National 4 Chemistry

Unit 1
Chemical changes and structures

Material sourced from BBC Bitesize Revision Website

1 - Rates of reaction

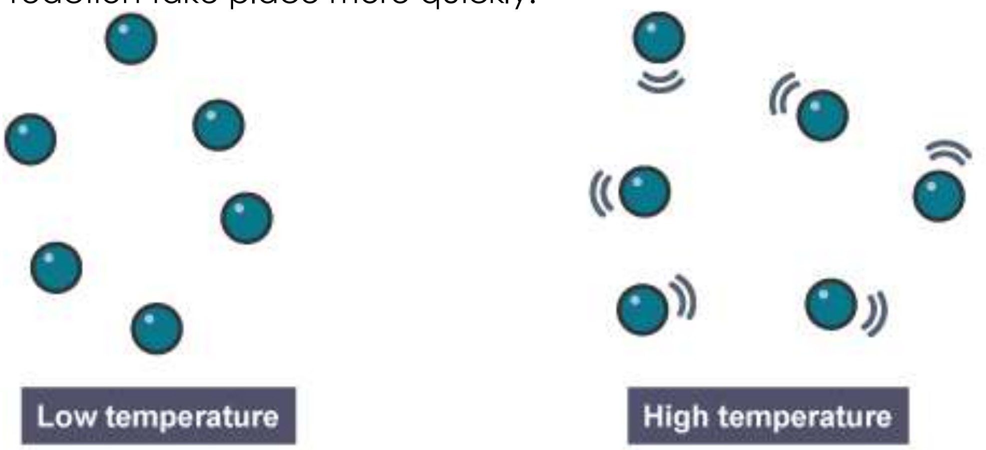
Different chemical reactions occur at different rates or speeds. Some are very slow, like a car rusting, while others are very fast like a sudden explosion.

There are four factors that affect the rate of a chemical reaction:

- temperature
- concentration
- particle size
- use of a catalyst

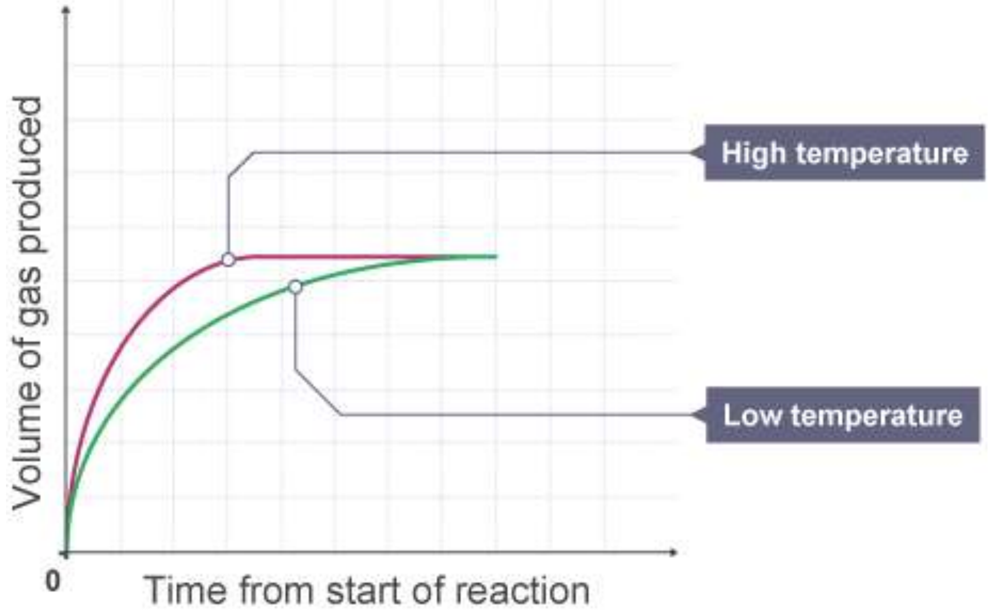
a) Temperature

Increasing the temperature a reaction takes place at increases the rate of reaction. At higher temperatures, particles can collide more often and with more energy, which makes the reaction take place more quickly.



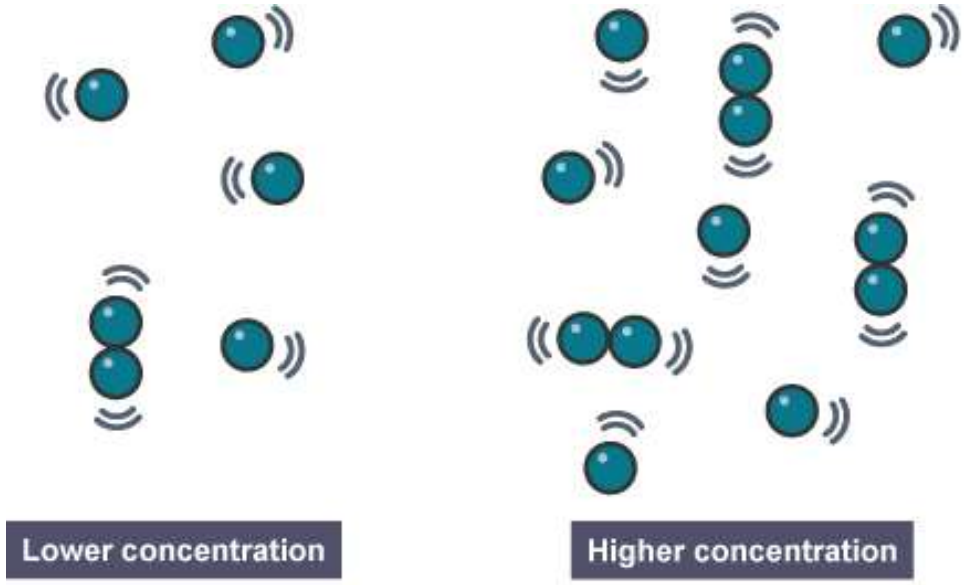
Particles at low temperatures move more slowly than those at high temperatures

The graph below shows how changing the temperature affects the rate of reaction between an acid and chalk. The magenta line represents a faster reaction because it is steeper. Both reactions release a gas and both finish at the same volume.



b) Concentration

If you increase the concentration of a reactant, there will be more of the chemical present. More reactant particles moving together allow more collisions to happen and so the reaction rate is increased. The higher the concentration of reactants, the faster the rate of a reaction will be.



c) Particle size

By decreasing the particle size of a reactant, there are more surfaces that collisions can take place on. The smaller the particle sizes the faster the reaction.

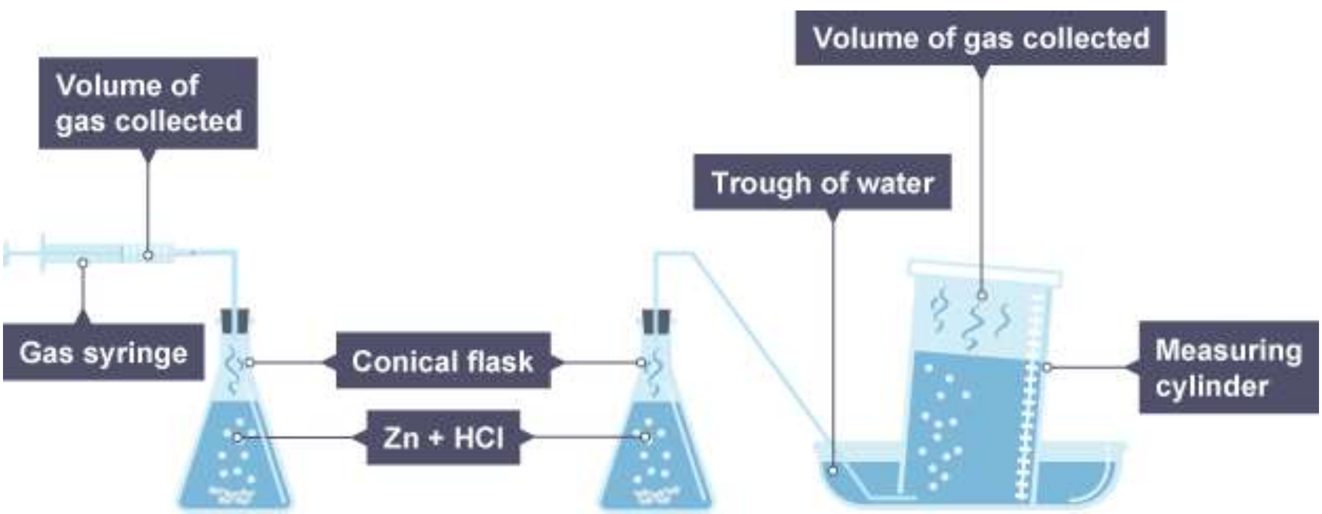
d) Monitoring the rate of a reaction

The rate of a chemical reaction is a measure of how fast the reactants are being used up and how fast the products are being made.

Reactions in which a gas is produced can be used to monitor the rate.

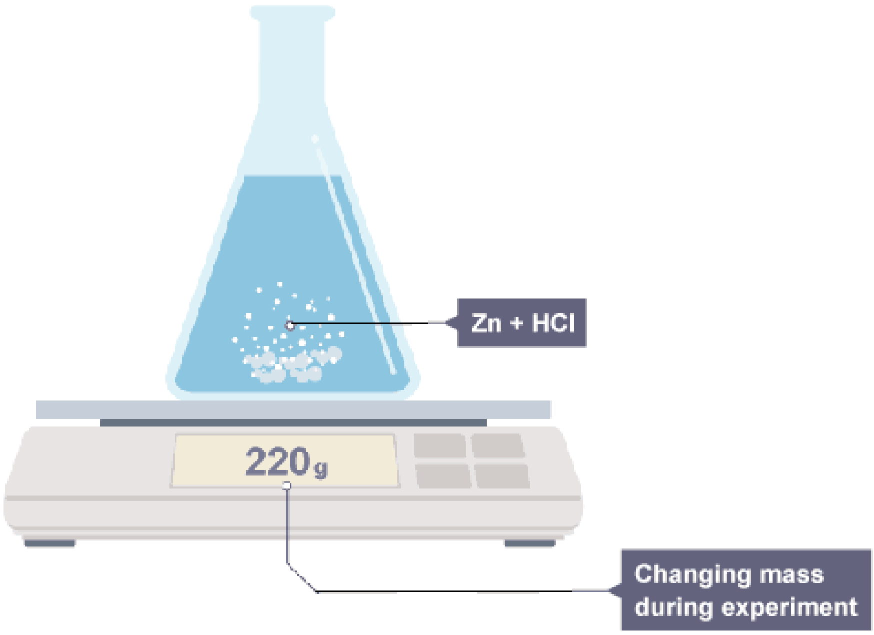
For example, hydrogen gas is one of the products released when dilute hydrochloric acid reacts with zinc metal.

By collecting the hydrogen gas that is produced over water or in a syringe, rate graphs can be produced. The volume of gas produced and the time taken need to be recorded.



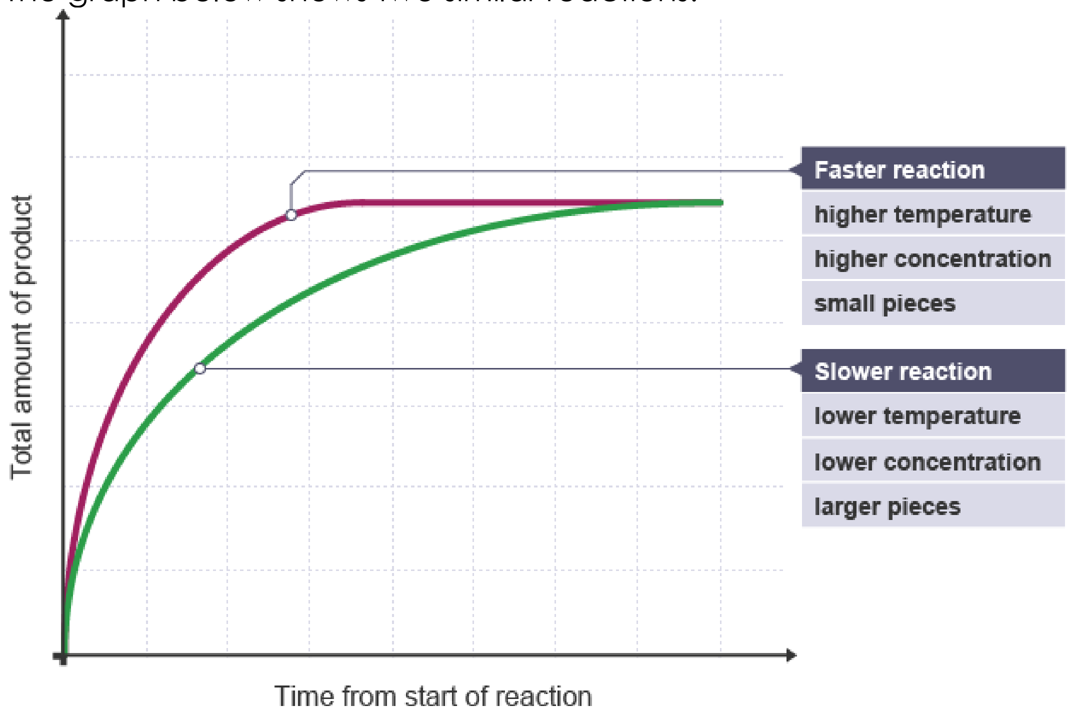
Two different ways to measure the volume of a gas that is produced

The rate of the same reaction could be monitored by measuring the change in the mass of reactants as they react to form products.
If the reaction was set up on a balance as shown, the mass of the apparatus can be monitored and recorded at time intervals throughout the reaction. As hydrogen bubbles escape, the apparatus will lose mass



e) Rate graphs

In chemistry, graphs can be used to follow the course of a reaction. A graph can tell us many things about a reaction.
The graph below shows two similar reactions.



The magenta line has a steeper gradient and represents conditions favouring a faster reaction than the green line. When the reaction is finished (the end-point) the graph goes flat as no more products are being produced.

2 - Energy changes of chemical reactions

Every chemical reaction involves a change in energy. During the reaction, bonds inside the substances that are reacting together must be broken and new chemical bonds must be formed in the products that are being made. There are two different types of energy change that can take place.

a) Exothermic reactions

Exothermic reactions involve energy being released. This energy is most commonly a release of heat energy which would be indicated by a temperature rise.

Energy could also be released in a chemical reaction in the form of a sound or light being produced but the most exciting chemical reactions will probably have all three going on!

Exothermic reactions happen around us in everyday life. Fuels burning in combustion reactions involve energy being released. It doesn't matter if it's a small object like a match or a whole bonfire that is burning, both heat energy and light energy are given out.

Not every exothermic reaction is as exciting as a combustion reaction. When acids and alkalis react together, the energy released is not as obvious. Mixing the two solutions and stirring results in a small increase in the temperature of the reaction mixture.

b) Endothermic reactions

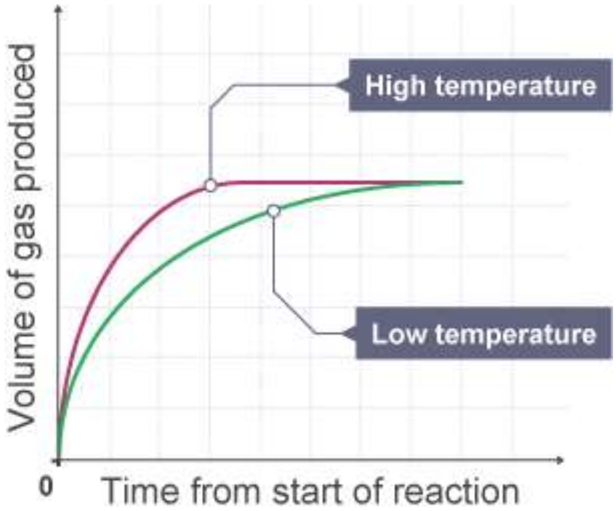
An endothermic reaction is one in which heat energy is taken in. Normally this is shown by a drop in temperature.

There are fewer examples of endothermic reactions in everyday life. Chemical cold packs that are used to treat bumps and sprains use an endothermic reaction to cool down. Squeezing the cold pack bursts a small inner bag allowing two chemicals to mix. The result is an endothermic reaction that cools the pack down and it can be used to stop or reduce swelling.

Rates of Reaction and Energy Changes Minitest

1 Which of these factors will speed up a chemical reaction?
- o Decreasing the temperature of the reaction
- o Decreasing the particle size of reactants
- o Decreasing the concentration of reactants

2 In an experiment calcium carbonate was added to hydrochloric acid and the volume of gas given off was measured.
This graph was drawn from the results.



Which of the following statements is correct?
- o Experiment A was 5g of calcium carbonate chips, B was 2.5g of calcium carbonate powder
- o Experiment A was 5g of calcium carbonate chips, B was 5g of calcium carbonate powder
- o Experiment A was 5g of calcium carbonate powder, B was 5g of calcium carbonate chips

3 Cutting potatoes into smaller pieces makes them cook faster when they are boiled.
Which of the following correctly explains why this happens?
- o The smaller potatoes have a larger surface area
- o The smaller potatoes cook at a higher temperature
- o The knife acts as a catalyst in the reaction

4 Which of the following could not be used to directly measure the volume of a gas given off during a reaction?
- o A gas syringe
- o A balance
- o A trough of water and a measuring cylinder

5 When a fuel burns it reacts with oxygen and gives out heat and light energy.
How can this reaction be described?
- o Exothermic
- o Endothermic
- o Neutralisation

6 Which of the following reactions would be the slowest?
- o 0.5 mol/l hydrochloric acid reacting with zinc powder
- o 1mol/l hydrochloric acid with zinc powder
- o 0.5 mol/l hydrochloric acid reacting with a lump of zinc

7 In which of the following reactions would hydrogen be produced the fastest?
- o Calcium powder and 2 mol/l hydrochloric acid
- o Calcium lumps and 2 mol/l hydrochloric acid
- o Calcium powder and 4 mol/l hydrochloric acid

8 What does a catalyst do?
- o Speeds up a reaction and is not used up in the reaction
- o Slows down a reaction and is not used up in the reaction
- o Speeds up a reaction and is used up in the reaction

9 Which factor is always measured when comparing the rate of reactions?
- o Temperature
- o Change in volume
- o Time

10 Which line on this rate graph shows the slowest reaction?

- o A
- o B
- o C

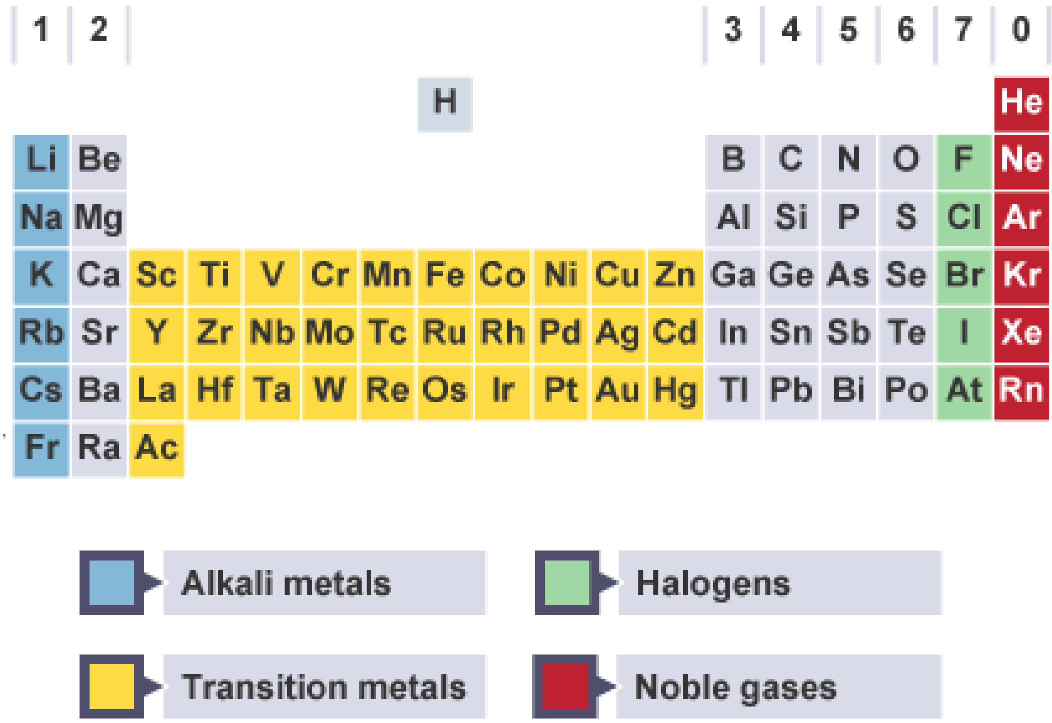
3 - Atomic Structure and Bonding Related to Properties of Materials

Everything is made of atoms. Atoms themselves are made of smaller particles. Elements can join together in different ways to form compounds with different properties.

a) The Elements

Everything in the world is made from about 100 different chemical elements that join together in different ways to form all the solids, liquids and gases we see around us.
An element is a substance that contains only one type of atom. As a result, they are the simplest substances known.
All of the elements have been arranged into the periodic table.

In some periodic tables there is a dark zigzag line that separates the metal elements from the non-metal elements.



To the left of the zigzag line are the metals and on the right hand side of the zigzag line are the non-metals.

The periodic table can be divided into periods (horizontal rows) and groups (vertical columns).
Elements that are in the same group of the periodic table have similar chemical properties (they react in the same way). Some groups have their own names.

b) <u>Structure of the atom</u>

Everything in the world is made up of atoms. The structure of the atom is what gives an element its chemical and physical properties.
Atoms are made up of three smaller particles called electrons, protons and neutrons.

<u>Electrons</u>

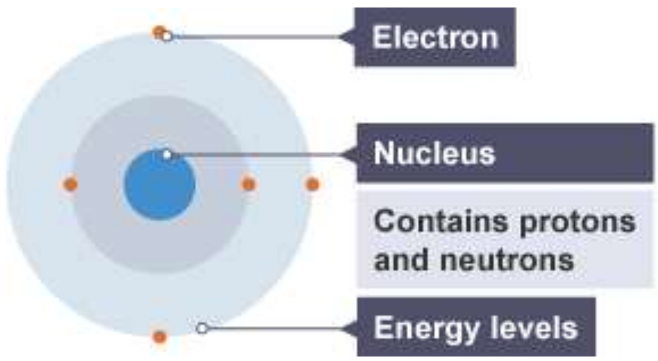
Negatively charged particles that spin around the positive centre of the atom in circles called energy levels. Their mass is so small it is nearly zero.

<u>Protons</u>

Positively charged particles that are contained in the nucleus of the atom (the centre) they have a mass of 1amu (atomic mass unit).

<u>Neutrons</u>

Particles with no charge are also contained in the nucleus of the atom. They too have a mass of 1amu.



The nucleus has an overall positive charge as it contains the protons.

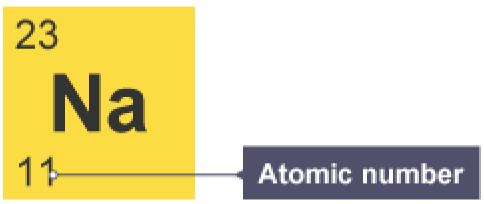
Particle	Mass	Charge	Location
Electron	Approx 0	-1	Energy level
Proton	1 amu	+1	Nucleus
Neutron	1 amu	0	Nucleus

Every atom has no overall charge (neutral). This is because they contain equal numbers of positive protons and negative electrons. These opposite charges cancel each other out making the atom neutral.

<u>Atomic number</u>

Each element has its own atomic number.

Elements are arranged in the periodic table in order of increasing atomic number. For example hydrogen has the atomic number of one, helium two, lithium three etc.



Mass number

The mass number is given at the top left of the element's symbol, for example, sodium has a mass number of 23.

We know that the atomic number of sodium is 11. This tells us that sodium has 11 protons and because it is neutral it has 11 electrons.

The mass number of an element tells us the number of protons AND neutrons in an atom (i.e. the two particles that have a measureable mass).

Sodium has a mass number of 23amu. Since sodium has 11 protons, the number of neutrons is given by mass number – number of protons (23 - 11) = 12 neutrons.

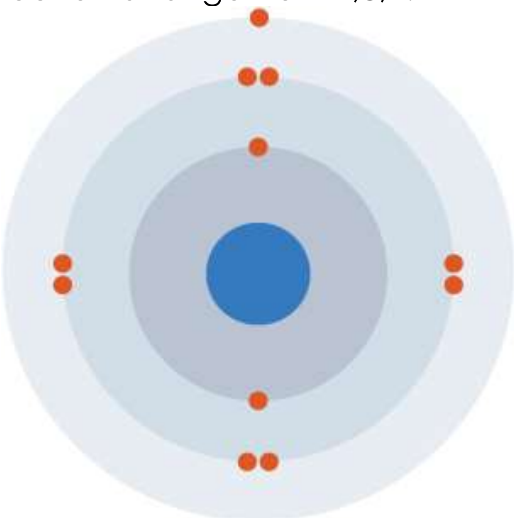
Element	Mass number	Protons	Neutrons
Magnesium	24	12	12
Potassium	39	19	20
Carbon	12	6	6

Electron Arrangement

The electron arrangement of all atoms can be found in the data booklet. All the electrons are arranged into energy levels. These energy levels can only hold a certain number of electrons.

The first energy level (the one nearest the nucleus) can hold a maximum of 2 electrons with the others being able to hold up to a maximum of 8 electrons (only true for the first 20 elements).

Example: sodium has the electron arrangement 2,8,1.



An atom of sodium has 11 electrons. The first two fill the innermost energy level. The second energy level is also full, holding eight electrons and one electron remains in the outer energy level.

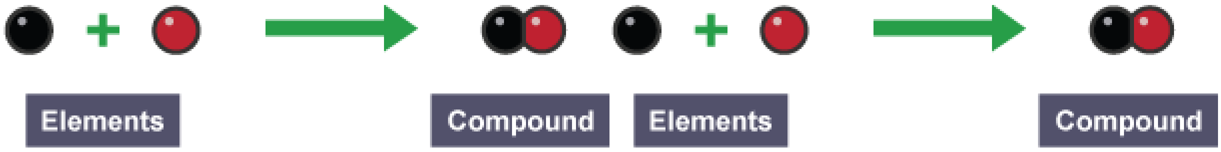
Elements in the same group of the periodic table have the same number of outer electrons.

It is the number of outer electrons that give an element its chemical properties. This is why elements in the same group of the periodic table have similar properties.

c) <u>Compounds</u>

When elements combine or join together new substances are formed. These substances are called compounds.

This is shown in the diagram below



There are millions of different compounds and all of them have different properties. The properties of compounds are linked to the type of bonds formed within them.

<u>Naming compounds</u>

Naming compounds is easy if you follow these 3 simple rules.

- Rule one:

  The element that is furthest left in the periodic table comes first, eg Sodium Chloride/Carbon dioxide

- Rule two:

  If there are only two elements in the compound then the compounds name ends in –ide, eg A compound of copper and sulfur is called copper sulfide.

- Rule three:

  If the compound contains three elements one of which is oxygen then the compound name will end in –ate or –ite, eg Calcium carbonate contains calcium, carbon and oxygen.

Sometimes the name of the compound gives information about the formula of that compound. Names of these compounds have prefixes that give the number of atoms of certain elements in each molecule.

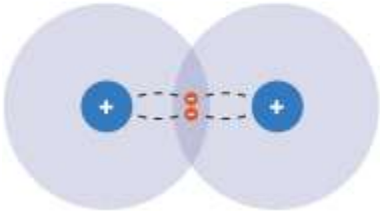
Prefix	Number of atoms
Mono-	One
Di-	Two
Tri-	Three
Tetra-	Four
Penta-	Five
Hexa-	Six

Example – Carbon monoxide contains one carbon atom joined to one oxygen atom, so it has the formula CO.

d) Bonding in Compounds

Covalent compounds

A covalent bond is a shared pair of electrons between two non-metal atoms, for example carbon dioxide.



A covalent bond happens when the positive nuclei from two different atoms are held together by their common attraction for the shared pair of electrons held between them.

Covalent bonds are strong bonds.

Atoms that share pairs of electrons form molecules. A molecule is a group of atoms held together by covalent bonds. Covalent compounds do not conduct electricity.

Substances that consist of covalent molecules are usually gases or liquids at room temperature.

Ionic compounds

Ionic bonds are formed between a metal and non-metal, for example, sodium chloride. Outer electrons are transferred from the metal to the non-metal.

Sodium will lose an electron and form a positive ion.

Chlorine will gain an electron and form a negative ion.

The ionic bond is the force of attraction between the oppositely charged ions - a positively charged metal ion and a negatively charged non-metal ion.

For example Magnesium (Mg) has the electron arrangement 2,8,2.

To become stable it must lose its two outer electrons to obtain a full outer energy level.

Atoms are neutral because they have equal numbers of protons and electrons however, when they lose two electrons they are no longer neutral. They change into ions with a two positive charge.

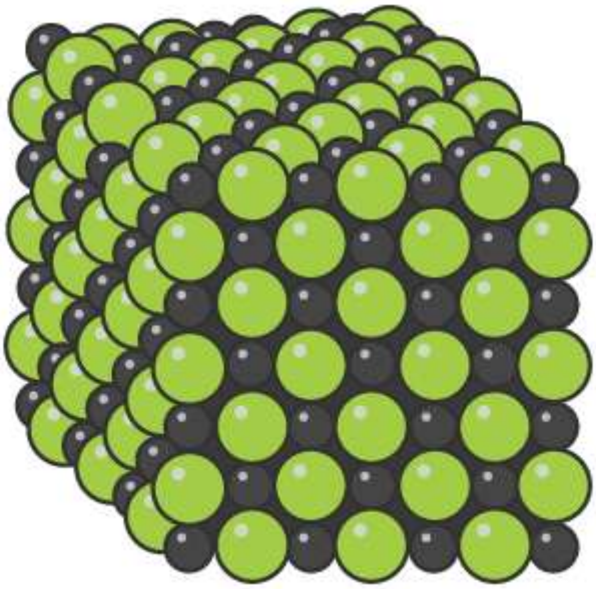
$$\begin{array}{ll} Mg \rightarrow & Mg^{2+} + 2e^- \\ 2,8,2 & 2,8 \end{array}$$

Non-metals form negative ions because they gain electrons to become stable.

$$\begin{array}{lll} Cl & + \quad e^- \rightarrow & Cl^- \\ 2,8,7 & & 2,8,8 \end{array}$$

When these two charged particles come together they form an ionic bond because the positive magnesium ion is attracted to the negatively charged chlorine ion.

Ionic compounds form what is known as a lattice structure. This is a regular arrangement of metal and non-metal ions which creates compounds with very high melting points which conduct when molten or in solution but NEVER when solid.



Ionic compounds dissolve in water easily, when they do this their lattice breaks up completely. Therefore they can conduct as their ions are free to move.

<u>Summary of bonding and properties</u>

	Ionic lattice	**Covalent molecular**
Boiling and melting points	High	Low
State at room temperature	Solid	Liquid or gas
Conduction of electricity	Only when molten or in solution	Never

3 - Atomic Structure and Bonding Related to Properties of Materials Minitest

1 What is the centre of an atom called?
- o The protons
- o The nucleus
- o The electrons

2 What is the charge on an electron?
- o One positive
- o No charge
- o One negative

3 Which of the three sub-atomic particles is the lightest?
- o The proton
- o The neutron
- o The electron

4 If atoms contain charged particles, why do they not have a charge?
- o They contain the same number of protons as electrons
- o The charge is locked away in the nucleus
- o They contain equal numbers of protons and neutrons

5 What is the atomic number of an atom equal to?
- o The number of protons in the nucleus
- o The number of neutrons in the nucleus
- o The numbers of protons and neutrons in the nucleus

6 Where are the electrons inside an atom?
- o The electrons are in the nucleus of an atom
- o They are arranged in energy levels
- o The electrons are spread equally throughout the atom

7 Which elements have similar chemical properties?
- o Elements in the same period of the periodic table
- o Elements with the same number of electrons in their outer energy level
- o Elements with similar mass numbers

8 What name is Group 7 of the periodic table known by?
- o Alkali metals
- o Halogens
- o Noble Gases

9 Sodium and chlorine react together to form the compound sodium chloride.

How are sodium and chlorine held together in this compound?
- o Sodium and chlorine share electrons and are held together by their attraction for the shared pair of electrons
- o Sodium and chlorine join together to form molecules
- o Positive sodium ions and negative chloride ions form a crystal lattice

10 Which elements are found in the compound calcium carbonate?
- o Calcium, carbon and oxygen
- o Calcium and carbonate
- o Calcium and carbon

4 – Acids & bases

The pH scales measures the acidity or alkalinity of a solution. Acids and bases have a wide variety of uses and can react together in neutralisation reactions.

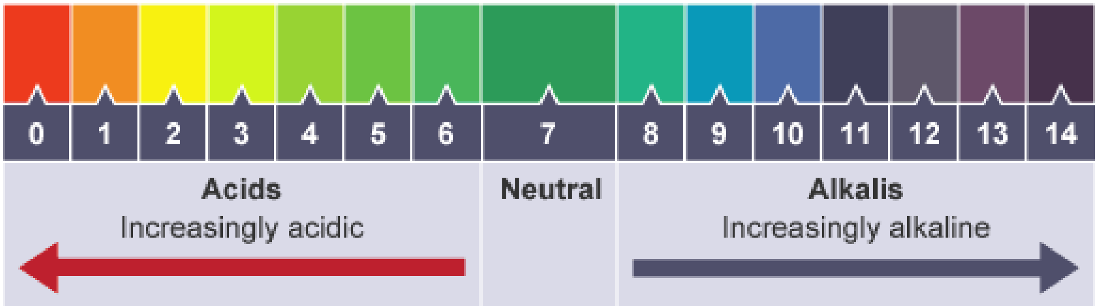
a) The pH scale

How acidic or alkaline a substance is (the pH of the substance) can be measured using the pH scale, a continuous range that stretches from below 0 to above 14. Most common pH values occur between 0 and 14.

Acids have a pH of less than 7.

Alkalis have a pH more than 7.

Water and neutral solutions have a pH of exactly 7.



b) Forming acids and alkalis

Soluble metal oxides (or metal hydroxides) produce alkaline solutions.

Soluble non-metal oxides produce acidic solutions.

Insoluble oxides will not affect the pH of water.

Example one

What will happen to the pH of water if barium oxide is added?

Using the data booklet we find that barium oxide is a metal oxide. Checking its solubility on page 8 of the data booklet we see that it will dissolve. It is therefore a soluble metal oxide and it will increase the pH.

Example two

What will happen to the pH of water if sulfur dioxide is added?

Using the data booklet we find that sulfur dioxide is a non-metal oxide. We know it is soluble because it contributes to acid rain. It is therefore a soluble non-metal oxide and it will decrease the pH.

Example three

What will happen to the pH of water if aluminium oxide is added?

Using the data booklet we find it is a metal oxide. Checking its solubility on page 8 we find it is insoluble. It will therefore have no effect on the pH of water.

c) <u>Common acids and alkalis</u>

Acids and alkalis are not only found in chemistry labs, they are actually very common. We use acids and alkalis in our daily lives for things like cleaning, cooking and you even eat and drink some substances that are acidic or alkaline.

Common lab acids include:

- Hydrochloric acid
- Sulfuric acid
- Nitric acid

Acids can be found in everyday products like:

- Fizzy drinks
- Vinegar
- Fruit juices

Common lab alkalis include:

- Sodium hydroxide
- Potassium hydroxide
- Ammonia

Alkalis are found in everyday products like:

- Oven cleaner
- Baking soda
- Drain unblocker

d) <u>Diluting acids and alkalis</u>

Adding water to an acid or base will change its pH.

When an acidic solution is diluted with water the pH of the solution increases gradually, making the solution less acidic as more water is added.

Similarly, when an alkali is diluted with water the pH of the alkali will fall towards 7, making the solution less alkaline as more water is added.

e) <u>Neutralisation</u>

Neutralisation is the reaction of an acid with a base that results in the pH moving towards seven. It is a useful process that occurs in everyday life such as in the treatment of acid indigestion and the treating of acidic soil by adding lime.

When an acid is neutralised, its pH increases towards seven. When an alkali is neutralised, its pH decreases towards seven.

Several different bases can neutralise acids, and water is always produced as a result of these reactions.

<u>Equations for neutralisation</u>

$$Acid + alkali \rightarrow salt + water$$

$$Acid + metal\ oxide \rightarrow salt + water$$

Metal oxides and alkalis are two types of base. Basic substances neutralise acids, resulting in the pH of the acid increasing towards 7, and water being produced. A soluble base dissolves in water to form an alkali.

f) <u>Naming salts</u>

To name the salt, the metal ion from the alkali (or base) replaces the hydrogen ion from the acid - (alkali to front, acid to back).

For example:

hydrochloric acid + sodium hydroxide → sodium chloride + water

Acid name	Salt name ending
Hydrochloric acid	...chloride
Sulfuric acid	...sulfate
Nitric acid	...nitrate

During every neutralisation reaction, water is formed.

Acids are neutralised by bases

A neutralisation reaction is one in which an acid reacts with a base to form water. A salt is also formed in this reaction.

Bases are metal oxides, metal hydroxides and metal carbonates.

In the neutralisation reaction between an acid and a metal carbonate, there are three products, a salt, water and also carbon dioxide gas.

hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide

The salt is named in the same way as before, taking the metal's name from the metal carbonate and the ending from the type of acid used.

Carbon dioxide can be tested for using lime water (turns from colourless to chalky white).

g) <u>Acid rain</u>

Acid rain is a pollution problem caused by the release of acidic gases into the atmosphere. It contributes to pollution in a variety of ways including:

- damage to plants and the wildlife
- erosion of limestone buildings/structures
- corrosion (rusting) of iron bridges/structures

The three main acidic gases responsible for lowering the pH of rainwater are non-metal oxides produced by the burning of fossil fuels like coal, oil and natural gas.

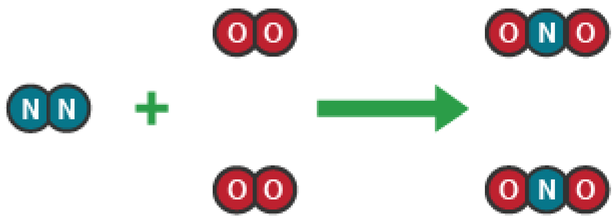
Sulfur dioxide (SO_2)

Sulfur dioxide is produced when fossil fuels containing sulfur impurities are burned.

When the gas sulfur dioxide dissolves in water an acidic solution is formed. Clouds are made from water so this gas rises and dissolves in the clouds to form an acid which falls as rain.

Nitrogen dioxide (NO_2)

Nitrogen dioxide is produced in cars with petrol engines. The spark plugs used to ignite the fuel provide enough energy to break the strong bonds between the nitrogen atoms allowing them to combine with oxygen. This also happens naturally during lightning storms.



Carbon dioxide (CO_2)

Carbon dioxide is produced from burning fossil fuels and another large contribution is made by cement manufacturing for use in new buildings. Carbon dioxide dissolves in oceans to cause ocean acidification which is harmful to shellfish and coral. The release of carbon dioxide is also linked to global warming.

Acids & Bases Minitest

1 Which of the following are correct**?**
- o pH 9 is acid and pH 7 is neutral
- o pH 4 is acid and pH 7 is neutral
- o pH 6 is acid and pH 8 is neutral

2 What type of solution would be formed when sulfur dioxide dissolves in water**?**
- o Alkaline solution
- o Acidic solution
- o Neutral solution

3 What would be the pH of the solution formed when sodium oxide dissolves in water**?**
- o Above 7
- o Equal to 7
- o Less than 7

4 Which of these everyday substances is alkaline**?**
- o Fizzy juice
- o Vinegar
- o Drain unblocker

5 Which salt is made when sodium hydroxide reacts with hydrochloric acid**?**
- o Sodium chloride
- o Sodium sulfate
- o Sodium nitrate

6 Which of the following are the correct products from the reaction between magnesium hydroxide and sulfuric acid**?**
- o Magnesium sulfate + water
- o Magnesium sulfate + water + carbon dioxide
- o Magnesium sulfate + hydrogen

7 What is the name of the type of reaction that happens between acids and alkalis**?**
- o Neutralisation
- o Addition
- o Polymerisation

8 What happens to the pH of an acidic solution as water is added**?**
- o It decreases
- o It increases
- o It stays the same

9 Which of the following is a pollution problem associated with acid rain**?**
- o Ozone layer depletion
- o Global Warming
- o Erodes limestone statues

10 Which of the following happens to the pH of an acid when it is neutralised**?**
- o The pH does not change
- o The pH increases towards 7
- o The pH decreases towards 7

Term	Meaning
atom	All elements are made of atoms. An atom consists of a nucleus containing protons and neutrons, surrounded by electrons.
atomic number	The number of protons in the nucleus of an atom. Also called the proton number.
electron	Sub-atomic particle, with a negative charge and a negligible mass relative to protons and neutrons
electron arrangement	The order electrons are arranged into between different energy levels.
mass number	The number of protons and neutrons found inside the nucleus of an atom.
neutron	Uncharged sub-atomic particle, with a mass of 1 relative to a proton.
nucleus	The central part of an atom. It contains protons and neutrons, and has most of the mass of the atom. The plural of nucleus is nuclei.
proton	Sub-atomic particle with a positive charge and a relative mass of 1.
catalyst	Changes the rate of a chemical reaction without being changed by the reaction itself.
enzyme	Proteins which catalyse or speed up chemical reactions.
product	A substance formed in a chemical reaction.
reactant	Chemicals present at start of a reaction.
volume	The volume of a three-dimensional shape is a measure of the amount of space or capacity it occupies, eg a can of cola has a volume of 330 ml.