Reactions

A chemical reaction is a process that leads to the transformation of one set of chemical substances to another. Classically, chemical reactions encompass changes that only involve the positions of electrons in the forming and breaking of chemical bonds between atoms, with no change to the nuclei (no change to the elements present), and can often be described by a chemical equation.

Chemical equation

A chemical equation is the symbolic representation of a chemical reaction in the form of symbols and formulae, wherein the reactant entities are given on the left-hand side and the product entities on the right-hand side.

Suppose two reactants A in solid form and B in liquid form reacts to form C in liquid form and D in gaseous form. This reaction can be showed as below

$$A_{(S)} + B_{(L)} \rightarrow C_{(L)} + D_{(G)}$$

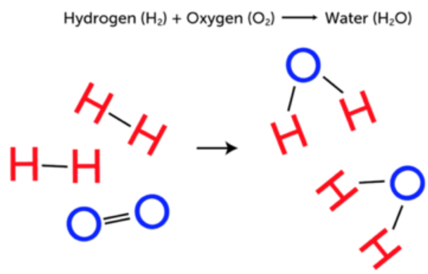
For chemical equations the state symbols are written in subscript next to the chemical involved. It is very much important to write the state symbol as it helps us understand the reaction better.

Another important aspect of chemical equations is that they have to be balanced in both the side. For any reactions mass and charge has to be balanced (same) on both left hand side and right hand side.

What happens in a chemical reaction

The reactants and products in a chemical reaction contain the same atoms, but they are rearranged during the reaction. As a result, the atoms are in different combinations in the products than they were in the reactants. This happens because chemical bonds break in the reactants and new chemical bonds form in the products.

Consider the chemical reaction in which water forms from oxygen and hydrogen gases. The Figure below represents this reaction. Bonds break in molecules of hydrogen and oxygen, and then new bonds form in molecules of water. In both reactants and products there are four hydrogen atoms and two oxygen atoms, but the atoms are combined differently in water.



Types of reactions

Type of Reaction	General Equation	Example
Synthesis (Addition)	A+B ⟶ C	$2Na + Cl_2 \rightarrow 2NaCl$
Decomposition	AB ⟶ A + B	$2H_2O \rightarrow 2H_2 + O_2$
Single Replacement (Displacement)	A+BC ⟶ B+ AC	$2K + 2H_2O \rightarrow 2KOH + H_2$
Double Replacement (Double decomposition)	AB+ CD ⟶ AD + CB	NaCl+ AgF⟶NaF + AgCl
Combustion	fuel + oxygen ⟶ carbon dioxide + water	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

For any chemical reactions there are some considerations we need to take care of. Some of the common considerations include:

- What is the energy change in a reaction?
- What is the limiting the reaction?
- How much energy we need to provide to start a reaction?
- How fast the reaction is happening?
- How to improve the reactions?

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Limiting reactants

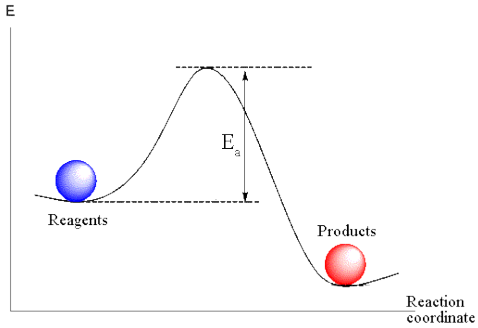
For any reaction the reactant that gets used up first is known as the limiting reactant. The reactant that does not get all used up is known as excess reactant.

10,000,000 Na + 1 Cl --> NaCl + 9,999,999 Na

In the reaction above 10,000,000 Na and 1 Cl so here Cl is the limiting reactant so when reaction occurs only 1 Na is reacted and rest 9,999,999 Na stays as it is.

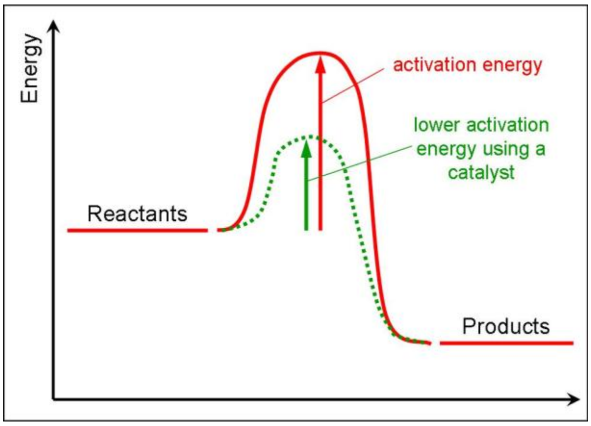
Activation energy

For any reaction to occur initially we need to provide some energy to the reaction. This energy is known as the activation energy. In the diagram (Below left) energy E_a is the activation energy.



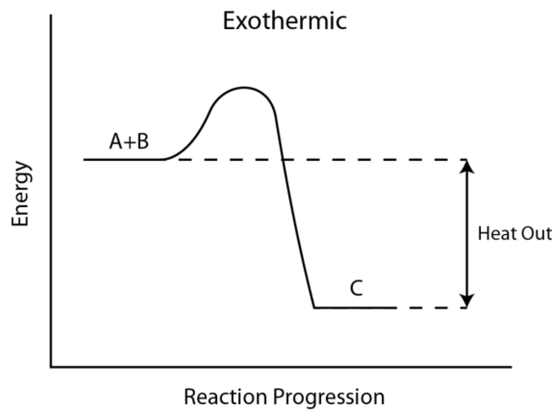
Catalyst

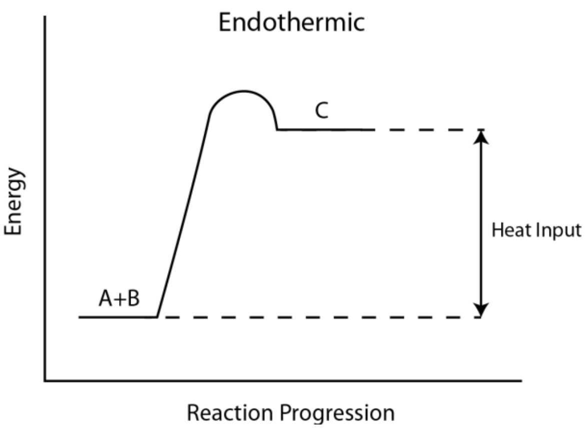
A catalyst is a substance that speeds up a chemical reaction, but is not consumed by the reaction; hence a catalyst can be recovered chemically unchanged at the end of the reaction it has been used to speed up, or catalyze. The diagram right show a reaction without catalyst requires more activation energy but as catalyst is used the activation energy requirement is less.



Heat of Reaction (Enthalpy)

Breaking molecular bonds releases energy stored in those bonds. The energy is released in the form of heat. Similarly, forming new bonds requires an input of energy. Therefore, a chemical reaction will either absorb or give off heat, depending on how many and what kind of bonds are broken and made as a result of that reaction. A reaction that absorbs energy is called **endothermic**. A container in which an endothermic reaction takes place gets cold, because the heat of the container is absorbed by the reaction. A reaction that gives off energy is called **exothermic**. Burning gasoline is an exothermic reaction—it gives off energy





So if a reaction is exothermic after reaction the vessel in which reaction occurs will be hot as energy is released to the system and for endothermic it will be cold and energy is taken into the reaction.

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Increase in Disorder (Entropy)

Disorder, or entropy, is the lack of regularity in a system. The more disordered a system, the larger its entropy. Disorder is much easier to come by than order. Sometimes, arrangement and order can be achieved. Atoms and molecules in solids, such as snowflakes, have very regular, ordered arrangements. But given enough time (and temperature), the snow melts, forming less ordered liquid water. So, although reactions that lead to a more ordered state are possible, the reactions that lead to disorder are more likely. The overall effect is that the disorder in the universe keeps increasing.

Rates of reactions

The rate of a reaction is the speed at which a chemical reaction happens. If a reaction has a low rate, that means the molecules combine at a slower speed than a reaction with a high rate. Some reactions take hundreds, maybe even thousands, of years while others can happen in less than one second. If you want to think of a very slow reaction, think about how long it takes plants and ancient fish to become fossils (carbonization). The rate of reaction also depends on the type of molecules that are combining. If there are low concentrations of an essential element or compound, the reaction will be slower.

The **collision theory** says that as more collisions in a system occur, there will be more combinations of molecules bouncing into each other. If you have more possible combinations there is a higher chance that the molecules will complete the reaction. The reaction will happen faster which means the rate of that reaction will increase.

Factors affecting rate of a reaction

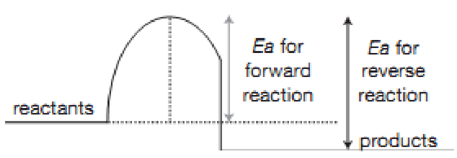
Temperature: When you raise the temperature of a system, the molecules bounce around a lot more. They have more energy. When they bounce around more, they are more likely to collide. That fact means they are also more likely to combine. When you lower the temperature, the molecules are slower and collide less. That temperature drop lowers the rate of the reaction.

Concentration: If there is more of a substance in a system, there is a greater chance that molecules will collide and speed up the rate of the reaction. When you want the rate of reaction to be slower, you will add only a few drops at a time instead of the entire beaker.

Pressure: Pressure affects the rate of reaction, especially when you look at gases. When you increase the pressure, the molecules have less space in which they can move. That greater density of molecules increases the number of collisions. When you decrease the pressure, molecules don't hit each other as often and the rate of reaction decreases.

Reversible and Irreversible Reactions

Some reactions can proceed in both directions—reactants can form products, which can turn back into reactants. These reactions are called reversible. Other reactions are irreversible, meaning that reactants can form products, but once the products form; they cannot be turned back into reactants. While wood can burn (react with oxygen) to produce heat, water, and carbon dioxide, these products are unable to react to form wood. You can better understand reversibility if you look at the Activation energy diagram discussed earlier. The hill that needs to be crossed by reactants to form products is much lower than the hill that needs to be crossed by products to form reactants. Most likely, such a reaction will be irreversible. Now look at the diagram below. The hill that needs to be crossed is almost the same for reactants and for products, so the crossing could take place from both sides—the reaction would be reversible.



The activation energies (Ea) for the forward reaction (reactants forming products) and for the reverse reaction (products forming reactants) are about the same. Such a reaction is reversible.

If a reaction is reversible it will form a chemical equilibrium where there will be both the reactant and the product present.

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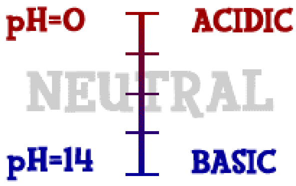
Acids and Bases Are Everywhere

Every liquid you see will probably have either **acidic** or **basic** traits. Water (H_2O) can be both an acid and a base, depending on how you look at it. It can be considered an acid in some reactions and a base in others. Water can even react with itself to form acids and bases. It happens in really small amounts, so it won't change your experiments at all. It goes like this:

$$2H_2O \rightarrow H_2O + H^+ + OH^- \rightarrow H_3O^+ + OH^-$$

Most of the time, the positive and negative ions in distilled water are in equal amounts and cancel each other out. Most water you drink from the tap has other ions in it. Those special ions in solution make something acidic or basic. In your body there are small compounds called amino acids. The name tells you those are acids. In fruits there is something called citric acid. That's an acid too. But what about baking soda? When you put that in water, it creates a basic solution. Vinegar? Acid. So what makes an acid or a base? A chemist named Svante **Arrhenius** came up with a way to define acids and bases in 1887. He saw that when you put molecules into water, sometimes they break down and release an H^+ (hydrogen) ion. At other times, you find the release of an OH^- (hydroxide) ion. When a hydrogen ion is released, the solution becomes acidic. When a hydroxide ion is released, the solution becomes basic. Those two special ions determine whether you are looking at an acid or a base. For example, vinegar is also called acetic acid. (Okay, that gives away the answer.) If you look at its atoms when it's in water, you will see the molecule CH_3COOH split into CH_3COO^- and H^+. That hydrogen ion is the reason it is called an acid. Chemists use the word "**dissociated**" to describe the breakup of a compound.



Scientists use something called the **pH** scale to measure how acidic or basic a liquid is. Although there may be many types of ions in a solution, pH focuses on concentrations of hydrogen ions (H^+) and hydroxide ions (OH^-). The scale measures values from 0 all the way up to 14. Distilled water is 7 (right in the middle). Acids are found between 0 and 7. Bases are from 7 to 14. Most of the liquids you find every day have a pH near 7. They are either a little below or a little above that mark. When you start looking at the pH of chemicals, the numbers can go to the extremes. If you ever go into a chemistry lab, you could find solutions with a pH of 1 and others with a pH of 14. There are also very strong acids with pH values below 1, such as battery acid. Bases with pH values near 14 include drain cleaner and sodium hydroxide (NaOH). Those chemicals are very dangerous.

Acid: A solution that has an excess of H^+ ions. It comes from the Latin word acidus, which means "sharp" or "sour".

Base: A solution that has an excess of OH^- ions. Another word for base is alkali.

Aqueous: A solution that is mainly water. Think about the word aquarium. AQUA means water.

Strong Acid: An acid that has a very low pH (0-4).

Strong Base: A base that has a very high pH (10-14).

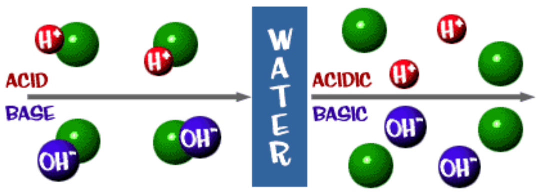
Weak Acid: An acid that only partially ionizes in an **aqueous** solution. This means that not every molecule breaks apart. Weak acids usually have a pH close to 7 (3-6).

Weak Base: A base that only partially ionizes in an aqueous solution. This means that not every molecule breaks apart. Weak bases usually have a pH close to 7 (8-10).

Neutral: A solution that has a pH of 7. It is neither acidic nor basic.

Brønsted-Lowry idea of acid and base

These two chemists from Denmark and England looked at **acids as donors and bases as acceptors**. What were they donating and accepting? Hydrogen ions. It's a lot like the first definition we gave, where an acid breaks up and releases/donates a hydrogen ion. This newer definition is a little bit more detailed. Scientists used the new definition to describe more bases, such as ammonia (NH_3). Since bases are proton acceptors, when ammonia was seen accepting an H+ and creating an ammonium ion (NH_4^+), it could be



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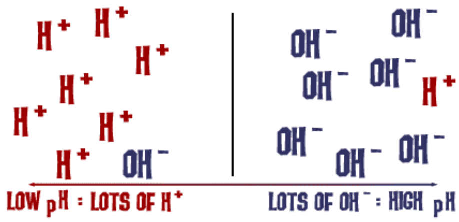
labeled as a base. You didn't have to worry about hydroxide ions anymore. If it got the H+ from a water molecule, then the water (H_2O) was the proton donor. Does that mean the water was the acid in this situation? Yes.

A chemist named **Lewis** offered a third way to look at acids and bases. Instead of looking at hydrogen ions, he looked at pairs of electrons (remember our pictures with dot structures in Atoms and Elements?). In Lewis' view, acids accept **pairs of electrons** and bases donate pairs of electrons. We know that both of these descriptions of acids and bases use completely opposite terms, but the idea is the same. Hydrogen ions still want to accept two electrons to form a bond. Bases want to give them up. Overall, Lewis' definition was able to classify even more compounds as acids or bases.

What Really Happens?

What really happens in those solutions? It gets a little tricky here. Let's look at the breakup of molecules in aqueous (water-based) solutions one more time for good measure. Acids are compounds that dissociate (break) into hydrogen (H+) ions and another compound when placed in an aqueous solution. Remember that acetic acid example? Bases are compounds that break up into hydroxide (OH^-) ions and another compound when placed in an aqueous solution.

That **pH scale** we talked about is actually a measure of the number of H^+ ions in a solution. If there are a lot of H^+ ions, the pH is very low. If there are a lot of OH^- ions compared to the number of H^+ ions, the pH is high.



Think about this idea for a second: Why would a liquid with high levels of NaOH be very basic, yet dangerous at the same time? The Na-OH bond breaks in solution and you have sodium ions (positive) and hydroxide ions (negative). The sodium ions don't really pose a danger in solution, but there are a huge number of hydroxide ions in solution compared to the hydrogen ions that might be floating around as H_3O^+ (a hydronium ion).All of those excess OH^- ions make the pH super high, and the solution will readily react with many compounds. The same thing happens on a less dangerous scale when you add baking soda to water. During the dissociation, OH^- ions and carbonic acid are released in the solution. The number of OH^- ions is greater than the number of H_3O^+ ions (H^+ and H_2O), and the pH increases. It's just not as strong a difference as in sodium hydroxide.

Acid–Base Reactions: Neutralization Reactions

When a strong acid and a strong base solution are mixed, a neutralization reaction occurs, and the products do not have characteristics of either acids or bases. Instead, a neutral salt and water are formed. Look at the reaction below:

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$$

The anion from the acid (Cl^-) reacts with the cation from the base (Na^+) to give a salt, and a **salt** is defined as any compound formed whose anion came from an acid and whose cation came from a base. When a strong acid and a weak base are mixed, the resulting salt will be acidic; likewise, if a strong base and a weak acid are mixed, the resulting salt will be basic.

Balancing Chemical reactions

As mass is conserved during a chemical reaction, chemical equation must be balanced. To balance a chemical equation, first look at the formulas and write the equation first. for reaction of formation of water hydrogen react with oxygen to form water.

$$H_2 + O_2 \rightarrow H_2O$$

Now check for a reactant to have same number of atoms. Here in the left side there is 2 oxygen but on the right side there is only one so the right side will be multiplied by 2.

$$H_2 + O_2 \rightarrow 2H_2O$$

But now the right side has 4 hydrogen atoms and left side has only 2 so hydrogen atoms on the left needs to be multiplied by 2 again

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

This is the basic method for balancing equations and this method can be used for other reactions also.

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Home Task: Balance the following reactions given

1) ____ N2 + ____ H_2 → ____ NH_3

2) ____ $KClO_3$ → ____ KCl + ____ O_2

3) ____ NaCl + ____ F_2 → ____ NaF + ____ Cl_2

4) ____ H_2 + ____ O_2 → ____ H_2O

5) ____ $Pb(OH)_2$ + ____ HCl → ____ H_2O + ____ $PbCl_2$

6) ____ $AlBr_3$ + ____ K_2SO_4 → ____ KBr + ____ $Al_2(SO_4)_3$

7) ____ CH_4 + ____ O_2 → ____ CO_2 + ____ H_2O

8) ____ C_3H_8 + ____ O_2 → ____ CO_2 + ____ H_2O

9) ____ C_8H_{18} + ____ O_2 → ____ CO_2 + ____ H_2O

10) ____ $FeCl_3$ + ____ NaOH → ____ $Fe(OH)_3$ + ____NaCl

11) ____ P + ____O_2 → ____P_2O_5

12) ____ Na + ____ H_2O → ____ NaOH + ____H_2

13) ____ Ag_2O → ____ Ag + ____O_2

14) ____ S_8 + ____O_2 → ____ SO_3

15) ____ CO_2 + ____ H_2O → ____ $C_6H_{12}O_6$ + ____O_2

16) ____ K + ____ $MgBr_2$ → ____ KBr + ____ Mg

17) ____ HCl + ____ $CaCO_3$ → ____ $CaCl_2$ + ____H_2O + ____ CO_2

18) ____ HNO_3 + ____ $NaHCO_3$ → ____ $NaNO_3$ + ____ H_2O + ____ CO_2

19) ____ H_2O + ____ O_2 → ____ H_2O_2

20) ____ NaBr + ____ CaF_2 → ____ NaF + ____ $CaBr_2$

21) ____ H_2SO_4 + ____ $NaNO_2$ → ____ HNO_2 + ____ Na_2SO_4

22) ____Fe + ____ Cl_2 → ____$FeCl_3$

23) ____Fe + O_2 → ____Fe_2O_3

For practicing more of equation balancing you can find more equations from chemistry department at California State University, Dominguez Hills here https://i.shparvez.net/ebaalance

For a broader knowledge of chemistry for GED level http://www.chem4kids.com/ is helpful.

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Balancing answers

1) $1\ N_2 + 3\ H_2 \rightarrow 2\ NH_3$

2) $2\ KClO_3 \rightarrow 2\ KCl + 3\ O_2$

3) $2\ NaCl + 1\ F_2 \rightarrow 2\ NaF + 1\ Cl_2$

4) $2\ H_2 + 1\ O_2 \rightarrow 2\ H_2O$

5) $1\ Pb(OH)_2 + 2\ HCl \rightarrow 2\ H_2O + 1\ PbCl_2$

6) $2\ AlBr_3 + 3\ K_2SO_4 \rightarrow 6\ KBr + 1\ Al_2(SO_4)_3$

7) $1\ CH_4 + 2\ O_2 \rightarrow 1\ CO_2 + 2\ H_2O$

8) $1\ C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$

9) $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$

10) $1\ FeCl_3 + 3\ NaOH \rightarrow 1\ Fe(OH)_3 + 3\ NaCl$

11) $4\ P + 5\ O_2 \rightarrow 2\ P_2O_5$

12) $2\ Na + 2\ H_2O \rightarrow 2\ NaOH + 1\ H_2$

13) $2\ Ag_2O \rightarrow 4\ Ag + 1\ O_2$

14) $1\ S_8 + 12\ O_2 \rightarrow 8\ SO_3$

15) $6\ CO_2 + 6\ H_2O \rightarrow 1\ C_6H_{12}O_6 + 6\ O_2$

16) $2\ K + 1\ MgBr_2 \rightarrow 2\ KBr + 1\ Mg$

17) $2\ HCl + 1\ CaCO_3 \rightarrow 1\ CaCl_2 + 1\ H_2O + 1\ CO_2$

18) $1\ HNO_3 + 1\ NaHCO_3 \rightarrow 1\ NaNO_3 + 1\ H_2O + 1\ CO_2$

19) $2\ H_2O + 1\ O_2 \rightarrow 2\ H_2O_2$

20) $2\ NaBr + 1\ CaF_2 \rightarrow 2\ NaF + 1\ CaBr_2$

21) $1\ H_2SO_4 + 2\ NaNO_2 \rightarrow 2\ HNO_2 + 1\ Na_2SO_4$

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