2019 Version

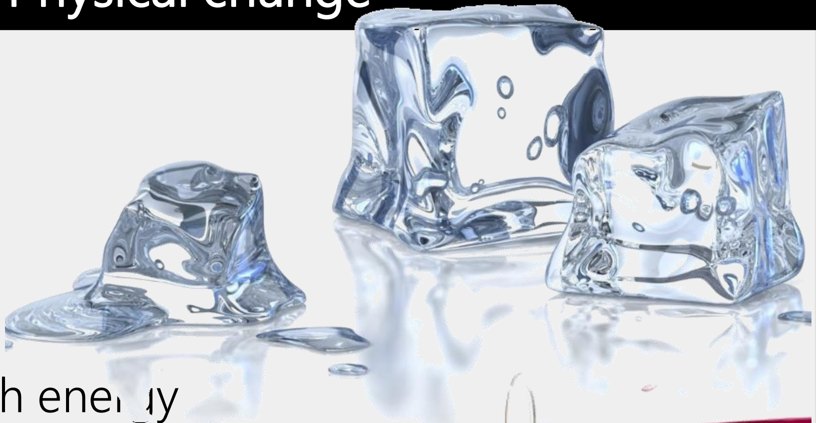
Acids, Bases and Reaction Rates

Junior Science

GZ Science Resources

Background Knowledge

Chemical and Physical change



Physical changes are concerned with energy and states of matter. A physical change <u>does not produce a new substance</u>. The starting and ending materials of a physical change are the same, even though they may look different. Changes in state (melting, freezing, vaporization, condensation, sublimation) are physical changes. Examples of physical changes include bending a piece of wire, melting icebergs, and breaking a bottle

A **chemical change** makes a substance that wasn't there before.

<u>Evidence for a chemical change </u>could be a colour change, a new smell, the chemicals get hotter or colder or a gas is produced.

Background Knowledge

Observing reactions

To observe means to record or make note of something we have experienced. We also think of observations as watching something, but in Science, observations may be made with any of our senses (by seeing, feeling, hearing, tasting, or smelling) or even using tools to make observations that are then changed into something our senses detect.

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Chemical reactions

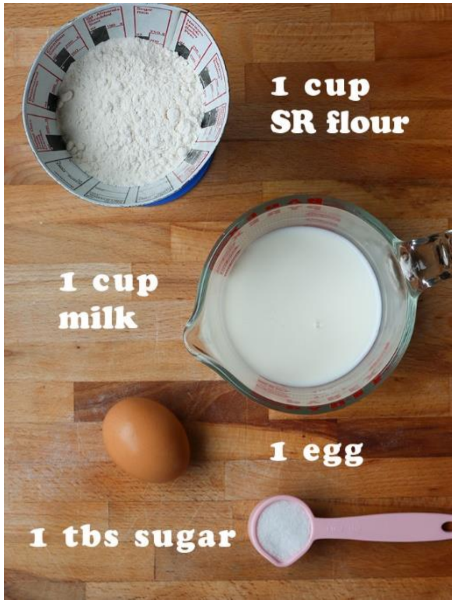
A **chemical reaction** is a process that produces a chemical change to one or more substances.
A chemical reaction will produce a **new substance.** Other observations of a chemical reaction may include a temperature change, a colour change or production of gas.

Reactants: $Zn + I_2$ → Product: $Zn\ I_2$

Reactants and products in a chemical reaction

The original substances that you start with, in a chemical reaction are known as **reactants.** Those that are formed are known as **products**. It is important to note that no matter is created or destroyed during a chemical reaction, but rather rearranged to form new substances.

Reactants → Products



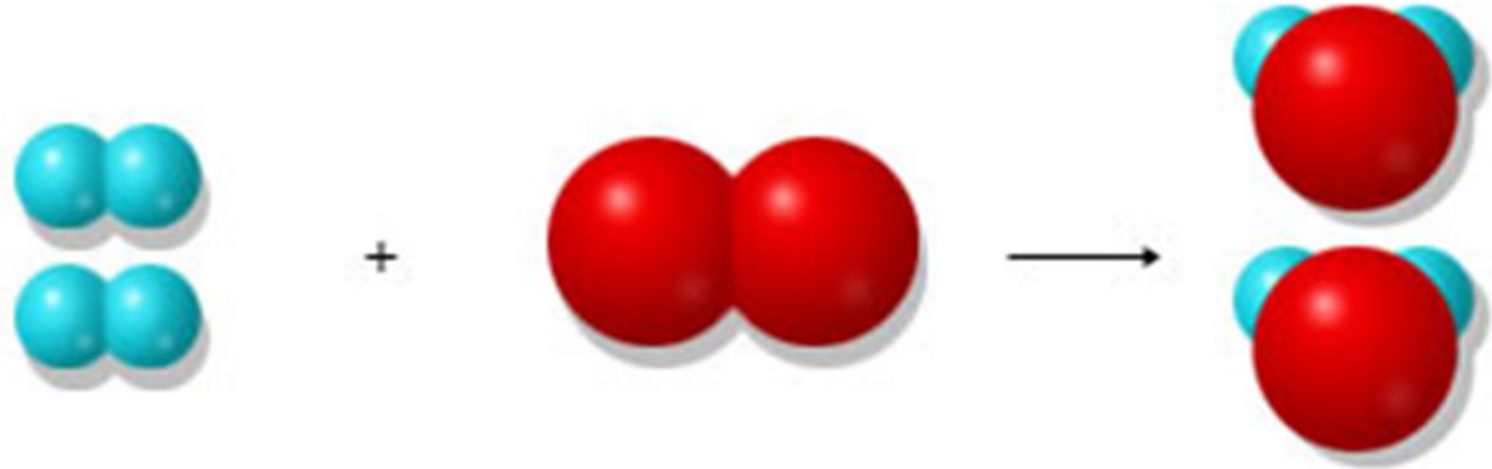
For example: making pancakes is a chemical change.
The reactants (ingredients you start with) are flour, milk, egg and sugar.
The product is pancakes.

Reactants join together to form new products during chemical reactions

The atoms present in the **reactants** rearrange themselves in different combinations and form new bonds. The new combinations of atoms are called **products** and can either be single atoms or molecules.

Reactants / Products

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



2 hydrogen molecules + 1 oxygen molecule yields 2 water molecules

Chemical reactions – word equations

When we convert descriptions of reactions into word equations there is a set way of writing it. A word equation can also be written as a formula equation.

For example: When we use a BBQ we cook with propane gas (C_3H_8) which needs oxygen gas in the air (O_2) to combust (or burn). The burning process creates water (H_2O) and carbon dioxide gas (CO_2)

The word equation therefore will be:

Reactants on the left

Products on the right

Propane + oxygen → water + carbon dioxide

Add chemicals with a +

Show reactants turning into products with a →

Chemical reactions – word equations

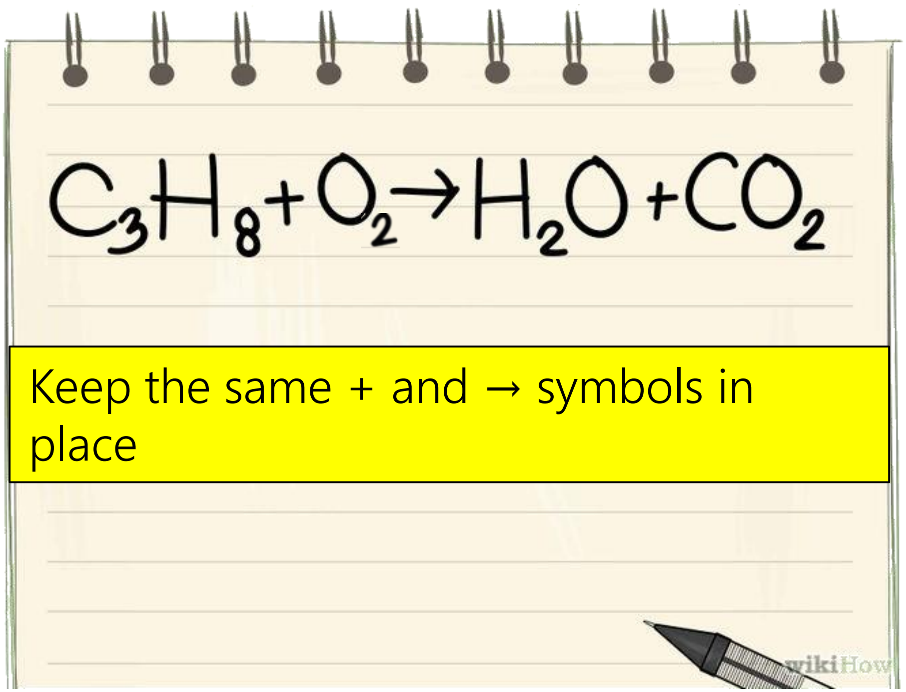
When products are made in a reaction the name of it is often a combination of the names of the chemicals it is formed from. For example $MgCl_2$ is called magnesium chloride

Cation			Anion	
1+	2+	3+	2-	1-
H Hydrogen	Mg Magnesium	Fe Iron (III)	O Oxide	Cl Chloride
Na Sodium	Ca Calcium		SO_4 Sulfate	OH Hydroxide
K Potassium	Cu Copper	Al Aluminium	CO_3 Carbonate	NO_3 Nitrate
NH_4 Ammonium	Pb Lead		S Sulfide	HCO_3 Hydrogen Carbonate
Ag Silver	Zn Zinc	Fe Iron (III)		F fluoride
Li Lithium	Fe Iron (II)			

Writing symbol equations

The word equation is:

Propane + oxygen → water + carbon dioxide



Keep the same + and → symbols in place

Once you can write word equations practice by writing the formula underneath

You are expected to know the formula for simple compounds
water – H_2O
Carbon dioxide – CO_2
Oxygen gas – O_2
Hydrogen gas – H_2

You will also need to remember formula for common acids and bases (given later in the unit)

You will need to use ion charts to write the formula for compounds made of ions.

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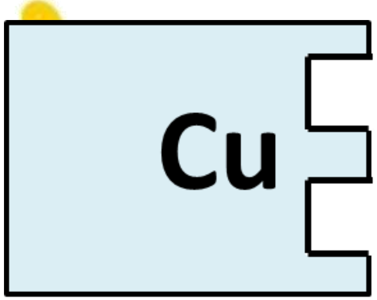
The visual method for balancing compounds



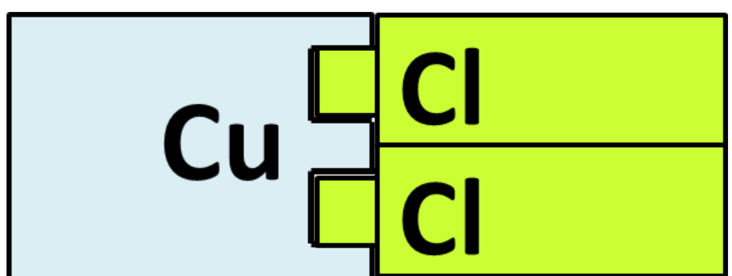
Copper

Chloride

Copper forms a positive copper ion of Cu^{2+}. It loses 2 electrons – shown by the 2 "missing spaces" in the shape

Chlorine forms a negative chloride ion of Cl^{-}. It gains 1 electron – shown by the 1 "extra tab" in the shape

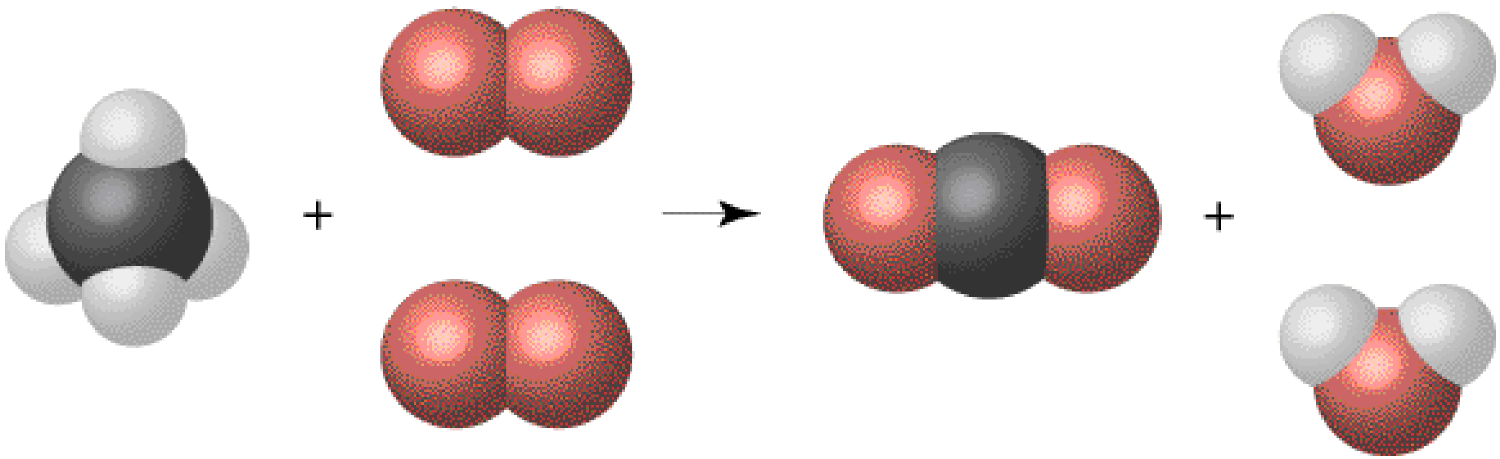
If we want to form a balanced ionic compound then each space in the positive ion must be filled by a tab from the negative ion. In this case 2 chloride ions are needed for each copper ion to form copper chloride.



Copper Chloride

Balancing Chemical equations

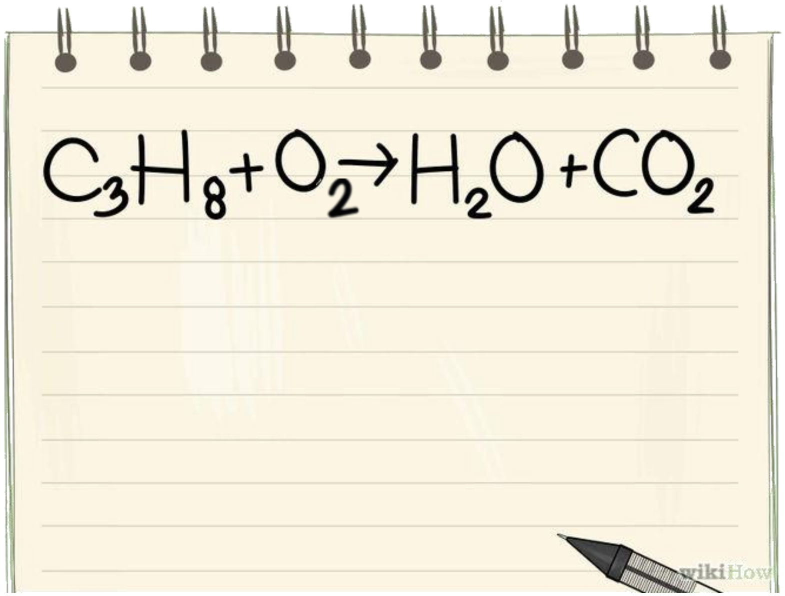
In a chemical equation the **total number of atoms in the reactants must equal the total number of atoms in the products** as no atoms are created or destroyed just rearranged with new bonds formed or bonds broken



One methane molecule	+	Two oxygen molecules	→	One carbon dioxide molecule	+	Two water molecules
CH_4	+	$2O_2$	→	CO_2	+	$2H_2O$
(1 C, 4 H)		(4 O)		(1 C, 2 O)		(2 O, 4 H)

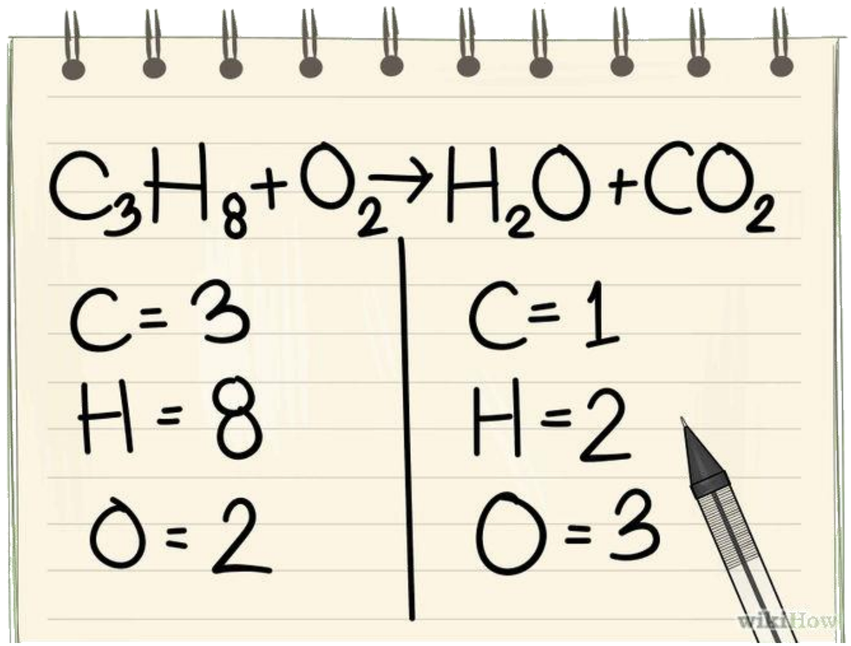
Balancing Chemical equations

1. To balance an equation first write down the equation



The total number of each type of atom must be the same for reactants and products if they equation is balanced

2. Count the total number of each atom for reactants and products



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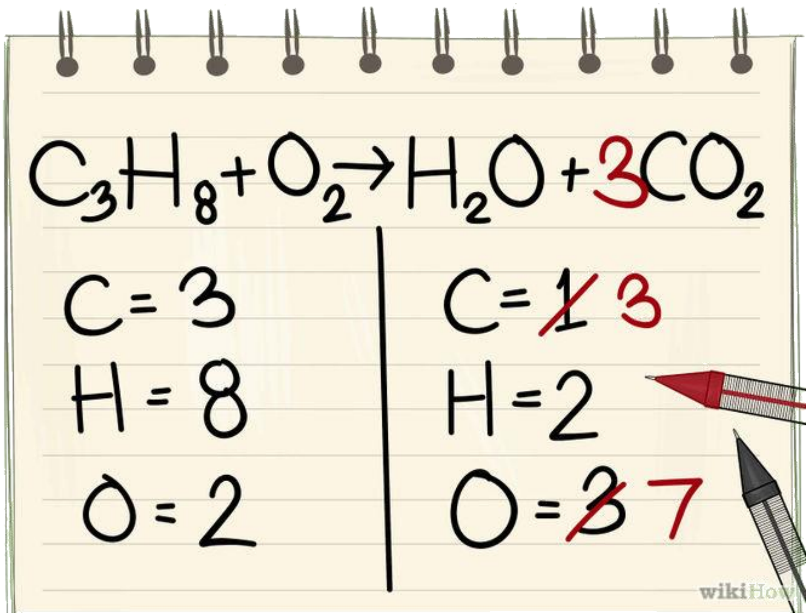
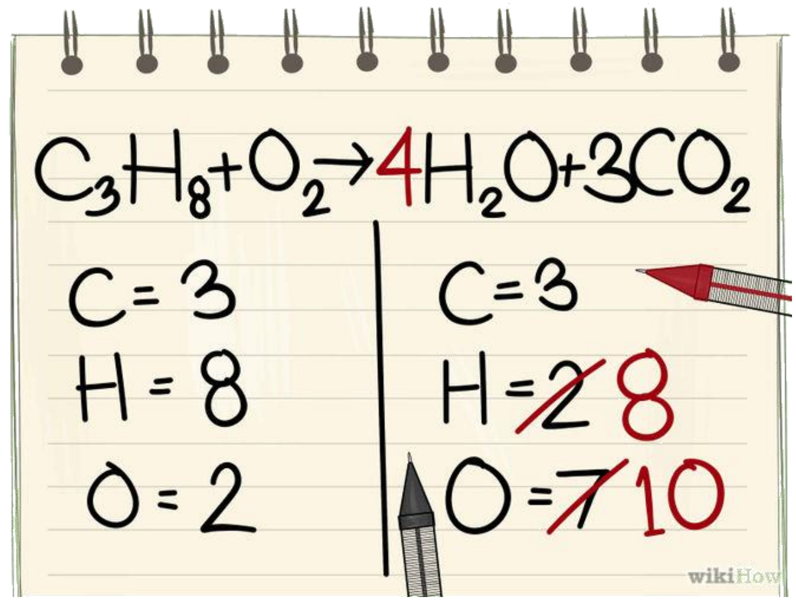
Balancing Chemical equations

3. Starting with the first atom (C) **multiply until it is the same on both sides** – and place this number in front of the compound. You may change the number of another atom but you can sort this as you move down the list



Only put numbers in front of compounds **NOT** after an atom as this changes the formula

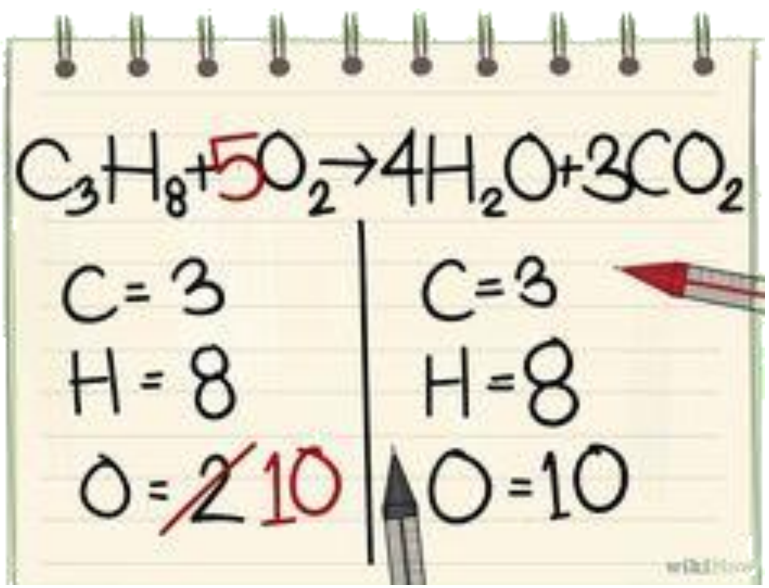
4. Moving down the list to the next atom (H) multiply until both sides are the same – again you may also increase another atom but sort that out after



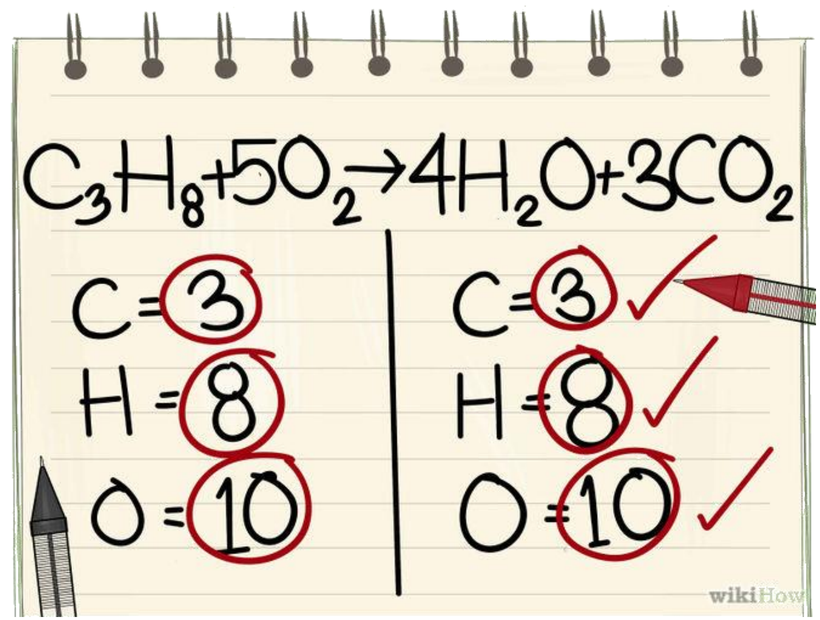
Balancing Chemical equations

Sometimes you may have to go back and rebalance another atom again for the second time

5. Moving to the last atom on this list (O) multiply until it is the same number on both sides



6. If all atoms are **the same number on both sides** then the equation is **balanced**!



Testing for Oxygen gas

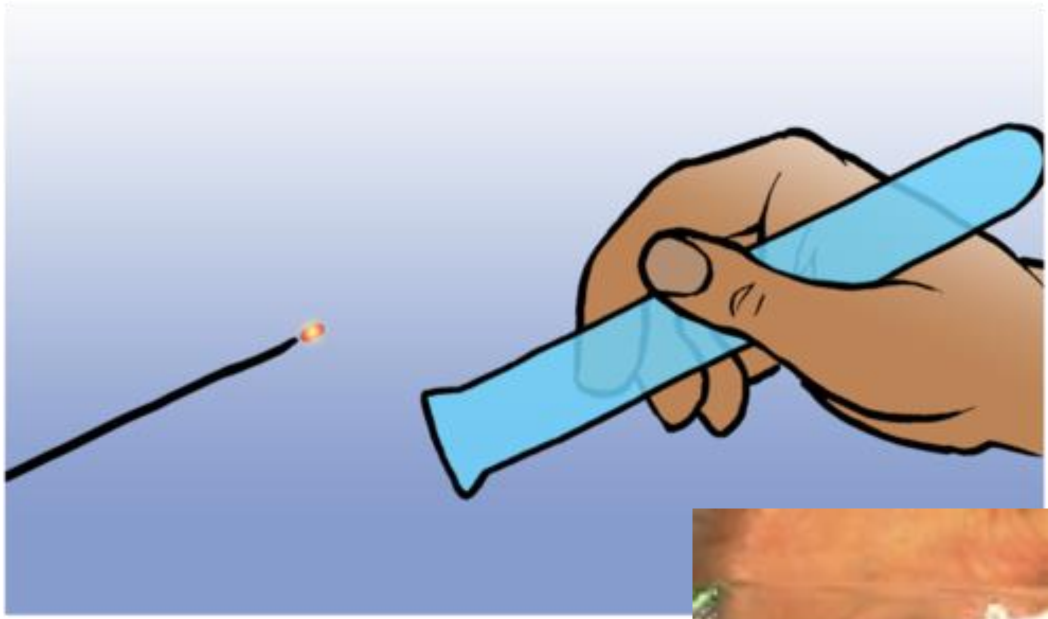
How to test for Oxygen Gas

1. Put a small amount of Manganese dioxide into a boiling tube and add hydrogen peroxide. **BE CAREFUL WITH THESE CHEMICALS and ALWAYS FOLLOW LAB SAFETY RULES**
2. Put a bung with a delivery tube over the boiling tube and put the delivery tube into an upside down test tube to collect any gas.
3. Heat the tube gently with a Bunsen burner.
4. Remove delivery tube and place thumb over test tube.
5. Remove thumb quickly and place a glowing splint into the test tube.
6. If the splint re-ignites then it is likely the gas produced was oxygen.

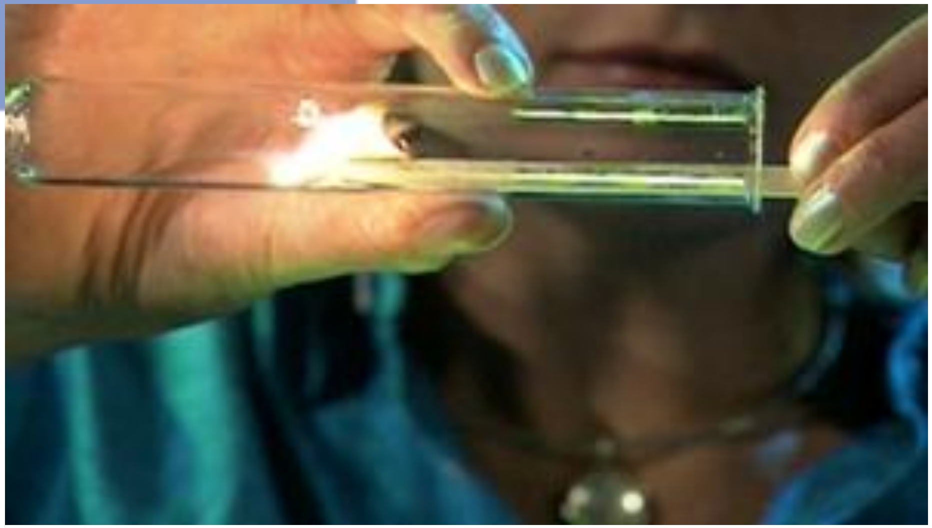
Oxygen gas is a molecule formed from two bonded oxygen atoms

Oxygen in the air combines with iron to form rust.

Testing for Oxygen gas



All types of combustion (burning) need oxygen. By supplying pure oxygen the glowing splint begins to combust at a faster rate which we see as flames.



Testing for Hydrogen gas

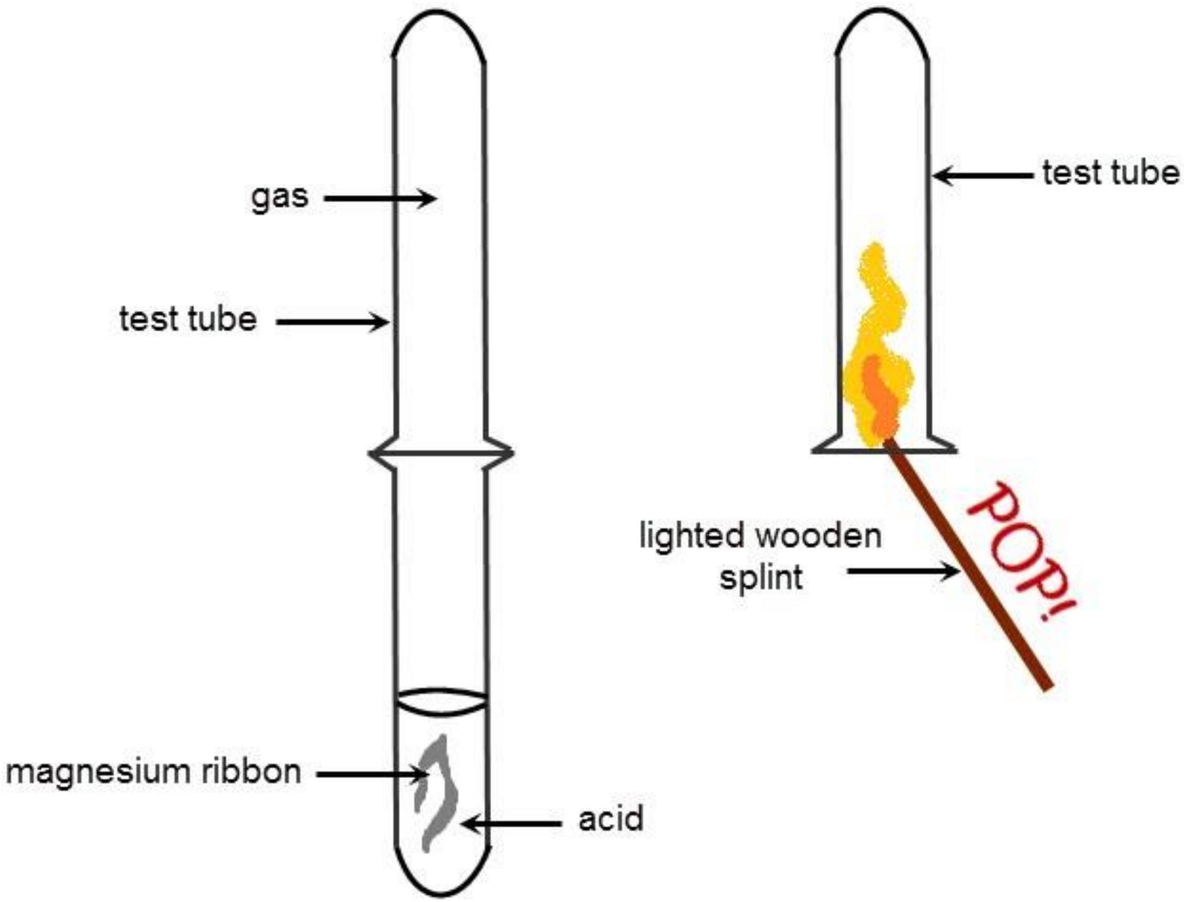
How to test for Hydrogen Gas

1. Put a small piece of magnesium metal into a test tube with a small amount of dilute hydrochloric acid.
2. Place another test tube upside down over top of the first test tube
3. Collect the gas in the upside down test-tube.
4. Place thumb over top of the test tube
5. Hold a lit match at the mouth of the test tube and remove thumb quickly
6. If the gas makes a loud 'pop' then it is likely that the gas produced is hydrogen.

Hydrogen in Jupiter's Atmosphere

Rocket fueled by liquid hydrogen

Testing for Hydrogen gas

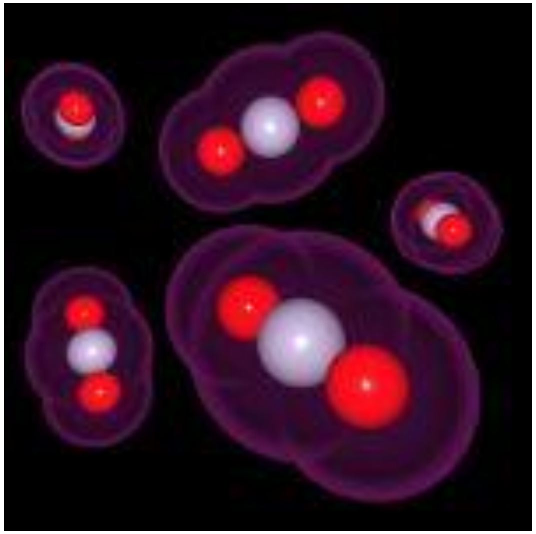


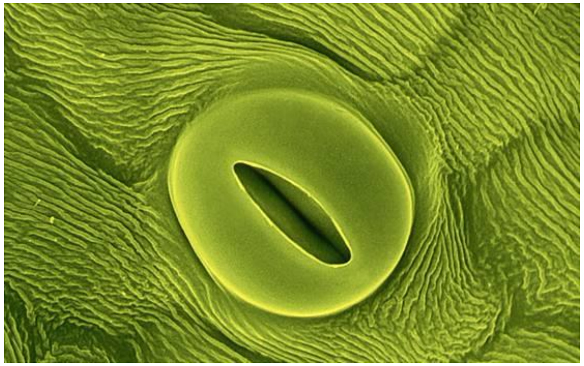
Hydrogen gas is lighter than air so it will rise to the top of any container. Hydrogen is very reactive so with the flame as **energy,** it will react with the oxygen in the air to form a much more stable water molecule. The difference in energy levels between the reactants (hydrogen and oxygen) and the products (water) is released as an explosion (a ‘pop’).

Testing for Carbon Dioxide gas

How to test for Carbon Dioxide Gas

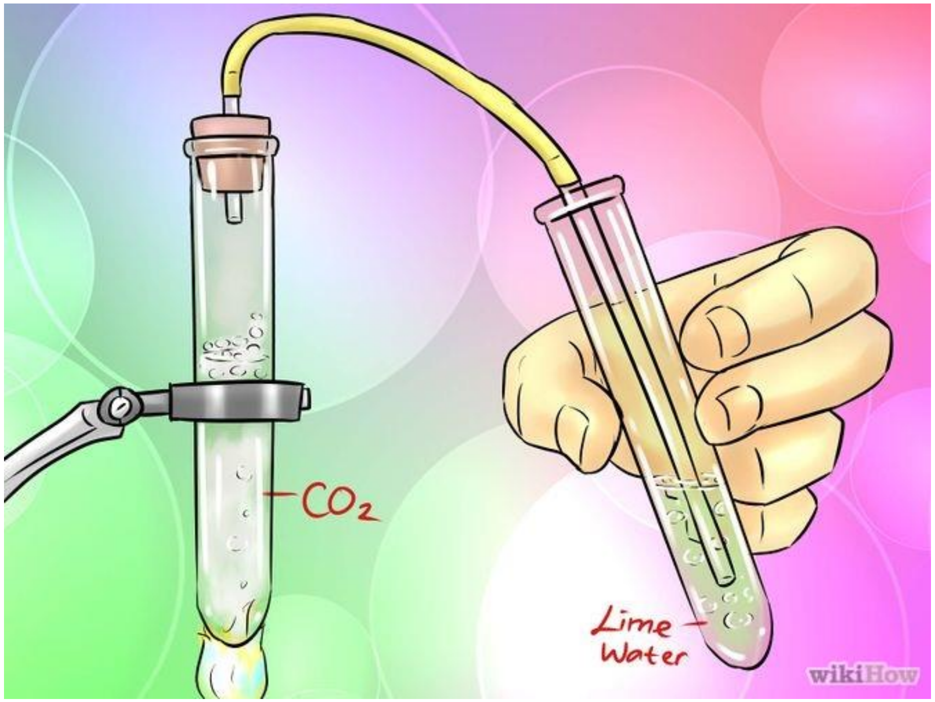
1. Put a small amount of calcium carbonate with dilute hydrochloric acid into a boiling tube.
2. Put a bung with a delivery tube over the boiling tube.
3. Place the delivery tube into a test-tube filled with clear limewater
4. Observe the gas bubbling into the limewater.
5. If the limewater turns cloudy then it is likely that the gas produced is carbon dioxide.

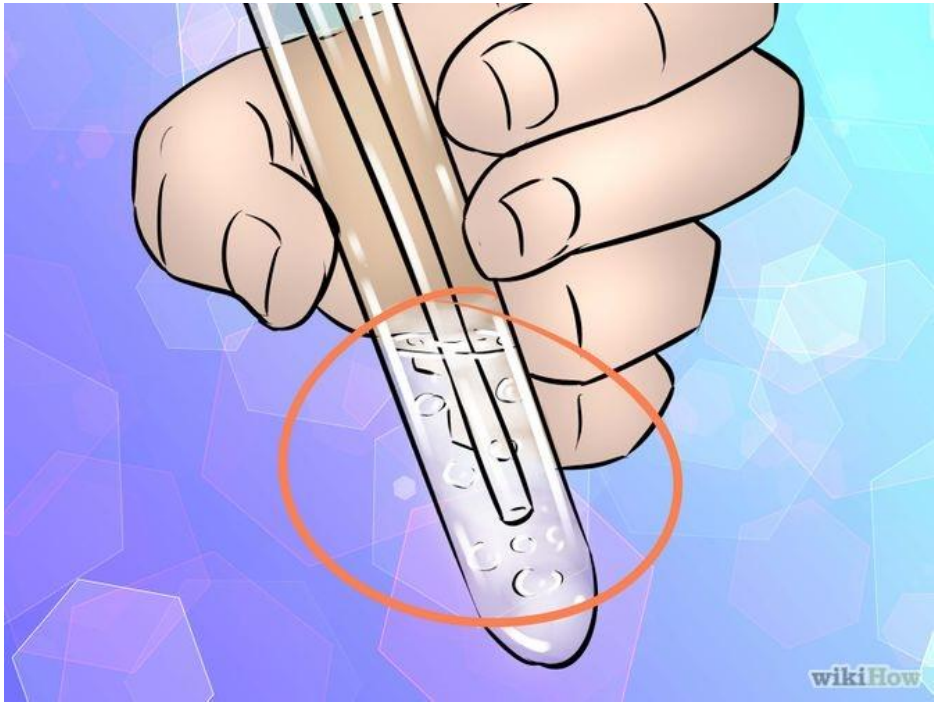




Plant stomata which allows CO_2 gas into the leaf

Testing for Carbon Dioxide gas





Carbon Dioxide is a colourless gas and limewater is a solution of calcium hydroxide in water which is also colourless. The carbon dioxide gas reacts with the limewater and changes it into calcium carbonate which is not soluble (can not dissolve) in water and appears as a milky white colour.

Acids– their characteristics

Acids are a family of substances which all show **acidic characteristics** or properties. These properties relate to how the acids react with other chemicals.

They have a **sour taste** and react with metals. Acids can be found in nature and called **organic acids** or manufactured in the laboratory and called **mineral acids**.

Common acids - names and formula

Name	Chemical formula
Hydrochloric Acid	HCl
Sulfuric Acid	H_2SO_4
Nitric Acid	HNO_3
Ethanoic acid	CH_3COOH

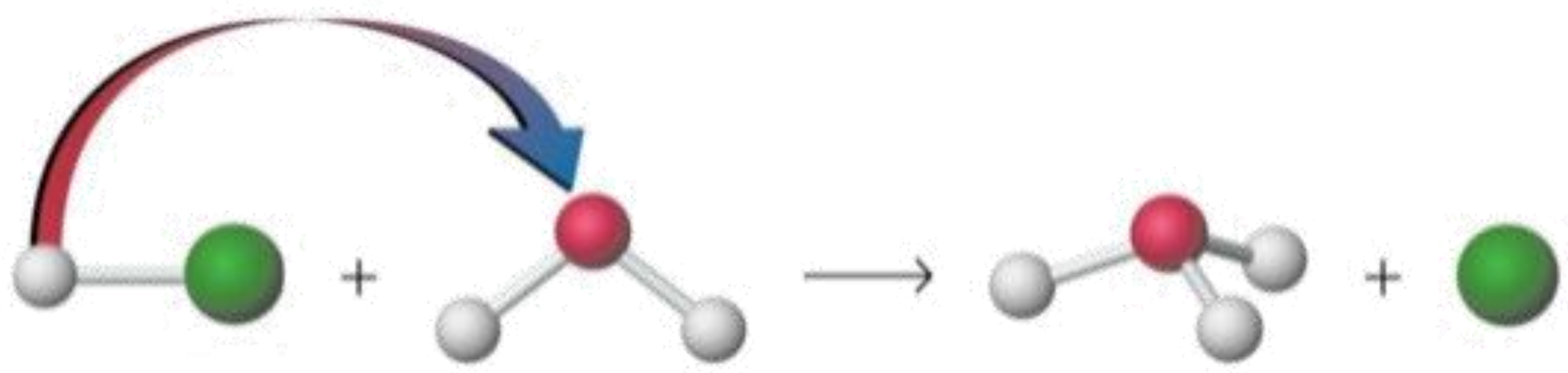
React with most metals to form hydrogen gas
Taste sour (like lemons)
Frequently feel "sticky"
Usually gases or liquids

You need to learn these three acids and their formula

Defining an Acid

All acids contain hydrogen. When an acid reacts it gives away its **Hydrogen ion** (H^+), which is really just a proton, and the electron remains behind.

Before the reaction | **After the reaction**



Acid giving its hydrogen ion (H^+) in a reaction

Acid with the hydrogen ion removed

Bases – their characteristics

Bases are a family of Chemicals that have hydroxide ions present (OH^-). They have opposite properties from acids.

Common Household bases include floor clearers and antacid tablets to fix indigestion. A Base that dissolve into water are called an **alkali**.

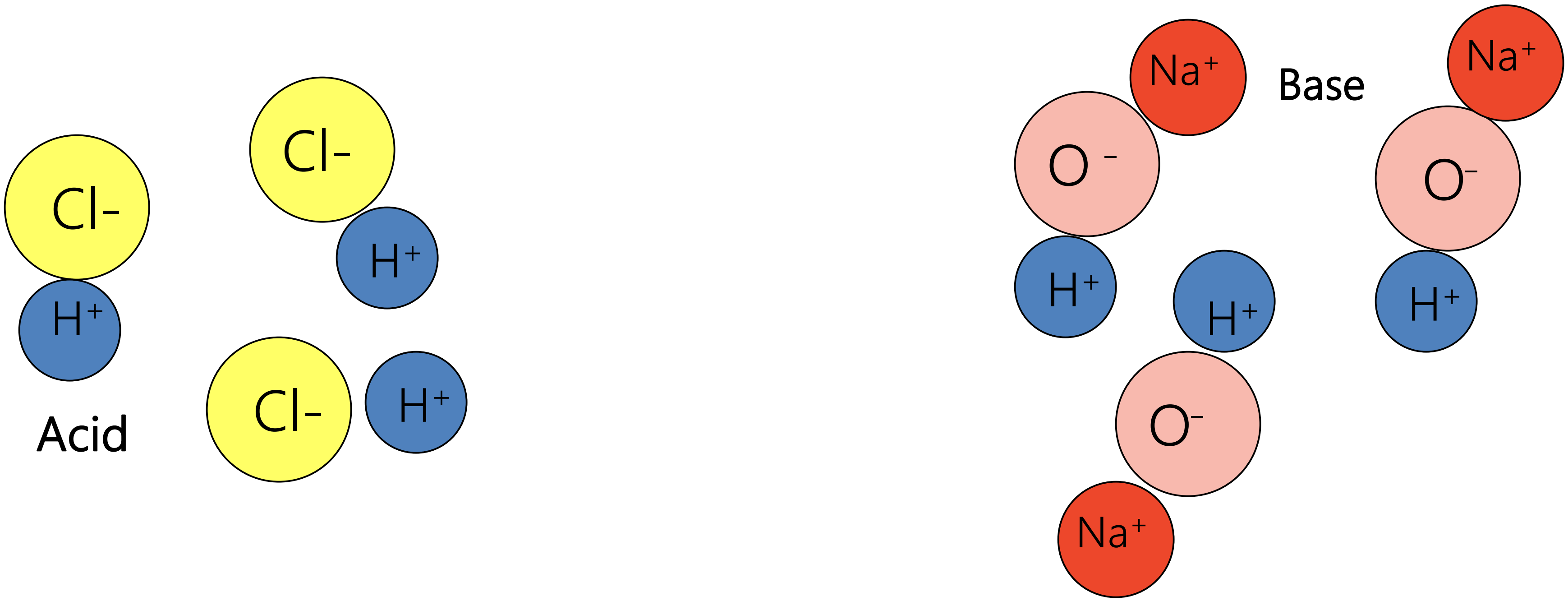
Common bases - names and formula

Name	Chemical formula
Sodium Hydroxide	$NaOH$
Calcium carbonate	$CaCO_3$
Ammonia	NH_3
Potassium hydroxide	KOH

Feel "slippery". (because your skin dissolves a little when you touch them.)
Taste bitter (like baking soda)
React with oils and greases (used as cleaners)
Frequently solids

Acid and Base definition

An **acid** is a molecule or ion that is gives away a hydrogen ion (proton, H+), and a **base** can contain a hydroxide ion (OH^-)



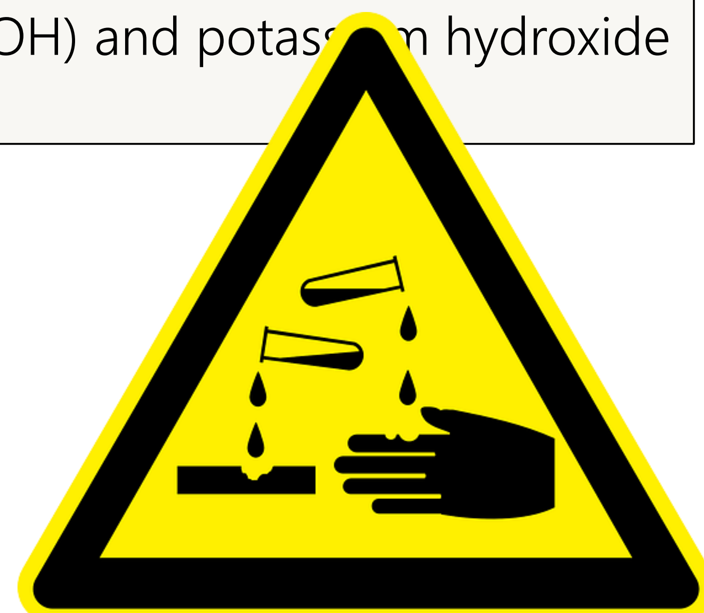
When an acid and alkali react together they form salt (an ionic salt made of positive and negative ions) and water extra info

What is an Alkali

A base that dissolves in water and **produces a OH^- ion** (hydroxide) is known as an **alkali**. The solution is creates with water is known as alkaline.
Common alkalis are sodium hydroxide (NaOH) and potass[illegible]m hydroxide (KOH)

The concentration of H^+ and OH^- ions in a solution determine how acidic or basic it is.

High H^+ concentration and low OH^- concentration mean the solution is acidic.
Low H^+ concentration and high OH^- concentration mean the solution is basic.
When the concentration of H^+ ions and OH^- ions are equal then the solution is said to be **neutral**, neither acidic or basic.



Corrosive

Indicators determine whether substances are acid, base or neutral.

Indicators can be used to determine the pH (how acid or base) of a solution by the colour change.

An indicator is a large organic molecule that works like a " colour dye". They respond to a change in the hydrogen ion concentration. Most of the indicators are themselves weak acids.

The most common indicator is found on **litmus paper**. It turns/remains red for acid and turns/remains blue for a base.

Universal Indicator, which is a solution of a mixture of indicators that provide a full range of colours for the pH scale.

Red and Blue Litmus paper works as an indicator

Added to…	Blue Litmus	Red litmus
Acid solution	Turns red	Stays red
Base solution	Stays blue	Turns blue
Neutral solution	Stays blue	Stays red

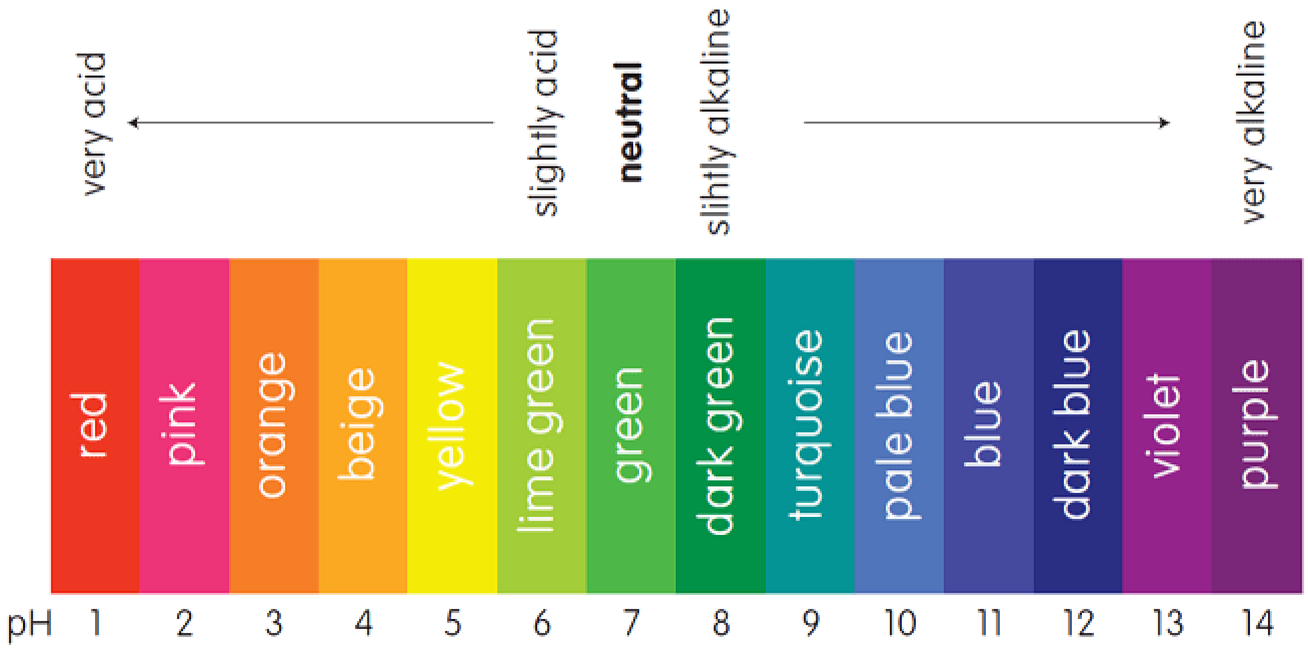
Blue litmus paper turning red in acid

Red litmus paper turning blue in base

Litmus paper is easy to use, but it does not tell you how acid or base a solution is, or if it is neutral – unless you use both red and blue litmus paper

Universal Indicator is used to give the strength of the acid or base

https://www.minichemistry.com/ph-scale-indicators.html

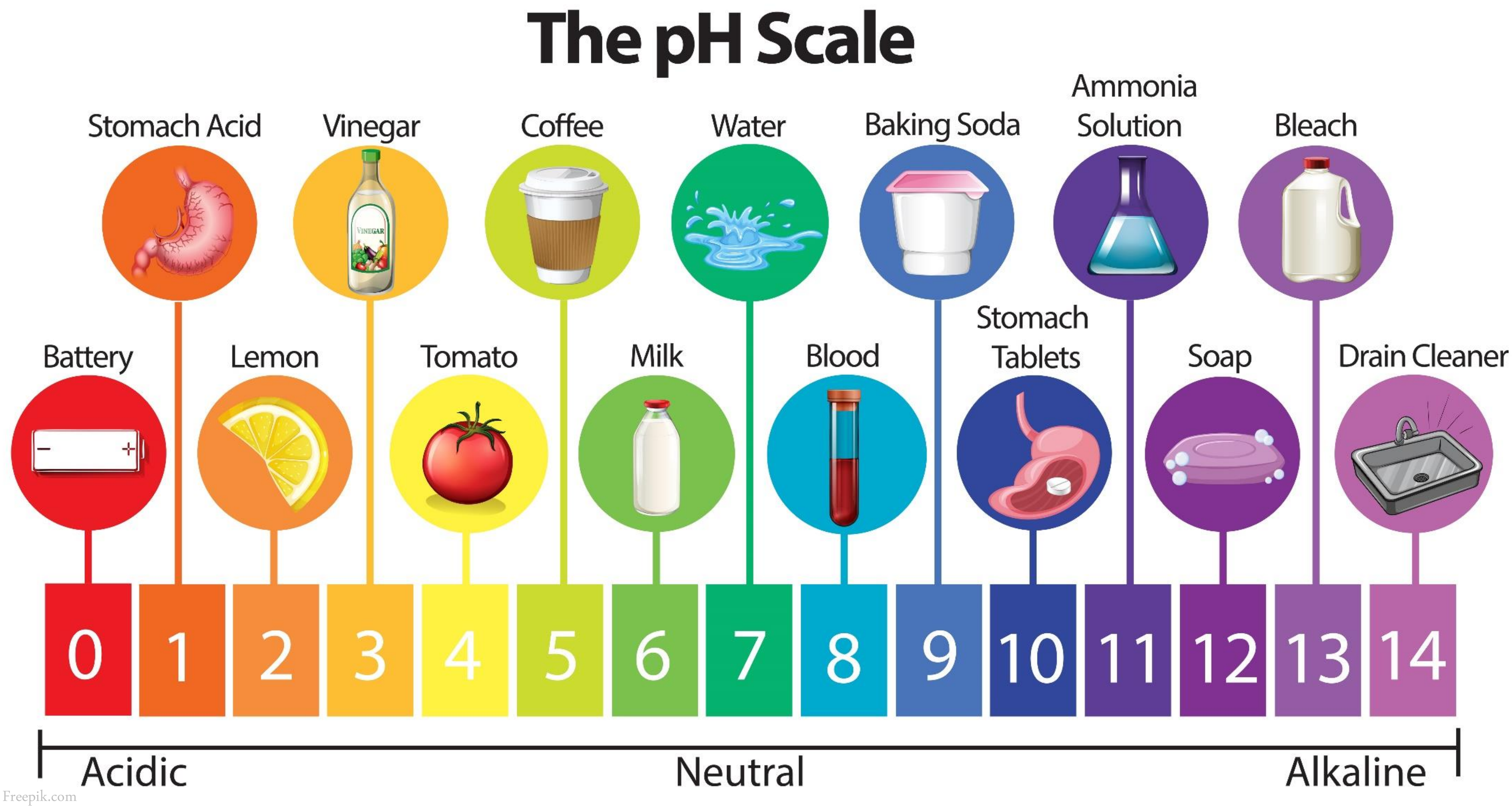


The Universal Indicator is similar to the Litmus paper in that the acids turn the indicator mostly red and the bases turn the indicator mostly blue.

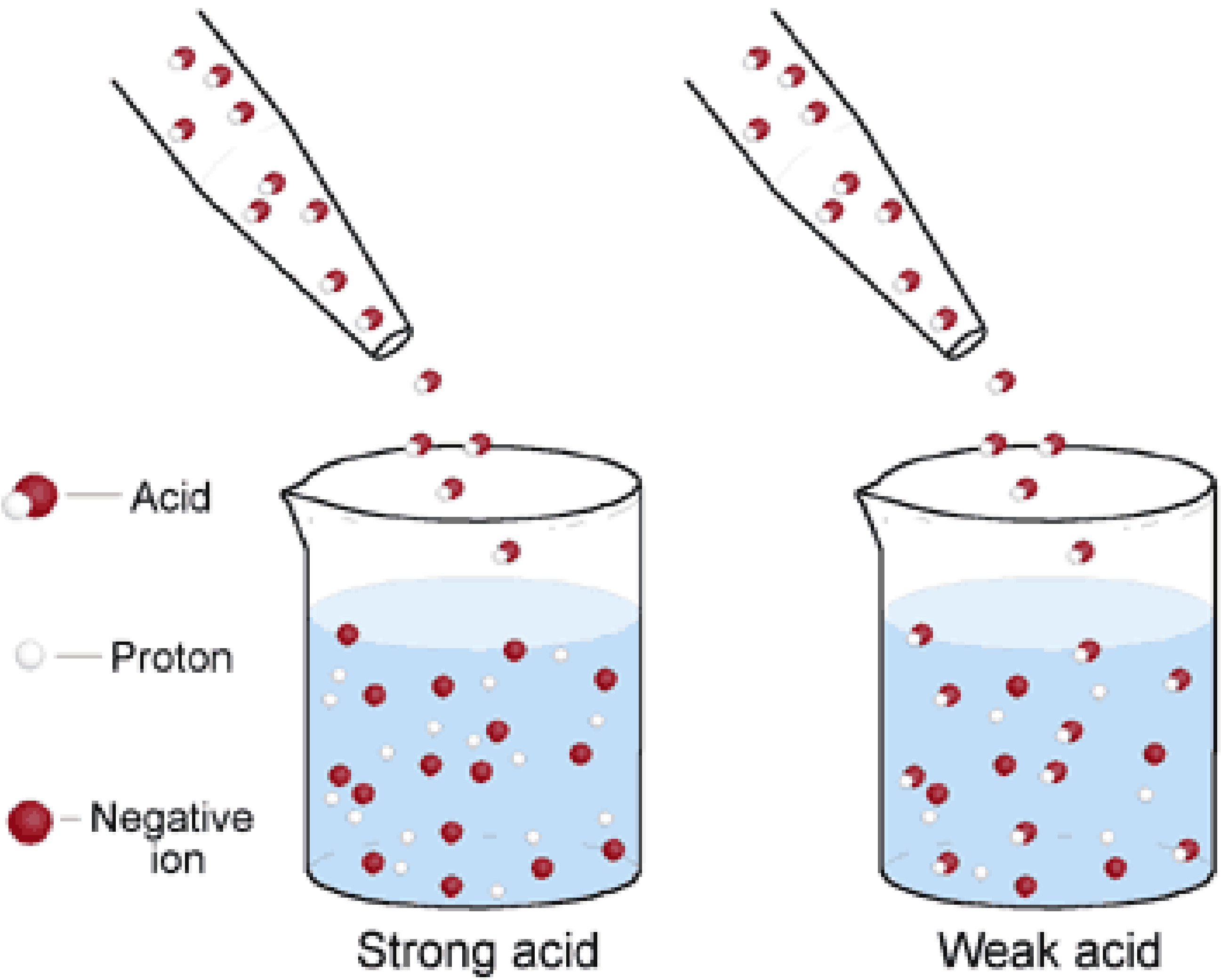
It does have an advantage over the litmus paper as it shows neutral by having a green colour and also has different colours for weak acids and weak bases.

Common acidic, alkaline and neutral substances.

Pure water is **neutral**. But when chemicals are mixed with water, the mixture can become either acidic or basic.



strong and weak acids

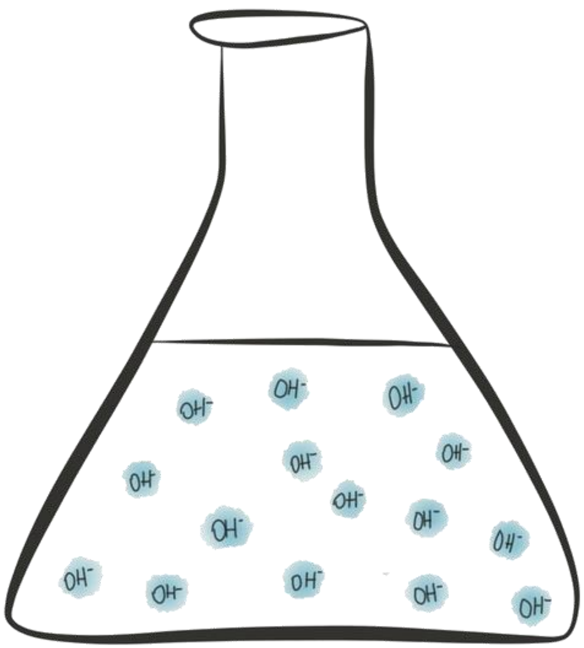


You can define acids and bases as being "strong" or "weak". **Strong acids** are compounds have a large amount of H^+ ions. (proton in picture)
A **weak acid** has much less H^+ ions.

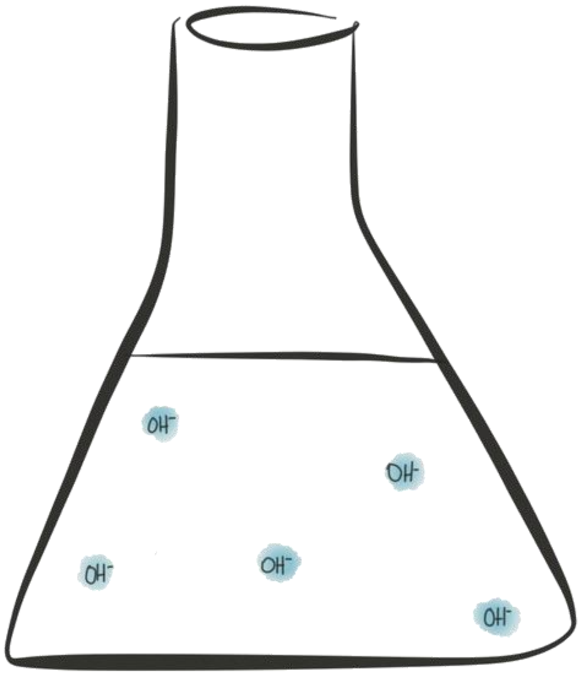
Hydrochloric, nitric and sulfuric acid are all strong acids, while ethanoic acid is a weak acid

Strong and weak bases

Strong base



Weak base



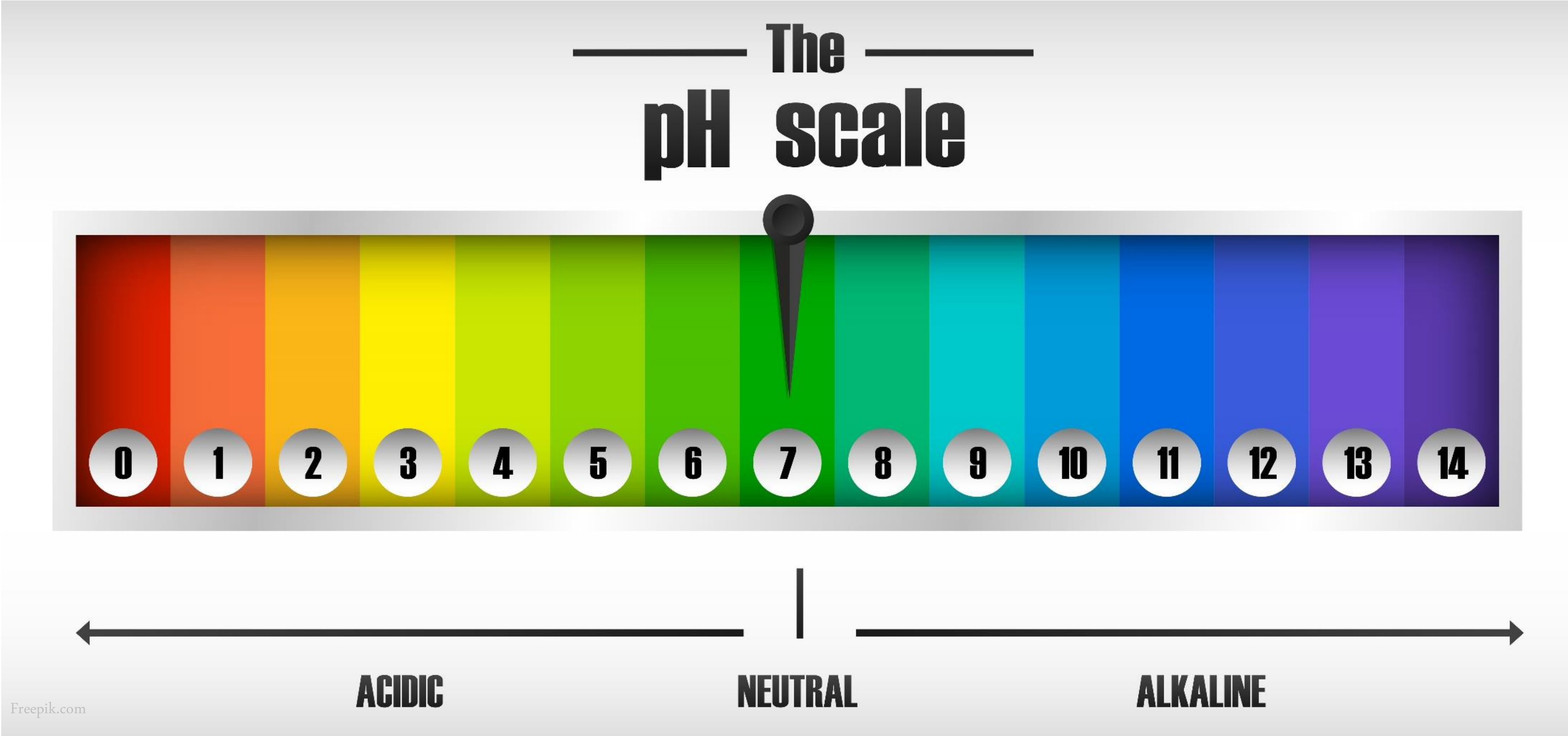
You can define bases as being "strong" or "weak". **Strong bases** are compounds where there are a large amount of OH^- ions.

A **weak base** is a compound where there are much less OH^- ions. Most weak base molecules remain unreacted.

Sodium hydroxide (NaOH) is a strong base, while most carbonate bases tend to be weak.

The pH scale.

A scale from 0-14 is used to indicate how acid or base a substance is. The pH scale is **logarithmic** and as a result, each whole pH value below 7 is ten times more acidic than the next higher value. For example, pH 4 is ten times more acidic than pH 5 and 100 times more acidic than pH 6.



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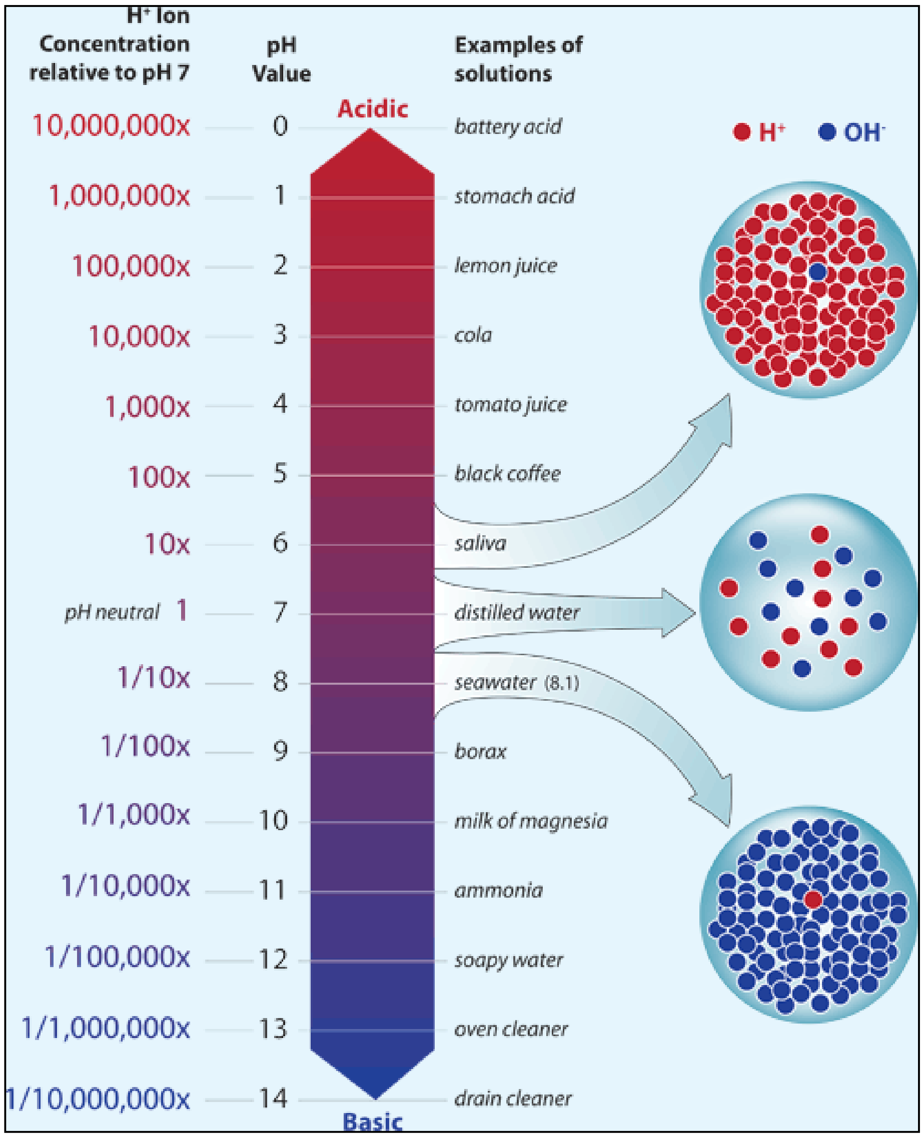
The pH scale measures level of acidity and alkalinity



Substances with a pH of 7 are **neutral**, substances with a pH greater than 7 are **alkaline** (or 'basic') and substances with a pH lower than 7 are **acidic**. Remember alkalis are 'bases' that are soluble in water. (All alkalis are bases but not all bases are alkalis.)

The pH of a substance is determined by the concentration of hydrogen ions compared to hydroxide ions. The higher the concentration of hydrogen ions the lower the pH.

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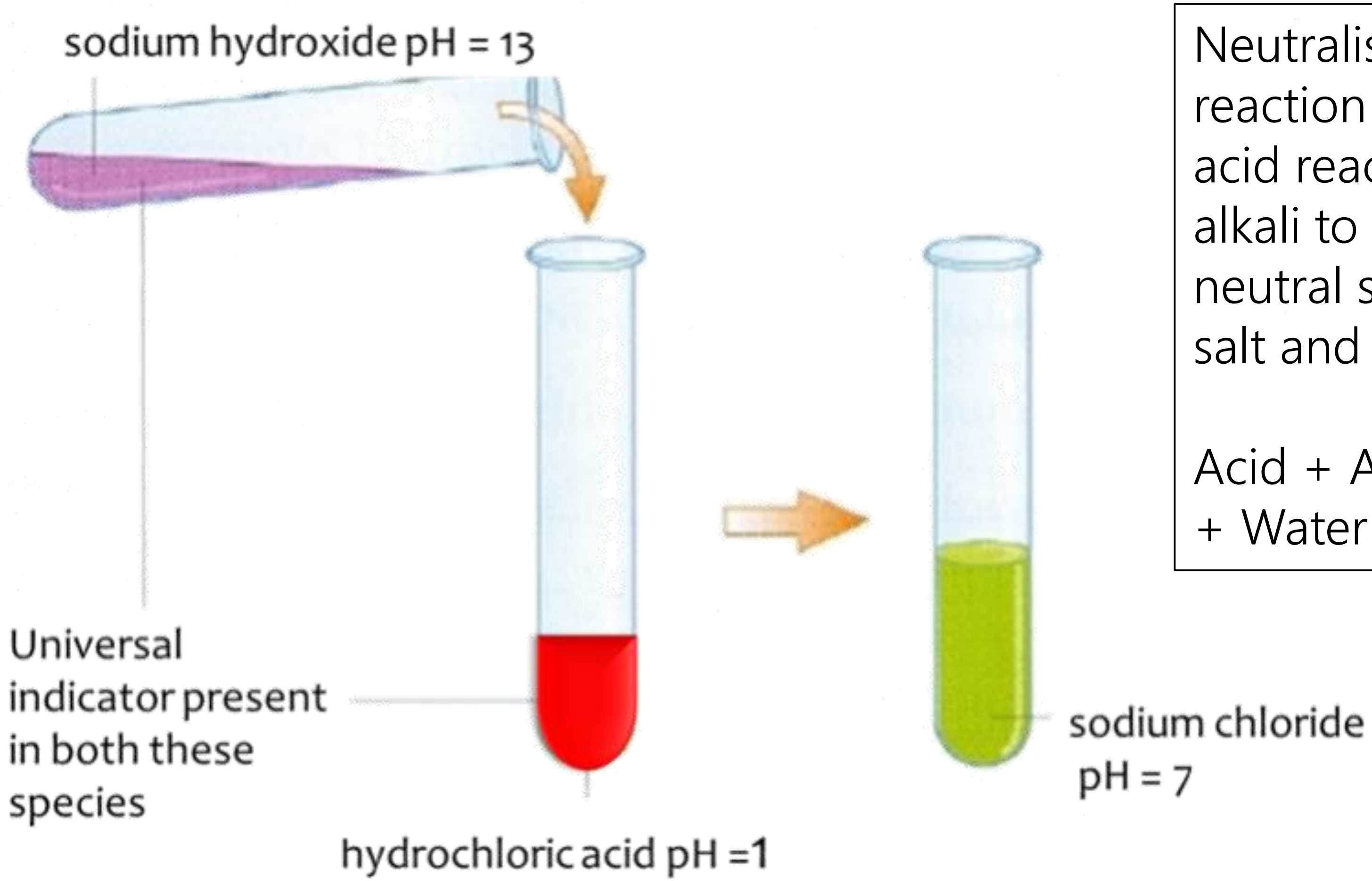
Putting it all together

Blue litmus					
Red litmus					
Universal indicator					
pH	**1 - 2**	**3 - 6**	**7**	**8 - 12**	**13 - 14**
description	**Strong Acids** Readily donate all their protons when dissolved	**Weak Acids** donate only a small proportion of protons	**Neutral solution**	**Weak Bases** Accept only a small proportion of protons	**Strong Bases** Readily accept protons
H_3O^+ / OH^- concentration	Concentration of H+ ions is **greater** than that of OH- ions		Concentration of H+ ions is the **same** as that of OH- ions		Concentration of H+ ions is **less** than that of OH- ions

Increasing acidity ⟷ **Increasing alkalinity**

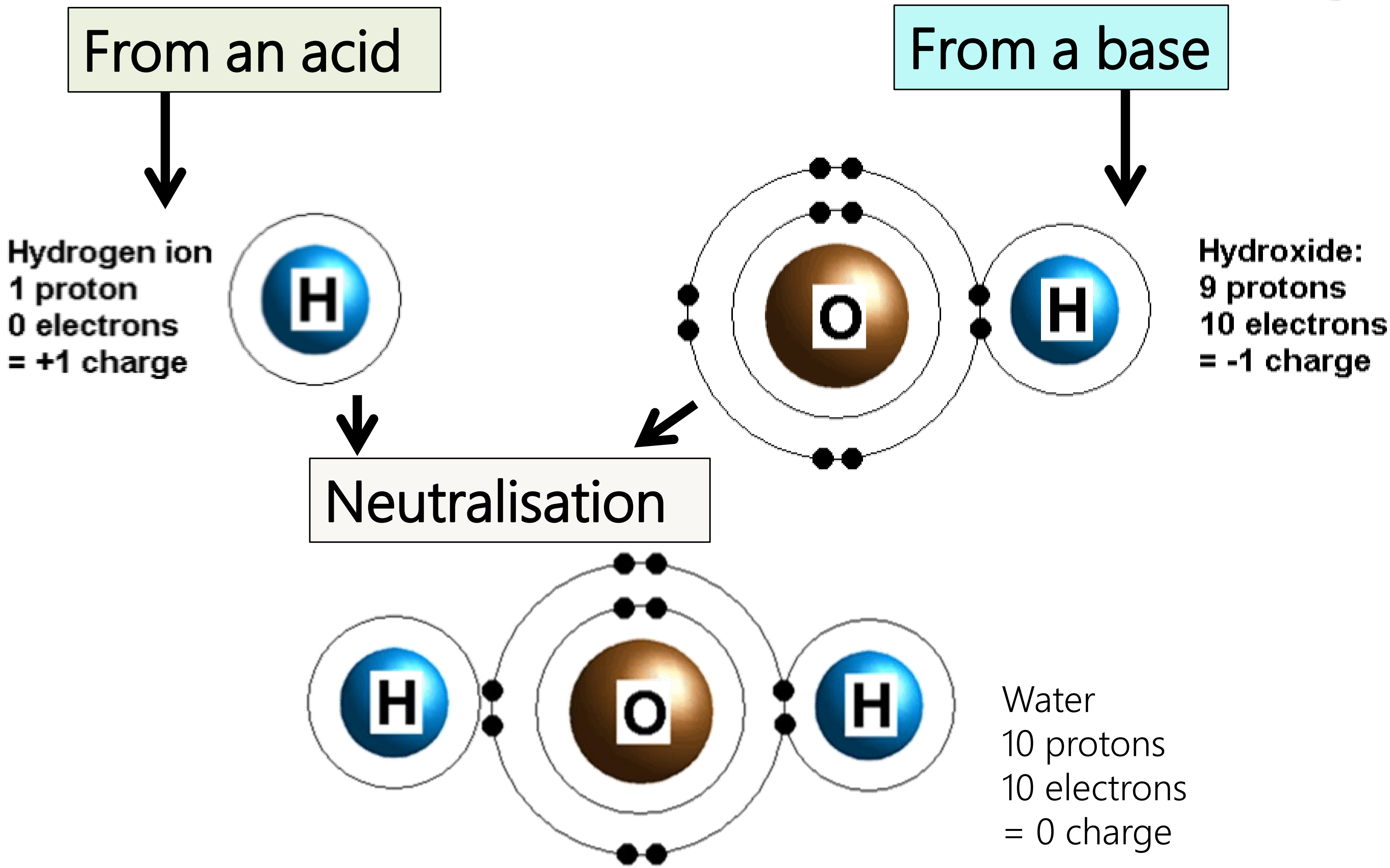
Neutralisation



Neutralisation is a reaction where an acid reacts with an alkali to form a neutral solution of a salt and water.

Acid + Alkali → Salt + Water

During neutralisation reactions hydrogen ions combine with hydroxide ions to form water molecules.



Balanced equations for salt formation

Bases **neutralise** acids and a salt and water are formed

H^+ Acid + Base OH^- → Salt + H_2O

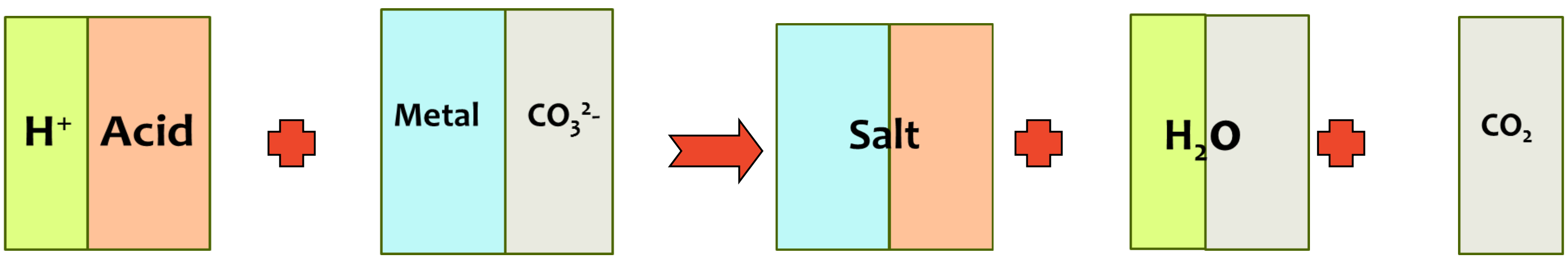
Example

$HCl + NaOH \rightarrow NaCl + H_2O$

Hydrochloric Acid + Sodium Hydroxide → Sodium Chloride + Water

Metal carbonates form salts , water and carbon dioxide gas when reacting with acid

Acids react with Carbonates to give a salt and water and carbon dioxide.



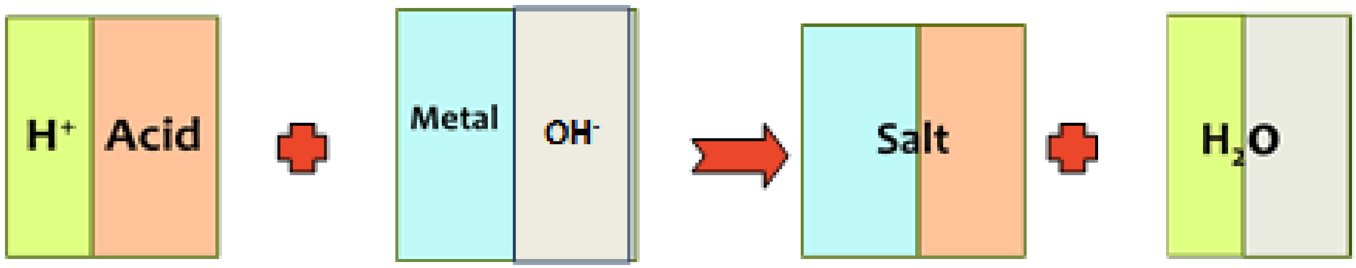
H_2SO_4 + $CaCO_3$ → $CaSO_4$ + H_2O + CO_2

sulfuric acid + calcium carbonate → calcium sulfate + water + carbon dioxide

We can test to see if carbon dioxide has formed by bubbling the gas into another test tube filled with lime water. The lime water will turn cloudy if the gas is carbon dioxide.

Metal hydroxides form salts and water when reacting with acid

Acids react with hydroxides to give a salt and water.



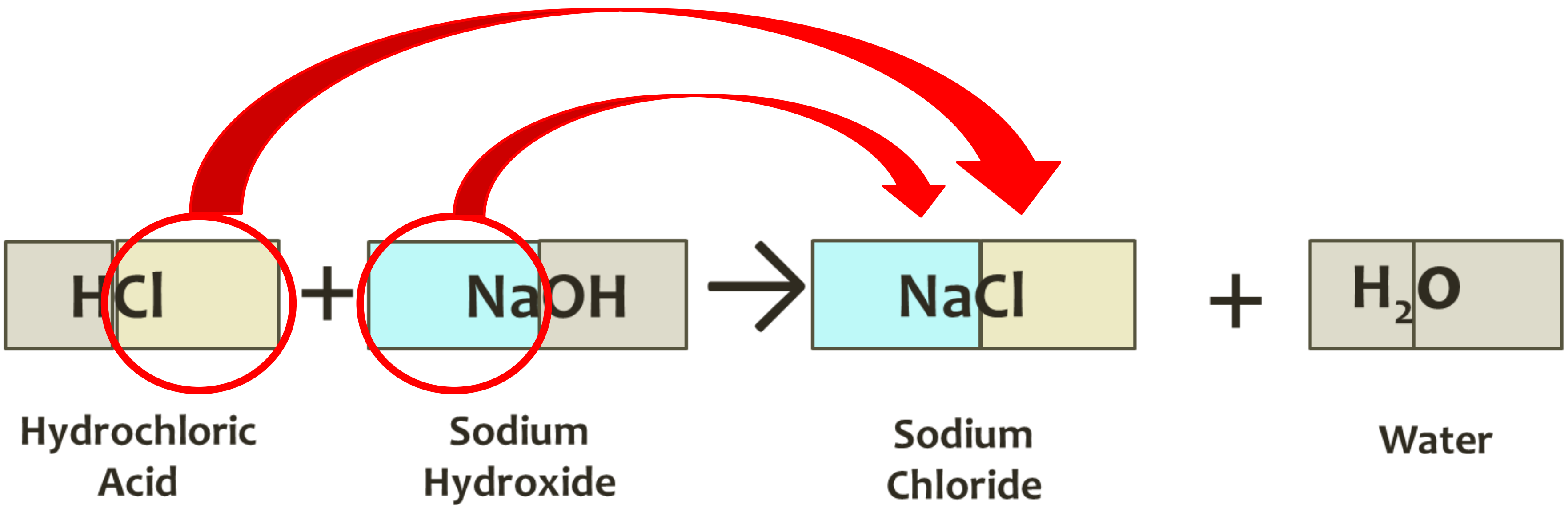
H_2SO_4	+	$CaCO_3$	→	$CaSO_4$	+	H_2O
sulfuric acid		calcium hydroxide		calcium sulfate		water

We can test to see if a solution has been neutralized (all of the acids and base has reacted to form salt and water) by testing with universal indicator which will turn green.

Names of salts

When salts are formed the name depends upon the acid reacted and the metal that forms part of the base compound.

Name of acid	Name of salt formed
Hydrochloric acid	chloride
Sulfuric acid	sulfate
Nitric acid	nitrate



Acid reactions summary

1. Acid and Base

General equation acid + metal oxide → salt + water

Word equation nitric acid + copper oxide → copper nitrate + water

Formula equation $2HNO_3 + CuO \rightarrow Cu(NO_3)_2 + H_2O$

2. Acid and Metal Carbonate

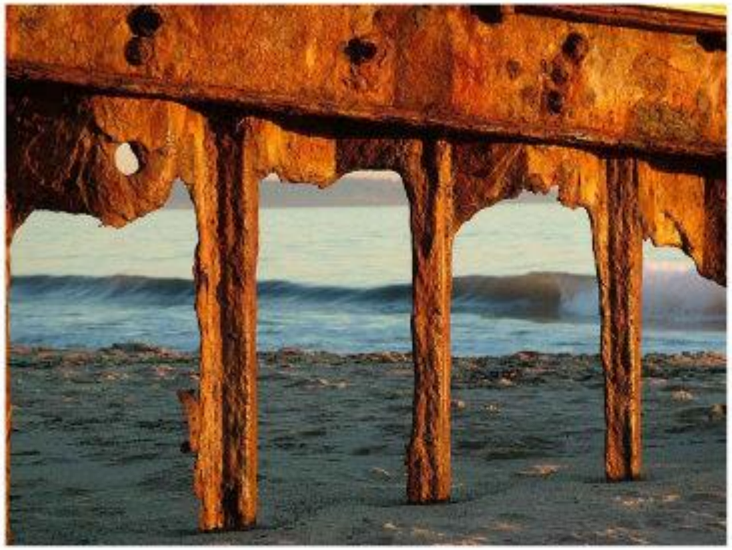
General equation acid + metal carbonate → salt + water + carbon dioxide

Word equation hydrochloric acid + magnesium carbonate → magnesium chloride + water + carbon dioxide

Formula equation $2HCl + MgCO_3 \rightarrow MgCl_2 + H_2O + CO_2$

Reaction Rate

The reaction rate is the speed at which a chemical reaction occurs.
This is measured by how quickly the reactants change into products or how quickly one of the reactants disappears.
Reactions can vary in their reaction rate

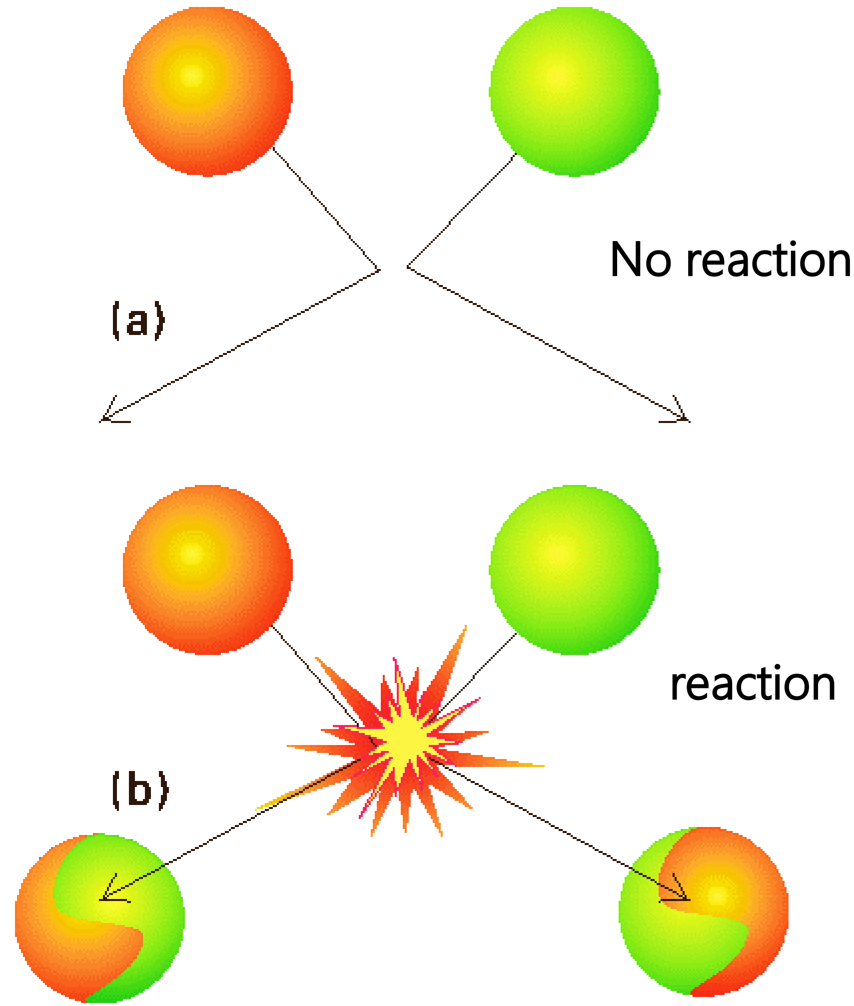


Iron oxidising

oxygen and hydrogen combusting

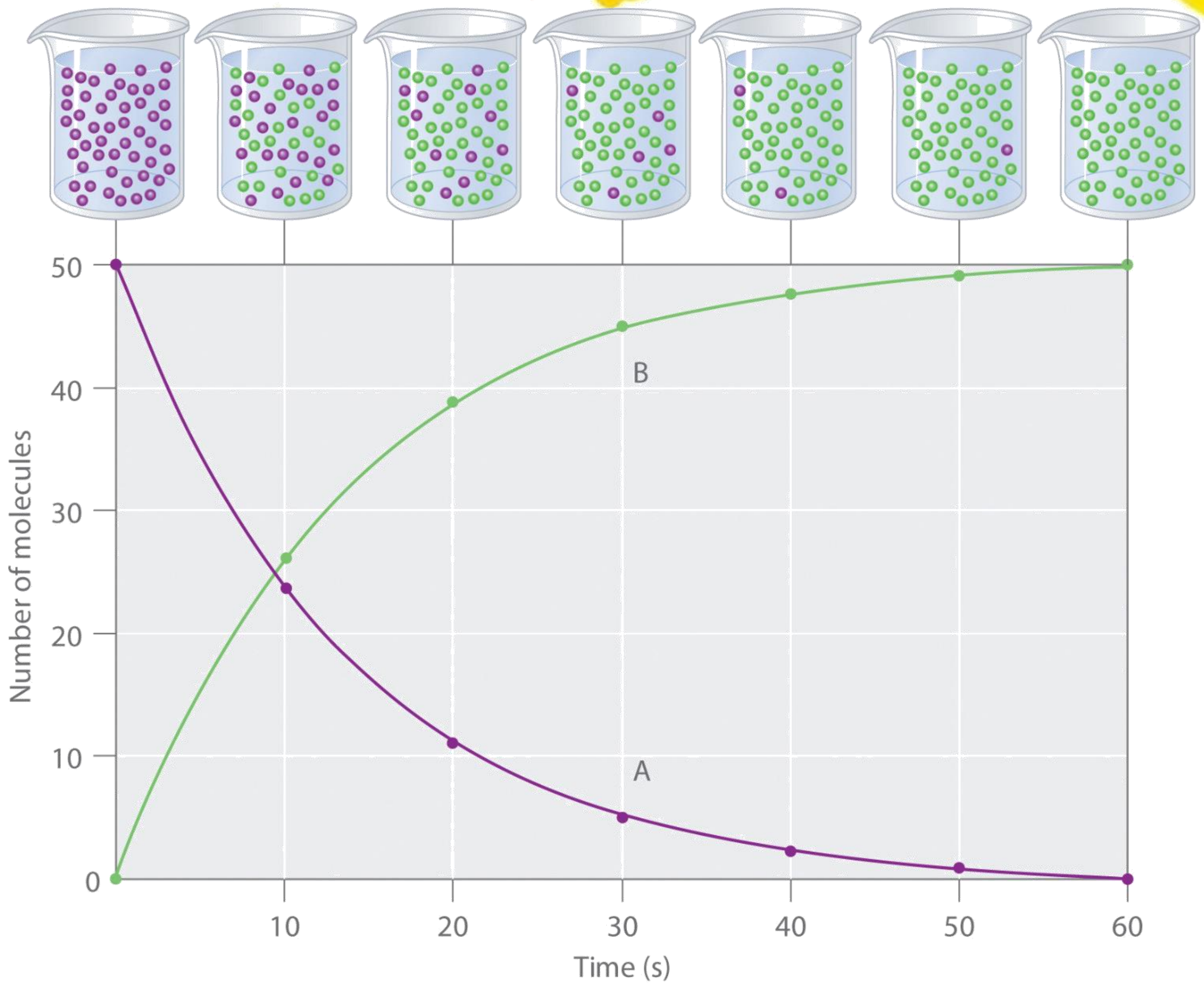
Chemical reactions occur when particle collide successfully

Chemical reactions between particles of substances only occur when the particles collide successfully.
Changing factors such as temperature, concentration of reactants, surface area and adding a catalyst can change how many successful collisions occur or how quickly they occur. This then affects the reaction rate. Increasing these factors will increase the reaction rate.

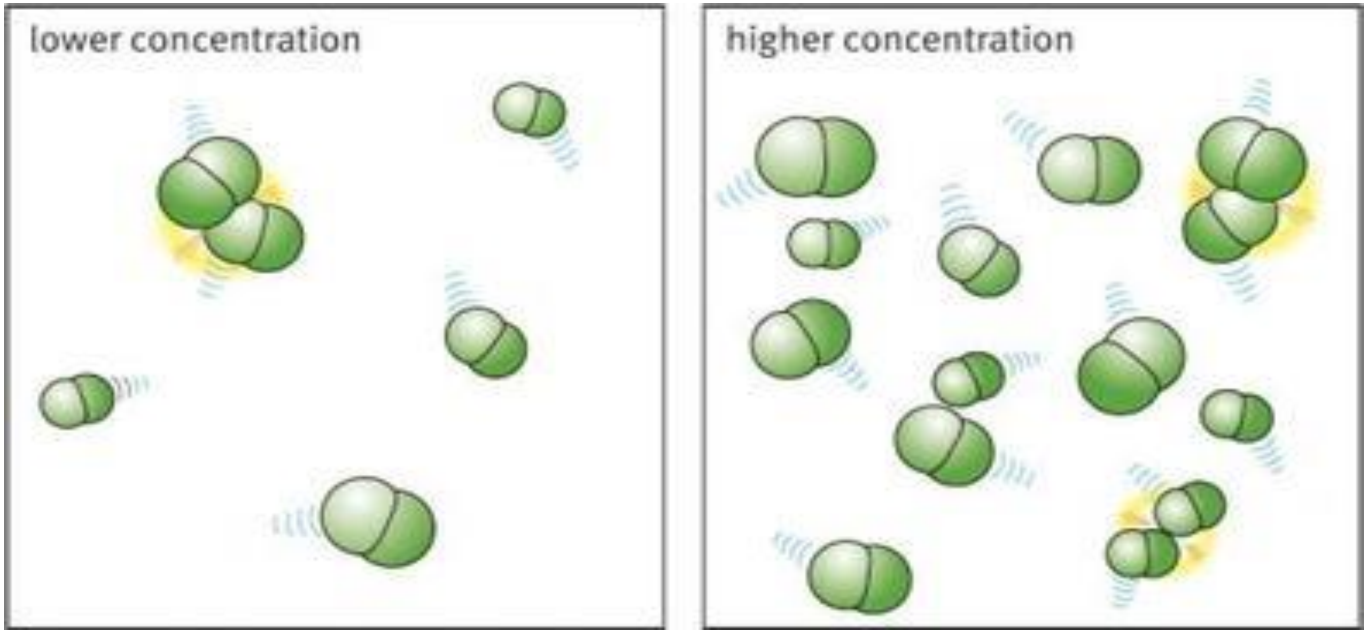


Reaction Rate

Reactions take place over time. As the amount of reactants decrease the amount of products increase. The reaction rate is shown as a curve because the amount of reactants at the start is greater and the reaction rate slows as they decrease

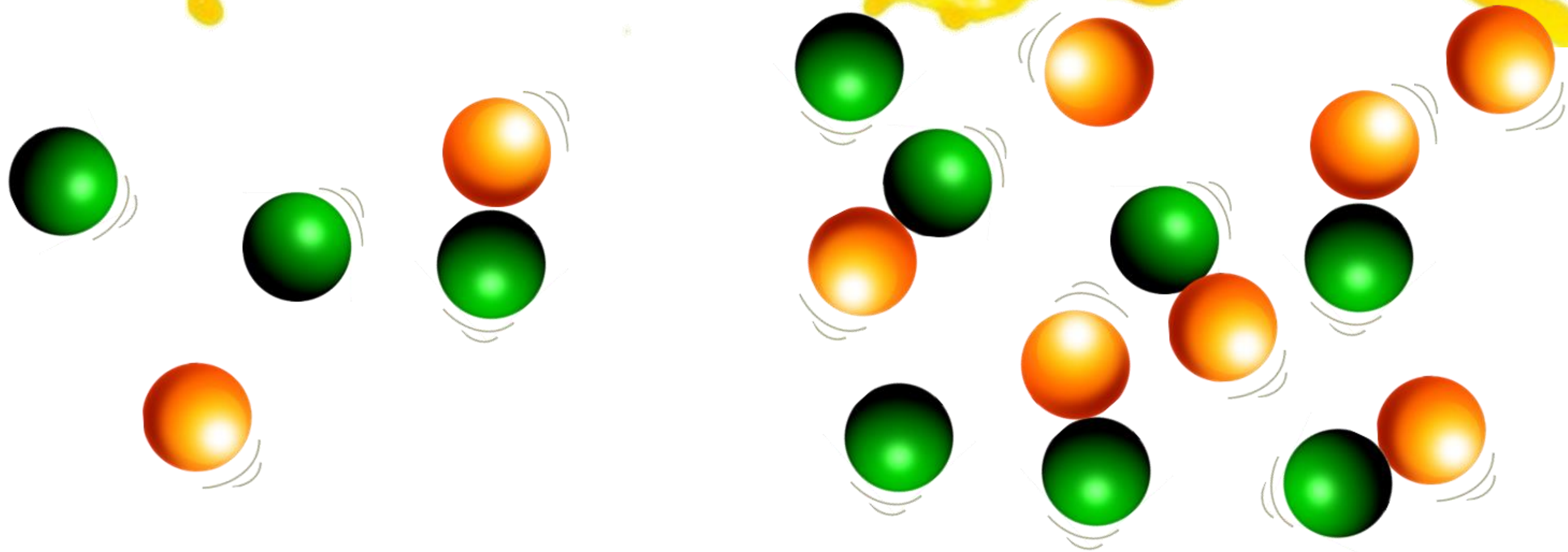


Reaction rate can be increased by increasing the concentration



Increasing the concentration of one or more of the reactants will increase the reaction rate.
Decreasing the concentration of one or more of the reactants will decrease the reaction rate.

Reaction rate can be increased by increasing the concentration

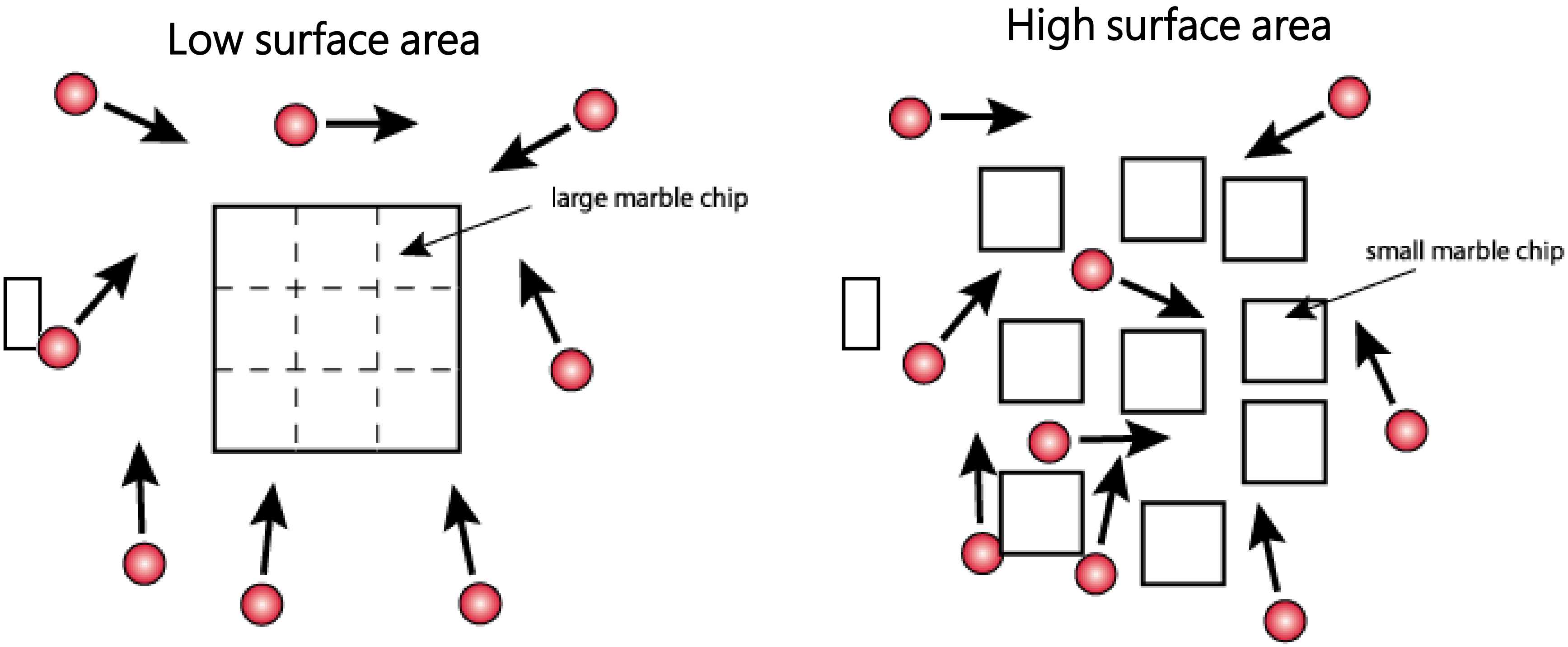


Low concentration = few collisions **High concentration = more collisions**

If there is a **higher concentration of a reactant**, there is a greater chance that particles will collide because there is less space between particles. There are **more particles per unit volume**. The **higher frequency of collisions** means there are more collisions per unit of time and this will **increase the rate of the reaction**.

If there is a lower concentration, there will be fewer collisions and the reaction rate will decrease.

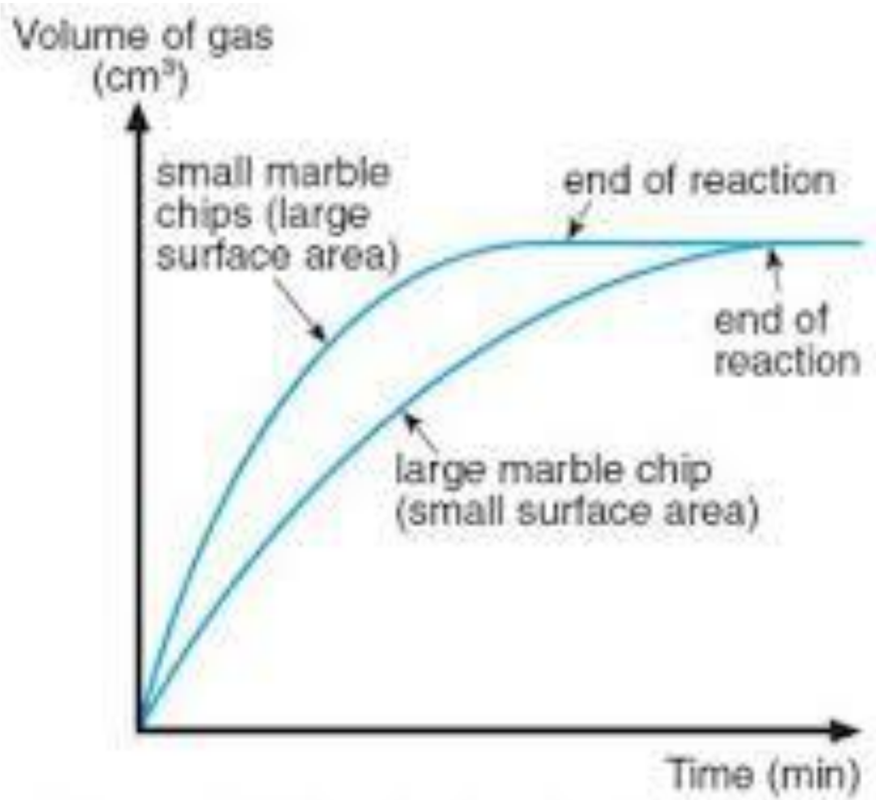
Reaction rate can be increased by increasing the Surface Area



Surface area can be increased by grinding and crushing large lumps into a finer powder. The smaller the pieces the greater the surface area.

Reaction rate can be increased by increasing the surface area

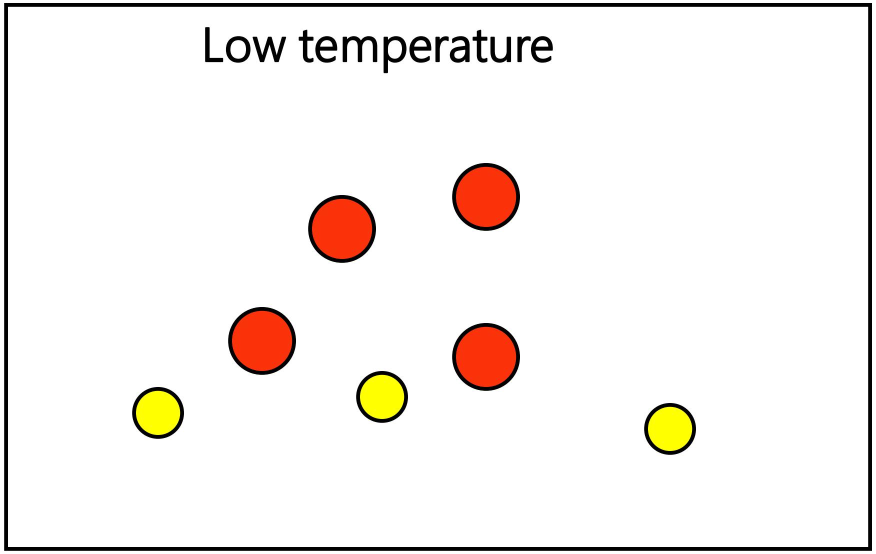
By increasing surface area a greater number of reactant particles are exposed and therefore able to collide. The frequency of collisions (number of collisions per unit of time) will increase and therefore the reaction rate will also increase.

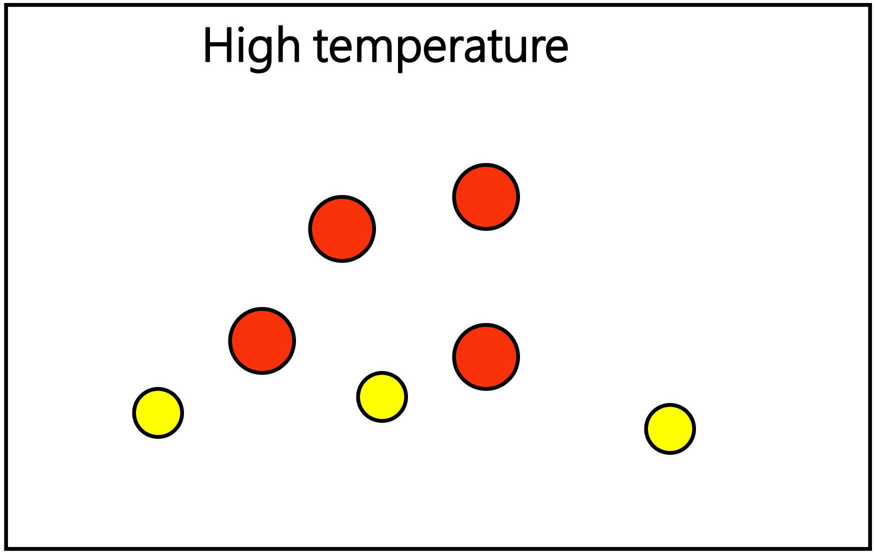


An example is comparing the reaction between marble (calcium carbonate) and hydrochloric acid to produce carbon dioxide gas.

Note: although the reaction rate is higher for the smaller marble chips the total amount of gas (CO_2) produced is the same for both reactions as they both started off with the same amount of reactants.

Reaction rate can be increased by increasing the Temperature





Increasing the temperature (kinetic energy) of the reacting particles will increase the reaction rate.
Decreasing the temperature (kinetic energy) of the reacting particles will decrease the reaction rate.

Reaction rate can be increased by increasing the Temperature

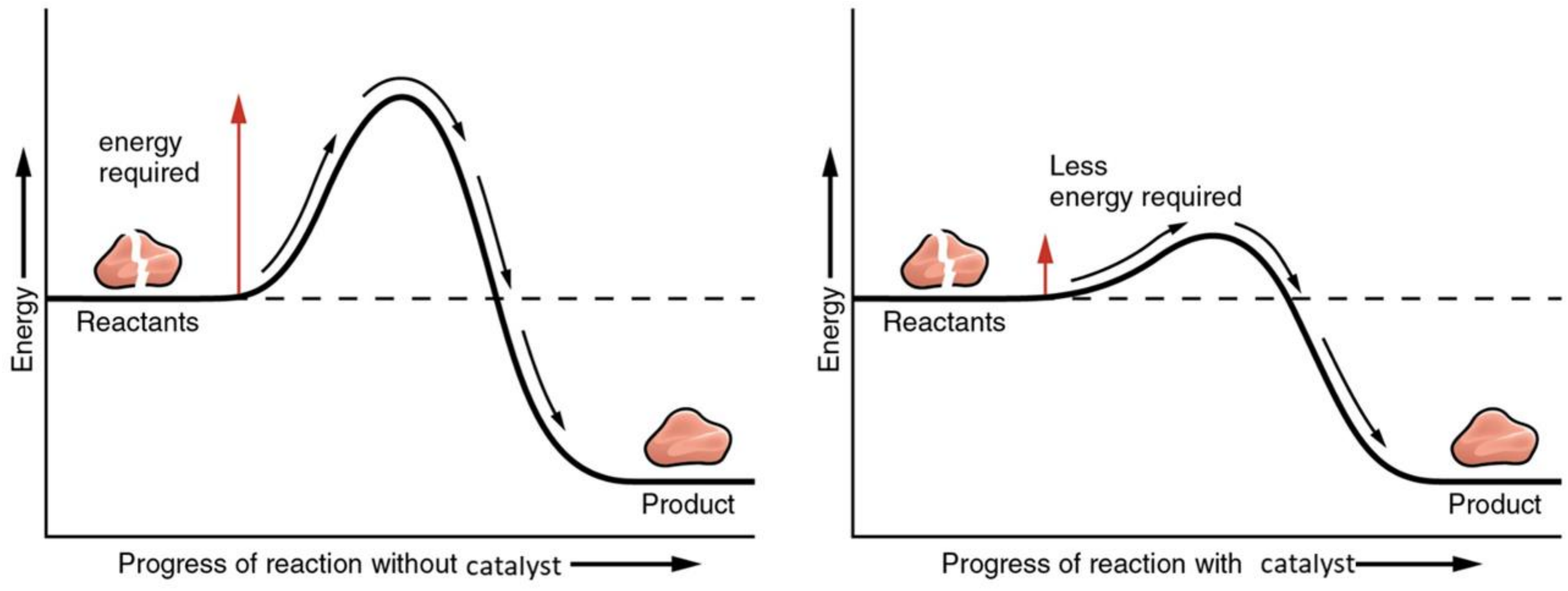
Increasing temperature effects the reaction rate in <u>two ways</u>.

Firstly when you raise the temperature of a system, the particles move around a lot more (because they have more kinetic energy). When they move around more, they are **more likely to collide and the frequency of collisions increases**, therefore the reaction rate increases. When you lower the temperature, the molecules are slower and collide less frequently therefore the reaction rate decreases.

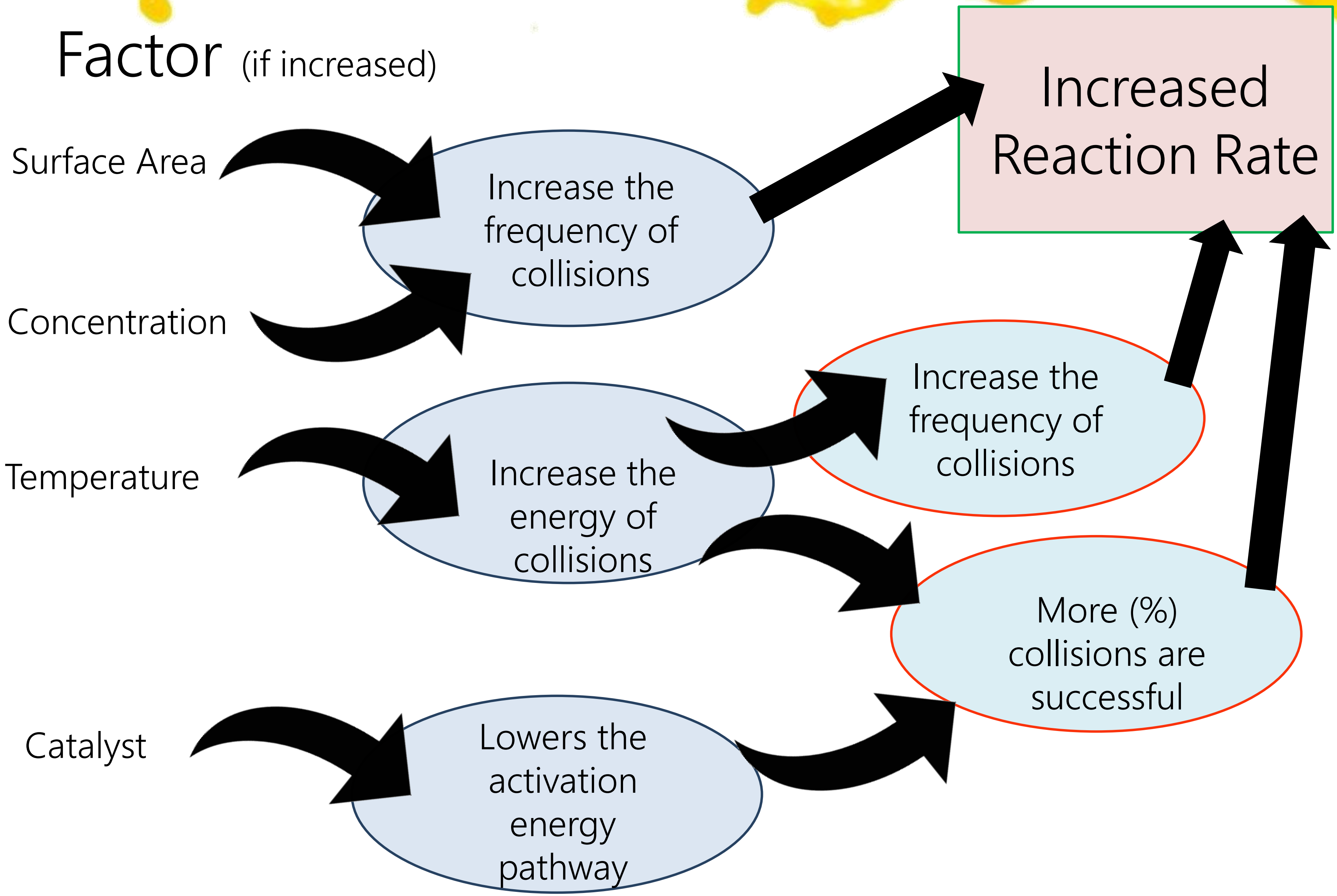
Secondly at a higher temperature a **larger proportion of particles have sufficient (kinetic) energy to have the energy required during a collision for it to be successful** and therefore a reaction to occur. This increases the proportion of successful collisions and therefore the reaction rate.

Reaction rate can be increased by using a catalyst.

A catalyst is a substance that increases the reaction rate without being used up or forming part of the products. Only some reactions have catalysts that are effective, but for many reactions there is no catalyst that works.
A catalyst lowers the minimum amount of energy required for a reaction to take place. This means that the particles can successfully collide with less energy than they required before the catalyst was added. **A greater proportion of particles will successfully collide**, and therefore the reaction rate will be increased.



Summary of Reaction rates



Factors affecting Reaction Rate

<u>Increase the frequency of collisions</u>

- By **increasing surface area**: smaller pieces of reactant expose more reactant particles to collisions. Stirring will also in crease the reaction rate
- By **increasing the concentrations**: more reactant particles exist in a given volume so more collisions occur (per unit volume)

<u>Increase the energy of collisions</u>

>by **increasing temperature**: particles move faster so have more kinetic energy. More collisions will be effective (successful)

Note: increasing temp also increases frequency of collisions (collisions per unit time)

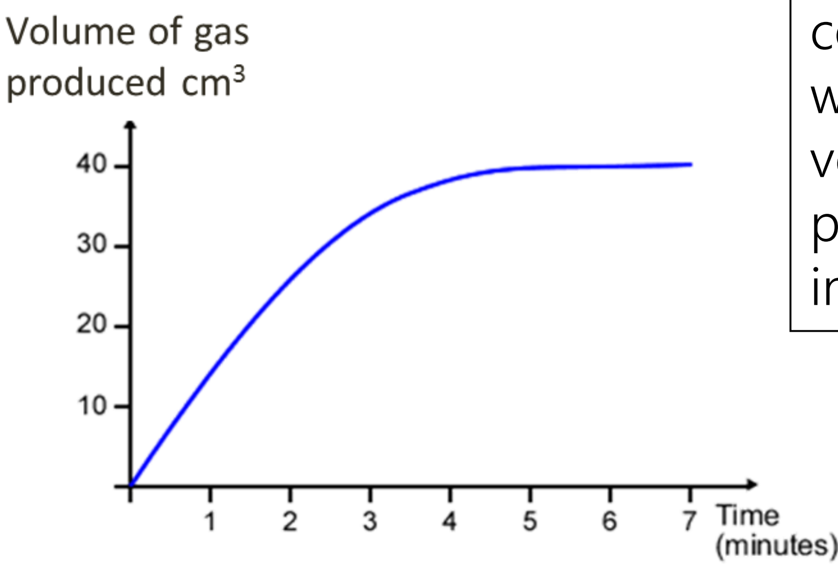
<u>Make it easier for reaction to occur</u>

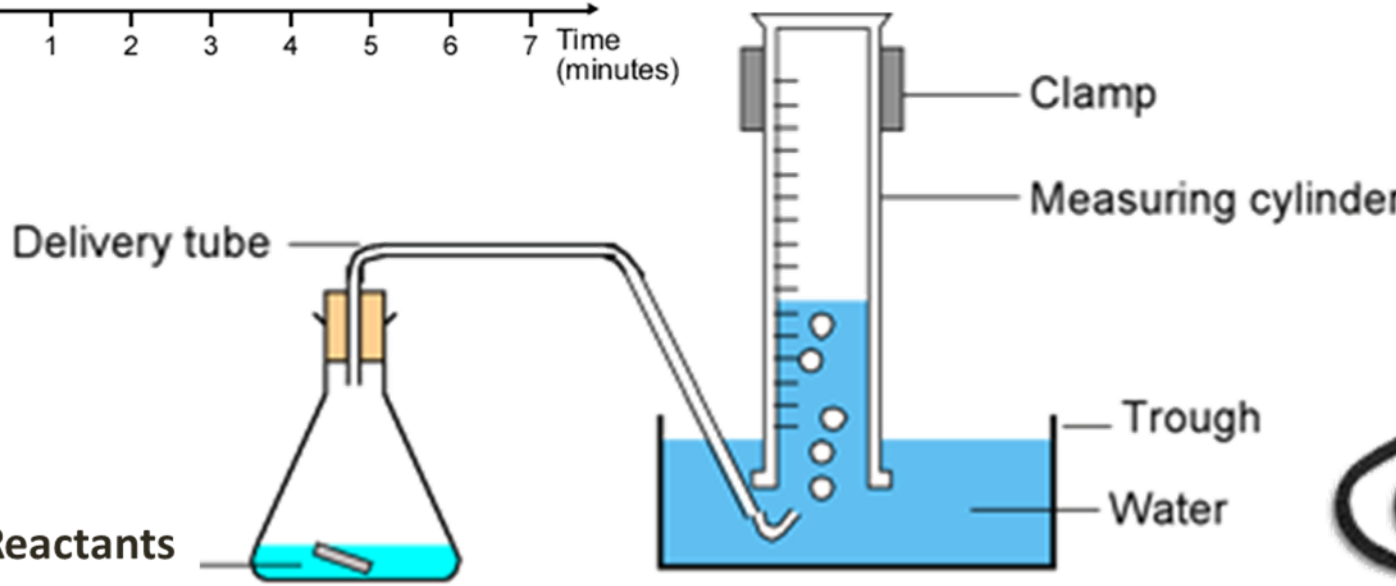
>by **using a catalyst**: allows reaction to occur along a different energy pathway so more collisions are effective (successful)

Reaction rate can also be slowed down by decreasing these

Measuring the rate of reaction

When gas is one of the products it can be collected in an upside down cylinder. The water displacement is a measure of the volume of gas produced. The amount produced needs to be recorded at set time intervals and then graphed.





Reaction rate case study

Hydrochloric acid was reacted with calcium carbonate in the form of marble chips (lumps) and powder (crushed marble chips) in an experiment to investigate factors affecting the rate of a chemical reaction..
Explain why the hydrochloric acid would react faster with the powder.

When the marble chips are crushed there is a **greater surface area**. This means there are now **more particles for collisions** to occur between the acid and the calcium carbonate. Because more collisions can now occur **more frequently** the **reaction rate is faster**.