Representing Chemical Reactions

If there's one thing you've learned from your general chemistry courses, it's that you're surrounded by chemistry every day. However, this world isn't static. Things aren't fixed, and your environment- made of chemistry- changes and fluctuates all the time as well. As a result of this, you're not just surrounded by chemistry; you're surrounded by chemical reactions!

But let's start from the beginning. What are chemical reactions, and how can we represent them? You may already know that there are a whole bunch of signs that indicate that a chemical reaction is taking place. But how would we write on a piece of paper the transformation that is taking place? And how do chemists convey this information to the general public and each other in a way that's easy to digest and understandable?

Overview

- In this lesson, we'll cover the basic **structure of chemical reactions**.
- Then, we'll show you a **visual representation** of chemical reactions to try to help comprehension.
- Next, we'll show the **written short representation** of chemical reactions, which uses symbols such as letters to represent elements and molecules, and arrows to represent reaction direction.
- Finally, we'll discuss the **different types** of chemical reactions, and how these are written.

Structure of Chemical Reactions

Let's start with the basics. What is a chemical reaction, and what are the components of one? You've probably seen what you think might be reactions, such as ice melting into water, or condensation on your glass. These are physical reactions as opposed to chemical reactions, as it deals with one substance staying the same. In these examples, that substance is water. From this, there is an implied basic definition for chemical reactions.

Definition

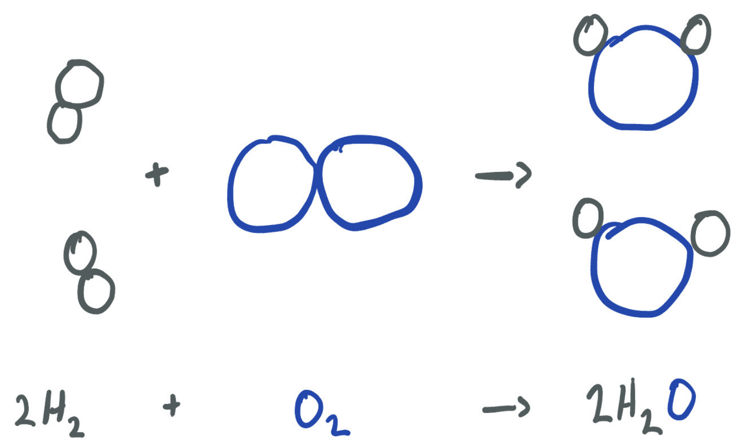
A chemical reaction is any transformation that involves changing one (or more) substances into different substances.

This "substance change" is done through the rearrangement of atomic bonds within molecules. If we imagine a chemical reaction taking place, the original substance(s) we start with are the **reactants**, and the substance(s) we end up with after the reaction are the **products**.

Let's try to think about this in an example that doesn't involve chemicals. Did you know that it's my hedgehog Gideon's birthday? If you and I wanted to make Gideon a nice cake, what ingredients would we need? For starters, we'd probably need flour, salt, butter, sugar, and water. These are our reactants for our "cake reaction." The product, of course, would be the cake. We'll show you how to write this down in a more compact notation, but for now, let's try to visualize what a chemical reaction might look like at the atomic level.

Visual Representation of Chemical Reactions

Let's try to visualize what's going on at the atomic level. Let's talk about water like we did before. You've probably heard that water is H_2O. What does that mean though? It means that the molecule water consists of 2 atoms of hydrogen and 1 atom of oxygen. To visualize a reaction, however, imagine 2 molecules of hydrogen gas (with the formula H_2) and one molecule of oxygen gas (with the formula O_2). How would we make water from this?



Drawn visual representation of hydrogen and oxygen reacting to make water.

Above, we see our visualized white hydrogen gas molecules, and our blue oxygen molecule. Notice how these combine to create water, which can be considered a different substance because the atomic bonds between each respective hydrogen and oxygen molecule have broken and recombined to create water molecules. To reiterate, the reactants in this reaction would be the two hydrogen gas molecules as well as the single oxygen gas molecule. The products of this reaction would be the newly formed water molecules.

This should make sense on an intuitive level, however, if chemists had to draw out chemical reactions in this manner... it would take forever. This is where the written symbolic notation for chemical reactions comes into play.

Short Representation of Chemical Reactions

Let's go back to our example in the Structure of Chemical Reactions section of this lesson. I want to make my pet Gideon that cake, but because you're new to making chemistry birthday cakes, I need to go over the reaction with you again. No worries! If I wanted to quickly convey to you the reactants and products of our "cake reaction," I could write something like this.

Flour + Salt + Butter + Sugar + Water → Birthday Cake

In this notation, we see that each reactant is on the left side of the arrow, and is separated by a plus sign. Our arrow represents a chemical reaction, and our product is on the right side of the arrow. So, if we wanted to verbally communicate what we joke wrote, we could say that "flour, salt, butter, sugar, and water react to yield a birthday cake."

Now, let's move our attention from a birthday cake to our water reaction example that we covered in the Visual Representation section. If we wanted to quickly write the reaction that we drew out, how would we do that? Let's take an approach opposite to the birthday cake reaction. We know that "two hydrogen gas molecules and one oxygen gas molecule react to yield two water molecules." How do you think we'd write this out symbolically?

$$2H_2 + O_2 \rightarrow 2H_2O$$

This written formula represents the reaction we just drew. At this point, you might want to refer back to the visual representation if you're having trouble understanding the connection. Two of our H_2 (hydrogen gas) molecules and one of our O_2 (oxygen gas) molecules react to form two H_2O (water) molecules.

The **subscripts** in each molecule are the little numbers to the right of each letter, and they convey how many of each atom are in each molecule. This means that in O_2, there are two oxygen atoms. We can confirm that this is true by referring back to our visual representation.

The big number to the left of each letter is called the **coefficient**, and it tells us the number of molecules that we have. $2H_2$, therefore, means that we have two molecules of H_2, each of which contains two hydrogen atoms bonded to each other. Once more, checking with our visual confirms this. Let's try one more example:

> Example
>
> Question 1: Try to write this reaction symbolically: "One molecule of hydrogen gas (H_2) and one molecule of chlorine gas (Cl_2) react to make two molecules of hydrogen chloride gas (HCl)."

Now that we've established how to visualize these reactions symbolically, let's talk about the different types of chemical reactions.

Types of Chemical Reactions

Broadly speaking, there are five different types of chemical reactions. Chemical reactions can be broken down into five categories: combination, decomposition, single-replacement, double-replacement, and combustion. For each of these reactions, we will use four imaginary different molecules: A, B, C, and D.

Combination and Decomposition Reactions

Combination and Decomposition reactions are opposite reaction types. In **Combination reactions**, multiple reactants form to combine a single product. For example, the example reaction we covered earlier in the Short Representation section where hydrogen molecules and chlorine molecules react to make hydrogen chloride gas is a combination reaction. The general form for Combination reactions is as follows:

$$A + B \rightarrow AB$$

Decomposition reactions are the opposite of that: one reactant breaks down to form multiple simple substances. The general form for Decomposition reactions looks like this:

$$AB \rightarrow A + B$$

To practice your understanding, discern if the reaction below is a Combination or a Decomposition reaction. (The answer is at the end of the lesson.)

> Example
>
> Question 2: $H_2CO_3 \rightarrow CO_2 + H_2O$

Single-Replacement and Double-Replacement Reactions

Single-Replacement and Double-Replacement reactions both involve replacing a reactant that is made up of different components. To visualize this, let's start with the general form of a **Single-Replacement** reaction, by which a single element is swapped with a similar element.

$$A + BC \rightarrow AC + B$$

Double-Replacement reactions do the same thing but happen twice over. This means that two elements are swapped with similar elements. Be careful to keep track of what is moving where!

$$AB + CD \rightarrow AD + CB$$

To see if you understand this concept, label the reaction below as a Single or Double-Replacement reaction. (Like Question 1, the answer is also at the end of the lesson.)

> Example
>
> Question 3: $K + NaCl \rightarrow KCl + Na$

Combustion Reactions

Lastly, we have the **Combustion** reaction, where oxygen gas is a reactant, and energy (in the form of heat and light) is a product. As long as a reaction has these two requirements, it can be considered a Combustion reaction.

$$2H_2 + O_2 \rightarrow 2H_2O$$

For example, the water reaction we covered earlier in the Short Representation section where hydrogen molecules and oxygen molecules react to make water is a combination reaction.

Hopefully, you now have a grasp of the structure and types of chemical reactions. With this knowledge, you'll be able to build a wonderful understanding of the transformations taking place in the world all around you. Now, if you excuse me, I have Gideon's birthday cake to finish baking.

Answers to the two example problems:
Question 1: $H_2 + Cl_2 \rightarrow 2HCl$
Question 2: Decomposition
Question 3: Single-Replacement

Representing Chemical Reactions - Key takeaways

- In this lesson, we covered the basic structure of chemical reactions.
- After that, we showed you a visual representation of chemical reactions.
- Next, we showed you the written short representation of chemical reactions, which uses symbols and arrows to show elements, molecules, and reaction direction.
- Finally, we went over the different types of chemical reactions, and how these are written as well.