Chemical Equations

Skills to Develop

- Write and interpret chemical equations

Chemical equations are a way to show what happens in a chemical reaction. A chemical equation looks something like this:

$$A \rightarrow B \tag{1}$$

In this case, A represents a reactant or reagent, and B represents a product. Usually one element doesn't turn into another element, so A and B might represent different molecules that are too complicated to just write the formulas. There might also be multiple reactants and products, like this:

$$A + B \rightarrow C + D \tag{2}$$

In this class, we will mostly study reactions of simple molecules, so we will use their formulas in equations, like this:

$$Cl_2 + Mg \rightarrow MgCl_2 \tag{3}$$

Often, we might want to show the state of the reactants and products, so we can use (g, l, s, or aq) to show if it is a gas, liquid, solid, or in a water solution (solutions in water are called **aqueous** solutions). For the example above, this becomes, assuming we do the reaction dry

$$Cl_2(g) + Mg(s) \rightarrow MgCl_2(s) \tag{4}$$

Notice that the numbers showing how many atoms of each element are in the formula go after the element, as a subscript $_{\text{like this}}$. When we write chemical equations, usually we want them to be **balanced equations**, which means that they have the same number of each kind of particle on each side of the equation. Here's an example of an unbalanced equation:

$$Br_2(l) + Na(s) \rightarrow NaBr(s) \tag{5}$$

In this example, there are 2 bromine atoms on the left, and only 1 on the right. We always have to balance the number of each type of nucleus on each side, like this:

$$Br_2(l) + 2Na(s) \rightarrow 2NaBr(s) \$\$ OR like this: \$\$ \frac{1}{2}Br_2(l) + Na(s) \rightarrow NaBr(s) \tag{6}$$

Notice that we have put the number of sodium atoms needed for the reaction in front of the symbol for sodium, and not in a $_{\text{subscript}}$ after the symbol. This is called a **coefficient**, and it is different because it tells us how many of a molecule we need, not how many atoms are in the molecule, like this:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \tag{7}$$

We also have to balance the number of electrons on each side. The easiest way to do this is usually to make sure the charges on both sides add up to the same number. For example, here's an equation that isn't balanced for electrons, even though it is balanced for nuclei:

$$Mg(s) + Ag^+(aq) \rightarrow Mg^{2+}(aq) + Ag(s) \tag{8}$$

To balance this equation we have to make both the charges and the nuclei balanced, like this:

$$Mg(s) + 2Ag^+(aq) \rightarrow Mg^{2+}(aq) + 2Ag(s) \tag{9}$$

Equations Need to Represent What's Actually Happening in a Reaction

This means that the number of each type of particle must be the same on both sides of the equation, because particles (nuclei or electrons) can't appear or disappear (except under special circumstances, which we call nuclear chemistry, so don't worry about that right now). This is why equations need to be balanced.

The second important thing is that the formulas in the equation need to match the actual molecules that are used or produced in the reaction. So if you are given the formulas, and you change them instead of changing the coefficients when you balance the equations, the equation and the reaction it represents has changed! You can't do this. On the other hand, if you are trying to write a chemical equation but you aren't sure what the formulas are, you can definitely use balancing to help you decide, and in this case you could change the formulas and the coefficients, as long as the formulas you use match all the information you have.

Balancing Equations to Avoid Mistakes

Here's an example of how balancing equations can help you avoid mistakes, based on some wrong answers my students gave on an exam last year. The question was, what reaction happens between calcium ions and carbonic acid in the ocean (a water solution)? To answer this, we have to translate it into formulas. Calcium ions: this is an alkaline earth metal, so Ca^{2+}. Carbonic acid is H_2CO_3. Carbonic acid will dissociate a little bit, making some hydrogen ion (H^+), some bicarbonate ion (HCO_3^-), and some carbonate ion (CO_3^{2-}). Calcium carbonate is insoluble, so it will form a solid, ionic material. You could write the reaction like this:

$$Ca^{2+}(aq) + H_2CO_3(aq) \rightarrow CaCO_3(s) + 2H^+(aq) \tag{10}$$

This equation is balanced. What if you wrote it like this?

$$Ca^{2+}(aq) + H_2CO_3(aq) \rightarrow CaCO_3(s) + H_2(aq) \tag{11}$$

Now it isn't balanced, because the charge on the left side is 2+ and the charge on the right side is 0. This means that there are 2 more electrons on the right than on the left, which is a problem! They can't come from nowhere, so this isn't a complete equation: we are missing the source of the electrons. The mistake may have been confusing $2H^+$ with H_2 (the difference between 2 before H and 2 after H is important!), or it might have been confusing Ca^{2+} with Ca metal. For instance, this reaction is fine:

$$Ca(s) + H_2CO_3(aq) \rightarrow CaCO_3(s) + H_2(aq) \tag{12}$$

However, in the context of the question, it would be very surprising to have Ca(s) in the ocean, because alkaline earth metals, like alkali metals, react with water. So we have lots of Ca^{2+}, Mg^{2+}, and Na^+ ions in the ocean, but no atomic Ca, Mg, or Na in the ocean.

Outside Links

- Khan Academy: Balancing Chemical Equations (14 min)
- CrashCourse Chemistry: Stoichiometry (13 min)

Contributors and Attributions

- Emily V Eames (City College of San Francisco)