous HCl to give hydrogen gas and zinc chloride, according to the equation shown below; **balance this equation**.
_____Zn *(s)* + _____HCl *(aq)* → _____H_2 *(g)* + _____$ZnCl_2$ *(aq)*
g. Iron(III) oxide reacts with chlorine gas to give iron(III) chloride and oxygen gas, according to the equation shown below; **balance this equation**.
_____Fe_2O_3 *(s)* + _____Cl_2 *(g)* → _____$FeCl_3$ *(s)* + _____O_2 *(g)*
h. Sodium metal reacts with ammonia to give sodium amide and hydrogen gas, according to the equation shown below; **balance this equation**.
_____Na *(s)* + _____NH_3 *(l)* → _____H_2 *(g)* + _____$NaNH_2$ *(s)*
i. Ethane reacts with oxygen gas to give carbon dioxide and water vapor, according to the equation shown below; **balance this equation**.
_____C_2H_6 *(g)* + _____O_2 *(g)* → _____CO_2 *(g)* + _____H_2O *(g)*