Reversible and irreversible reactions are both chemical reactions that describe a plethora of reactions in life. Many of these reactions are responsible for events that occur daily, such as the breakdown of ammonia.

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Introduction

The world believed that all chemical reactions were irreversible until 1803 when French chemist Claude Louis Berthollet introduced the concept of reversible reactions. In the beginning, he only knew that sodium carbonate and calcium chloride reacted to yield calcium carbonate and sodium chloride. But after observing that sodium carbonate was formed around the edges of salt lakes, he realized that large amount of salts in the evaporating water reacted with calcium carbonate to form sodium carbonate, which meant that the reverse of the reaction occurred.

Chemical reactions are represented by chemical equations. These chemical equations typically have a unidirectional arrow (→) to represent irreversible reactions. Other chemical equations may have an equilibrium arrow (⇌) that represents reversible reactions.

Irreversible Reactions

As children, we learned that chemical reactions occurred when reactants reacted with each other to form products. These unidirectional reactions are known as irreversible reactions. In other words, irreversible reactions are reactions where the reactants convert to products and where the products cannot convert back to the reactants. These reactions are essentially like baking. The ingredients, acting as the reactants, are mixed and baked together to form a cake, which acts as the product. This cake cannot be converted back to the reactants (the eggs, flour, etc.), just as the products in an irreversible reaction cannot change into the products.

As stated above, a cake cannot be "uncooked" and so the reaction is irreversible.
A real-life example of an irreversible reaction is combustion. Combustion usually involves the burning of an organic compound, like a hydrocarbon, and oxygen to produce carbon dioxide and water. Since water is stable in its polyatomic state, like below, it will not react with the other product, CO$_2$, to form the reactants. Combustion can take the following form:

$$C_xH_y + O_2 \rightarrow CO_2 + H_2O$$

**Reversible Reactions**

In reversible reactions, the reactants and products are never used up. In fact, they are *both* constantly reacting and being produced. A reversible reaction can take the following summarized form:

$$A + B \rightleftharpoons C + D$$

This reversible reaction can be broken into two reactions.

Reaction 1: $$A + B \rightarrow C + D$$

Reaction 2: $$C + D \rightarrow A + B$$

These two reactions are occurring *simultaneously*, which means that the *reactants* are reacting to yield the *products*, as the *products* are reacting to produce the *reactants*. Collisions of the reacting molecules cause chemical reactions in a closed system. After products are formed, the bonds between these products are broken because the molecules collide with each other, producing sufficient energy needed to break the bonds of the product and reactant molecules.

Below is an example of the summarized form of a reversible reaction and a breakdown of the reversible reaction N$_2$O$_4 \rightleftharpoons 2$NO$_2$

Reaction 1 and Reaction 2 happen at the same time because they are in a closed system.

*Blue:* Nitrogen    *Red:* Oxygen
Imagine a ballroom. Let reactant A be 10 girls and reactant B be 10 boys. As each girl and boy goes to the dance floor, they pair up to become a product. Once five girls and five boys are on the dance floor, one of the five pairs breaks up and moves to the sidelines, becoming reactants again. As this pair leaves the dance floor, another boy and girl on the sidelines pair up to form a product once more. This process continues over and over again, representing a reversible reaction.

Unlike irreversible reactions, reversible reactions lead to equilibrium because reversible reactions have the reaction proceeding in both directions while irreversible reactions only have the reaction proceeding in one direction.

If the reactants are being made at the same rate as the products are being made, a dynamic equilibrium exists. For example, if a water tank is being filled with water at
the same rate as water is leaving the tank (through a hypothetical hole), the amount of water remaining in the tank remains consistent.

**Connection to Biology**

How Hemoglobin circulation is related to reversible reactions: There are four binding sites on a hemoglobin molecule. Hemoglobin molecules can either bind to carbon dioxide or oxygen. As your blood travels through the alveoli of your lungs, hemoglobin molecules picks up oxygen-rich molecules and binds to the oxygen. As the hemoglobin travels through the rest of the body, it drops off oxygen at the capillaries for the organ system to use oxygen. After expelling the oxygen, it picks up carbon dioxide. Since this process is constantly carried out through the body, there are always hemoglobin molecules that are picking or expelling oxygen and other hemoglobin molecules that are picking up or expelling carbon dioxide. Therefore, the hemoglobin molecules, oxygen, and carbon dioxide are reactants while the hemoglobin molecules with oxygen or carbon dioxide bound to them are the products. In this closed system, some reactants convert into products as some products are changing into reactants, making it like a reversible reaction.

**References**


**Outside Links**

- Reversible Reactions - Wikipedia
- Reversible Reaction between ethylene and distannyne - Youtube
  - [http://www.youtube.com/watch?v=hOEbSpU0h3I](http://www.youtube.com/watch?v=hOEbSpU0h3I)

**Problems**

1. What is the key difference between reversible and irreversible reactions?
2. Why is combustion an example of an irreversible reaction?
3. How can a reversible reaction occur?
4. Is the following hypothetical reaction reversible?
   A + B → C
5. Why can't irreversible reactions lead to equilibrium?

**Solutions**

1. In a irreversible reaction, the reactants react to form the products, which cannot revert back into reactants. In reversible reactions, as the reactants react with
other reactants to form products, the products are reacting with other products to form reactants.

2. Combustion cannot be undone.

3. When the reactant molecules are placed in a closed environment, the reactant molecules will collide with each other, producing energy that can break the bonds between reactant and product molecules. Breaking such bonds will allow the products to become reactants and the reactants to become products.

4. No, it is not reversible, as indicated by the unidirectional arrow.

5. Irreversible reactions only proceed in one direction, so the reaction can never be at equilibrium.

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