Year 10 Combined Science BiE2

Exam content and knowledge organisers

The biology paper could assess:

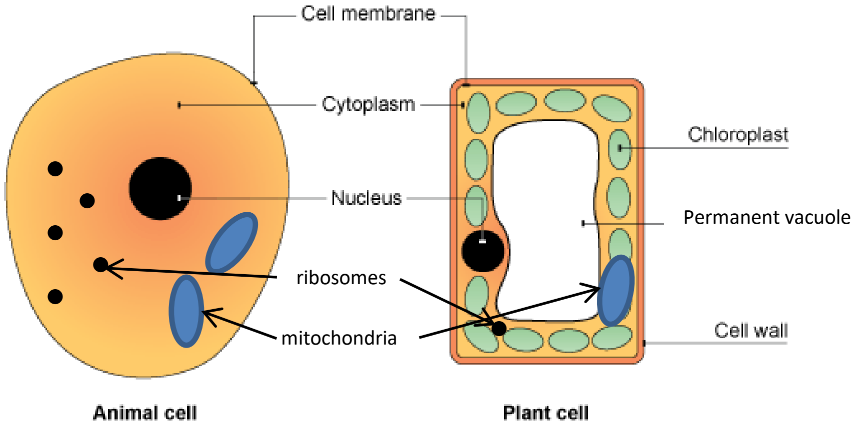
Knowledge Organiser Topics:

- Biology Threshold Concepts
- Cell Cycle
- Staying Alive
- Obtaining and Using Energy
- Disease

Combined Science Biology Knowledge Organiser
Topic 3: Biology Threshold Concepts

Eukaryotic Cells

Eukaryotic cells include all plant, animal and fungus cells. Their most important feature is that they have a nucleus, unlike prokaryotic cells. Learn how to identify the general cell structures shown below.

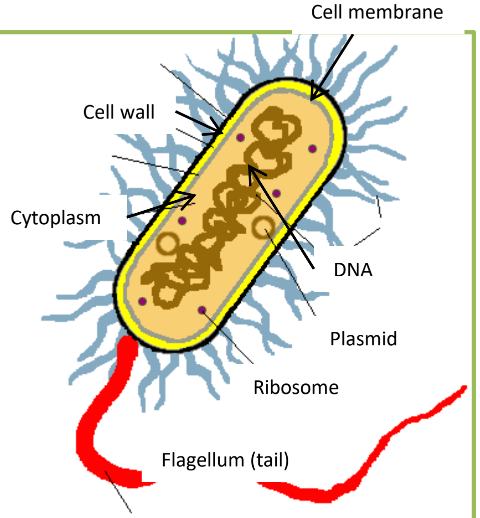


Prokaryotic Cells

Bacteria are prokaryotic cells (all bacteria are single-celled organisms). The most important differences to eukaryotic cells are that they are smaller and their genetic material (DNA) is not enclosed in a nucleus.

Prokaryotic cells have DNA in a loop, and, in addition to the main loop of DNA, they have small loops of DNA called plasmids.

Plasmids allow bacteria to swap genetic information between them.

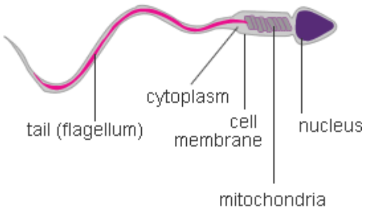


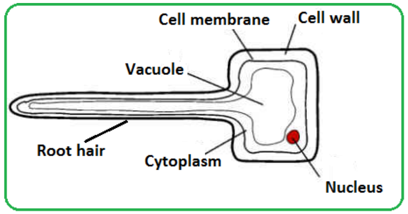
Key Terms	Definitions
cell	The basic unit of all forms of life. (All living organisms are made of a least one cell.)
eukaryotic cells	Cells with a nucleus – e.g. plant and animal cells.
prokaryotic cells	Bacterial cells; these don't have a nucleus to enclose their genetic material.
cell membrane	The border of all types of cell. The cell membrane separates the inside of the cell from the environment. It controls the movement of substances into and out of the cell.
sub-cellular structure	A part of a cell. (Sub- means less than – so these are the component parts of cells.)
nucleus	The enclosure for genetic material found in plant and animal cells.
cytoplasm	The interior of a cell, where most of the chemical reactions needed for life take place.
mitochondria	The sub-cellular structure where aerobic respiration takes place.
ribosome	The sub-cellular structure where proteins are made (synthesised)
chloroplast	A sub-cellular structure responsible for photosynthesis – only found in plant cells and algal cells.
permanent vacuole	A sub-cellular structure only found in plant and algal cells – it is filled with cell sap (a store of nutrients for the cell).
cell wall	A sub-cellular structure that is never found in animal cells. It is made of cellulose, it is outside the cell membrane and it strengthens the cell.
DNA	The molecule that holds the genetic information in a cell. In eukaryotic cells, it is one linear strand. In prokaryotic cells, the DNA forms a loop.
plasmid	A small loop of DNA, only found in prokaryotic cells.

Combined Science Biology Knowledge Organiser
Topic 3: Biology Threshold Concepts

Multicellular Organisms

You are a multicellular organism, just like all animals, plants and many types of fungus. But, not all your cells are the same. Cells become specialised by **differentiation**, which means they develop new features to help them perform a specific function. E.g. sperm cells and root hair cells.





Tissues are formed when cells with similar structures and functions work together. For example: muscle tissue in animals; phloem tissue in plants.

Organs are formed from multiple tissues working together. For example: the stomach in animals; the leaf in plants.

Organ systems are formed when multiple organs work together. For example: the digestive system in animals; the vascular (transport) system in plants.

Microscopy

Use of a microscope is called microscopy. Microscopes allowed scientists to discover cells and find all the sub-cellular structures.
Because cells and their parts are very small, it is not useful to measure them in metres. Instead, we use small divisions of the metre as follows:

Centimetre = 1/100 metre (10^{-2} m). A centimetre is 1 one hundredth of a metre. (cm)
Millimetre = 1/1000 metre (10^{-3} m). A millimetre is 1 one thousandth of a metre. (mm)
Micrometre = 1/1 000 000 (10^{-6} m). A micrometre is 1 one millionth of a metre. (µm)
Nanometre = 1/1 000 000 000 (10^{-9} m) A nanometre is 1 one billionth of a metre. (nm)

Electron microscopes were a vital invention for understanding cells. They have higher magnification and more resolving power than light microscopes, so they let you see smaller structures.

Key Terms	Definitions
organism	Any living thing: can be made of one cell or be multicellular. An organism has many organ systems, all contributing to its survival.
multicellular	This describes an organism that is made of lots of cells – such as animals or plants.
specialised cell	Almost all cells in multicellular organisms have a particular job, or function. While they usually have all the parts labelled on your cell diagrams, they change to suit their functions. This may include developing different sub-cellular structures (e.g. the tail of a sperm cell).
tissue	A group of cells with similar structures and functions – i.e. a group of specialised cells.
organ	An organ is a collection (or aggregation) of tissues performing a specific function.
organ system	Organs don't operate alone: they work together to form organ systems.
light microscope	A usual school microscope is a light microscope. You can see large sub-cellular structures like a nucleus with it, but not a lot more detail than that.
magnification	This is the measure of how much a microscope can enlarge the object you are viewing through it.
resolution	This is the measure of the level of detail you can see with a microscope.
electron microscope	A type of microscope with much high magnification and resolution than a light microscope. Essential for discovering the smaller sub-cellular structures.

Equation	Meanings of terms in equation
$magnification = \frac{size\ of\ image}{size\ of\ real\ object}$	*The image Is how it looks through the microscope. The real object is what you are looking at. The image and object must be measured with the same unit, e.g. both in nm.*

Practical Methods Knowledge Organiser
Topic 3: Microscopy

Equipment List

- a small piece of onion
- a knife or scalpel
- a white tile
- forceps
- a microscope slide
- a coverslip
- a microscope
- iodine solution in a dropping bottle.

Method

To make the slide

1. Use a dropping pipette to put one drop of water onto a microscope slide.
2. Separate one of the thin layers of the onion.
3. Peel off a thin layer of epidermal tissue from the inner surface.
4. Use forceps to put this thin layer on to the drop of water that you have placed on the microscope slide.
5. Make sure that the layer of onion cells is flat on the slide.
6. Put two drops of iodine solution onto the onion tissue.
7. Carefully lower a coverslip onto the slide. Do this by placing one edge of the coverslip on the slide and then using a mounted needle to lower the other edge onto the slide.
8. Use a piece of filter paper to soak up any liquid from around the edge of the coverslip.

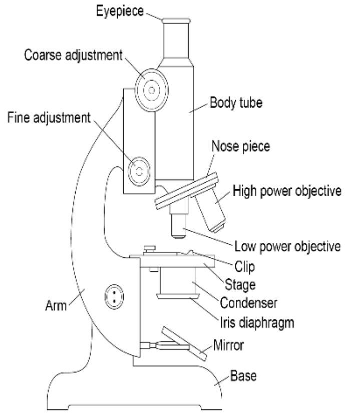
To view the cells

1. Put the slide on the microscope stage.
2. Turn the nosepiece to the lowest power objective lens.
3. Looking from the side (**not** through the eyepiece) turn the coarse adjustment knob so that the end of the objective lens is almost touching the slide.
4. Now looking through the eyepiece, turn the coarse adjustment knob in the direction to increase the distance between the objective lens and the slide. Do this until the cells come into focus
5. Now rotate the nosepiece to use a higher power objective lens.
6. Slightly rotate the fine adjustment knob to bring the cells into a clear focus and use the low-power objective (×40 magnification) to look at the cells.
7. When you have found some cells, switch to a higher power (×100 or ×400 magnification).
8. Draw a clear, labelled drawing of some of these cells. Make sure that you draw and label any component parts of the cell.
9. Use an eyepiece graticule to measure the length of one of the l cells that you have drawn. Remember to include the units. Now measure the same cell in your drawing.
10. Calculate the magnification of your drawing, using the formula:

magnification = length of drawing of cell/actual length of cell

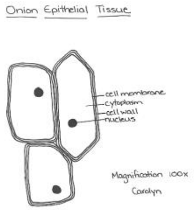
Key Terms	Definitions
coarse adjustment	Moves the stage up and down to bring the cells into focus.
fine adjustment	Adjusts the focus so you can get a clear image of the cells
cover slip	A piece of transparent plastic or glass placed on top of the specimen you are magnifying
objective lens	This is the lens used to magnify objects
stage	The flat plate where the slides are placed for observation.
eyepiece	The lens at the top of the microscope that you look into.

Diagram



Expected Results

You should draw your results neatly, with a pencil and should be drawn with clear, unbroken lines**.** All organelles should be drawn in proportion, you should also include a title and the magnification. After you have calculated the actual length of the cell, this should also be included in the diagram.

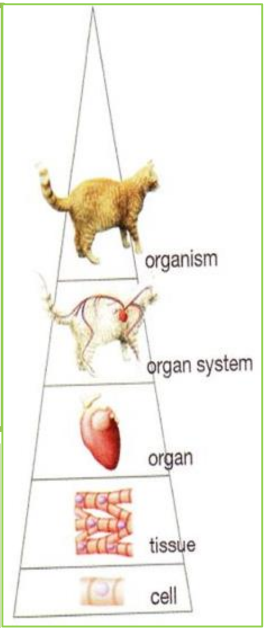


Combined Science Biology Knowledge Organiser
Topic 6: Organisms

Unicellular vs. multicellular organisms

Unicellular organisms' bodies are simply one cell. All bacteria and other prokaryotic organisms are unicellular. **Multicellular** organisms are made of many cells and are much more complex. In multicellular organisms, cells **differentiate** to become **specialised cells**, carrying out specific roles in the organism.

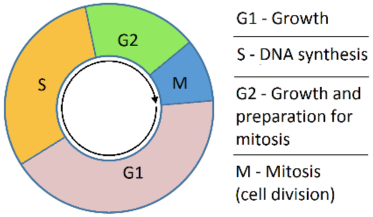
The levels of organisation in multicellular organisms form a **hierarchy**. In biology, hierarchies get simpler as you go down; or more complex as you go up because the upper things are made up of the things below them. The organisational hierarchy in multicellular organisms is shown here.

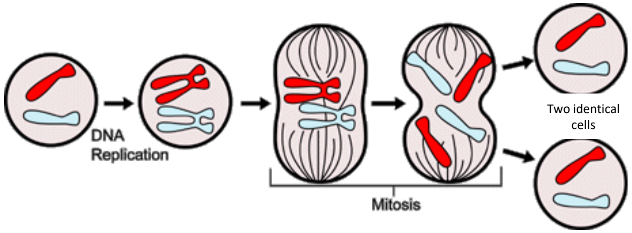


Stem cells

Once cells are specialised, they can't go back to being an unspecialised cell. This is why we all start life as a mass of unspecialised cells, called **stem cells** – this is what an embryo is. Stem cells can divide to make new cells and can differentiate to become specialised cells.

In an young embryo, <u>all</u> the cells are stem cells, so they can be taken, cloned and used to produce any human cells by differentiation.
In adults, there are not many stem cells left – most have differentiated. But there are some, for repair and replacement of specialised cells. For instance, there are stem cells in the bone marrow. These can be collected, cloned and made to differentiate into any type of blood cell. Using stem cells in this way is an active area of medical research, to treat conditions like diabetes and paralysis.





Key Terms	Definitions
unicellular	Describes organisms formed of only one cell: like all prokaryotic organisms
multicellular	Describes organisms made of many cells.
differentiation	The process of becoming a specialised cell. Specialised cells are the result of differentiation of **stem cells**.
stem cells	Cells that are undifferentiated. Stem cells are capable of forming many more cells of the same type (by cell division), and forming certain types of specialised cell by cell division.
embryo	A very young multicellular organism, formed by fertilisation. Embryos are made of stem cells.
cell cycle	The series of stages during which cells divide to make new cells. In the cell cycle, the DNA is replicated (copied exactly) and the cell splits by mitosis into two cells with one set of DNA each.
mitosis	The specific part of the cell cycle where the cell divides to make two new cells, which are identical.
chromosome	A structure made from one molecule of DNA. One chromosome contains many genes. In body cells, chromosomes are found in **pairs** (since you inherit one copy of each chromosome from your mother and one copy from your father).

The cell cycle – diagram bottom left

Cells divide to make new cells, for growth and repair, in the **cell cycle**. It isn't as simple as the cell splitting in two: it must prepare before doing that.

1. The cell grows larger and makes more sub-cellular structures, such as ribosomes and mitochondria. (It makes enough for two cells!)
2. The genetic material (**DNA**) is doubled by making an <u>exact replica</u> of the chromosomes. So, there are two copies of every chromosome at this point in the cell cycle.
3. Then, **mitosis** occurs: tiny fibres in the cell pull the copies of each chromosome to opposite ends of the cell, breaking the replica chromosomes apart. This means there are two full sets of chromosomes at each end of the cell.
4. The cytoplasm and cell membranes divide to form two <u>genetically identical</u> cells. This is summarised in the diagram immediately to the left.

Combined Science Biology Knowledge Organiser
Topic 7: Staying Alive

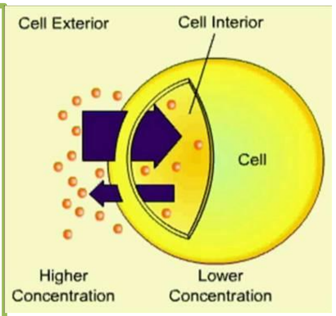
Exchange and Transport

To stay alive, all organisms must **exchange** substances with their environment. This means they must transport **into** cells the substances they need from the environment and transport **out** waste products to the environment.

Substances can be transported into or out of cells by: **diffusion, osmosis** or **active transport**.

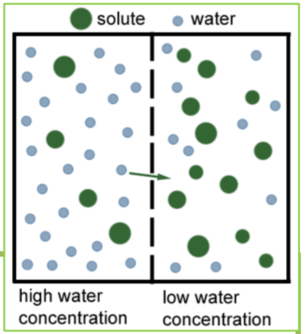
Diffusion

Diffusion allows many substances to move into or out of cells. Thanks to the random motion of particles in liquids and gases, particles will spread out until the concentration is equal throughout. If there is a cell membrane that lets the substance through (is **permeable**) in the way, it doesn't matter. Overall, the **net movement** of the substance will be from higher to lower concentration, as the diagram shows.



Diffusion is the process by which oxygen is transported into the bloodstream, and carbon dioxide is transported out (in the lungs, or gills of fish). It is also how the waste product **urea** moves from cells into the bloodstream, before removal in the urine.

The <u>rate</u> of diffusion is affected by:
1. the steepness of the concentration gradient
2. the temperature (a higher temperature increases the rate of diffusion as particles have more kinetic energy)
3. The surface area of the membrane (a larger surface area of cell membrane increases the rate of diffusion into/out of a cell).



Osmosis

Osmosis is the movement of water from a more dilute solution (more 'watery') to a more concentrated solution (less 'watery') across a <u>partially permeable membrane</u>, such as a cell membrane. Osmosis causes cells to swell up if they are placed in a dilute solution, or shrivel up if they are placed in a concentrated solution (a solution of salt, for instance, or sugar).

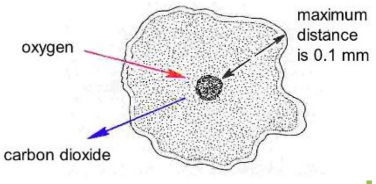
Key Terms	Definitions
diffusion	The net (overall) movement of particles from a higher concentration to a lower concentration, simply due to the random motion of particles in a liquid or gas. Diffusion happens across cell membranes, from higher to lower concentration. It does not require any energy from the cell.
concentration gradient	The difference in concentration of a substance between two places. A 'steeper' concentration gradient means there is a bigger difference in concentration.
surface area to volume ratio	The surface area divided by the volume of an organism, organ or cell. Generally, the smaller an organism is, the larger the surface area to volume ratio.
exchange surface	A place, such as the walls of the small intestine, where exchange of substances takes place e.g. by diffusion across it.
diffusion pathway	The distance over which a substance must diffuse. A thin wall or membrane is a short diffusion pathway.
osmosis	Osmosis only describes the movement of water. It is the diffusion of **water** from a dilute solution to a more concentrated solution across a partially permeable membrane.
partially permeable membrane	A membrane that only allows some substances through – others are prevented from travelling through. (e.g. a cell membrane)
active transport	The movement of substances **against** the concentration gradient – from <u>lower to higher</u> concentration. This requires energy from respiration.

Active transport

Active transport is so-named because it <u>requires energy</u>. A good example of where it happens is in plant roots. Root hair cells (see specialised cells topic) absorb mineral ions (like magnesium ions and nitrate ions) from the very dilute solution in the soil by active transport. They need ions like these for healthy growth. An example in animals is absorption of sugar from the intestine into the blood – the blood has a higher sugar concentration so active transport is needed. The sugar is needed by all cells in the body for respiration.

Combined Science Biology Knowledge Organiser
Topic 7: Staying Alive

Adaptations for efficient exchange and transport



Unicellular organisms have a very large surface area to volume ratio compared to multicellular organisms. This means that they simply exchange substances through their cell membrane directly with their environment. They are small enough that diffusion is sufficient to meet their needs (see diagram).

However, in multicellular organisms, cells that are not at the surface wouldn't be able to directly exchange substances with the environment. This is why organs with specialised exchange surfaces have evolved. Without lungs, gills, or leaves, for example, multicellular organisms wouldn't be able to obtain enough of the substances they need to survive, or be able to get rid of waste products efficiently.

Specialised exchange surfaces

To be effective at exchanging substances with the environment, any exchange surface must have a **large surface area**, and a thin wall/membrane for a **short diffusion pathway**. In animals, a constant blood supply also increases effectiveness, and in the lungs, ventilation (breathing in and out) increases effectiveness by refreshing the concentration gradient with each breath.

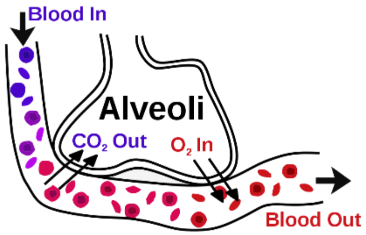
Exchange in animals and plants

Gas exchange in many animals, including us, happens in the lungs. The structures in the lungs where it happens are the **alveoli**. There are millions of these tiny air sacs, so in total their surface area is gigantic. They also have a short diffusion pathway, a good blood supply and air supply due to **ventilation**. (look at the diagram of one alveolus)

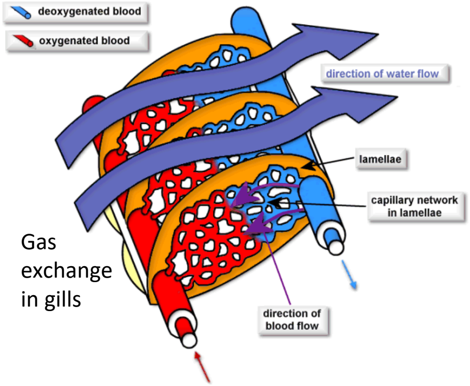
In fish, gills are where gas exchange takes place (see diagram). Again, a huge surface area increases the efficiency of gas exchange, along with a short diffusion pathway and good blood supply. The huge surface area comes from the division of gills into very thin plates of tissue called **lamellae**. This also creates the short diffusion pathway.

In plants, the **roots** absorb water and mineral ions. The root hair cells have **long projections** that increase the surface area of this exchange surface, and shorten the diffusion pathway. The **leaves** are responsible for gas exchange, including oxygen out and water vapour out, and carbon dioxide in. Being flat and broad increases the effectiveness of the leaves as exchange surfaces, by increasing the surface area and shortening the diffusion pathway. In leaves, exchange happens through microscopic holes called **stomata**.

Key Terms	**Definitions**
small intestine	The organ in the digestive system where products of digestion are absorbed into the bloodstream.
lungs	The organs were gas exchange takes place. The air sacs where gases are actually exchanged are called **alveoli**.
gills	The organs in fish where gas exchange takes place. Oxygen is absorbed from the water into the blood, and carbon dioxide is transferred to the water.
leaves	The plant organs responsible for gas exchange.
ventilation	Technical term for breathing in and out. Breathing in brings fresh air, with a relatively high oxygen concentration, into the lungs, and breathing out removes the air with a relatively high concentration of carbon dioxide (and low concentration of oxygen).

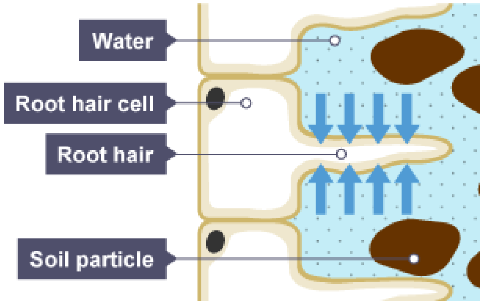


Gas exchange in lungs

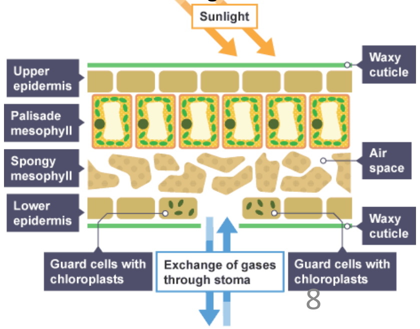


Gas exchange in gills

Substance exchange in roots



Gas exchange in leaves



Practical Methods Knowledge Organiser
Topic 7: Osmosis and Plant Tissues

Equipment List

- a potato
- a cork borer
- a ruler
- a 10 cm^3 measuring cylinder
- labels
- three boiling tubes
- a test tube rack
- paper towels
- a scalpel
- a white tile
- 1 M sugar solution
- 0.5 M sugar solution
- distilled water
- a top-pan balance

Method

1. Using a cork borer, cut three potato cylinders of the same diameter.
2. Trim the cylinders so that they are all the same length (about 3 cm).
3. Accurately measure and record the length and mass of each potato cylinder.
4. Measure out 10 cm^3 of the 1 M sugar solution and place into the first boiling tube (labelled 1 M sugar).
5. Measure out 10 cm^3 of 0.5 M sugar solution and place into the second boiling tube (labelled 0.5 M sugar).
6. Measure out 10 cm^3 of the distilled water into the third boiling tube (labelled water).
7. Add one potato cylinder to each tube (make sure you know which one is which in terms of the length and mass).

Key Terms	Definitions
osmosis	The spread of water molecules from a region of higher water concentration to a lower water concentration.
cork borer	Equipment that is used to remove cylinders from a potato.

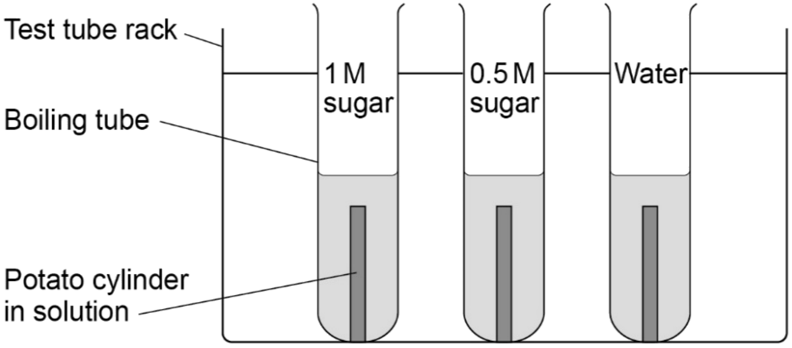
Experimental variables

The independent variable was the concentration of the solution the cylinders were soaked in. The sugar concentration is changed to investigate if water will leave or enter the cylinders. The dependent variable was the length and mass of the potato cylinders. The control variable is the same potato and the time the potato were left in the solution

Expected Results and explanation.

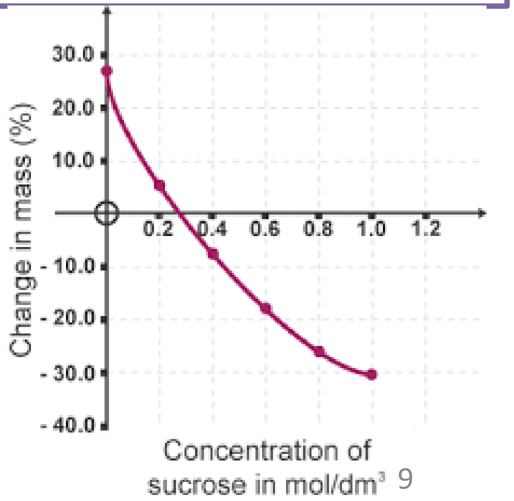
In the 1M sugar solution, the mass and length of the cylinder would decrease the most as water leaves the cylinder by osmosis. The same applies to the cylinder in the 0.5M sugar solution, but the decrease in mass and length would be less. For the one immersed in water, water would move into the cylinder so the mass and length of the cylinder would increase as a result.

Diagram



Graphical presentation of results

The graph on the left below shows that as concentration of sugar solution increases, the mass decreases. The graph showing the length of potato cylinders should show the same pattern – a best fit line sloping downwards to show that the length decreases with increasing concentration of sugar solution.

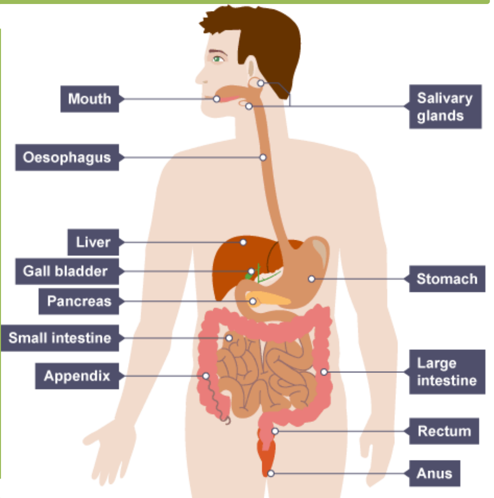


Combined Science Biology Knowledge Organiser
Topic 7: Staying Alive

The human digestive system

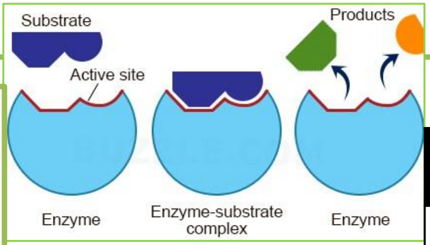
The digestive system breaks down food molecules into molecules our cells can actually use, and absorbs the simpler molecules resulting from digestion. The products of digestion are used to make new molecules we need, and the glucose is used in respiration. It is an **organ system**; the organs of the digestive system are shown on the diagram.

Mechanical digestion occurs in the mouth and stomach especially, where food is physically broken up into smaller pieces. This does not, however, break down the large molecules that our food is made from (carbohydrates, lipids and proteins). That is the role of chemical digestion, which is what enzymes do.



Enzymes and digestion

Enzymes are large proteins; there are many different types. All organisms use enzymes to control chemical reactions (**metabolism**). Enzymes are **catalysts**, so they speed up chemical reactions. They work by having an **active site** with a specific shape. A specific molecule slots into the active site (like a key into a lock) and the reaction takes place. So, the shape of the active site is vitally important, and only one sort of enzyme will work on each substrate. The diagram shows this 'lock and key' model of enzyme action.



Bile

Bile is a vital substance for digestion. It is made in the **liver** and stored in the **gall bladder** before being released into the small intestine just after the stomach. It is **alkaline**, to neutralise the stomach acid and to make the partly digested food pH 8 – the optimum pH for enzymes in the small intestine. It also **emulsifies** fats, meaning it breaks them up into small droplets. This increases the fat droplets' surface area, increasing the rate of digestion by lipase.

Key Terms	Definitions
enzyme	A biological catalyst that speeds up chemical reactions in living organisms. Enzymes are large proteins.
digestive enzyme	Enzyme that works in the digestive system, breaking down large food molecules into simpler, smaller molecules for absorption into the blood. Learn the examples from the table.
active site	The part of an enzyme where the reaction takes place. They are very specific in shape, so that a specific substrate fits into the active site.
denature	To disrupt the shape of the active site of an enzyme. Denaturation happens when the enzyme is at too high a temperature or at the wrong pH for that enzyme.
substrate	The molecule that fits into an enzyme's active site and reacts to make a product or products.
carbohydrate	A type of molecule found in all living things. Made of carbon, hydrogen and oxygen. Simple sugars like glucose are carbohydrates, and so are complex sugars like starch – in fact, starch is made of many glucose molecules joined up.
lipid	Scientific name for fat. Lipids are made up of **glycerol** and **fatty acids**. Made mainly of carbon and hydrogen (+ oxygen).
protein	Type of molecule made from **amino acids**. Proteins in the body can be **structural** (e.g. muscle is made mainly of proteins) or **metabolic** (control chemical reactions – e.g. enzymes). Made mainly of carbon, hydrogen, oxygen and nitrogen.
optimum	The ideal temperature or pH for enzymes to work.

Digestive enzyme	Site of production	Site of action	Substrate	Product
Carbohydrase - e.g. amylase	Salivary glands, pancreas and small intestine wall	Mouth, small intestine	Complex carbohydrates - e.g. starch	Simple sugars - e.g. glucose
Protease	Stomach, pancreas, small intestine wall	Stomach, small intestine	Proteins	Amino acids
Lipase	Pancreas, small intestine wall	Small intestine	Lipids	Glycerol and fatty acids

Practical Methods Knowledge Organiser
Topic 7: Food Tests

Equipment List

- food to be tested
- a pestle and mortar
- a stirring rod
- a filter funnel and filter paper
- 5 × beaker, 250 ml
- a conical flask
- 4 × test tube
- Benedict's solution
- iodine solution
- Sudan III stain solution
- Biuret solution
- Warm water bath
- safety goggles.

Method – Benedict's test

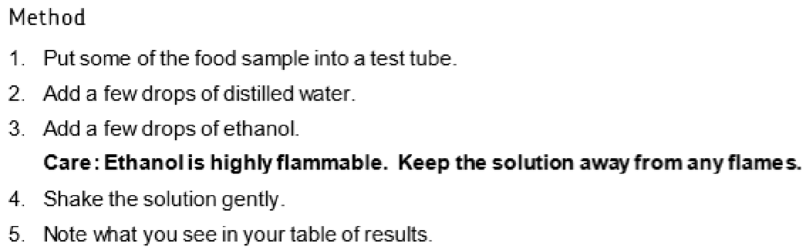
1. Use a pestle and mortar to grind up a small sample of food.
2. Transfer the ground up food into a small beaker. Then add distilled water. Stir the mixture so that some of the food dissolves in the water.
3. Filter using a funnel with filter paper to obtain as clear a solution as possible. The solution should be collected in a conical flask.
4. Half fill a test tube with some of this solution.
5. Add 10 drops of Benedict's solution to the solution in the test tube.
6. Put hot water from a kettle in a beaker. The water should not be boiling. Put the test tube in the beaker for about five minutes. Note any colour change. If a reducing sugar (such as glucose) is present, the solution will turn green, yellow, or brick-red. The colour depends on the sugar concentration.

Method – Biuret test, Iodine test

1. Use a pestle and mortar to grind up a small sample of food.
2. Transfer the ground up food into a small beaker. Then add distilled water. Stir the mixture so that some of the food dissolves in the water.
3. Filter using a funnel with filter paper to obtain as clear a solution as possible.
4. The solution should be collected in a conical flask.
5. Put 2 cm^3 of this solution into a test tube.
6. Add 2 cm^3 of Biuret solution to the solution in the test tube. Shake gently to mix.
7. Note any colour change. Proteins will turn the solution pink or purple.
8. Repeat the above steps using iodine solution instead of Biuret's solution.

Key Terms	Definitions
Benedict's test	A chemical test which tests for reducing sugars.
biuret's test	A chemical test which tests for protein.
iodine test	A chemical test that tests for starch.
ethanol test	A chemical test that tests for Fats

Method – Ethanol test



Method

1. Put some of the food sample into a test tube.
2. Add a few drops of distilled water.
3. Add a few drops of ethanol.
   Care: Ethanol is highly flammable. Keep the solution away from any flames.
4. Shake the solution gently.
5. Note what you see in your table of results.

Positive and negative results of each test

Test	Nutrient tested for	Positive results	Negative results
Benedict's test	Sugars	Brick red/orange/yellow precipitate	Solution remains blue
Biuret's test	Protein	Solution turns from blue to purple	Solution remains blue
Iodine test	Starch	Solution turns from brown to blue-black	Solution remains brown
Ethanol test	Lipids (fats)	Cloudy layer formed	Solution remains colourless

Practical Methods Knowledge Organiser
Topic 7: The Effect of temperature on Enzyme Activity

Equipment List

- test tubes
- a test tube rack
- water baths (electrical or Bunsen burners and beakers)
- spotting tiles
- a 5 cm^3 measuring cylinder or syringe
- a glass rod
- a stop watch
- starch solution
- amylase solution
- iodine solution
- thermometers

Method

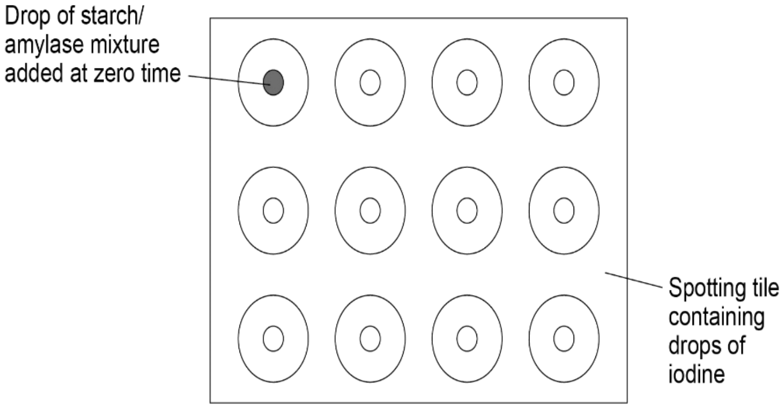
1. Place one drop of iodine solution into each depression on the spotting tile.
2. Set up water baths for every temperature you want to test (suggest one cold with ice, one at room temperature, one around body temperature 35–40 °C and one above 50 °C).
3. Measure out 5 cm^3 of starch solution, using the measuring cylinder or syringe, into 4 test tubes.
4. Place one test tube of starch solution into each water bath.
5. Measure out 1 cm^3 of amylase solution, using a measuring cylinder or syringe, into 4 different test tubes.
6. Place one test tube of amylase solution into each water bath.
7. Leave the test tubes in the water baths until the contents of each test tube have reached the temperature of the water baths. Check this with a thermometer.
8. When the contents of the test tubes in one water bath have both reached the required temperature, make a note of this temperature. Then, carefully pour the amylase solution into the test tube with the starch solution and mix with the glass rod.
9. Remove one drop of the mixed solution on the end of the glass rod and place on the first depression of the spotting tile with the iodine solution. This is ‘time zero’.

Expected Results

As 37°C is the optimum temperature for enzymes, it would be expected that the starch is broken down fastest in the 37°C water bath. This will be seen by the iodine solution no longer turning blue/black and remaining brown.
For the enzyme above 50 °C you would expect that the enzyme would denature and would therefore not break down the starch. This would mean the iodine would not turn brown at any point during the experiment.
For temperatures below 37 °C the starch would be broken down but more slowly.

Key Terms	Definitions
spotting tile	A plastic tray with small dips, that allows small samples of solution to be tested.
water bath	A piece of equipment that heats water
iodine solution	A solution that will turn blue/black in the presence of starch.

Diagram



Alternative experiments

There are three factors that affect the activity of an enzyme. These are pH, temperature and substrate concentration. As long as two of these are kept the same the other can be changed to investigative the affect it has.

For example the experiment outlined on this page could be carried out but instead of changing the temperature the pH could be changed.

There are also many other enzymes that could be investigated.

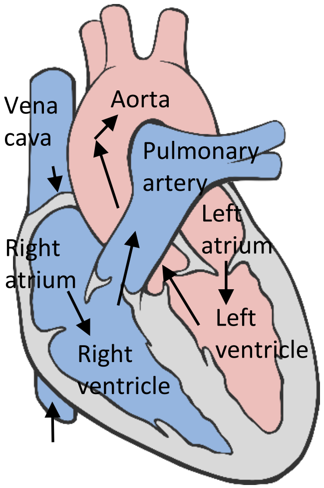
Combined Science Biology Knowledge Organiser
Topic 7: Staying Alive

The heart

The heart is an organ whose role is to pump blood around the body. In humans and other mammals, the heart is part of a **double circulatory system**. This means the blood goes through the heart twice on its route around the body. It goes: right side of heart → lungs → left side of heart → body (and back to the right side of the heart again).

Learn the labelled parts of the heart. The arrows show the direction of blood flow. The heart walls are made mainly of muscle – when the heart 'beats', the muscle contracts to pump the blood.

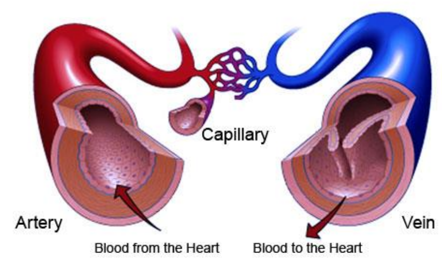
The natural resting heart rate is controlled by a group of specialised cells in the right atrium that act as a **pacemaker**. These cells set off the impulses that make the heart muscle contract. If there is a fault in the heart and the heart rate is irregular, an **artificial pacemaker** can be fitted to correct these irregularities.



Key Terms	Definitions
ventricles	The larger chambers in the heart. The right ventricle pumps blood to the lungs; the left ventricle pumps blood around the whole body.
atria	Smaller chambers of the heart. These fill with blood from the vena cava and pulmonary vein, then pump the blood into the ventricles.
aorta	The artery leaving the left ventricle. It branches off to supply, in the end, every cell of the body with blood.
vena cava	The major vein transporting blood from the whole body back to the heart (to the right atrium)
pulmonary artery	The blood vessel leaving the right ventricle, carrying blood to the lungs.
pulmonary vein	Vein leading from the lungs back to the heart (to the left atrium).
artery	Blood vessel that carries blood away from the heart, at relatively high pressure.
capillary	Very small, thin-walled blood vessel where exchange of substances between the blood and body cells takes place.
vein	Blood vessels that return blood to the heart at relatively low pressure. Only these vessels have **valves** in them.
coronary blood vessel	The heart muscle needs its own blood supply. This comes from branches from the aorta as soon as it leaves the heart called **coronary** arteries.

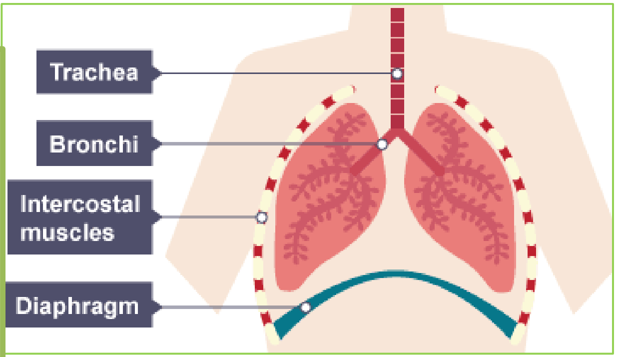
Blood vessels

Blood is restricted to blood vessels in the body (unless you cut yourself!). There are three types: **arteries**, **capillaries** and **veins**. Blood being pumped by the heart always travels in the order arteries → capillaries → veins and veins return the blood to the heart. Arteries carry the blood at high pressure, so they have **thick, elastic** walls. Capillaries are where **exchange** takes place, so their walls are **only one cell thick** (for a *short diffusion pathway*). Veins carry the blood back to the heart at low pressure, so their walls are thinner than arteries (much thicker than capillaries though). However, to prevent blood flowing back the wrong way, veins have **valves** in them, which you can see on the diagram.



The lungs

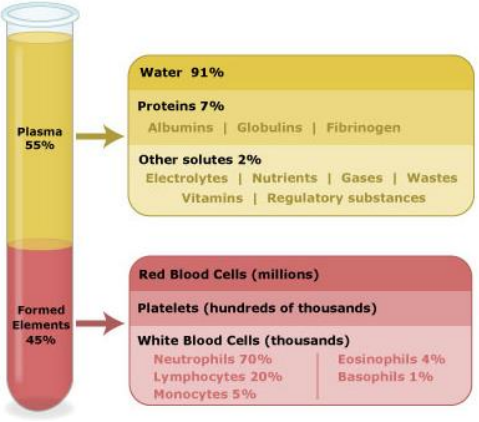
The lungs are the organs responsible for gas exchange in humans and other mammals. Air flows in while breathing in, through the **trachea** (windpipe), through the **bronchi** to each lung, and eventually to the **alveoli**, that you've looked at before. Muscle contraction allows us to breathe in – the **diaphragm** and **intercostal muscles** contract. When they relax, we breathe out.
The lungs are adapted for efficient gas exchange with their short diffusion pathway, huge surface area, and good blood and air supplies.



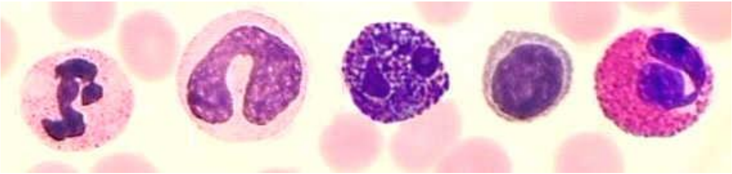
Combined Science Biology Knowledge Organiser
Topic 7: Staying Alive

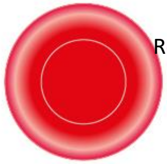
The blood

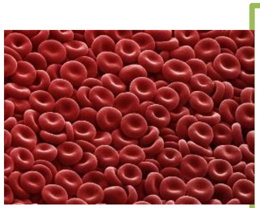
Blood is a tissue. When separated into the component parts as a the diagram shows, we find that just over half of it is made up of plasma. The cells components (mostly red blood cells) are **suspended** in the plasma – meaning they are normally mixed evenly throughout the plasma. The majority of the cell parts is made up of red blood cells, which transport oxygen. The other components are white blood cells and platelets.



Key Terms	Definitions
plasma	The liquid part of the blood, mostly made of water, but with substances like glucose, proteins, ions and carbon dioxide dissolved in it.
red blood cells	Disc-shaped cells that contain **haemoglobin**, which can bind to oxygen, so it can be transported from the lungs to tissues.
white blood cells	Cells in the blood that fight infection caused by pathogens.
platelets	Fragments of cells that cause clotting of blood at a wound, to reduce blood loss.
clot	A solid clump of blood formed when there is an injury.




Red blood cell




White blood cell

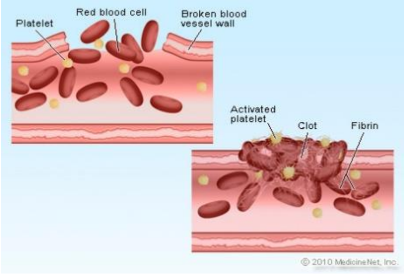

Platelet

Red blood cells

As you can see in the photograph (taken with a microscope of course!), red blood cells are disc shaped and have a concave surface on each side. This increases their surface area for absorbing and transporting oxygen from the lungs to body tissues. Red blood cells are unusual in that they don't have a nucleus or other organelles. This makes more room for **haemoglobin** – the red-coloured chemical that oxygen actually binds to for transport.

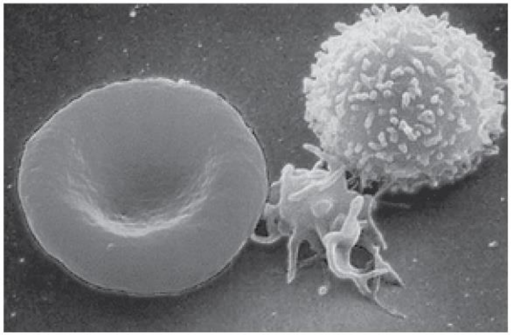
White blood cells

There are actually numerous types of white blood cell, as the photo shows, but they are all part of the immune system and fight communicable disease (disease caused by **pathogens**). They all have large nuclei, because they are very active cells. They can also change shape, which is useful because they can get out of the blood (through tiny gaps in the walls of capillaries) and so they can **engulf** microorganisms – like the photo below of a white blood cell engulfing a yeast cell.



Platelets

Platelets are *fragments* of cells – produced deliberately by your body (they aren't simply broken cells!). The photograph here shows a platelet between a red blood cell and a white blood cell. Their role is to initiate (start off) the process of **clotting** at a wound, as shown in the diagram to the left. They create a clot, which blocks the injury in the blood vessel until proper healing can happen, preventing excessive blood loss.



Combined Science Biology Knowledge Organiser
Topic 7: Staying Alive

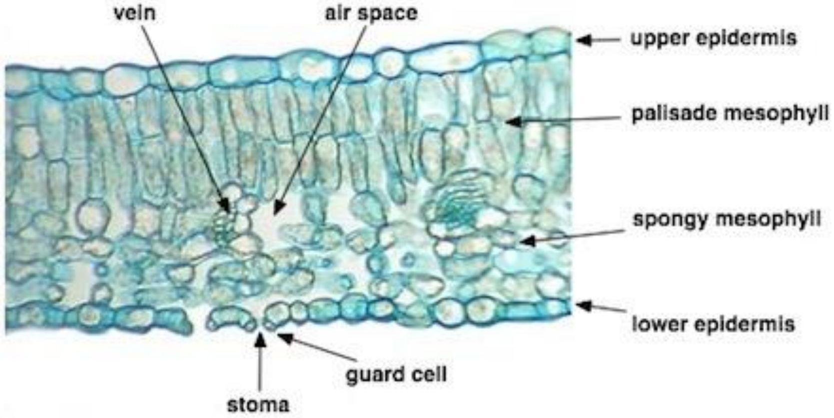
Plant tissues in the leaf and transpiration

Look at the key terms and definitions for the key types of plant tissue. Leaves are **organs** in plants that contain many of those types of tissue. Together with the stem and roots, they form an **organ system** for transport of substances around the plant. The photograph shows the **transverse section** of a leaf – a thin slice through the leaf, looking edge-on.

The **vein** contains the xylem and phloem vessels. The **stomata** (singular: stoma) are the holes through which gases are exchanged. This includes water vapour. Plants absorb **all** their water in the roots (you've already looked at root hair cells), and keep water moving constantly through by losing water as vapour from the leaves. The constant flow of water up the plant is called the transpiration stream. This loss of water vapour from the leaves is called **transpiration**. Transpiration is sped up by:

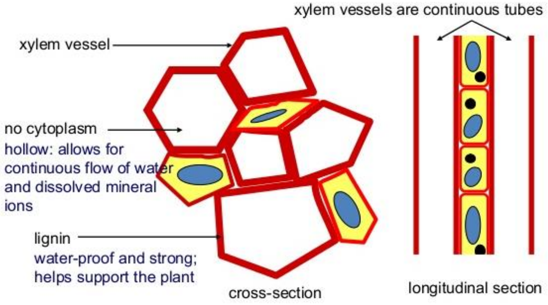
- a *higher temperature*, since water molecules have more kinetic energy so diffusion out of stomata is faster
- *Lower humidity* (drier air), since there is a steeper concentration gradient if the air outside the plant is relatively drier than the air in the air spaces
- *Higher air flow* (being windier!), since this refreshes the concentration gradient all the time, as water vapour is blown away from the leaves
- *Higher light intensity*: this increases the rate of photosynthesis, which uses water, so water flows more rapidly up through the plant.

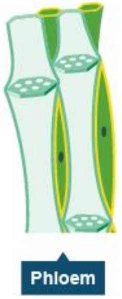
Key Terms	Definitions
epidermal	Type of plant tissue that covers the surface of a plant
palisade mesophyll	Tissue in the leaf where photosynthesis takes place
spongy mesophyll	Tissue in the leaf with air spaces between cells – specialised for gas exchange
xylem	Narrow tubes in the roots, stem and leaves, which transport water and mineral ions up the plant from the roots
phloem	Other tubes that run alongside xylem, but transport sugars dissolved in water instead – a process called **translocation**
meristem	Type of tissue found at growing tips of roots and shoots, containing stem cells so they can differentiate into different sorts of plant cell
guard cell	In pairs, guard cells form the stomata on leaves – the holes through which gases are exchanged. They can open and close the stomata as required by the plant.
transpiration	The process by which plants lose water, as vapour, from their leaves through the stomata.



Stomata, guard cells and transpiration

Stomata must be open at least some of the time, to allow carbon dioxide to enter the leaf for photosynthesis. However, guard cells can control how many stomata are open, and how wide open they are. This is useful in dry conditions, because the plant can conserve water instead of losing lots of it through transpiration.





Xylem and Phloem

Xylem tissue is made of hollow tubes, formed from the cell walls of dead cells, and strengthened by a substance called **lignin**. The diagram shows their adaptations to the function of transporting water and minerals.

Phloem, on the other hand, is a tissue made of living cells. They are elongated and stacked to form tubes. Phloem tubes transport food – dissolved sugars – made in the leaves to other parts of the plant, for use in respiration or for storage. The sugary substance they transport is called cell sap, and its transport is called **translocation**. Cell sap flows from one phloem cell to the next through **pores** (holes) in the ends of the cells.

Combined Science Biology Knowledge Organiser
Topic 10: Obtaining and Using Energy

Photosynthesis

For us, it is a very good thing that photosynthesis evolved. The process of photosynthesis, carried out by plants and algae, is at the foot of every food chain. It captures light energy from the sun and redistributes it to chemical potential energy – we can make use of chemical potential energy: that's what our food contains! Since photosynthesis involves the transfer of light energy to chemical potential energy in cells, it is an **endothermic** reaction.

The reaction can be shown in these equations:

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$$

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

The oxygen released by photosynthesis has built up in the atmosphere over millions of years – again, good news for us, since we require oxygen for respiration, just like all living organisms.

Photosynthesis occurs in the **chloroplasts** of plant cells. Simple molecules like carbon dioxide and water can't be used as food. However, glucose and other more complex molecules can – so you can think of photosynthesis as a reaction that produces food.

Using The Glucose From Photosynthesis.

Obviously, plants didn't evolve simply for our benefit. They carry out photosynthesis to meet their own needs. The glucose produced in photosynthesis can be:

- Used in <u>respiration</u> in the cells of the plant/algae
- Converted into **starch** for <u>storage</u>. Starch is good for storage as it is *insoluble*, so it doesn't affect the osmosis occurring in the plant, unlike glucose.
- Used to produce **fats or oils (lipids)** for <u>storage</u>. This is particularly noticeable in seeds and nuts.
- Used to produce **cellulose**, which is a component of the cell wall. Cellulose strengthens the cell wall.
- Used to produce **amino acids**, which in turn are used to <u>synthesise proteins</u> (in the ribosomes). To produce amino acids, plants also require **nitrates** from the soil.

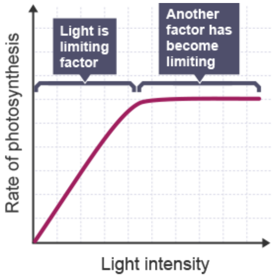
Simple lab tests can be used to identify starch, glucose and protein. Starch turns **iodine** a blue-black colour. Glucose turns **Benedict's solution** orange-red when heated with it. Proteins turn **Biuret's reagent** purple.

Key Terms	Definitions
photosynthesis	The endothermic reaction that transfers light energy to chemical potential energy. In it, simple molecules (CO_2 and H_2O) are converted into more complex molecules (glucose) that can be used for food.
nitrates	Ions containing nitrogen and oxygen. These are found in the soil; plants need nitrates to produce amino acids.
rate	As always, rate means how quickly something happens.
light intensity	The amount/strength of light. Use this term instead of 'amount of light'.
chlorophyll	The green pigment in leaves that absorbs light for photosynthesis. Chlorophyll is found in **chloroplasts**.

The Rate Of Photosynthesis.

The following factors affect the rate of photosynthesis:

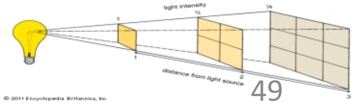
- **Temperature**: because all chemical reactions speed up as the temperature increases. However, as photosynthesis is controlled by enzymes, too high a temperature prevents photosynthesis (more on this in the metabolism section).
- **Carbon dioxide concentration**: the higher the concentration of CO_2 in the air, the more is available for photosynthesis, so the rate of photosynthesis increases as concentration increases.
- **Light intensity**: as the equation shows, photosynthesis requires light energy. So, the higher the light intensity, the higher the rate of photosynthesis.
- **Amount of chlorophyll**: more chlorophyll means more light can be absorbed. Some leaves have pale parts, as you may have seen, due to a lack of chlorophyll. The rate of photosynthesis is obviously much lower in the pale parts compared to the deep green parts.



<u>HT:</u> at any given time, any one of these factors may be **limiting** the rate of photosynthesis. This can be shown on graphs – see example. When it comes to light intensity, it varies with distance according to an *inverse square law*:

$$\text{light intensity} = \frac{1}{\textit{distance from source}^2}$$

In commercial growing of plants (e.g. tomatoes in a greenhouse), the conditions are optimised to maximise the rate of photosynthesis and obtain the highest profit.



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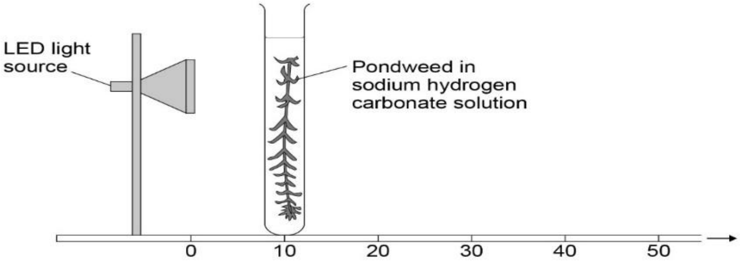
Practical Methods Knowledge Organiser
Topic 10: Photosynthesis

Equipment List

- a boiling tube
- freshly cut 10 cm piece of pondweed (*Cabomba* or *Elodea*)
- a light source
- a ruler
- a test tube rack
- a stop watch
- 0.2% solution of sodium hydrogen carbonate solution
- a glass rod

Method

1. Set up a test tube rack containing a boiling tube at a distance of 10 cm away from the light source
2. Fill the boiling tube with the sodium hydrogen carbonate solution.
3. Place the piece of pondweed into the boiling tube with the cut end uppermost. Gently push the pondweed down with the glass rod.
4. Leave the boiling tube for 5 minutes.
5. Start the stop watch and count the number of bubbles produced in one minute.
6. Record results in a table
7. Repeat the count twice more so that the mean number of bubbles per minute can be calculated.
8. Move the test tube rack to a distance of 20 cm from the light source and repeat steps 4–6.
9. Repeat using distances of 30 cm, 40 cm and 50cm between the test tube rack and the light source.

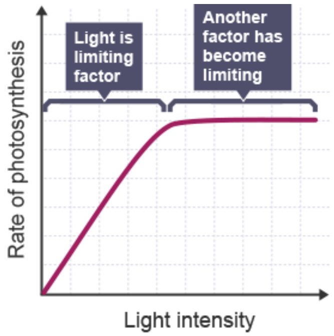


Variables

I.V Distance between lamp and plant (light intensity)
D.V Number of bubbles given off in one minute
C.Vs Type and mass of pondweed, time in which bubbles are counted, volume of solution, temperature of solution.

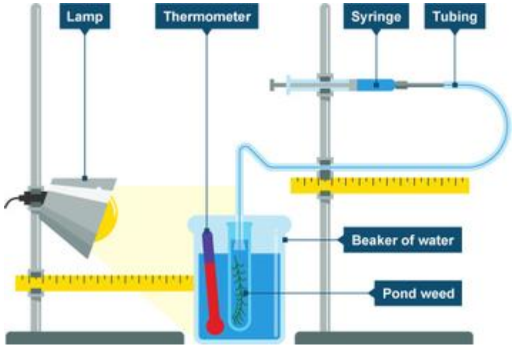
Expected Results

As the lamp gets closer to the pondweed the number of bubbles should increase as more oxygen is being produced. However, when the lamp gets very close, there will no longer be an increase in bubbles as something else (temperature or carbon dioxide concentration) becomes the limiting factor. A graph should look like this:



Increasing Accuracy

A syringe could be used to increase the accuracy of the volume of gas given off.



Combined Science Biology Knowledge Organiser
Topic 10: Obtaining and Using Energy

Respiration.

Photosynthesis produces chemicals (like glucose) that can be used as food by all living organisms. In **respiration**, the chemical potential energy stored in food molecules is transferred through **oxidation** reactions (where oxygen, originally from the air, reacts with the food molecules). The energy transferred allows living cells to do **work**.

As you know, doing work means transferring energy. The kinds of work done by cells and organisms include:
- Chemical reactions to build larger molecules from smaller ones. E.g. making proteins such as enzymes from amino acids.
- Movement. E.g. movements of our body are possible due to muscle contractions. This requires energy from respiration.
- Keeping warm. This is an example of homeostasis: using energy from respiration to maintain body temperature at a set point (37ºC).

There are two types of respiration: **aerobic** and **anaerobic**.

Aerobic vs. Anaerobic Respiration.

Aerobic respiration occurs when oxygen is used in the reaction. It is shown by these equations:

glucose + oxygen → carbon dioxide + water

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

This reaction releases energy that can be used by organisms, as described above. Compared to anaerobic respiration, aerobic respiration releases much more energy.

Anaerobic respiration occurs when there is insufficient oxygen available for complete oxidation of the glucose. The reaction that happens is different in animal cells compared to plant and yeast cells.

In *animals*: glucose → lactic acid
In *plants* and *yeast*: glucose → ethanol and carbon dioxide
$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

Anaerobic respiration releases much less energy than aerobic respiration. In yeast, we call the anaerobic respiration **fermentation**. This is a very useful process: for making bread (the CO_2 makes it rise) and making alcoholic drinks (since ethanol is a type of alcohol).

Key Terms	**Definitions**
aerobic	Using oxygen
anaerobic	Not using oxygen
oxidation	A reaction with oxygen. In this case, food molecules like glucose reacting with oxygen.
fatigue	Tiredness. Fatigue in muscles is caused by a build-up of lactic acid, which is produced during anaerobic respiration (when there is insufficient oxygen).
oxygen debt	After exercise, the lactic acid has built up and caused an **extra** need for oxygen – called the oxygen debt.
lactic acid	Chemical produced by the incomplete oxidation of glucose (anaerobic respiration).

The Response To Exercise.

During exercise, more energy is required by the body that when resting, due to increased muscle contractions. The body reacts to this increased **demand** for energy:
- ➢ The heart rate, breathing rate, and volume of each breath all increase. Together, these increase the amount of **oxygenated blood** reaching the muscles. The oxygenated blood provides the extra oxygen and glucose needed for respiration in muscle cells, to transfer more energy to meet demand.

However, if insufficient oxygen reaches muscles but exercise continues, the muscle cells use **anaerobic respiration** to transfer energy. From the equation, you can see that incomplete oxidation of glucose takes place and **lactic acid** is produced. The lactic acid builds up and causes an **oxygen debt**. The lactic acid building up also causes **fatigue**. Removing the lactic acid after exercise is the cause of the oxygen debt – the oxygen debt is why you breathe deeply after exercise for some time. You are 'repaying' the oxygen debt.

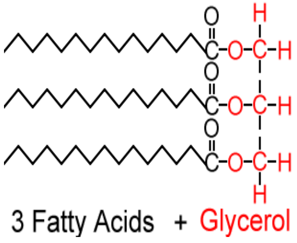
HT: oxygen debt, to be precise, is the amount of extra oxygen needed to react with lactic acid in muscles and remove it from cells. The blood flow through muscles removes lactic acid and transports it to the liver. In the liver, the lactic acid is converted back into glucose. This reaction requires energy, hence the extra need for oxygen (for aerobic respiration to provide that energy).

Combined Science Biology Knowledge Organiser
Topic 10: Obtaining and Using Energy

Metabolism.

Metabolism is a very big term in biology. It is the name given to collectively describe ALL the chemical reactions happening in a cell or in the whole body. So, respiration in all cells is an example of metabolism, and so is photosynthesis in plants.

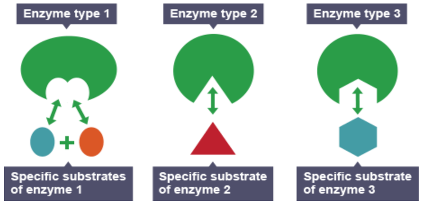
Many reactions that cells perform require **energy**, so metabolism relies on energy transferred by respiration. Furthermore, chemical reactions in cells are controlled by **enzymes**. As we're talking about chemical reactions, *reactants* are used to make *products*: new molecules are synthesised.



To learn: metabolism includes these reactions:

- Conversion of glucose to glycogen (in animals), or to starch or cellulose (in plants).
- Making lipid (fat) molecules from one molecule of **glycerol** and three molecules of **fatty acids** (see diagram).
- In plants, the use of glucose and nitrate ions to make amino acids. These amino acids are then used to synthesise proteins.
- Respiration, both aerobic and anaerobic.
- Breaking down excess proteins into amino acids, then into **urea** for excretion in the urine.

Factors Affecting Enzymes.



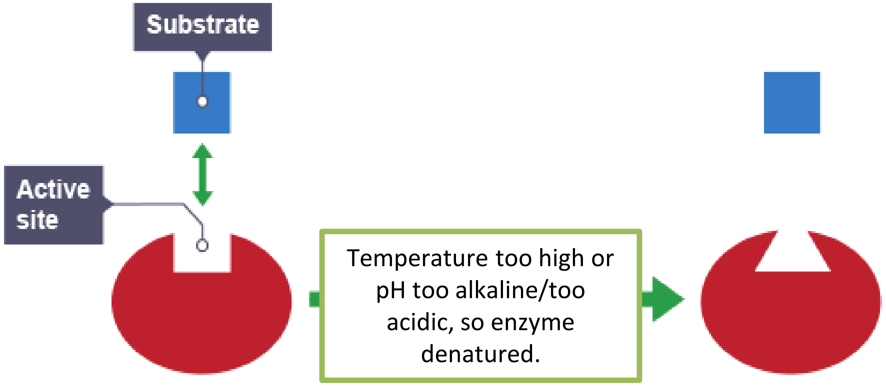
Recap your knowledge of how enzymes work from Topic 7.

Enzymes are highly **specific**, meaning that each type of enzyme only causes a reaction by one type molecule. This comes about due to the specific shape of the active site: only one molecule (according to its shape) will fit into the active site. See diagram for an illustration.

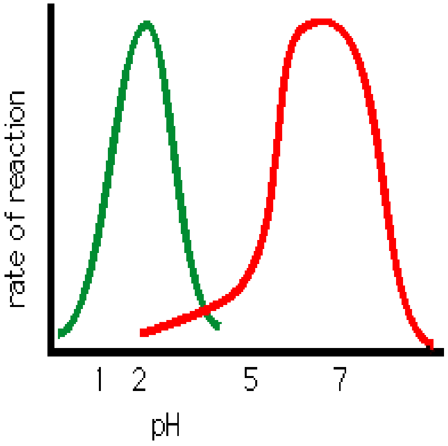
Enzymes have an optimum temperature and pH. If the temperature is **too high** (for most enzymes, above about 45ºC), or the pH is **too acidic** OR **too alkaline**, the enzyme **denatures**. This means the active site changes shape. As a result, the substrate no longer fits into the active site, to the enzyme doesn't work any more (see diagram).

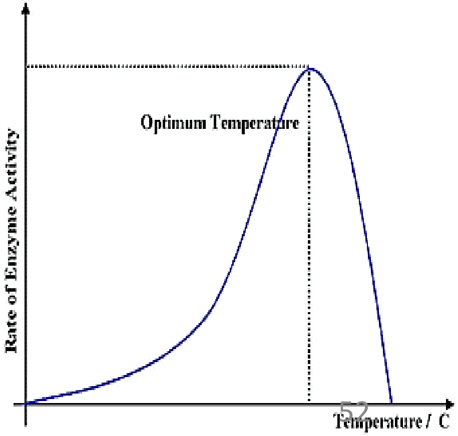
This leads to results with enzyme controlled reactions as shown in the graphs. The rate of the reaction catalysed by the enzyme is on the y-axis. The peak represents the optimum temperature/pH. Notice that different enzymes have different optimums – as shown on the pH graph with the two lines.

Key Terms	**Definitions**
metabolism	The sum of all the chemical reactions in a cell or in the body of an organism.
enzyme	Large protein molecule that acts as a biological catalyst, dramatically speeding up chemical reactions in organisms.
synthesis	Making something new. E.g. new molecules in metabolism.
active site	The part of an enzyme molecule into which the substrate fits – so the shape of the active site is vital.
substrate	The molecule an enzyme 'works on' to make a product/products.
optimum	The ideal or perfect condition . Enzymes have an optimum temperature and an optimum pH.



Temperature too high or pH too alkaline/too acidic, so enzyme denatured.





Combined Science Biology Knowledge Organiser
Topic 13: Disease

Health and disease

Health is the state of physical and mental wellbeing. So, ‘good health’ involves good physical and mental wellbeing. ‘Poor health’ involves problems with one or both aspects. Diseases are major causes of ill-health. Diseases can be classified as **communicable** (can be passed on, as they are caused by **pathogens**) and **non-communicable** (cannot be passed on). Other factors affect health: such as diet, lifestyle, stress, and genetic inheritance, for instance. Often, ill-health is caused or made worse by an interaction of different factors. Some examples to know:

- If their immune system has a defect, someone is more likely to suffer from communicable diseases, since their body will be worse at fighting pathogens.
- Some viruses, which live inside cells, can trigger cancers. For instance, the HPV virus can trigger cervical cancer (hence the vaccine in year 9 for girls).
- Severe physical health problems can lead to mental health problems, such as depression.
- Immune reactions to infection by a pathogen can trigger allergic reactions, like skin rashes or asthma.

Non-communicable diseases

Diseases that are **not** caused by pathogens – non-communicable diseases – are often linked to many different **risk factors**, and these factors may interact to increase the risk. These risk factors may come from someone’s lifestyle, or from substances in their body or substances in their environment. In some cases, the link between a risk factor and a particular disease is very clear: we know the risk factor *actually causes* the disease. For other risk factors, we know the linked diseases but not really how the risk factor causes them.

Here are some causal links we do know:

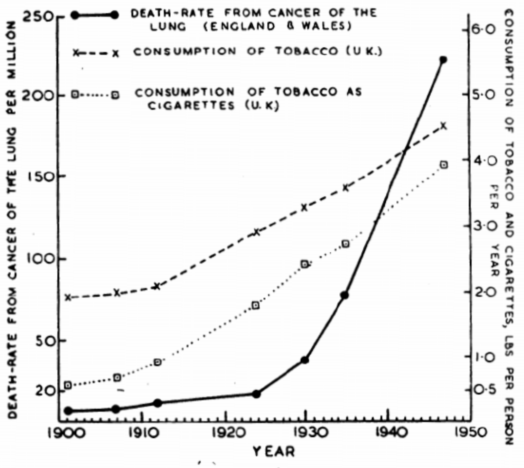
- ➢ Poor diet, lack of exercise and smoking have a proven link to **cardiovascular disease**.
- ➢ Obesity can cause type 2 diabetes.
- ➢ Alcohol causes liver damage and damages brain function.
- ➢ Smoking causes lung cancer and other lung diseases (like emphysema).
- ➢ Smoking and drinking alcohol during pregnancy causes problems in unborn babies.
- ➢ Carcinogens, such as *ionising radiation* (next topic), can cause cancer.

It is important to realise that while these risk factors are real, they don’t guarantee the disease. E.g. not ALL obese people will get type 2 diabetes; however, being obese greatly increases the risk of developing the disease.

Key Terms	Definitions
disease	Any condition that reduces health/causes ill-health.
communicable	Type of disease that can be passed on. These diseases are caused by **pathogens**, such as viruses. Be clear that the pathogen is the microorganism, and the disease is the collection of symptoms resulting from infection by the pathogen.
non-communicable	Describes diseases that are not caused by pathogens and cannot be passed on. These are often caused by many factors acting together, known as **risk factors** for the disease.
pathogen	A microorganism that can infect another organism (a host) and cause disease in that organism. E.g. bacteria and viruses.
risk factor	Any factor that increases the chance of developing a non-communicable disease, such as smoking or diet.

Using data to discover risk factors

Risk factors aren’t always obvious: it requires scientific research to find out what factors are linked to what disease. For many years, people smoked cigarettes thinking it was perfectly healthy (including doctors!). However, research by a scientist called Richard Doll showed that increased use of tobacco in the UK was linked to increased **incidence** of lung cancer (incidence is just how many people get it), as the graph shows (from his 1950 publication). He **sampled** the population and found this **correlation** between the risk factor (smoking) and the disease (lung cancer).



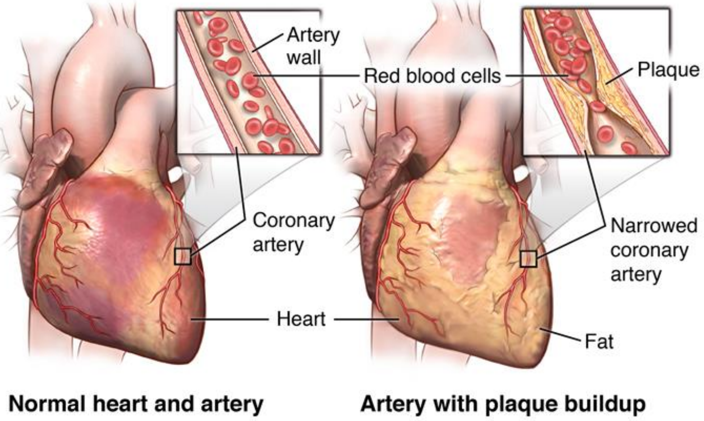
THE RATES ARE BASED ON 3 YEAR AVERAGES FOR ALL YEARS EXCEPT 1947.

FIG. 2.—Death rate from cancer of the lung and rate of consumption of tobacco and cigarettes.

Combined Science Biology Knowledge Organiser
Topic 13: Disease

Coronary heart disease: a non-communicable disease

Recall that **coronary** arteries are the arteries that provide the heart muscle with blood, so they get oxygen and glucose (and to take away waste products). Coronary heart disease involves the narrowing of these arteries, due to the build up fatty material (called a **plaque** – see diagram) in there. This reduces the blood flow through the coronary arteries, so the heart muscle receives insufficient oxygen. When serious, this leads to a heart attack (where part of the heart muscle dies due to lack of oxygen).



Normal heart and artery **Artery with plaque buildup**

__Treatments__ for coronary heart disease:

- Insert a **stent** into the narrowed artery to widen it again. This is a kind of wire mesh that pushes the artery walls out and __keeps the artery open__.
- Take **statins**. These drugs __reduce__ blood **cholesterol** levels, which is linked to the fatty material deposits. Lowering cholesterol reduces the rate of fatty material build up.

Heart transplants

If the heart fails (called **heart failure**) and cannot be repaired, the heart can be transplanted. In fact, the heart and lungs can be transplanted together if required. The replacement heart has to come from a **donor** – many people agree to donate their organs after they die to save the lives of others.

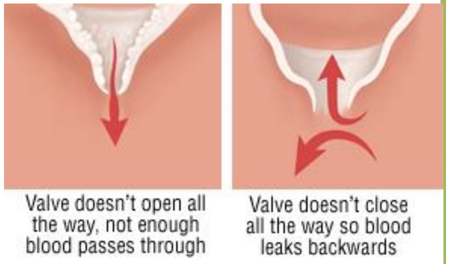
However, there is a shortage of donor organs, like hearts. So people with heart failure may have to wait a while. In this case, **artificial hearts** can be used to keep someone alive while they wait. These are pretty amazing – have a look at the photo.

Key Terms	Definitions
coronary	To do with the heart, especially the blood vessels that supply the heart muscle with blood.
stent	A mesh or cage-like structure that keeps coronary arteries open so blood can flow through.
statins	Medicinal drugs used to lower blood cholesterol. High blood cholesterol is a risk factor for coronary heart disease.
valve	Structures in the heart that prevent blood flowing the wrong way.
heart failure	Where the heart cannot pump blood around the body properly.

Other heart diseases

The valves in the heart are vital to prevent blood flowing in the wrong direction. In some people there is fault in the heart valves. The valve may get a leak, or might not open fully – see diagram.

- ➢ If one or more of the valves **leaks**, blood flows backwards in the heart. This means the blood does not transport oxygen as efficiently and also increases the risk of infection in the heart.
- ➢ If a valve **doesn't open fully**, the heart has to work harder to pump the blood as your body requires. This increases strain on the heart, making other heart problems more likely.



These valve problems can be treated by replacing the valves. Replacement valves can be **biological** – from a living organism (including pigs! Their heart is the same size as ours so their valves fit) or **mechanical** – a synthetic version. See the photos – mechanical on the right.

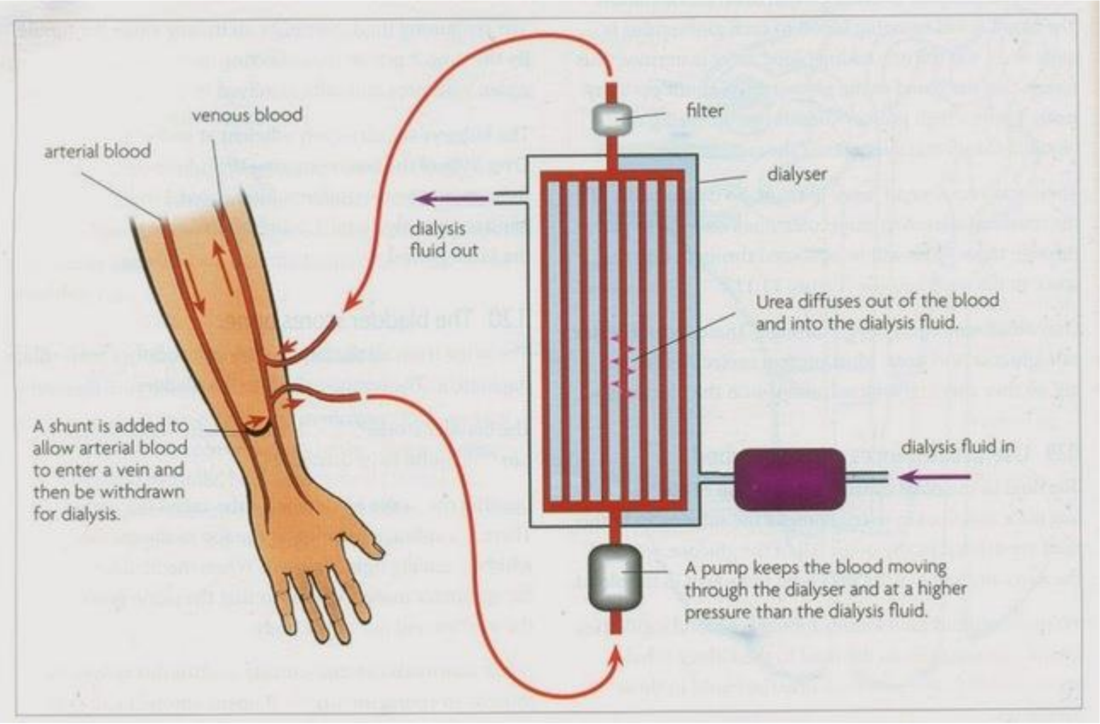
Combined Science Biology Knowledge Organiser
Topic 13: Disease

Kidney failure

If they kidneys fail, it is extremely dangerous. Kidney failure can be treated by a kidney **transplant** or using kidney **dialysis.** A transplant has the benefit for the patient of not needing to spend lots of time on a dialysis machine. However, they need to take **immunosuppressant drugs** to prevent rejection of the transplanted kidney. These leave them more susceptible to infections.

Dialysis machines keep people with kidney failure alive because they filter the blood for them. However, the patient would need to spend many hours a week connected to the machine to prevent urea reaching unsafe levels in the bloodstream.

The dialysis machine works as shown in the diagram. Notice that inside the machine, there is a large surface area to increase the rate of diffusion of urea out of the bloodstream.



Key Terms	Definitions
dialysis	Treatment for kidney failure, in which a machine filters toxic substances from the blood instead of the kidneys.
diabetes	Condition where blood glucose concentration is not controlled properly by the body.
insulin	The hormone, produced in the pancreas, that reduces blood glucose concentration by making cells absorb glucose from the blood.
immunosupp-ressant	Type of drug that reduces the responses of the immune system. This makes sure that 'foreign' organs (like a transplanted kidney) are not fought by the immune system – a situation called rejection.

Diabetes – a non-communicable disease

Diabetes is a group of disorders where blood glucose cannot be properly regulated by the body, which is potentially very dangerous. There are two types, with different causes and treatments.

Type 1 diabetes	Type 2 diabetes
Caused by a defect in the pancreas, where the cells that produce insulin don't work.	There is no problem with the pancreas – it produces insulin as usual. BUT, body cells no longer respond to the insulin.
The effect: Blood glucose concentration cannot be controlled by the body.	The effect: Blood glucose concentration cannot be controlled by the body.
Treatment is injections of insulin.	Insulin injections will have no effect, so the treatment is a carbohydrate-controlled diet and exercise.
The cause is unknown, but we do know it involves the insulin-producing cells getting destroyed.	Obesity is a major risk factor for type 2 diabetes. There is also a genetic risk factor.

Combined Science Biology Knowledge Organiser
Topic 13: Disease

Cancer – a non-communicable disease

Cancer is a non-communicable disease. There are many types of cancer, but they all involve changes in cells (**mutations**) that lead to the cells growing and dividing in an uncontrolled way. Normally, the **cell cycle** (see topic 6) controls cell growth and division, so the body only replaces lost cells. However, in cancer, the control mechanisms are broken and cells divide out of control, producing a mass of cells called a **tumour**.

- **Benign tumours** are growths of abnormal cells, but these do not invade other parts of the body. This is because the tumour is restricted to one area and often surrounded by a membrane. This makes them much less dangerous than **malignant tumours**.
- **Malignant tumours** cause cancer as you'd normally think of it. The cells grow out of control and invade nearby tissues. When mutated cells break off the tumour and get into the bloodstream, the cancer can spread around the body. The mutated cells can then cause more tumours, elsewhere. These are called **secondary tumours**.

In terms of risk factors for cancer, some are very clearly identified (like smoking as a risk factor for lung cancer). There can be **genetic** risk factors for some types of cancer (so the risk factor is inherited from the parents).

Communicable diseases and pathogens

Communicable diseases are sometimes called infectious disease, since they always result from an infection by a **pathogen**. All organisms can be infected by pathogens, so all organisms can suffer from communicable diseases (yes, including plants, and even bacteria can be infected by viruses!). You need to know details of specific diseases (next page), but here is a general description of how each kind of pathogen causes disease:

- **Bacteria** can cause disease if they enter our bodies. They **reproduce** rapidly and can release poisonous chemicals, called **toxins**, that damage our cells. Examples of diseases caused by pathogenic bacteria include cholera, tuberculosis (TB) and food poisoning.
- **Viruses** need a host to survive. They cause disease symptoms by reproducing **inside** cells, and bursting the cell from the inside. This releases them, so they can be passed onto other host cells or other people (e.g. by coughing or sneezing out mucus that contains the viruses).
- **Fungi** can also cause disease, by growing on living tissue (for example, athlete's foot is caused by a fungus).
- **Protists** can cause disease, as they can live in host organisms. A good example is the malarial protist, that causes malaria.

Key Terms	Definitions
mutation	Change to DNA, altering its function (this is not necessarily dangerous). In cancer, a specific mutation causes cells to divide uncontrollably.
protist	Whole kingdom of organisms, including some that cause disease.
transmission	The passing of a pathogen from one organism to another, leading to the spread of communicable (infectious) disease.
host	The organism that a pathogen lives in or on. When you have a cold, you are the host for the cold virus.

Spread of communicable diseases is caused by the transmission of pathogens

A big problem with pathogens is that they can be passed from one host to another, so the disease they cause can spread. See the table for the methods by which pathogens can be **transmitted**.

We can attempt to reduce the transmission of pathogens by: vaccinating people; destroying vectors (e.g. killing mosquitos with pesticides); being hygienic (i.e. washing our hands!); isolating people who are infected in special hospital wards.

Direct types of transmission	Indirect types of transmission
Direct contact e.g. shaking hands or kissing	A vector (animal) carries the pathogen e.g. mosquitos carry the pathogen that causes malaria
Sexual contact	Droplet infection: droplets of mucus containing a pathogen are sneezed or coughed out by an infected person, and breathed in by someone else. We can also say the pathogen is airborne.
From mother to foetus over the placenta	Waterborne – the pathogen infects water and moves between people when they drink the water

Combined Science Biology Knowledge Organiser
Topic 13: Disease

Viral diseases

Measles is caused by a virus. It is spread by droplet infection: you'd catch it if you inhaled the droplets containing the virus that someone infected coughed or sneezed out. The symptoms include **fever** and a **red rash on the skin**. Measles is a serious disease – it can even be **fatal** if there are complications. So, most young children are vaccinated against measles.

HIV is a virus that can only be spread by exchange of body fluids: sexual contact or when blood is mixed – which can happen when *intravenous drug users* share needles. HIV cannot be transmitted by kissing or by droplet infection. Infection with HIV causes flu-like symptoms first, but these go away after a couple of weeks. However, the virus has not gone from body – it is living inside immune cells (white blood cells). HIV is NOT the same thing as AIDS, but AIDS can arise from infection by HIV unless treatment takes place. The treatment is **antiretroviral drugs** (so called because HIV is a type of virus called a retrovirus). Without this treatment, AIDS will occur. Here, the body's immune system is so badly damaged it cannot fight off other infections or cancers – so it is very serious.

Tobacco mosaic virus (TMV for short) is a pathogen affecting **plants**. In spite of its name, it affects many species of plant (including tomatoes – see photo). TMV causes discolouration of the leaves, giving a mosaic pattern. This hinders photosynthesis, so plants don't grow very well if they are infected by TMV.

Bacterial diseases

***Salmonella* food poisoning** is caused by a bacteria found in food, or on food where it is prepared in unhygienic conditions. The bacteria can be found in poultry (e.g. chickens), so these animals are **vaccinated** against *Salmonella* to reduce the spread of the pathogen. Inside the body, the bacteria reproduce and produce **toxins** which cause disease. **Symptoms** of *Salmonella* food poisoning include: fever, abdominal cramps, vomiting and diarrhoea.

Gonorrhoea is the name of a **sexually transmitted disease** (STD or STI), rather than the name of the pathogen. The pathogen is a bacterium that is transmitted by sexual contact, so transmission can be prevented with a barrier-type of **contraception**, like a condom. The symptoms include a thick yellow or green discharge from the vagina or penis and pain when urinating (weeing). It used to be that gonorrhoea was easily treated with an **antibiotic** (penicillin, in this case), but there are now many **resistant strains** of bacteria that cause gonorrhoea. (Resistant strains are species of the bacteria on which certain antibiotics do not work.)

Key Terms	Definitions
fever	Disease symptom linked to raised body temperature, thanks to disruption of the normal homeostasis mechanisms.
HIV	Human Immunodeficiency Virus. A virus that uses immune cells as host cells. HIV infection causes AIDS, but if treated properly, AIDS will never develop in an infected individual.
AIDS	Acquired Immunodeficiency Syndrome. A condition in which the immune system is seriously weakened due to infection by the HIV virus.
Salmonella	A genus of bacteria that can cause food poisoning.
discharge	A substance being produced by the body that should not be there – a sign of disease.

Fungal diseases

Rose black spot is a fungal disease that affects plants. It causes purple or black spots to develop on leaves (hence the name – see picture). The whole leaf often turns yellow and drops early (i.e. before autumn). Like TMV, the plant's growth is inhibited because the rate of photosynthesis is reduced. The fungus is spread on the wind or in water, transmitting the pathogen to other plants. Treatment options: remove the affected leaves, or use a **fungicide** (a chemical that kills fungi).

Protist diseases

Malaria is a disease caused by a *protist* (see topic 6 for a reminder). The protist has a life cycle that requires it to live inside a **mosquito** for some of the life cycle, and in the body of a mammal – like a human – for other stages of the life cycle. In the mosquito, the protist is found in the salivary glands, which is why the protist can be transmitted to a person when the mosquito sucks their blood. The mosquito acts as a **vector**. In the human, the protist causes malaria. Symptoms include recurrent (repeating) **fever** and malaria can be **fatal**. We can attempt to reduce transmission by targeting the mosquitos: preventing them breeding and avoiding bites using **mosquito nets**.

Combined Science Biology Knowledge Organiser
Topic 13: Disease

Human defence systems

Pathogens are all over the place, so humans have evolved defence systems to deal with them. We have **non-specific defences**, which keep pathogens from entering the body (although, of course, they can fail to do this – otherwise you'd never get sick!). If pathogens do get in, we have the **immune system**, which destroys the pathogen inside the body.

Non-specific defences:

- The **skin**! Our main barrier against pathogens getting in. The vast majority of pathogens cannot get through the skin at all – they have to enter somewhere else. Also, the skin scabs over to provide a quick barrier if there is a cut or wound.
- The **nose** has hairs and mucus to trap microorganisms so they don't get any further than the nose. If you don't blow your nose, the mucus ends up in the back of the throat and you swallow it – this is harmless, because the stomach acid kills any microorganisms in there.
- The **trachea** and **bronchi** also contain mucus. This traps microorganisms that are breathed in, and the mucus, again, can be swallowed harmlessly.
- The **stomach** produces hydrochloric acid (at pH 2), which kills most microorganisms that are swallowed.

The immune system responds if pathogens enter the body properly – i.e. if they get into the bloodstream. The most important cells in the immune system are the white blood cells. They help defend against pathogens by:

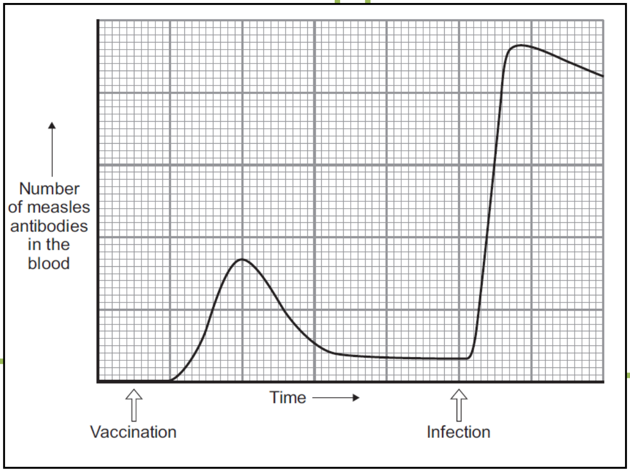
- **Phagocytosis**. This is the *engulfing* and *digesting* of pathogens by white blood cells, destroying the pathogens.
- **Antibody production**. White blood cells produce chemicals called antibodies that bind to pathogens and destroy them. These are *specific*, meaning only one particular antibody type will bind to one particular pathogen.
- **Antitoxin production**. Some pathogens, especially bacteria, produce poisonous toxins. These are neutralised by antitoxins – another sort of chemical produced by white blood cells. Again, antitoxins are specific to specific toxins.

Key Terms	Definitions
defence systems	Structures and mechanisms we have to prevent pathogens entering the body, and to fight them off if they do enter. Includes non-specific defences (act on any pathogen) and specific defences (target the particular pathogen you've been infected by).
mucus	A sticky substance produced by many epithelial (surface-covering) tissues in the body, to trap dust particles and microorganisms so they can't enter the body.
antibody	Chemical produced by white blood cells that destroys specific pathogens.
antitoxin	Chemical produced by white blood cells that neutralises specific toxins.

Vaccination

Vaccination is great on two fronts: it stops the vaccinated individual from getting ill AND it helps prevent the spread of communicable diseases. If a large proportion of the population is vaccinated, it is very unlikely that an *unvaccinated* person would be exposed to the pathogen, so everyone is protected.

1. A vaccine contains a small quantity of a **dead or inactive** form of a **pathogen** (usually a virus, such as the measles virus – see graph).
2. Delivering a vaccine stimulates a **primary** immune response. White blood cells produce antibodies to destroy the pathogen, but this is slow.
3. **Specialised white blood cells** (memory cells) remain in the blood afterwards.
4. This means that if an infection by the real pathogen takes place in the future, there is a **secondary** immune response by the white blood cells.
5. The secondary immune response starts faster (see graph), involves the production of far more antibodies (a *stronger* response) and the level of antibodies stays higher for longer.
6. This means the pathogen is destroyed before you even realise you are ill.



Combined Science Biology Knowledge Organiser
Topic 13: Disease

Treating disease with drugs

Despite our non-specific defences and our immune systems, we still get sick due to communicable diseases. Fortunately, we've developed a huge range of drugs to treat diseases. (Drugs and medicines are synonymous; we can also say 'medical drugs' to mean those that treat disease rather than drugs taken for recreation.)

Antibiotics

Antibiotics have only been produced since the 1940s, but they have changed the world in that time. The first antibiotic was discovered (not made – it was produced by a fungus!) by Alexander Fleming. He found that a fungus called *Penicillium* worked to kill bacteria he was growing in an agar plate. Named for the fungus that produced the chemical, this was the first antibiotic: penicillin. It is still used today.

Antibiotics treat **bacterial** diseases **only**, because they kill pathogenic bacteria in the body. In this way, they can cure bacterial diseases. Antibiotics are *specific* – so you need to use the right antibiotic to kill the particular bacteria that has infected you. So, antibiotics have saved millions of lives, by successfully treating people with bacterial infections. However, a big issue with the use of antibiotics is that many strains (types) of **resistant bacteria** have emerged (more on this in topic 16).

Antibiotics CANNOT kill viruses, so cannot treat viral diseases. Since viruses live *inside* host cells, it is very difficult to kill viruses without also damaging the body tissues they live in.

Painkillers

Painkillers are examples of medical drugs that treat the **symptoms** of disease, without actually getting to the cause and killing the pathogens. An example is **aspirin**, a painkiller that was first extracted from the bark of willow trees.

Discovering new drugs

There is a constant demand for new drugs – for better treatments, to treat diseases without any current cures, and to deal with antibiotic resistance. Chemicals that *might* work as effective drugs are constantly being discovered or synthesised in labs. Many drugs were discovered in living organisms: e.g. the heart drug **digitalis** originates from **foxgloves**. There are other examples above. However, any of these newly discovered/made chemicals must be thoroughly tested before they can be used in humans.

Key Terms	Definitions
drug	Any chemical that causes chemical changes in the body. Most drugs are medical – used to treat disease.
antibiotic	Type of drug that treats bacterial disease by killing pathogenic bacteria.
antiretroviral	Type of drug that *can* kill viruses: these are used to treat infection by HIV.
painkiller	Drug that only treats the symptoms of disease, rather than killing pathogens.
symptoms	Problems with the body arising from disease and indicating that there is a disease. E.g. coughing, headaches, vomiting.
toxicity	From 'toxic', toxicity means how harmful a drug is to healthy body tissues.
efficacy	How well a drug actually treats the disease it is designed to treat.
dose	How much of a drug is given to a patient, and how many times a day and so on.

Development and testing of new drugs

New chemicals, potential medical drugs, are tested to find out if they are **safe** and **effective** (they actually treat the disease they are supposed to!). There are many stages to this testing. We refer to the part before giving the drug to humans as 'preclinical testing' and to the stages where humans received the drugs as ' clinical trials'. Together, these stages tell us about the drug **toxicity, efficacy** and information about the **dose** that should be given. Here's the sequence:

1. **Preclinical testing** is in a lab. The drug is tested on cells and tissues grown for drug testing, and on animals like rats bred for drug testing. This checks that the drug is not toxic, and can give information about efficacy too.
2. **Clinical trials** are tests on humans. First, new drugs are given in very low doses to healthy volunteers, to check that they are not toxic and don't cause major side effects.
3. If the drug is safe, clinical trials using people with the disease take place. These trials test how well the drug works for the disease, and identifies the optimum dose.

In any clinical trial, **double blind** testing is often used. Some patients are given a **placebo** (fake version of the drug), and neither scientist/doctor or patient know who has the placebo and who has the real drug until afterwards. This ensures that effects due to people's expectations can be ruled out.

The chemistry paper could assess:

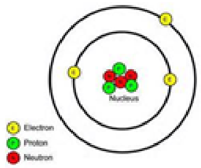
Knowledge Organiser Topics:

- Chemistry Threshold Concepts
- Atoms and the Periodic Table
- Materials, Structure, Bonding and Reactions
- Quantitative Chemistry and Electrolysis
- Energetics

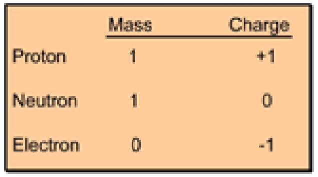
Combined Science Chemistry Knowledge Organiser
Topic 2: Chemistry Threshold Concepts

The Structure of the Atom

- All matter is made from atoms. Atoms are very small. The radius of atom is about $1x10^{-10}$ m (this is also known as 0.1 nanometres).
- The central part of the atom is known as the nucleus. It is only $1x10^{-14}$m across, which is 10,000 times smaller than the total atom.
- An atom is made up of three subatomic particles: **protons**, **neutrons** and **electrons**.
- Protons and neutrons are found in the **nucleus**
- Electrons are found orbiting the nucleus in <u>shells</u> (also known as *energy levels*).



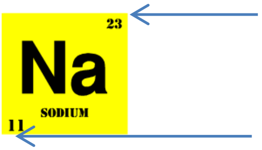
- The mass and charges of the sub atomic particles is shown below:



	Mass	Charge
Proton	1	+1
Neutron	1	0
Electron	0	-1

- Atoms have **no overall charge** because they have the same number of positive protons as negative electrons.

Atomic Number and Mass Number



Mass number: This is the total protons+neutrons

Atomic number: This is the number of protons

Therefore sodium has 11 protons, 11 electrons and 23 – 11 = 12 neutrons

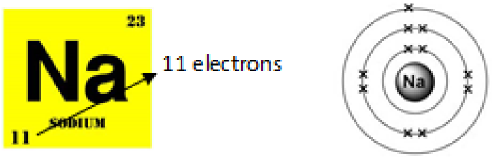
Key Terms	Definitions
atom	Smallest particle of an element with a specific number of protons.
nucleus	The centre of an atom; it is made of protons and neutrons.
nanometre	A unit of measurement: $1x10^{-9}$m
proton	A sub atomic particle found in the nucleus, it has an electric charge of +1 and a relative mass of 1.
electron	A sub atomic particle found in the shells of an atom, it has an electric charge of -1 and a negligible mass
subatomic	Describes particles smaller than an atom (protons, neutrons, electrons)
neutron	A subatomic particle found in the nucleus of an atom, it has a charge of 0 and a mass of 1
atomic number	The number of protons in an atom.
mass number	The total of protons and neutrons in an atom.

Electron Configuration/Electronic Structure

There are very strict rules about how electron fill up the electron shells, the inner shell is always filled first. Each shell has a maximum number of electrons it can take.

Shell 1: maximum 2 electrons
Shell 2: maximum 8 electrons
Shell 3: maximum 8 electrons

Example:



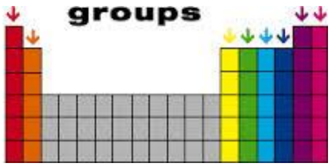
The electronic configuration of Sodium (Na) can also be written like this: 2,8,1. This shows there is 2 electrons in the 1st shell, 8 electrons in the second shell and 1 electron in the 3rd shell.

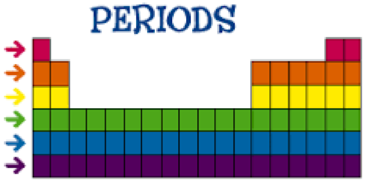
Combined Science Chemistry Knowledge Organiser

Topic 2: Chemistry Threshold Concepts

Elements

- An ***element*** is a substance made from only one type of atom. All elements are given a symbol and are found on the periodic table. You need to learn the symbols for the first 20.
- The Periodic Table is arranged into groups (columns) and periods (rows), as shown below.





Elements in the same group have:

- The same number of electrons in their outer shell
- Similar properties

Elements in the same period have:

- The same number of electron shells

Compounds

- Compounds are made of 2 or more elements that are chemically bonded
- These are made in chemical reactions.
- Compounds are given a formula. For example, carbon dioxide is CO_2 means 1 carbon atom and 2 oxygen atoms.
- Another example is calcium hydroxide $Ca(OH)_2$ which means 1 calcium, 2 oxygen atoms and 2 hydrogen atoms

Chemical Reactions always Conserve Mass

- In some chemical reactions it may appear that there are less products than there were reactants; however, this is often because a gas has been made and this has escaped into the atmosphere.

Key Terms	Definitions
element	A substance made up of just one type of atom
mixture	A mixture is two or more different atoms which are not chemically bonded
compound	A chemical substance made of 2 or more different elements chemically bonded together
group	The columns on the periodic table
period	The rows on the periodic table
reactant	Chemicals you start with in a chemical reaction
product	Chemicals made in a chemical reaction

The Conservation of Mass

- In a chemical reaction, chemical bonds in the reactants are broken, the atoms are rearranged and new chemical bonds are made to form the products.
- In a chemical reaction, ***<u>mass is never lost;</u>*** you must start and finish with the same mass.

Balancing Equations

- We need to write balanced chemical equations represent chemical reactions and the conservation of mass.
- For example: The equation below shows hydrogen and oxygen making water but there are more oxygen atoms on the right than the left.

$$H_2 + O_2 \rightarrow H_2O$$

- In the equation below there are 4 hydrogen atoms on the left and right of the equation and 2 oxygen atoms on each side

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

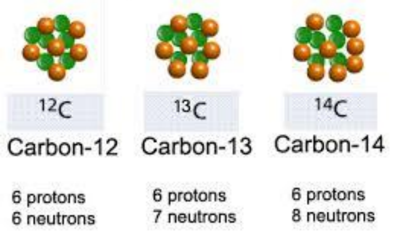
Combined Science Chemistry Knowledge Organiser
Topic 5: The Periodic Table and Separation Techniques

Key Terms	Definitions
Dimitri Mendeleev	A Russian Chemist, who in 1869 published a Periodic Table containing gaps.
periodic table	The table which organises the 118 elements based on atomic structure
isotope	Two atoms of an element with the same number of protons and electrons but a different number of **neutrons**
metal	An element which loses electrons to form a positively charged ion
non metal	An element which gains electrons to form a negatively charged ion
ion	A particle (e.g. an atom) with a positive or negative charge

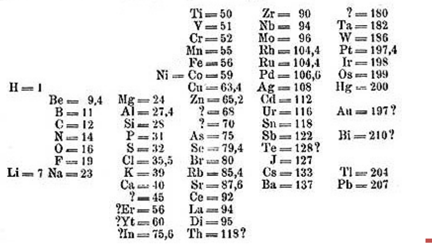
The History of the Periodic Table

- Throughout history scientists have tried to classify substances and many scientists attempted to construct a periodic table.
- Before the knowledge of protons, neutrons and electrons, scientists arranged the Periodic table by **atomic weight**. This meant the groups were not always correct.
- In 1869 Dimitri **Mendeleev**, a Russian Scientist, published his periodic table. It was slightly different to those that had been before. He still arranged elements by atomic weight but he also left gaps for where he predicted elements would be.
- He very accurately predicted the properties of elements that were not discovered until many years later; for example: Gallium.
- Mendeleev's Periodic Table is still different from the modern one as some of his masses were wrong due to the existence of **isotopes**
- Isotopes are elements with same number of **protons and electrons** but a different number of **neutrons** and therefore different atomic weights.

Isotopes of Carbon



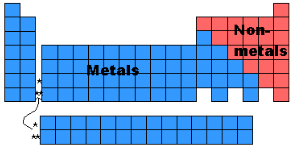
Mendeleev's Periodic Table



			Ti = 50	Zr = 90	? = 180
			V = 51	Nb = 94	Ta = 182
			Cr = 52	Mo = 96	W = 186
			Mn = 55	Rh = 104,4	Pt = 197,4
			Fe = 56	Ru = 104,4	Ir = 198
			Ni = Co = 59	Pd = 106,6	Os = 199
H = 1			Cu = 63,4	Ag = 108	Hg = 200
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35,5	Br = 80	J = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75,6	Th = 118?		

Metals and Non-Metals

- **Metals** are found on the left hand side of the periodic table. The majority of elements are metals.
- When metals react, they lose an electrons to form positive ions.
- **Non metals** gain electrons to form a negative charge.



Groups in the Periodic Table

Group	Physical properties	Chemical Properties	Equation	Trends/Explanation
Group 1 (Alkali metals)	Soft, low density	React vigorously with water releasing hydrogen	Sodium + Water→ Sodium Hydroxide + Hydrogen	More reactive as you go down, outermost electron further from the nucleus so it's easier to lose
Group 7 (Halogens)	Low melting point, exist as pair (Cl_2)	React with group 1 metals to form compounds . Can carry out displacement reactions	Sodium + Chlorine → Sodium Chloride Sodium Bromide + Chlorine → Sodium Chloride + Bromine	Higher melting point as you go down the group (higher molecular mass). Less reactive as you go down the group.
Group 0 (Noble Gases)	Low melting point/boiling point Eight electrons in outer shell (except helium)	Unreactive, as they have a full outer shell	N/A	Higher melting point and boiling point as you go down the group (due to increase in density)

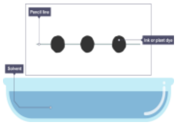
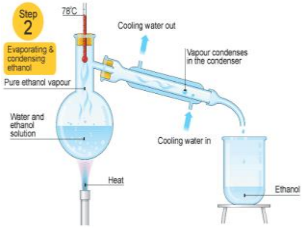
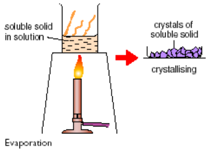
Combined Science Chemistry Knowledge Organiser
Topic 5: The Periodic Table and Separation Techniques

Key Terms	Definitions
pure	A substance made of only ONE type of element or compound
impure	A mixture of elements and/or compounds
chromatography	A technique where mixtures can be separated based on their solubility.
distillation	A separation technique which means a mixture of two liquids is heated
crystallisation	Method of mixture separation where a solvent is evaporated, leaving the solute behind.

Pure and Impure Substances

- A pure substance contains only <u>one</u> type of **element** or **compound.**
- **An impure substance** contains more than one type of element or compound in a mixture, for example salt water contains NaCl and H_2O. All mixtures are impure substances.
- Mixtures are much easier to separate than elements or compounds as they are not chemically bonded
- There are a variety of ways that mixtures can be separated and they are outlined below. Remember that these are all physical changes and chemical bonds are not broken during any of these processes.

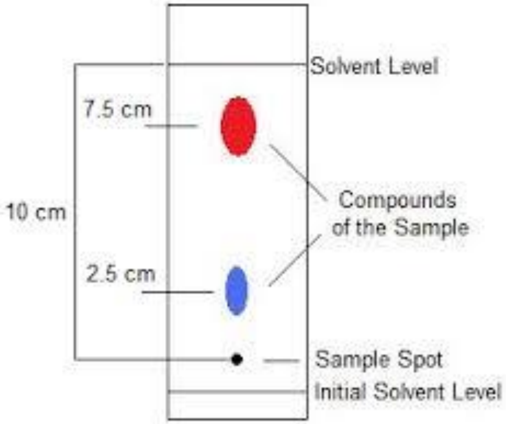
Separating Impure Substance

Method	Diagram	Explanation
Chromatography		• Different substances travel different distances up the paper depending on their solubility in the solvent used (it is often water but not always). The more soluble, the further it moves up the paper • Line must be drawn with pencil because pencil will not run. • Artificial colours in foods can be identified using chromatography. Additives do not necessarily have a colour and therefore are identified using chemical analysis.
Distillation		• **Distillation is** when two liquids with *different boiling points* are separated • For example ethanol (alcohol) boils at 78 °C and water boils at 100 °C • If you heat a mixture of water and ethanol to 80°C the ethanol will **evaporate** but the water will not. • You then **condense** the ethanol and collect the pure ethanol
Crystallisation		• Crystallisation is when a solvent is evaporated from a solute. The evaporation should not begin until the solution is **saturated** (has as much solid dissolved in the solution as possible). The solution should the be allowed to cool, as the solution cools crystals will form. The crystals can then be separated and dried.

Combined Science Chemistry Knowledge Organiser
Topic 5: The Periodic Table and Separation Techniques

Chromatography and R_f values

- When carrying out chromatography we can calculate an R_f (retention factor) value.
- The retention factor is a ratio between the distance travelled by the solvent and the distance travelled by a compound, which is written down as a decimal less than 1.
- Chromatography has two phases- a **stationary phase** where particles can't move (the filter paper in most cases), a **mobile phase** where particles can move (a solvent for example water).
- Different compounds will have different R_f values in different solvents. This allow us to see whether a substance is pure or impure.
- To calculate R_f value you need to divide the distance moved by the solvent by the distance moved by the spot.
- For example to work out the Rf for the spot further up the paper:
- $R_f = \frac{B}{A}$ $R_f = \frac{7.5}{10} = 0.75$
- There are no units as the answer is a ratio.
- The higher the R_f value, the further the spot has moved up the paper, compared to the solvent.



Key Terms	Definitions
retention factor	The ratio between the distance travelled by the substance and the distance travelled by the solvent.

Equation	Meanings of terms in equation and units
$R_f = \frac{B}{A}$ *	*R_f = Retention Factor (no units)* *B = Distance travelled by solute substance (cm)* *A= Distance travelled by solvent (cm)*

Melting Point and Boiling point

- A chemically pure substance will melt or boil at a very specific temperature.
- If a substance is chemically impure it will melt or boil at a lower temperature and across a broader range.
- The closer the substance is to the melting point the purer the substance.

Formulations

- Formulations are mixtures made using a precise proportion of each substance, so they can serve a particular purpose.
- For example, paints, medicines and Coca Cola are formulations.

Practical Methods Knowledge Organiser
Topic 5: Chromatography and R_f Values

Equipment List

- 250cm^3 beaker
- Glass rod
- A rectangle of chromatography paper
- Four known food colourings labelled A to D
- An unknown mixture of food colourings labelled U
- Glass capillary tubes

Method

1. Using a ruler, draw a horizontal pencil line 2cm from a short edge of the chromatography paper. Mark five pencil spots at equal intervals across the line, keeping at least 1cm away from each end. The **stationary phase is the filter paper, the mobile phase is the water.**
2. Use a glass capillary tube to put a small spot of each known colouring and the unknown one on the five pencil spots. Try to make sure each spot is no more than 5mm in diameter. Label each spot **in pencil.**
3. Pour water into the beaker to a depth of **no more than 1cm.**
4. Attach the edge of the paper furthest from the spots to the glass rod so that when the rod is rested on the top edge of the beaker, the bottom edge of the paper dips into the water.
5. Without disturbing the beaker, wait for the water solvent to travel at least three quarters of the way up the paper. Carefully remove it and draw another pencil line on the dry part of the paper as close to the wet edge as possible.
6. Hang the paper up to dry thoroughly.
7. Measure the distance in mm between the two pencil lines. This is the distance travelled by the water solvent. Write the same distance in the table below for each colouring.
8. For each of the four known colours, measure the distance in mm from the bottom line to the centre of each spot. Write each measurement in the table.
9. Use the equation:

$$R_f = \frac{\text{distance moved by substance}}{\text{distance moved by solvent}}$$

To calculate the retention factor of different

Expected Results

If the substance **is pure**, you will only see one spot for that substance on the chromatogram, if the substance is **impure** then you will see more than one spot on the chromatogram.
A substance can be identified by their Rf values, if a substance has the same Rf value as another substance it is highly likely it is the same substance.

Rf values will be different if a different solvent is used.

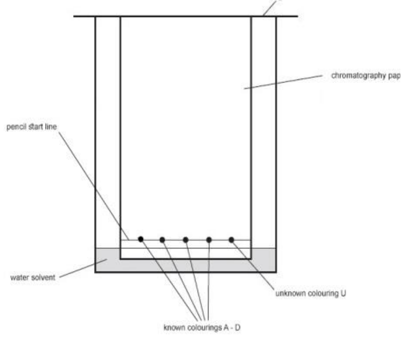
Key Terms	Definitions
Rf	Retention factor- a ratio that shows how far a substance has moved up the paper
chromatogram	The results from a chromatography experiment, the paper which shows the Rf values of the substances
pure	A substance which contains only one type of element or compound
impure	A substance which contains more than one kind of element or compound
stationary phase	The part of a chromatography experiment where the molecules can not move. In most cases this is a solid but it can be a very thick liquid
mobile phase	The part of the chromatography experiment where the molecules can move, this is a liquid or a gas

Risk Assessment

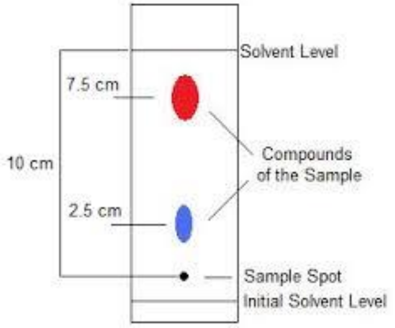
Care should be taken with sharp broken melting point tubes.

Diagram

This diagram shows how the experiment should be set up



How to calculate Rf



Rf for top spot= 7.5/10= 0.75

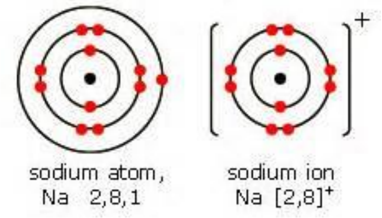
Common Errors

The baseline should be drawn in pencil as ink will be separated
The solvent front should not go all the way to the top of the paper
The solvent should not be higher than the baseline

Combined Science Chemistry Knowledge Organiser
Topic 9: Chemical Bonding, Structures and Reactions

Ions

All atoms of all elements react to get a full outer shell of electrons. Some atoms will lose electrons to get a full outer shell: these are metals. Some atoms will gain electrons to get a full outer shell: these **are non metals**. An ion is an atom with a positive or negative charge, these are formed by an atom gaining or losing electrons. For example, sodium has one electron in it's outer shell, it therefore loses one electron to form a Na^{+1} ion. We represent ions with square brackets around the ion and the charge in the top right corner.

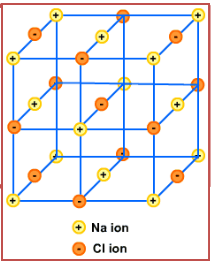


The **group number** indicates how many electrons an atom would have to lose or gain to get a full outer shell of electrons. See below to see what ions different groups form

Group	What happens to the electrons?	Charge on ions
1	Lose 1	+1
2	Lose 2	+2
3	Lose 3	+3
5	Gain 3	-3
6	Gain 2	-2
7	Gain 1	-1

Ionic Lattice

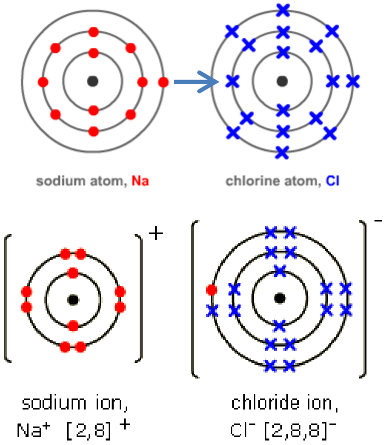
Ionic compounds form **regular structures** called **giant ionic lattices)** in which there are strong **electrostatic forces** of attraction in all directions between oppositely charged ions.



Key Terms	Definitions
metal	An element which loses electrons to form positive ions
non metal	An element which gains electrons to form negative ions
ion	An atom (or particle) with a positive or negative charge, due to loss or gain of electrons
ionic bond	A bond formed by the electrostatic attraction of oppositely charged ion
electrostatic	The force between a positive and negative charge.

Ionic Bonding

When a metal atom reacts with a non-metal atom electrons in the outer shell of the **metal atom are transferred to the non metal atom**. This means the metal has a positive charge and the non metal has a negative charge. This means there is an **electrostatic attraction** between the two ions, this is what forms an ionic bond. Both atoms will have **a full outer shell** (this is the same as the structure of a noble gas). See example to memorise below of sodium chloride.

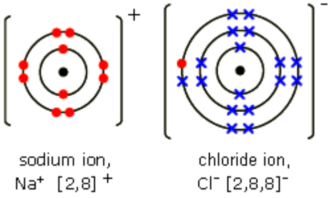


Combined Science Chemistry Knowledge Organiser
Topic 9: Chemical Bonding, Structures and Reactions

Ionic Bonding- Models

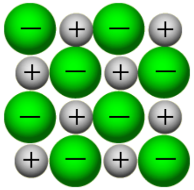
There are a number of ways we can represent ionic bonding all; of these have **advantages and limitations.** For example, all the diagrams below show ways we can represent **sodium chloride**

1. **Dot and cross diagrams-** These show clearly how the electrons are transferred. It does not, however, show the 3D lattice structure of an ionic compound or that this is a giant compound.



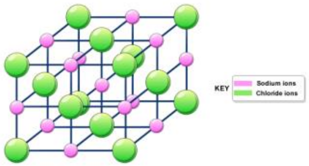
2. **2D ball and stick model of ionic bonding**

This has the advantage of showing that electrostatic forces exist between oppositely charged ions in an ionic compound. However, does not show the 3D structure of an ionic compound.



3. 3D Ball and Stick model of ionic bonding

This clearly shows the 3D structure of the **ionic lattice** and how different ions interact with other ions **in all directions** to create an ionic lattice.



Key Terms	Definitions
ionic lattice	The regular 3D arrangement of ions in an ionic compound
giant	When the arrangement of atoms is repeated may times, with large numbers of atoms or ions
aqueous	When a substance is dissolved in water
empirical formula	The simplest ratio of atoms in a compound

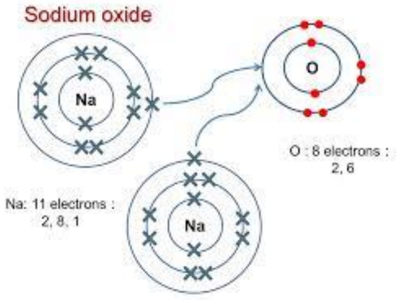
Properties of Ionic compounds

Ionic compounds have **high melting points, due to strong electrostatic forces between the oppositely charged ions.** This means a lot of energy is required to break these bonds. For example the melting point of sodium chloride is 801 °C.

Ionic compounds **do not conduct electricity** as a solid. They **do conduct electricity** if they are dissolved in water (aqueous) or in the liquid state. This is because the ions are free to move, carrying the electric charge.

Empirical Formula of Ionic Compounds

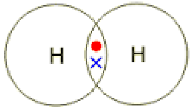
In sodium chloride, 1 sodium atom transfers one electron to a chlorine atom, therefore the empirical formula is NaCl. However, there are some examples where the ratio of atoms is not 1:1. For example when sodium bonds with oxygen, sodium only loses one electron but oxygen gains two. So there are two sodium atoms for every oxygen, so the **empirical formula is Na_2O.**



Combined Science Chemistry Knowledge Organiser
Topic 9: Chemical Bonding, Structures and Reactions

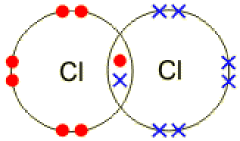
Covalent Bonding

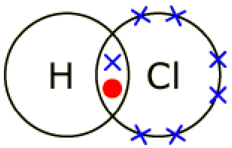
Covalent bonding occurs between atoms of non metal elements. E**lectrons are shared between the atoms**, so that they have a full outer shell. Covalent bonds are strong and require a lot of energy to break. The simplest example is hydrogen: both hydrogen atoms have **one electron in their outer shell. Therefore both hydrogen atoms share one electron each,** to give them both a full outer shell, we can show this bond on a dot and cross diagram.

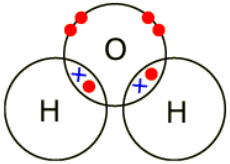


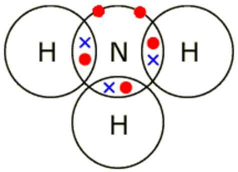
When drawing covalent molecules we use "dot cross diagrams" as we do with ionic compounds. It is important to represent the electrons on one atom with a dot and on the other atom with an X.

The first five examples, **hydrogen, chlorine, water, hydrogen chloride and ammonia (NH_3)** all share one electron per atom in a molecule to make a full outer shell of electrons on each atom.

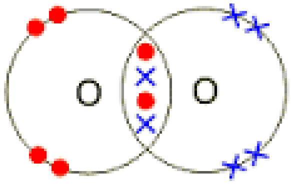


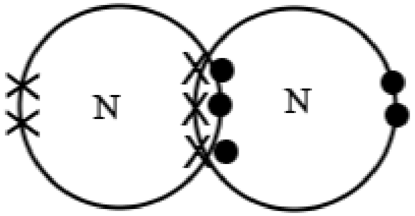






Some atoms need more than one electron to give them a full outer shell, for example oxygen needs 2 electrons to complete its outer shell. Oxygen therefore shares two electrons per atom to **make a double bond.** Nitrogen needs three electrons to complete its outer shell, this forms a triple bond between the two **nitrogen atoms, to make a nitrogen molecule.**

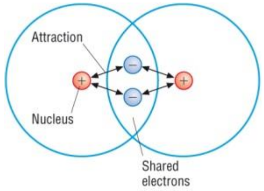




Key Terms	Definitions
covalent bonding	Bonding between 2 (or more) atoms where electrons are shared.
molecule	A substance which contains two or more covalently bonded atoms
lone pair	A pair of outer electrons that are not part of the covalent bond.

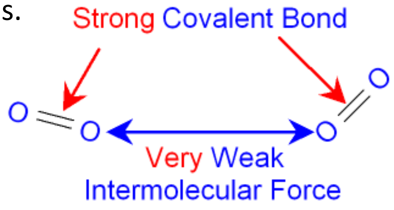
The Nature of a Covalent Bond

Covalent bonds are **strong** because there is electrostatic attraction between the electrons in the covalent bond and the positively charged nucleus. This means a lot of energy is required to break a covalent bond.



Properties of Simple Covalent Compounds

Simple covalent compounds have low melting and boiling points. They are often gases at room temperature: for example, **oxygen** and **carbon dioxide.** Although the covalent bonds between the atoms are strong, the **intermolecular forces between the molecules are weak. It is very important to remember that covalent bonds are strong but the intermolecular forces are weak.** This means that only a small amount of energy is required to overcome these weak forces.



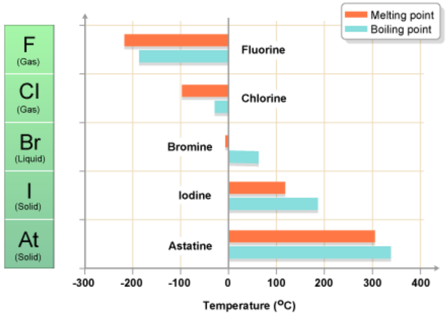
Please see the next page for more properties of covalent compounds.

Combined Science Chemistry Knowledge Organiser
Topic 9: Chemical Bonding, Structures and Reactions

Properties of Covalent Compounds-Continued

The size of the intermolecular force between molecules increases as the molecules get larger. For example, as you go down group 7, the boiling points increase because **the molecules get larger**.

As you can see from the graph below, the boiling point of fluorine is -188°C and is therefore a gas at room temperature, whereas the melting point of astatine is 302°C and is therefore a solid at room temperature. This is because the intermolecular forces between the larger astatine molecules are larger than between the **smaller fluorine molecules.**



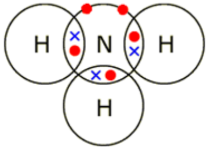
As well as having low melting points, covalent compounds **do not conduct electricity. T**his is because they have no free electrons or ions and therefore there is nothing to carry the electric charge. Remember pure water does not conduct electricity; only when it has ions dissolved in it will it conduct.

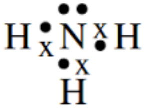
Key Terms	Definitions
polymer	A very large molecule, made from monomers
repeating unit	The shortest repeating section of a polymer
intermolecular forces	The force of attraction between two molecules

Representing Covalent Compounds

Like ionic compounds, there are variety of ways that scientists use to represent covalent compounds.

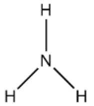
1. Dot cross diagram

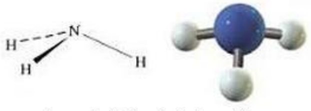




There are two dot cross representations of ammonia shown above. The advantages of these diagrams are that it is very clear, which electrons are used in bonding and which are lone pairs. However it does not show the 3D structure of the molecule and this can be extremely important for scientists.

2. Ball and stick model





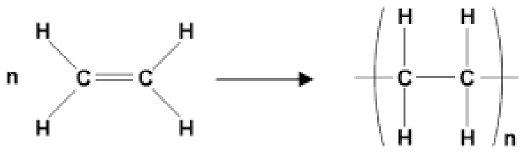
Ammonia (Ball and stick model)

A ball and stick diagram can either be 2D or 3D. While the 2D version clearly shows which atoms are bonded together, the 3D version gives the scientist more information about the 3D shape and the angles between the bonds in the molecule.

Polymers

Polymers are large covalent compounds which can be many thousands of atoms in length. They are made from small molecules known as **monomers.** Rather than drawing out all the atoms in a polymer we draw a **repeating unit** which is the structure of the monomer in square brackets, with a n representing a very large number of atoms.

Polymers have higher melting points than smaller covalent compounds like carbon dioxide as the intermolecular forces are stronger. However, these intermolecular forces are still not as strong as the bonds in ionic or giant covalent compounds so the melting points are lower than those compounds.



n = a big number of monomers

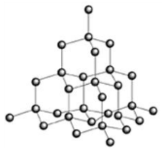
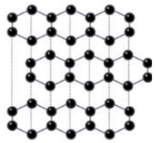
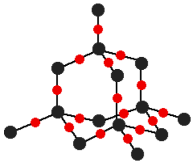
Combined Science Chemistry Knowledge Organiser
Topic 9: Chemical Bonding, Structures and Reactions

Key Terms	Definitions
giant covalent	Giant covalent structures contain a lot of non-metal atoms, each joined to adjacent atoms by covalent bonds
delocalised electron	An electron that is free, not part of an atom
allotrope	Different forms of the same element for example diamond and graphite are allotropes of carbon
macromolecule	A molecule which contains many atoms

Giant Covalent Compounds

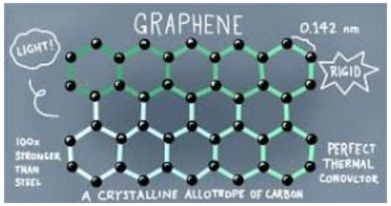
In a giant covalent structure all atoms are bonded to each other by <u>strong covalent bonds</u>. Giant covalent compounds have a **high melting point** because many strong covalent bonds need to be broken and this requires a lot of energy.

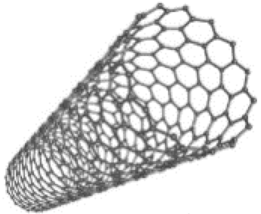
There are three examples you need to know, diamond, graphite and silica (see table below).

Substance	Diagram	Description	Properties
Diamond		Each carbon is covalently bonded to four other carbons	• Vey hard • Very high melting point, due to strong covalent bonds between all the atoms • Does not conduct electricity.
Graphite		Each carbon is covalently bonded to 3 other carbons, there are weak (non covalent) bonds between the layers.	• High melting point • Conductor of electricity due to **delocalised electrons** between the layers • Slippery as layers can slide over each other
Silica (silicon dioxide)		Every silicon atom is bonded to 2 oxygen atoms and vice versa	• Strong • High melting point

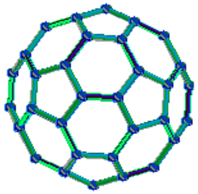
Graphene and Fullerenes

There are other forms of carbon which have been discovered recently: **graphene is a single layer of graphite** so it is 1 atom thick. Fullerenes are molecules of carbon with hollow shapes. The most famous example is Buckminsterfullerene (C_{60}). Fullerenes have use in drug delivery and as catalysts. Carbon nanotubes are cylinder shaped fullerenes, these are strong and are excellent conductors of both **heat and electricity.**





Carbon nanotube



Buckminsterfullerene

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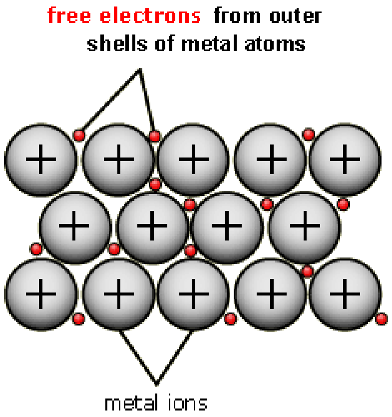
Topic 9: Chemical Bonding, Structures and Reactions

Metallic Bonding

Metals form giant structures. The metal atoms form a regular pattern and the donate their outer electron to the **"sea of delocalised electrons".** These electrons are free to move. The 2D structure of metallic bonding looks like this:



This would be the structure of a group 1 metal like sodium, if it were a group 2 metal (e.g. magnesium) then the charge on the ions would be 2+

Properties of Metals

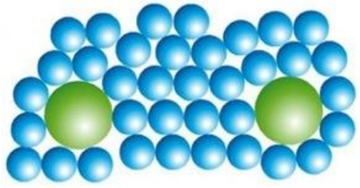
Metals are **good conductors of electricity**, due to the delocalised electrons, which can carry the electric charge. Metals are also **good conductors of heat** as the free electrons can transfer the heat energy through the metal.

Metals are also **malleable** (bendy) as the layers of ions can easily slide over one another. This means that many pure metals are too soft for uses such as building.

Key Terms	Definitions
metallic bonding	A type of bonding which occurs only in metals
alloy	A mixture of 2 or elements, one of which is a metal (the other element may be metal or non metal)
delocalised electron	An electron that is free, not part of an atom
malleable	The ability of a material to be bent into shape.

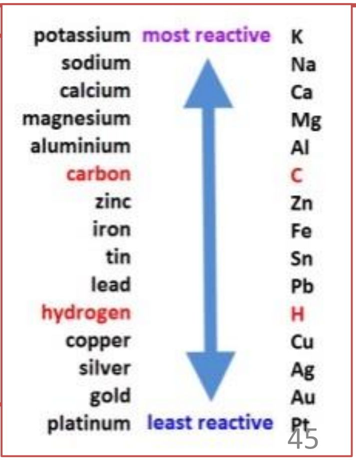
Alloys

Alloys are mixtures of **2 or more elements, one of which is a metal.** Examples of alloys include brass and steel. Metals are alloyed so that the regular structure of metals is changed and the layers of ions can no longer slide over one another; therefore making it much stronger.



Reactivity of metals

When a metal reacts it **forms a positive ion.** The easier it is for a metal to form a positive ion, the more reactive it is. This is shown in the reactivity series; you should memorise the position of these elements:



potassium	most reactive	K
sodium		Na
calcium		Ca
magnesium		Mg
aluminium		Al
carbon		C
zinc		Zn
iron		Fe
tin		Sn
lead		Pb
hydrogen		H
copper		Cu
silver		Ag
gold		Au
platinum	least reactive	Pt

Combined Science Chemistry Knowledge Organiser
Topic 9: Chemical Bonding, Structures and Reactions

Reactions of Metals

When a metal reacts with water it produces a metal hydroxide and **hydrogen gas.** The more reactive the metal is**,** the more vigorous the reaction. For example:

Lithium + Water → Lithium Hydroxide + Hydrogen

You see a similar pattern for the reaction between metals and acids however the products in these reactions are different, in this case you will make a salt and water, the salt will depend on the type of acid that you have used.

Lithium + Hydrochloric Acid → Lithium Chloride + Water

If sulphuric acid is used the salt made will be a sulphate, if nitric acid is used the salt will be a nitrate**.**

Metals also react with oxygen to form metal oxides; in this reaction the metal donates electrons to the oxygen. This means the metal is **oxidised as it has lost electrons. The oxygen is reduced as it has gained electrons.**

Extraction of Metals

A metal ore is a compound found in rock, dug out of the ground, that contains enough metal that it is **economical** to extract it. For example, magnesium oxide. In order for us to use the magnesium we need to **extract** it from the oxide.
Metals more reactive than carbon are extracted from their ore using **electrolysis**.
Metals which are less reactive than carbon are extracted from their ore using **reduction** (by adding carbon). Reduction is the removal of oxygen as seen in the example.

Example: Iron Oxide + Carbon → Iron + Carbon Dioxide

The least reactive metals such as gold and silver are found on their own—they do not form a compound. This means they do not need to be extracted from their ore.

Key Terms	**Definitions**
oxidation	The loss of electrons from an atom OR when an atom gains an oxygen atom
reduction	The opposite to oxidation: when an atom gains electrons OR when an atom loses an oxygen atom
redox reaction	A reaction where one atom is oxidised and another atom is reduced
acid	A substance which forms H+ ions in aqueous solution
alkali	A substance which forms OH- ions when dissolved: these are soluble bases
neutralisation	A reaction between an acid and an alkali making a salt and water
strong acid	An acid which totally dissociates in water
base	A substance that can neutralise an acid to make a salt and water

Oxidation Reactions

When working out whether a reaction is oxidation or reduction: in terms of electrons, remember OILRIG. This stands for oxidation is loss and reduction is gain.

HT - Oxidation Reactions of Acids

When an acid reacts with a metal, a salt and hydrogen are produced. For example the symbol the symbol equation for an acid reacting with lithium is:

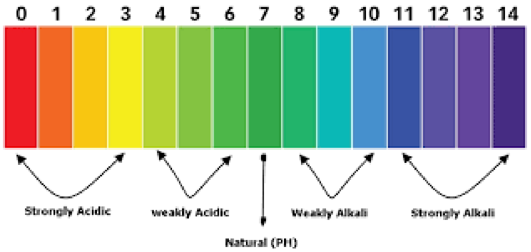
$$2Li + 2HCl \rightarrow 2LiCl+ H_2$$

In this reaction, lithium has been oxidised because it has lost an electron to form a +**1 ion** and hydrogen has been reduced from a +1 ion to a **hydrogen molecule.**

Combined Science Chemistry Knowledge Organiser
Topic 9: Chemical Bonding, Structures and Reactions

Acids and Alkalis

Acids produce hydrogen ions (**H^+) in aqueous** solutions. Aqueous solutions of alkalis contain **hydroxide ions (OH^-).**
We measure the acidity of a substance using the **pH scale which runs from 0-14** between 0 and 6 the substances are acidic, 7 is neutral and between 8 and 14 is alkaline. The pH scale is a logarithmic scale: a *decrease* of 1 on the pH scale makes a substance **10 times more acidic.**



The pH scale is a measure of H^+ concentration: the **<u>lower the pH the higher the concentration of H^+ ions</u>**.

Neutralisation Reaction

When a salt is made in a neutralisation reaction, it will either be **soluble** or **insoluble**. For example, sulphuric acid can be neutralised with copper oxide to make copper sulphate and water. The **copper sulphate is soluble in water.**
The steps outlined below can be used to make copper sulphate:

1. Add several spatulas of copper oxide to sulphuric acid in a **conical flask**
2. Stir until all the sulphuric acid has reacted
3. Filter off any excess copper oxide (it does not dissolve)
4. Place solution in evaporating basin
5. Allow water to evaporate and blue crystals of copper oxide should be left

Neutralisation

To work out the names and formulae of salts you will need to know the names and formulae of the common acids.

Acid	Name of salt	Negative ion in the salt
Hydrochloric acid (HCl)	Chloride	Cl^-
Sulphuric Acid (H_2SO_4)	Sulphate	SO_4^{2-}
Nitric Acid (HNO_3)	Nitrate	NO_3^{1-}

Neutralisation

When an acid reacts with an alkali a salt and water are produced. The <u>ionic equation</u> for the reaction of an **acid and an alkali is:**

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

Neutralisation

When an acid reacts with an alkali it will produce salt and water, below are the general equations for different types of neutralisation reaction:

- **Metal oxide + Acid → Salt + Water**
  - ➢ Copper oxide + Hydrochloric Acid→ Copper chloride +Water
  - ➢ $CuO + HCl \rightarrow CuCl_2 + H_2O$
- **Metal carbonate + acid → Salt +Water + Carbon Dioxide**
  - ➢ Magnesium Carbonate + Sulphuric Acid → Salt +Water +Carbon Dioxide
  - ➢ $MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + H_2O + CO_2$
- **Metal Hydroxide + Nitric Acid → Sodium Nitrate + Water**
  - ➢ Sodium Hydroxide + Nitric Acid→ Sodium Nitrate + Water
  - ➢ $NaOH_+ + HNO_3 \rightarrow NaNO_3 + H_2O$

Some of the reactants (for example copper oxide) are insoluble but these can still carry out a neutralisation reaction. We call these **bases** not **alkalis.**

HT - Strong and Weak Acids

Acids can be defined as either a **strong or weak acid** a strong acid is one which fully dissociates in water for example hydrochloric acid

$$HCl \rightarrow H^+ + Cl^-$$

A weak acid is defined as one which only partially dissociates in water. Strong acids are **not the same** as concentrated acids. Concentration is the number of particles in a given volume and not how much they dissociate.

Practical Methods Knowledge Organiser
Topic 9: Making Salts

Equipment List
- $40cm^3$ 1.0M dilute sulfuric acid
- Copper (II) oxide powder
- Spatula, glass rod, $100cm^3$ beaker, Bunsen burner, tripod, gauze, heatproof mat, Filter funnel and paper, clamp stand, conical flask, $250cm^3$ beaker, evaporating basin, crystallising dish.

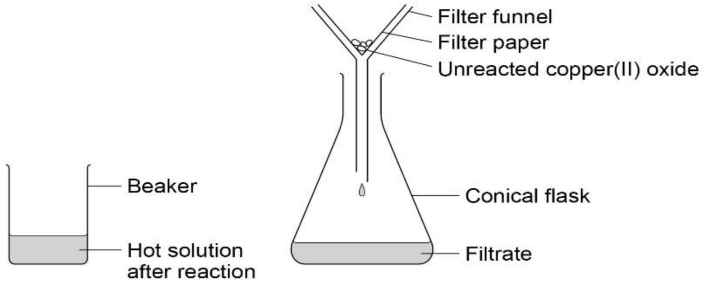
Method
1. Measure $40cm^3$ sulfuric acid into the beaker. The volume does not need to be very accurate, so you can use the graduations on the beaker.
2. Set up the tripod, gauze and heatproof mat. Heat the acid **gently** using the Bunsen burner until it is almost boiling. Turn off the burner.
3. Using the spatula, add **small** amounts of copper (II) oxide powder at a time, stirring with the glass rod. Continue to do this if, after stirring, the black powder disappears and the solution is clear blue.
4. Stop adding it when some black powder remains after stirring.
5. Set up the filter funnel and paper over the conical flask, using the clamp stand to hold the funnel. Filter the contents of the beaker from step 3.
6. When filtration is complete, pour the contents of the conical flask into the evaporating basin. Evaporate this gently using a water bath on the tripod and gauze (see diagram) until around half of the solution remains. You will have to estimate this volume.
7. Transfer the remaining solution to the crystallising dish. Leave this in a cool place for at least 24 hours.
8. Remove the crystals from the concentrated solution with a spatula and **gently** pat them dry between two pieces of filter paper. These are pure dry crystals of copper (II) sulfate.

Expected results
Copper sulphate crystals are a blue colour. The slower the solution is cooled during crystallisation, the larger the crystals will be.

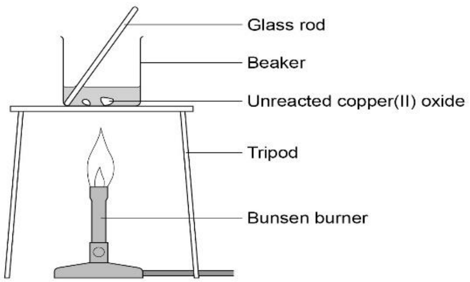
Key Terms	Definitions
excess	In this experiment the copper oxide is in excess as there are many more particles of copper oxide than there are of acid.
crystallising dish	A piece of equipment where crystals can from a solution

Diagrams

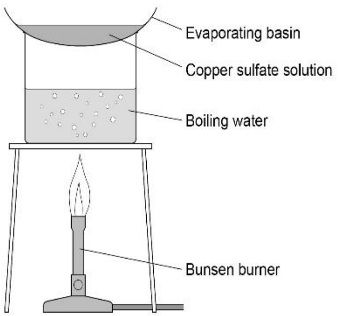
Stage 1



Stage 2



Stage 3



Risk Assessment
The sulphuric acid is an irritant and the copper oxide is harmful. Safety goggles need to be worn. The acid should not be heated to its boiling point, therefore the heating needs to be carefully controlled. Take care when filtering the warm solutions. Evaporating basins should not be evaporated to dryness on a Bunsen burner flame, this is likely to cause the evaporating basin to crack.

Combined Science Chemistry Knowledge Organiser
Topic 16: Quantitative Chemistry and Electrolysis

Relative formula mass (M_r)

This is the mass, in grams, of 1 mole of a substance. To calculate it you need to add up the relative atomic masses for all of the atoms in the chemical formula.

e.g 1. $NaCl = Na + Cl = 23 + 35.5 = 58.5$

e.g 2. $MgF_2 = Mg + (2 \times F) = 24 + (2 \times 19) = 62$

Higher tier -The Mole

A mole of an element is simply **6.02×10^{23} atoms (this number is known as Avogadro's number)**. Obviously, if the atoms are larger then 1 mole of that atom will be heavier.

For example, one mole of hydrogen atoms has a mass of 1 gram but 1 mole of carbon has a mass of 12 grams.

To calculate the number of moles of a substance in a certain mass of a substance, divide the mass by the relative atomic mass *or* relative formula mass.

Since the mole is just a certain number of particles, chemists use the mole to write numbers of atoms, molecules, ions or electrons.

Higher tier - Limiting Reactant/Reagent

When a chemical reaction is carried out, one reactants is in excess and one reactant is the limiting reactant. The **limiting reactant** is the reactant which is used up first in a chemical reaction. If all of this reactant is used up the reaction can no longer continue.

*For example, if a tiny amount of sodium is dropped into a large bowl of water there are a lot more water particles that there are sodium atoms. We therefore say that the sodium is the **limiting reactant** and the water is in **excess.***

The amount of product formed is **directly proportional** to the amount of limiting reactant. Therefore if you double the amount of limiting reactant you will get double the amount of product.

Key Terms	Definitions
mole	A mole is this specific number: 6.02×10^{23} This number is called **Avogadro's constant/number**. This is the number of atoms in 12 g of carbon-12
relative formula mass	The sum of the atomic masses of all the atoms in a chemical formula. 1 mole of a substance has a mass, in grams, equal to its relative formula mass.
limiting reactant	The reactant which is used up first in a chemical reaction.

Equation	Meanings of terms in equation
* $moles = \frac{mass}{M_r}$	*Mass is the mass of the substance in **grams*** *M_r is the relative formula mass of the compound (or use the relative atomic mass if it is a single atom)*

Higher Tier: Using moles and masses in balanced symbol equations

An understanding of the mole and of balanced symbol equations will allow you to calculate various things (see 4, 5, and 6).

Key facts needed:

1. Mass is conserved in chemical reactions, because all atoms in the reactants come out in the products.
2. A balanced symbol equation gives you the **mole ratio** of the reactants and products. The 'big numbers' in front of each substance gives exactly the ratio of moles of reactants needed to produce a certain number of moles of each product.
3. You can switch between mass of a substance and moles of a substance using the equation moles = mass ÷ M_r
   (and rearranged to mass = moles × M_r).
4. Therefore, from only knowing the mass of one substance in a reaction, you can calculate the mass of other reactants/products involved in the reaction.
5. If you are given the masses of chemicals that react and are produced, you can switch these masses to moles and find the mole ratio for the reaction. This leads to the balanced symbol equation.
6. Calculating the mole ratio for the reactants from masses you've been given allows you to work out which reactant is the limiting reactant and which one is in excess.

Combined Science Chemistry Knowledge Organiser
Topic 16: Quantitative Chemistry and Electrolysis

Concentration of Solutions

Many chemical reactions are done using solutions of chemicals. The concentration of a solution can be measured in grams per dm^3.

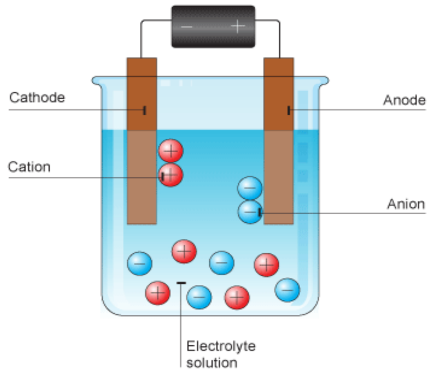
In chemistry we usually use dm^3 (decimetres cubed) to measure volume. One decimetre cubed is the same as one litre. Masses in chemistry are usually measured in grams.

Electrolysis

When an ionic compound is melted or dissolved in water, the **ions are free to** move about within the liquid or solution. These liquids and solutions are able to conduct electricity and are called **electrolytes.**

If an electric current is passed through this electrolyte the ions will move to the electrodes. The ions are **discharged** (change to neutral) at the electrodes, becoming elements.

- **Opposite electric charges attract each other**.
- **The positive ions (cations) will move to the negative electrode (cathode).**
- **The negative ions (anions) move to the positive electrode (anode).**



Key Terms	Definitions
electrolysis	The breaking down of a substance using electricity
electrolyte	The liquid that conducts electricity, and which is broken down during electrolysis
oxidation	The loss of electrons
reduction	The gain of electrons
anode	The positive electrode
cathode	The negative electrode

Equation	Meanings of terms in equation
$\text{conc} = \frac{mass}{vol}$ *	*Mass is the mass of the substance in grams* *Vol is the volume of the solution in* dm^3 *Conc is the concentration in* grams/dm^3

Higher Tier: Oxidation, reduction and half equations

- When a positive ion reaches the negative electrode, it gains electrons. This is a reduction reaction.
- When a negative ion reaches the positive electrode, it loses electrons. This is an oxidation reaction.
- We can represent these reactions using half equations.
- A half equation can represent the reaction at each electrode. Half equations show how electrons are transferred to or from ions. An electron is represented in an equation by the symbol $\mathbf{e^-}$.

Higher Tier: Ionic equations

- Ionic equations are types of symbol equation that show any changes to the charge on atoms/ions in a chemical reaction.
- Ionic substances are separated out in the equation to show the individual ions that they contain. *For example, NaCl is shown as* $Na^+ + Cl^-$ *in an ionic equation*
- **In an ionic equation it is important to check that both the atoms and the charges balance.**
- Ionic equations may contain **spectator ions**, which are ions whose charge does not change during the chemical reaction. It is ok to leave these out of ionic equations.

Combined Science Chemistry Knowledge Organiser
Topic 16: Quantitative Chemistry and Electrolysis

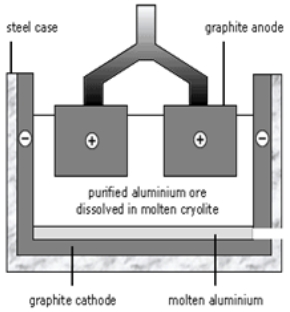
Extracting Aluminium using Electrolysis

Aluminium oxide (from aluminium ore) is dissolved in molten cryolite. Cryolite reduces the melting point of aluminium oxide meaning the process requires less energy.

- Aluminium ions (Al^{3+}) are attracted to the negative electrode.
- Aluminium atoms are formed at the negative electrode (gain 3 electrons)
- Oxide ions (O^{2-}) are attracted to the positive electrode
- Oxygen is formed at the positive electrode (each ion loses 2 electrons)
- Oxygen reacts with carbon to make carbon dioxide. This electrode needs to be replaced constantly.

At the negative electrode:

$Al^{3+} + 3e^- \rightarrow Al$



At the positive electrode

$2O^{2-} \rightarrow O_2 + 4e^-$

Overall equation:

$2Al_2O_3 \rightarrow 4Al + 3O_2$

Gas Tests

During electrolysis the products made are often gases. Below are the tests for three common gases you need to know:

Gas	Test	Result
Hydrogen	Place a lit splint into the gas	If a squeaky pop is heard hydrogen is present
Oxygen	Place glowing splint into gas	If splint is relighted then oxygen is present
Chlorine	Damp litmus paper placed in gas	If the litmus paper bleaches, chlorine is present
Carbon Dioxide	Bubble the gas through limewater	If the limewater goes cloudy, carbon dioxide is present

Electrolysis of Brine

- Any aqueous solution has the dissolved ions from the solute AND H^+ and OH^- ions from the water which is used as the solvent.
- Any positive ions are attracted to the cathode and any negative ions are attracted to the anode.
- Which elements form at which electrode depends on the **reactivity** of the elements involved.

The example to know is the electrolysis of brine. Brine is a **solution of sodium chloride**. However, there are also H^+ and OH^- ions from the water, which is used as the solvent. This means there are two different ions attracted to each electrode:

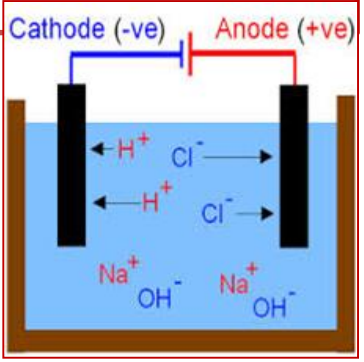
· **Positive ions:** sodium (Na^+) and hydrogen (H^+)
· **Negative ions:** chlorine (Cl^-) and hydroxide (OH^-)

When there is a mixture of ions, the products formed depends on the reactivity of the elements involved. There are three useful products from electrolysis of brine:

- Hydrogen is less reactive than sodium, so hydrogen gas (H_2) is produced at the negative electrode.
- Chlorine gas (Cl_2) is produced at the positive electrode.
- The solution that remains is sodium hydroxide solution.

Rules for Electrolysis of Aqueous Solutions

- At the negative electrode: if the positive ion in the solution is less reactive than hydrogen (for example copper) the metal will form. If it is more reactive than hydrogen (for example sodium) then hydrogen will form (be **discharged**) at the negative electrode.
- At the positive electrode, oxygen will always form (due to the movement of hydroxide ions) **unless** there is a halide ion present (F^-,Cl^-, Br^-, I^-), in which case the halogen molecule will be discharged at the positive electrode (for example Cl_2).



Practical Methods Knowledge Organiser
Topic 16: Electrolysis

Equipment List

- Copper(II) chloride solution
- Copper(II) sulfate solution
- Sodium chloride solution
- Sodium sulfate solution
- 100cm^3 beaker with petri dish lid
- Two carbon rod electrodes
- Two crocodile / 4mm plug leads
- Low voltage power supply
- Blue litmus paper
- Tweezers

Risk Assessment

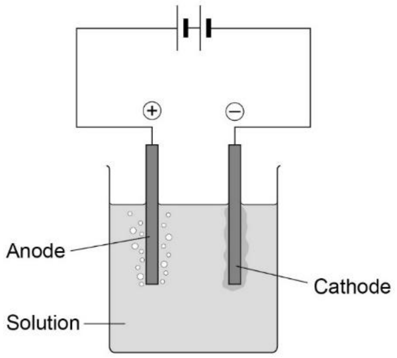
Ensure that electrodes are not touching before you turn on the power pack because this will create a short circuit.

Method

1. Pour copper (II) chloride solution into the beaker to about 50cm^3.
2. Add the lid and insert carbon rods through the holes. **The rods must not touch each other.**
3. Attach crocodile leads to the rods. Connect the rods to the **dc (red and black)** terminals of a low voltage power supply.
4. Select 4 V on the power supply and switch on.
5. Look at both electrodes. Is there bubbling at neither, one or both electrodes?
6. Using tweezers hold a piece of blue litmus paper in the solution next to the positive electrode. You will need to lift the lid temporarily to do this. Write your observations. If the litmus paper is bleached by the gas, the gas was chlorine.
7. After no more than five minutes, switch off and examine the negative electrode. Is there evidence of a metal coating on it? Copper is an orange-brown colour.
8. Clean out the equipment carefully and repeat the investigation with solutions of copper (II) sulfate, sodium chloride and sodium sulfate.

Key Terms	Definitions
anode	The positive electrode
cathode	The negative electrode
electrolyte	The molten/dissolved ionic compound which conducts electricity and that is broken down during electrolysis

Diagram



Expected Results

Electrolyte	What is formed at the anode?	What is formed at the cathode?
Copper Chloride	Chlorine gas	Copper
Sodium Chloride	Chlorine Gas	Hydrogen gas
Copper Sulphate	Oxygen gas and water	Copper
Sodium Sulphate	Oxygen gas and water	Hydrogen gas

Conclusion

The results will vary depending on the electrolyte. In each solution you will have an H$^+$ and OH$^-$ from the dissociation of water. You will also have a positive and negative ion from the ionic substance dissolved in solution. When the positive ion is more reactive than hydrogen, hydrogen gas will form at the cathode, for example in the electrolysis of sodium chloride. However if the positive ion is less reactive than hydrogen, then that element will form at the positive electrode for example , in the electrolysis of copper chloride, the copper will form at the cathode.

At the anode, water and oxygen will form (due to the reaction of the hydroxide ion) if a halide ion is not present, for example in the electrolysis of copper sulphate. However if a halide ion is present this will form at the anode.

Combined Science Chemistry Knowledge Organiser
Topic 18: Energetics in Chemical Reactions

Energy Changes in Chemical Reactions

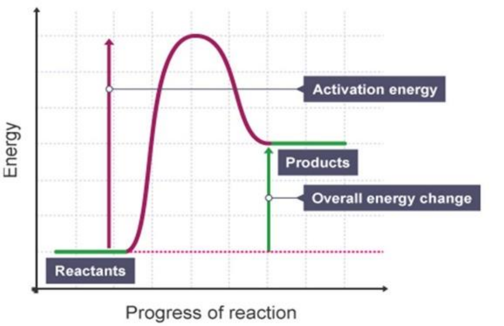
- In all chemical reactions, existing bonds are broken in the reactants and new bonds form to make the products.
- Breaking chemical bonds is **endothermic**, because it takes energy to overcome the force of attraction between atoms/ions**.**
- The process of bond formation is **exothermic:** energy is released when bonds form.
- The overall difference in the amount of energy involved in bond breaking and bond making decides whether the reaction overall is classed as exothermic (transfers energy to the surroundings) or endothermic (absorbs energy from the surroundings).

Type of reaction	What happens?	Why?	Examples
Exothermic Chemical Reaction	Heat energy is transferred to the surroundings **from** the chemical energy store	The energy required to break existing chemical bonds is less than the energy released when making new chemical bonds. Therefore, the excess is given off as heat to the surroundings.	Combustion reactions, reactions used in hand warmers
Endothermic Chemical Reaction	Heat energy is absorbed from the surroundings **into** the chemical energy store	The energy required to break existing chemical bonds is greater than the energy released when making chemical bonds. Therefore, heat is taken in from the surroundings.	The reaction of citric acid and sodium hydrogencarbonate, reactions used in sport injury ice packs

Higher Tier: Calculating overall energy change using bond energies

- For any particular chemical bond (e.g. carbon to carbon), there is an average amount of energy (the bond energy) required to break one mole of the bond. This amount of energy is identical to the amount of energy released when one mole of this particular bond forms.
- Average bond energy is given in kJ/mol.
- The difference between the sum of the energy needed to break bonds in the reactants and the sum of the energy released when bonds in the products are formed is the overall energy change of the reaction.
- In other words: *energy required for bond breaking* ***subtract*** *energy released during bond making* gives the overall energy change in a reaction.

Key Terms	Definitions
reaction profile	Graph which shows the energies of the products and reactants before, during and after a chemical reaction; the activation energy; and the overall energy change in the reaction.
activation energy	The minimum energy of reactant particles required for a chemical reaction to take place (due to a successful collision between reactant particles).
exothermic	Describes a process that gives out heat energy to the surroundings, especially the formation of chemical bonds.
endothermic	Describes a process that absorbs heat energy from the surroundings, especially the breaking of chemical bonds.

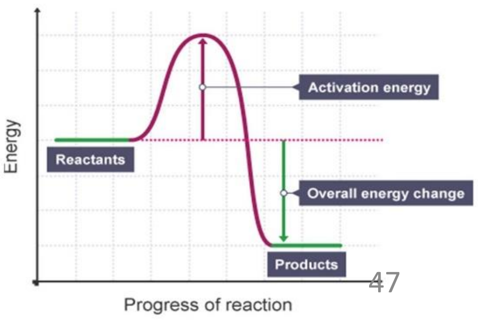


This is the reaction profile of an **endothermic reaction:** the chemical potential energy stored in the products is higher than that stored in the reactants. The difference in energy is taken in from the surroundings, cooling them down. The overall energy change is **positive**.

Reaction Profiles

Chemical reactions can occur only when reacting particles collide with each other with sufficient energy. The minimum amount of energy that particles must have to react is called the **activation energy**. **Reaction profiles** can be used to show the relative chemical potential energies of reactants and products, the activation energy and the overall energy change of a reaction.

This is the reaction profile of an **exothermic reaction:** the chemical potential energy stored in the products is lower than that stored in the reactants. The difference in energy is released as heat to the surroundings. The overall energy change for the reaction is **negative**.



Practical Methods Knowledge Organiser
Topic 18: Temperature Changes

Equipment List

- 2M dilute hydrochloric acid
- 2M sodium hydroxide solution
- Expanded polystyrene cup and lid
- 250cm^3 beaker
- 10cm^3 and 50cm^3 measuring cylinders.
- thermometer

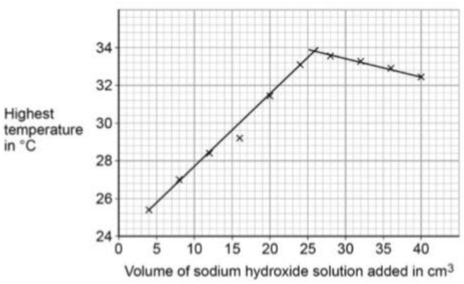
Method

1. Use the large measuring cylinder to put 30cm^3 dilute hydrochloric acid into the polystyrene cup.
2. Stand the cup inside the beaker. **This will make it more stable**.
3. Use the thermometer to measure the temperature of the acid. Record it in the first blank column of the table on the back of this sheet.
4. Put 5cm^3 sodium hydroxide solution into the small measuring cylinder.
5. Pour the sodium hydroxide into the cup, quickly fit the lid and gently stir the solution with the thermometer through the hole. When the reading on the thermometer **stops changing,** write the temperature in the next space in the table.
6. Repeat steps 4 and 5 to add further 5cm^3 portions of sodium hydroxide to the cup until a total of 40cm^3 has been added. The last few additions should produce a temperature fall rather than a rise.
7. Repeat the **whole investigation** (steps 1 – 6) a further 2 times and calculate an average temperature for each volume

Expected Results

The graph obtained should look like the one below. The temperature will rise to a maximum and then start to decrease as the volume is increased past the maximum.

Figure 3

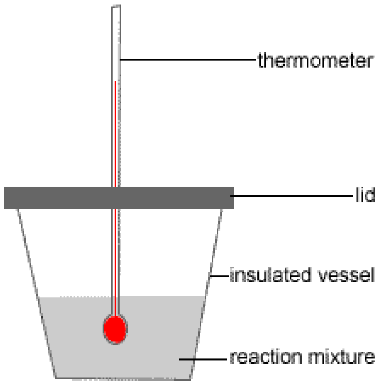


Key Terms	Definitions
exothermic	A reaction which gives out heat energy to the surroundings
endothermic	A reaction which takes in heat energy from the surroundings
neutralisation	A reaction between an acid and a base (remember an alkali is an example of a base)

Variables

IV: Volume of alkali
DV: Temperature change
CVs: Volume of acid, concentrations of acid and alkali

Diagram



Conclusions

The neutralisation reaction between hydrochloric acid and sodium hydroxide is **an exothermic reaction**. This means that heat energy is given out to the surroundings, including the chemicals in the container.

As you add more sodium hydroxide there are a larger number of particles undergoing the reaction and therefore more energy given out to the surroundings.

This reaches a maximum where the ratio of acid and alkali particles is 1:1. After this point the alkali is in excess and some of the heat energy made in the reaction is absorbed by the solution.

This method does have some problems as heat can be transferred to the surroundings and this can lead to errors in results. This is minimized by using a lid and a polystyrene cup to insulate the reacting chemicals.

The physics paper could assess:

Knowledge Organiser Topics:

- Energy Stores and Transfers
- The Particle Model
- Electricity
- Nuclear Physics

Combined Science Physics Knowledge Organiser
Topic 4: Energy, Work, Power and Elasticity

Weight

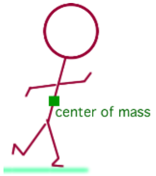
Weight is often mistaken for **mass**; for instance, when people say they are losing weight, they really mean they are losing mass. As a result, their weight will also drop (see equation), but really it is their mass they seek to change. Mass measures how much material there is (in kg), whereas weight measures the **force** acting on an object due to a **gravitational field**.

Looking at the equation, you can see that a mass of 100 g (=0.1 kg) has a weight of 1 N on Earth.

As the equation shows, weight and mass are **directly proportional**. We can show this like: $W \propto m$, using the symbol for a directly proportional relationship. On Earth, as mass increases by one unit, weight increases by ten units (as g = 10 N/kg).

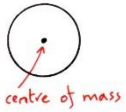
Measuring Weight

Weight can be determined by calculation using the equation, or directly measured using a **calibrated** (adjusted so the scale is right) spring balance – a **newtonmeter**. This can be mechanical or digital – a digital newtonmeter will likely have higher **resolution** (detects smaller differences in weight).



Centre of Mass

When drawing force diagrams and performing calculations, it is useful to show the weight (or other forces) acting on just a single point on the object. This is the exact centre of a symmetrical object (it will be more complicated for an asymmetrical object), and is called the **centre of mass**. Think of the centre of mass as the point where we consider weight to act: as a result, force arrows should start on the centre of mass.



Forces and Braking

Stopping a vehicle requires a force to be applied, since the speed must change – the vehicle must decelerate to 0 m/s. The **stopping distance** of a vehicle depends on two factors, which add up to make the stopping distance. These are the **thinking distance** (distance travelled while the driver reacts) and the **braking distance** (distance travelled under the braking force).

For a particular braking force, the greater the speed of the vehicle, the greater the stopping distance. This is because going from a higher speed to 0 m/s is a bigger change in speed than going from a lower speed to 0 m/s. The thinking distance is longer at a higher speed, because reaction times won't change according to the speed – so you'd go further in the same time if you're going faster. **Typical reaction times vary from 0.4 s to 0.9 s.**

Key Terms	Definitions
weight	Weight is a **force** (hence, it is a vector quantity), caused by gravity acting on a mass. Since it is a force, it is measured in newtons.
mass	Mass measures the amount of material in an object, and is measured in kilograms (kg). The weight of an object depends on the mass, but mass does not depend on weight. Mass is a scalar quantity.
gravitational field strength	Simply, the measure of how strong the gravitational field of a large object is. For instance, the gravitational field strength on Earth is about 10 N/kg. This means that a weight of 10 N acts on each kg of mass on Earth.
centre of mass	The point at which the weight of an object is considered to act – the 'middle' of the object's mass.
newtonmeter	A device to measure weight. It simply consists of a spring and a calibrated scale.
stopping distance	The distance a vehicle travels after the driver spots a danger and decides to stop. It is the sum of the thinking distance and braking distance.
thinking distance	Distance travelled during a driver's reaction time.
braking distance	Distance travelled while the driver is applying the brake (i.e. distance travelled under the braking force).

Equation	Meanings of terms in equation
$W = m\,g$ *	*W = weight (newtons, N)* *m = mass (kilograms, kg)* *g = gravitational field strength (newtons per kilogram, N/kg) – on Earth, this is about 10 N/kg*

Things which affect stopping distance

Thinking distance

(all these things are to with the drive)

drinking alcohol, taking drugs, tiredness, illness, not concentrating,

Braking distance

(all these things are to do with the car and road conditions)

worn tyres, poor brakes, wet roads, icy conditions, oil or grease on the road, etc.

Braking Force and Work Done

When force is applied to the brakes, work is done by the friction force between the brake pads and the wheel. The **kinetic energy** of the vehicle is transferred to **thermal energy** – this is why brakes get hot.

To stop a vehicle in a certain distance, the faster the vehicle the larger the force needed, since a larger deceleration is needed. However, this can lead to overheating of the brakes and/or loss of control of the vehicle.

Combined Science Physics Knowledge Organiser
Topic 4: Energy, Work, Power and Elasticity

Energy Stores and Systems

A **system** is simply a small part of the universe that we choose to study. It consists of an object or objects, and we use systems to describe how energy changes in terms of how it is stored. Energy has to be conserved in a system, so it cannot be created or destroyed. However, it can change from one store to another, in an **energy transfer**.

For example:
- Firing an object upwards transfers kinetic energy to gravitational potential energy
- When boiling water in kettle, electrical potential energy is transferred to thermal energy
- When using your phone, chemical potential energy is transferred to electrical energy, which is transferred to the surroundings, where it is stored as thermal energy.

The energy stored by an object can never be measured directly. However, it is simple to calculate, using a series of equations.

Potential Energy

When energy *changes* store, we say **work is done**. However, it is also possible for energy to be **stored** by an object or system. We call the stored energy **potential energy**. When something has potential energy, you won't be able to see anything going on, but if that energy is transferred to a new form, work will be done and you might be able to observe the results.

Chemical potential energy is an example: energy is stored in chemical bonds, and is transferred when a chemical reacts. Another example is gravitational potential energy – the energy stored by objects when they are above the ground in a gravitational field. Elastic potential energy is the form of energy stored by an object that is under **elastic deformation**. Think of a stretched rubber band – it isn't doing anything, but if you release it the stored elastic potential energy is transferred to kinetic energy, so you can fire it at someone.

Energy Redistribution/Transfer

In a system, the energy in the stores to start with can change form – we can say the overall energy in the system is **redistributed** – meaning it is transferred into other forms. In the end, the energy in the store is transferred to the surroundings. Often, the transfer to the surroundings is in the form of heat (thermal energy).

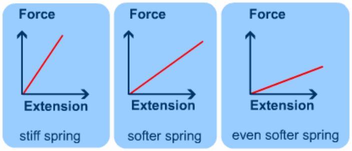
It is, in practice, very hard to go back the other way – for example, to transfer the heat energy stored in the surroundings back into chemical potential energy in a fuel is not something not normally happens!

Key Terms	Definitions
energy store	A system or object can act as an energy store. Energy allows work to be done (since work done = energy transferred). Good examples of energy stores are objects up high (they have gravitational potential energy), fuels (they have chemical potential energy), and stretched springs (they have elastic potential energy).
energy transfer	The change of energy from one store to another. *Aka* work.
dissipate	Simply, this means 'spread out'. When applied to energy being dissipated, this means that during energy transfers, some energy is stored in less useful ways. This can be called 'wasted' energy, since it is not transferred to form that is wanted.
kinetic energy	The form of energy of any moving object. Since the equation uses speed, not velocity, this is a scalar quantity.
thermal energy	The form of energy associated with heat. The thermal energy of an object is proportional to its temperature.
system	An object or group of object, and its/their interactions.
conservation of energy	A fundamental concept in physics. In a system, total energy is always conserved (it cannot be created or destroyed). However, it can be transferred from one store of energy to another.

Equation	Meanings of terms in equation and units
$E_p = m\,g\,h$ *	*E_p = gravitational potential energy (joules, J)* *m = mass (kg)* *g = gravitational field strength (newtons per kilogram, N/kg)* *h = height (metres, m)*
$E_k = \frac{1}{2} m\, v^2$ *	*E_k = kinetic energy (joules, J)* *m = mass (kg)* *v = speed (m/s) – this is **squared** in this equation*
$\Delta E = m\, c\, \Delta\theta$	*ΔE = change in thermal energy (joules, J)* *m = mass (kg)* *c = specific heat capacity (joules per kilogram per degree Celsius, J/kg ^oC)* *$\Delta\theta$ = temperature change (^oC)*

Combined Science Physics Knowledge Organiser
Topic 4: Energy, Work, Power and Elasticity

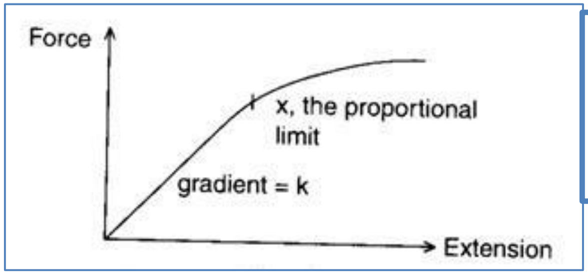
Force and Extension/Compression



The extension of an elastic object, like a spring, is directly proportional to the force applied to it, provided the limit of proportionality of the spring is not exceeded. This also works with the compression of an object – you can use the equations below too, '*e*' just means the amount of compression. The **spring constant** measures how much extension you get for your force. A large spring constant means it won't stretch far compared to a spring with a small spring constant, if the same force is applied (see graph examples above). The spring constant can be calculated from the gradient of a graph of force against extension.

Elastic potential energy is the form of energy stored by an object that is under **elastic deformation**. Think of a stretched rubber band – it isn't doing anything, but if you release it the stored elastic potential energy is transferred to kinetic energy, so you can fire it at someone.

When force is applied to a spring, it moves a distance, so **work is done.** In other words, energy is transferred. The energy gets stored in the spring (or elastic object) as **elastic potential energy** ***(E_e)***. The amount of elastic potential energy is calculated by the equation shown on the right.



On graphs showing force against extension, you can see when the limit of proportionality is reached by looking at where the graph starts to curve. (Labelled x on this example)

Key Terms	Definitions
elastic	Describes objects that return to their original shape after being deformed by a force, once the force is removed
elastic deformation	Deformation (bending, stretching or compressing an object) is elastic if the object returns to its original shape once the force is removed
deformation	Bending, stretching or compressing an object
extension	The change in length of an object such as a spring. Subtract length when NO force is applied from the length when a force is applied.
directly proportional	This term describes a type of relationship between two variables. The two variables are directly proportional if, for every increase of one variable by one unit, the other increases by the same amount. It is shown by a straight line on a graph that goes through the origin.
limit of proportionality	The limit of a directly proportional relationship. It can be shown on a graph if the line is straight to being with (indicating a directly proportional relationship) then curves.
linear relationship	Simply, a relationship between two variables that is graphed as a straight line.
non-linear relationship	A relationship between two variables that is shown with a curved line on a graph.
gradient	The gradient of a graph is how steep it is. Calculate gradient by dividing the change in the variable on the y-axis by the change in the variable on the x-axis.

Equation	Meanings of terms in equation
$F = k\,e$ *	*F = force (newtons, N)* *k = spring constant (newtons per metre, N/m)* *e = extension (metres, m)*
$E_e = \frac{1}{2} k\,e^2$	*E_e = elastic potential energy (joules, J)* *k = spring constant (newtons per metre, N/m)* *e = extension (metres, m) – this is **squared** in this equation*

Practical Methods Knowledge Organiser
Topic 4: Determining Specific Heat Capacity

Equipment List

- blocks of different materials wrapped in insulation, with two holes for a thermometer and heater
- thermometer
- pipette to put water in the thermometer hole
- immersion heater and power supply
- insulation to wrap around the blocks
- ammeter and voltmeter
- leads/wires
- stop watch or stop clock
- balance

Method

1. Set up equipment as shown in the diagram, including a few drops of water in the thermometer hole. This improves the reading of temperature. Newspaper would be a suitable material to use as insulation.
2. Measure the mass of the block of metal
3. Measure the initial temperature of the block of metal.
4. Switch on the power supply. Measure current with the ammeter and potential difference with the voltmeter. The current does work on the heater transferring electrical energy to thermal energy
5. Multiply current by potential difference to find the **power** of the heater. P=VI
6. Record the temperature, shown on the thermometer, every minute.
7. The power and the time you heat for allows you to work out the energy transferred (work done) from the heater to the block. Multiply the power by the time in seconds (the power should stay the same, the time just gets longer by 60 s each minute).
8. On a graph, plot the temperature (°C) against the work done (J).
9. Draw a line of bets fit.
10. Find the gradient of the line (the straight part, if it curves to begin with).
11. Calculate the heat capacity of your metal block: 1 divided by the gradient. This gives you the heat capacity of this block.
12. If the block was 1 kg, your last answer was also the specific heat capacity of the material. If it was not exactly 1 kg, divide your answer to step 10 by the mass in kg.

Expected Results

The specific heat capacity of a material is the energy required to heat 1 kg of the material by 1 °C. It is measured in J/kg °C. Different materials have different specific heat capacities. For instance, copper: 385 J/kg °C; iron: 500 J/kg °C. Any values you find in school can be checked against these published values. Any differences are most likely due to energy transfer to the surroundings – so, improving the insulation should improve the accuracy of results.

Key Terms	Definitions
immersion heater	An electric heater, rod shaped, that can be placed in a material to heat it up.
insulation	Material to prevent heat loss to the surroundings
power	The rate of energy transfer. (work done/time OR calculated by multiplying current by potential difference)
ammeter	Circuit component to measure current.
voltmeter	Circuit component to measure potential difference.
work done	Same as energy transferred.

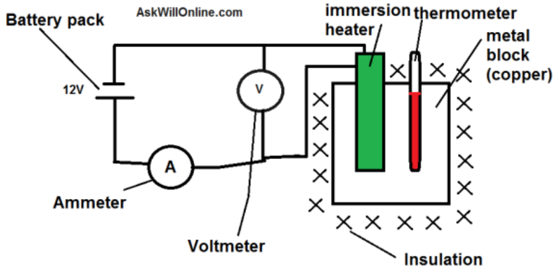
Variables

I.V- The material
D.V- The energy transferred
C.V -The mass of the material, the time it is heated for, electric current

Risk Assessment

The mains leads of the power supplies should be checked. The heater connections should also be checked. They will also get hot, particularly if left on without being in contact with the blocks.

Diagram



Conclusions

Different materials have different specific heat capacities. The specific heat capacity is the same no matter how much of the material you have (so the mass of the block shouldn't affect your final answer). Materials with *higher* specific heat capacities require more energy to heat them up by 1 °C.

Practical Methods Knowledge Organiser
Topic 4: Force and Extension (Hooke's Law)

Equipment List

- a spring of a suitable stiffness
- metre ruler
- suitable pointer – eg splint and tape
- weight stack appropriate for the spring eg 10 N in steps of 1N.
- clamp stand, 2 clamps and bosses
- A heavy weight to provide stability for the clamp stand

Method

1. Attach the two clamps to the clamp stand using the bosses. The top clamp should be further out than the lower one.
2. Place the clamp stand near the edge of a bench so that the ends of the clamps stick out beyond the bench.
3. Place a heavy weight on the base of the clamp stand to stop the clamp stand tipping over.
4. Hang the spring from the top clamp.
5. Attach the ruler to the bottom clamp with the zero on the scale at the top of the ruler
6. Adjust the ruler so that it is vertical, and the zero on the scale is at the same height as the top of the spring.
7. Attach the splint securely to the bottom of the spring. Make sure that the splint is horizontal and that it rests against the scale of the ruler.
8. Take a reading on the ruler – this is the length of the unstretched spring.
9. Carefully hook the base of the weight stack onto the bottom of the spring. This weighs 1.0 newton (1.0 N).
10. Take a reading on the ruler – this is the length of the spring when a force of 1.0 N is applied to it.
11. Add further weights, measuring the length of the spring each time.
12. Record your results in a suitable table. You will need a third column for the extension. This is the amount the string has stretched. To calculate this you subtract the length of the unstretched spring from each of your length readings.

Expected Results

The extension should increase in proportion to the force applied. A graph of force applied against extension will be a straight line through the origin. To calculate the spring constant k the **gradient** of the line needs to be taken. The stiffer the spring the **greater the gradient and larger the spring constant.** When the spring goes beyond the elastic limit, Hooke's law is no longer obeyed and the relationship between force and extension graph is no longer directly proportional.

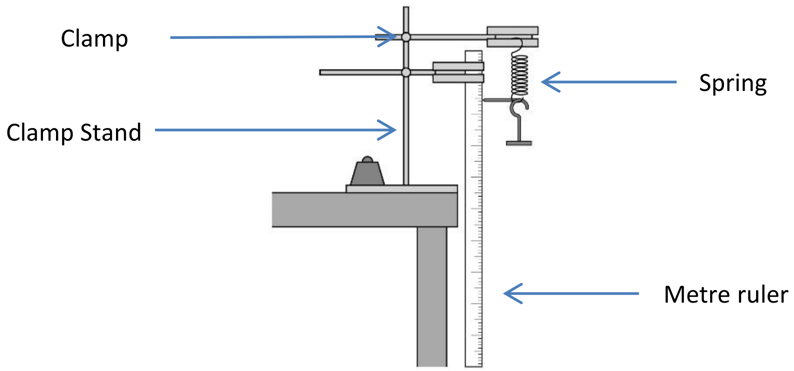
Key Terms	Definitions
directly proportional	Directly proportional means that the rate of increase in one variable is the same as the rate of increase in the other variable.
elastic limit	Beyond the elastic limit Hooke's law is no longer obeyed
Hooke's law	When an elastic object - such as a spring - is stretched, the increased length is called its extension. The extension of an elastic object is directly proportional to the force applied to it.

Risk Assessment

The springs should be checked so that the loops at the ends don't unravel when the greatest weight is used.

It is likely that the spring will extend below the edge of the bench. The clamp stand should be secure so as not to tip. Put something under the spring and weight to protect the floor in case things slip.

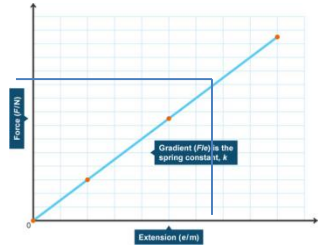
Diagram



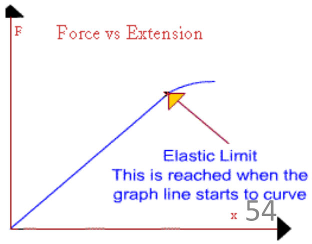
Variables

I.V- Force applied to the spring
D.V-**Extension** of the spring

Graphs



K= F(value on y axis)/ X (value on x axis)



Combined Science Physics Knowledge Organiser
Topic 4: Energy, Work, Power and Elasticity

Power

It is often useful to measure how **fast** an energy transfer is (or, how fast the work is done). The rate (speed) of energy transfer with respect to time is the **power**. The top two equations below show this.

Two things might transfer the same amount of energy (do the same amount of work), but if one does it faster than the other, it has a higher power. For instance, if two people of the same mass run the same distance, they transferred the same amount of energy. However, if one of them completing it faster than the other, they had a higher power. (The '*t*' in the equation would be smaller, leading to a larger value for '*P*'.)

Unwanted Energy Transfers

During any energy transfer, energy can be transferred usefully, meaning that the stored energy is transferred in a way that does useful work. However, some **dissipation** of the stored energy, in ways that are not useful, is unavoidable. We call the energy transferred in this way 'wasted energy' – meaning unwanted energy transfers have taken place.

Unwanted energy transfers can be reduced by, for instance, oiling/lubricating moving parts (reducing friction, therefore transfer to thermal energy) or insulating systems.

Thermal insulation is insulation that reduces transfer of thermal energy to the surroundings. Thermal conductivity measures how rapidly thermal energy is conducted by a material (so, metals have high thermal conductivity). For effective thermal insulation, you want materials with very low thermal conductivity. The thickness of the material also affects the effectiveness of thermal insulation. Not surprisingly, the thicker the material, usually the better the insulation.

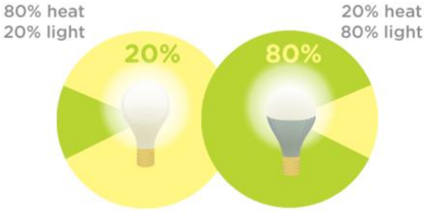
Efficiency of Energy Transfers

As you know, energy cannot be created or destroyed, just transferred. It is often useful to measure how much energy is transferred in the way we want, and how much is dissipated. This measure is called **efficiency** (see equations). Since there is **always** some wasted energy, efficiency must always be less than 1, or less than 100% if you convert the efficiency to a percentage.

To improve efficiency, we reduce the energy transferred in ways that are not useful (i.e. reduce the wasted energy). Methods such as insulation or lubrication improve efficiency, since they reduce the energy transfer to wasted forms of energy.

Key Terms	**Definitions**
power	Power is the **rate** of energy transfer – also known as the rate at which work is done. (Remember, energy transferred is the same as work done.) Since it is a rate, like speed, power is calculated by dividing by time (see equations).
watt (W)	The watt is the unit for power. One watt is one joule transferred in one second – or 1 J/s (1 joule per second).
efficiency	The measure of how much of the stored energy in a system is transferred usefully. More efficient devices transfer more energy usefully, which is the same as saying they waste less energy.

Equation	**Meanings of terms in equation and units**
$P = \frac{E}{t}$ *	*P = power (watts, W)* *E = energy transferred (joules, J)* *t = time (s)*
$P = \frac{W}{t}$ *	*P = power (watts, W)* *W = work done (J)* *t = time (s)*
$efficiency = \frac{useful\ output\ energy\ transfer}{total\ input\ energy\ transfer}$ *	*Efficiency doesn't have a unit. You can convert the efficiency (which will be a decimal) to a percentage by multiplying by 100.*
$efficiency = \frac{useful\ power\ output}{total\ power\ input}$ *	



In a simple example, the light bulb on the left wastes 80% (efficiency = 0.2 or 20%) of the input energy as heat energy, but the one on the right only wastes 20% (efficiency = 0.8 or 80%).

Combined Science Physics Knowledge Organiser
Topic 4: Energy, Work, Power and Elasticity

Energy Resources

Don't get energy resources and stores of energy mixed up. Energy resources are energy stores that we know how to use for our needs, such as generating electricity. Stores of energy are the ways we find energy in objects or systems – e.g. chemical potential energy, gravitational potential energy, or thermal energy.

The main energy resources on Earth are: fossil fuels (oil, coal and gas); nuclear fuel; biofuel; wind; hydroelectricity; geothermal; tides; the Sun and waves in the sea. These all are stores of energy we can access and transfer usefully, usually to electrical energy. We can also use these energy resources for transport (especially fossil fuels) and heating (especially geothermal – although not in the UK!).

Using Energy Resources

Some energy resources are more **reliable** than others. For instance, as you may have noticed, the Sun as an energy resource (using solar panels) is not totally reliable in the UK. So we couldn't totally rely on the Sun as an energy resource. Fossil fuels are reliable for the time being, as the supply is good, but they are non-renewable, so this may change in the future. Fossil fuels are also relied upon for transport. This is changing, but still the vast majority of vehicles use fossil fuels as their energy resource.

Environmental considerations about the use of energy resources should also be made. For instance, the combustion of fossil fuels adds to greenhouse gases in the atmosphere, causing climate change. On the other hand, renewable methods like hydroelectricity involve building dams that may displace people and destroy habitats. There are always ethical factors to weigh up too. Although science can identify issues such as environmental problems, scientists are not politicians and big decisions to deal with issues are out of their hands a lot of the time. Political, social, ethical or economic factors also affect decisions made about the use of Earth's energy resources.

Key Terms	Definitions
energy resources	Stores of energy on Earth that we can access and transfer to useful forms, such as electricity.
nuclear fuel (NR)	Elements that can be used to release massive amounts of energy for generating electricity. Nuclear fuel is based on uranium.
fossil fuel (NR)	A fuel, made from hydrocarbons, that formed millions of years ago from the bodies of animals and plants. Fossil fuels are a store of chemical potential energy.
Geothermal (R)	The energy resource found in Earth's crust, due to the thermal energy of the rock of the crust in certain places on Earth.
Biofuel (R)	Any type of fuel made from the bodies of organisms – such as fuels made from plants.
Hydroelectricity (R)	Water stored behind a dam has gravitational potential energy, so it is a store of energy we can make use of.
tidal energy (R)	Tides in the sea come in and out twice a day. This is a massive movement of water, whose kinetic energy can be transferred usefully to electrical energy.
wave energy (R)	Waves in the ocean have kinetic energy. With the right equipment, this energy can be transferred usefully to electrical energy.
solar energy (R)	The Sun is an abundant source of energy. Using solar panels, we can transfer light energy directly into electrical energy. We can also use the thermal energy from the Sun for heating and for generating electricity.
Wind energy (R)	The kinetic energy of wind can be usefully transferred to electrical energy
electricity	A form of energy that we find extremely useful, since it can be used to run so many devices. We use the energy resources described here mainly (but not only) to generate electricity.
renewable	Describes energy resources that are, or can be, replenished (replaced) as they are used. Shown by "R"
non-renewable	Describes energy resources that cannot be replenished. In other words, they get used up. Shown by "NR"

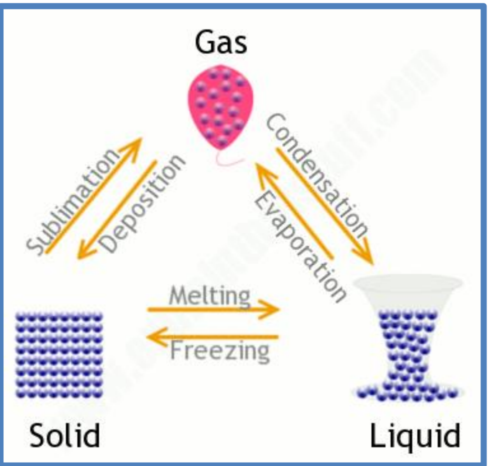
Combined Science Physics Knowledge Organiser
Topic 8: The Particle Model of Matter

States of matter and changes of state

Study the diagram. The particle model is used to explain differences between solids, liquids and gases, and to explain how changes from one state to another happen. Make sure you know how to draw the particles arrangement in each state, and know all the names for each state change shown on the diagram.

In a solid, the particles are **fixed in position** and only vibrate – they can't flow around. In a liquid, the particles are still **very close together** but they can **flow** past each other. In a gas, the particles move **randomly** and there is **empty space** between them.

In changes of state, no new substance is produced and there is no change in the **mass** of the substance. This is because no particles are created or destroyed.

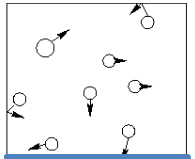


Density and the particle model

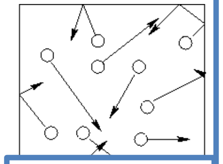
The particle model explains why 1 kg of a gas will have a **much** larger volume than 1 kg of a solid. This is because there is empty space between the particles in a gas, whereas in a solid, they are tightly packed together. Looking at the equation below, you should see that in this example the *m* is the same (1 kg), but the volume for the gas is much larger. Since we divide by volume, this must mean that the **density** of the gas is much smaller than the density of the solid.

Pressure in gases

Particles in a gas are constantly moving – so they store **kinetic energy**. They collide with the walls of their container, and exert a force when they do. The total force exerted on a certain area of the wall is the **gas pressure**.



Cooler gas – less kinetic energy



Hotter gas – more kinetic energy

The amount of kinetic energy that the particles have is related to the temperature of the gas. The higher the temperature, the more kinetic energy they have. This means they move faster, on average. Therefore, there are more collisions with the container walls and they exert a greater force when they collide with the walls. Thus, **increasing** the temperature of a gas (keeping the volume the same) **increases** the pressure of the gas.

Key Terms	Definitions
model	Models are used all the time in science. A model represents the real world and can explain many things about the universe. However, models are never perfect and there are limits to what they can explain. That doesn't stop them being extremely useful though!
particle model	The model that represents molecules or atoms as small, hard spheres. The important things to think about when using the particle model are the **arrangement** of the particles in each state of matter and the **kinetic energy** of the particles.
state of matter	The physical arrangement of particles determines the state of a particular substance: solid, liquid or gas. Changing from one state of matter to another is a physical process, NOT a chemical process. No new substance is produced, and if you reverse the state change, you have a substance with exactly the same properties as the stuff you started with.
density	The quantity that defines how much material (i.e. mass) is in a certain volume. See equation. If you have two objects the same size but different densities, the more dense object will feel heavier in your hand as there is more mass in the same volume.
melt/freeze	The change of state from solid to liquid/liquid to solid.
evaporate/ condense	Change of state from liquid to gas/ gas to liquid.
boil	Like evaporation, boiling is a change of state from liquid to gas. However, boiling involves heating of the liquid so it boils, rather than particles on the surface of the liquid becoming gas (like in evaporation).
pressure	Pressure is caused by the force exerted by particles in a gas when they hit the walls of a container.

Equation	Meanings of terms in equation
$\rho = \frac{m}{V}$ *	*ρ = density (kilograms per metre cubed, kg/m^3)* *m = mass (kg)* *V = volume (metres cubed, m^3)*

Practical Methods Knowledge Organiser
Topic 8: Density of Objects and Materials

Key Terms	Definitions
displacement/ Eureka can	A piece of equipment used to measure how much water is displaced

Equipment List

For the regular shaped solid objects:
- 30 cm ruler marked off in mm
- digital balance
- materials kits ie various regular shaped objects made of iron, copper, aluminium.

For the liquids:
- digital balance
- 250 ml beaker
- suitable liquid eg sugar solution.

For the irregular shaped solid objects:
- digital balance
- displacement can and something to stand it on (eg a brick)
- measuring cylinders
- 250 ml beaker of water and an extra empty beaker
- paper towels
- cotton or thin string
- various irregular shaped objects

Method for regular solids

1. Measure the length, width and height of each of the objects. Record your results in a table. Include columns for volume, mass, density and substance.
2. Measure the mass of each object using the digital balance, and record the results.
3. Calculate and record the volumes (length x width x height).
4. Calculate and record the densities (mass ÷ volume).

Method for liquids

1. Measure the mass of the empty beaker.
2. Record your results in a table. Your table will also need columns for the mass of the beaker with the liquid in, the mass of the liquid, the volume of the liquid and the density.
3. Pour about 100 ml of liquid into the measuring cylinder. Measure and record the volume.
4. Pour this liquid into the beaker. Measure and record the mass of the beaker and liquid.
5. Calculate and record the volume of the liquid.
6. Calculate the density of the liquid.
7. The density of water is 1 g/cm^3. Determine the mass of sugar per cm^3 dissolved in the water, assuming the sugar does not affect the volume of the water.

Method for irregular solids

1. Place a displacement can on a brick. Put an empty beaker under the spout and fill the can with water. Water should be dripping from the spout.
2. When the water has stopped dripping, place a measuring cylinder under the spout. Choose the measuring cylinder you think will give the most precise reading.
3. Tie the object to a piece of cotton and very carefully lower it into the displacement can so that it is completely submerged. Collect all of the water that comes out of the spout in the measuring cylinder.
4. Measure and record the volume of the collected water; this is equal to the volume of the object.
5. Measure the mass of each object using the digital balance, and record the results.
6. Calculate and record the density of the object.
7. Repeat for some of the other objects. Remember to refill the can each time.

Expected Results

In solids, metals should have the highest density. Which should be in the order of 1000 kg/m^3

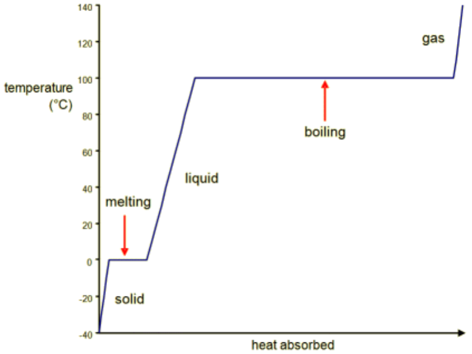
Accuracy and Error

To increase accuracy vernier callipers can be used to measure length, balances that have a high resolution can be used to measure mass and burettes can be used to measure volume to a higher resolution.

Errors are caused when balances do not reading 0 when substances are being weighed and when water is lost on the side of can/spout.

Combined Science Physics Knowledge Organiser
Topic 8: The Particle Model of Matter

Internal energy and the particle model



Any substance, whether solid, liquid or gas, **stores energy**. The particles (atoms and molecules) have kinetic energy (since they can move/vibrate) and potential energy. The total of the kinetic energy and the potential energy of the particles is called the **internal energy**.

When you heat something up, you increase the energy of the particles in the substance (or 'system'). When heating one state, you simply increase the temperature of the substance by increasing the kinetic energy of the particles. However, when a state change is occurring, the temperature does not increase. This is because the particles are increasing in potential energy (which doesn't affect the temperature). That's why the graph above goes horizontal when the changes of state are taking place.

Specific heat capacity

Some substances are harder to warm up than others, and cool down less easily. The measurement of this is called **specific heat capacity**. Learn the precise definition opposite. So, when heating something, the temperature rise that will actually happen depends on the specific heat capacity (which is different with different substances) of the substance being heated, the mass of the substance and the amount of energy put in. These four quantities are linked in the equation to the right.

Changes of state and specific latent heat

As noted above, during heating to cause changes of state the potential energy of particles increases but the kinetic energy does not. So the temperature stays the same. The **energy needed for a substance to change state is called the latent heat**. The specific latent heat is specific to a substance, and is the energy required to change its state (using 1 kg of the substance), with no change in temperature. The energy needed for a state change depends on mass and specific latent heat of a substance – as the second equation shows.

But which change of state? We use the symbol *L* for any change of state, but call it the **specific latent heat of fusion** for changes from solid to liquid. We call it the **specific latent heat of vaporisation** for changes from liquid to gas (vapour).

Key Terms	**Definitions**
internal energy	The energy stored by the particles in a system (solid, liquid or gas). Internal energy is the sum of the potential energy of particles and the kinetic energy of the particles.
kinetic energy	The energy associated with movement. The kinetic energy of particles in any state of matter is related to the temperature of the matter.
temperature	A measure of the average kinetic energy of particles in a substance. As temperature increases, the average kinetic energy increases. Note: temperature does not measure the potential energy of particles, just their average kinetic energy.
heating	Heating is one way to transfer energy from one store to another. On this page, we talk about how heating substances increases the internal energy of that substance (both the kinetic and potential energy of particles).
specific heat capacity	The amount of energy required to raise the temperature of 1 kg of a substance by one degree Celsius.
latent heat	Latent heat is linked to the potential energy of particles in a system – it is the energy needed for a substance to change state. It cannot be measured with a thermometer, since it is not linked to the kinetic energy of particles.
specific latent heat	When a substance is changing state, you can keep heating it but the temperature stays the same. The energy isn't disappearing (that's impossible!), but is adding to the internal energy. Specific latent heat measures this: it is **the amount of energy required to change the state of 1 kg of a substance** (without changing the temperature at all).

Equation	**Meanings of terms in equation**
$\Delta E = m\,c\,\Delta\theta$	*ΔE = change in thermal energy (joules, J)* *m = mass (kg)* *c = specific heat capacity (joules per kilogram per degree Celsius, J/kg °C)* *Δθ = temperature change (°C)*
$E = m\,L$	*E = energy (joules, J)* *m = mass (kg)* *L = specific latent heat (J/kg)*

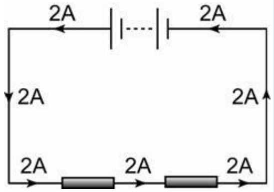
Combined Science Physics Knowledge Organiser
Topic 15: Electricity

Electric charge and current

Every atom contains particles with an electric charge: protons and electrons. By getting electric charges to **flow**, we can get them to do work (i.e. transfer energy) in all sorts of useful ways. For that is what happens in any electric circuit you can think of: *flowing charges transfer energy*.

If we want to get electric charges to flow, we must make a **closed**, or complete circuit – a loop of conducting materials, like metal wires. Then, we must provide a source of **potential difference**. The source of potential difference could be a cell, battery or the mains. What these sources do is to create a *difference* in electrical *potential* energy – hence the name. This provides the force to make the **electric charges** in the conductors **flow**. When electric charges, like electrons, are flowing, we call it an **electric current**.

The size of an electric current is simply the **rate** of flow of electric charge.
So current (I) = $\frac{Q}{t}$ or $Q = It$



In a circuit, in any closed loop of the circuit, the size of the current is the same throughout the loop. As shown on the diagram, the current is the same in all parts of the loop, including through the battery and through the resistors.

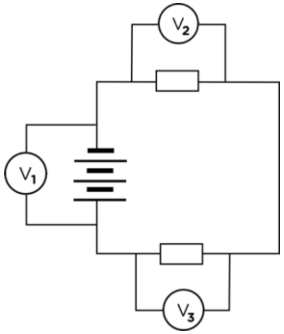
Current, resistance and potential difference

Cells and batteries etc. are **sources** of potential difference. This means they boost the potential energy of charges in a circuit. Other components, like resistors or bulbs, do **work** – so they take the potential energy of the charges and **transfer** it into some other form, like light or heat. In a circuit, all the energy provided by the cell/battery is transferred by the components in the circuit all together. So, in components like bulbs, the charges do work – i.e. they transfer energy. By definition, this means they have a potential difference **across** them. We say 'across' since it is a difference, from one side of the component to the other.

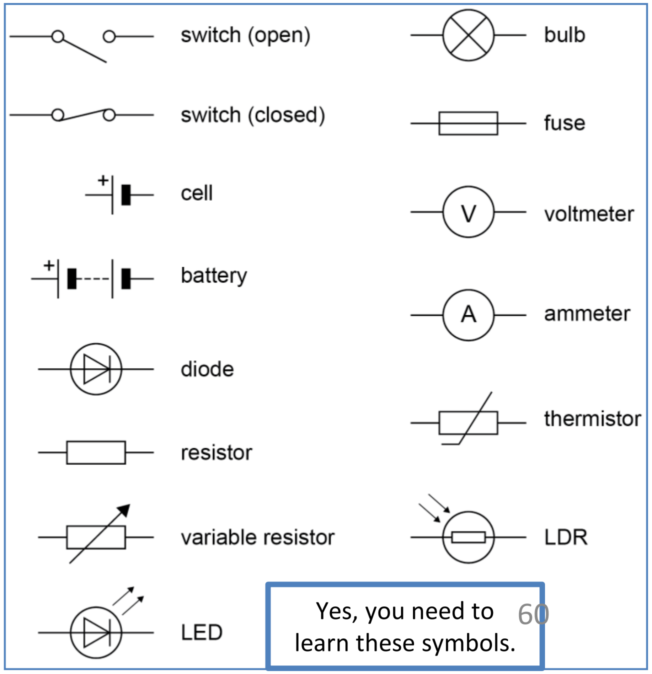
The **current** through a component depends on this **potential difference** across the component, but also its **resistance**. Without any resistance, a component would <u>do no work</u> (try putting a 0 in the equation!), so things like bulbs HAVE TO have resistance. The resistance of a component, along with the potential difference across it, determines the current through it, as shown in the second equation. It shows us that: if we keep the potential difference the same, but increase the resistance, the current must *decrease*. If we keep the potential difference the same, but decrease the resistance, the current must *increase*.

Key Terms	**Definitions**
electric charge	Just a positive or negative charge! In most electrical circuits, the electric charges that are flowing are **electrons** – which are of course negatively charged. Symbol: Q
current	The rate of flow of electric charge (i.e. speed). Calculated by dividing the size of the charge by the time. Symbol: I
potential difference	Also known as voltage, or p.d.. The potential difference is a measure of how much work is done per coulomb of charge.
resistance	Resistance determines the size of the current for a particular potential difference.

Equation	**Meanings of terms in equation**
$Q = I\,t$ *	*Q = charge flow (coulombs, C)* *I = current (amperes, A)* *t = time (seconds, s)*
$V = I\,R$ *	*V = potential difference (volts, V)* *I = current (amperes, A)* *R = resistance (ohms, Ω)*



Look how the voltmeters are added **across** the components to measure the potential difference across them.



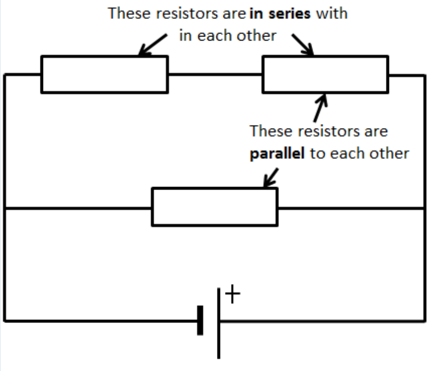
Yes, you need to learn these symbols.

Combined Science Physics Knowledge Organiser
Topic 15: Electricity

Series and parallel circuits

We can connect components in a circuit in series or in parallel. In some circuits, there are components in series AND components in parallel – see the example in the diagram.

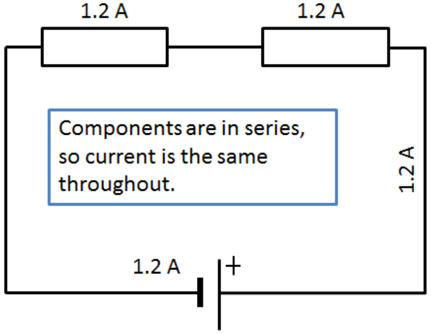
The quantities of resistance, current and potential difference behave differently in components connected in series compared to components connected in parallel. Study the table and diagrams carefully.

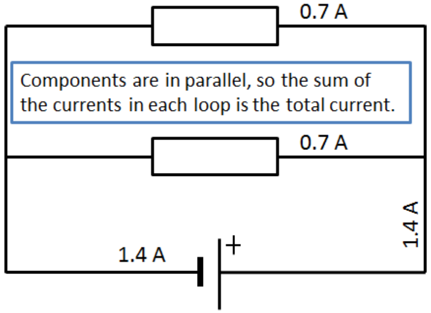


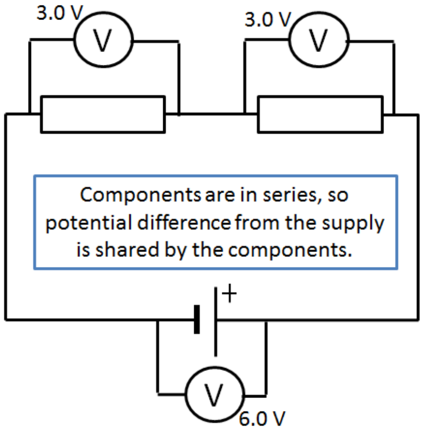
Quantity	Components connected in series…	Components connected in parallel…
Current	The current through each component is identical	Shared between the loops. The total current through the whole circuit is the **sum** of the currents through each loop of the circuit.
Potential difference	The potential difference provided by the power supply is shared between the components in series (not necessarily equally shared out – it depends on the resistance of each component).	Each loop receives the full potential difference provided by the power supply. If we are dealing with just two components in parallel, the potential difference across each is exactly the same, and exactly the same as the potential difference provided by the power supply.
Resistance	The total resistance of two components is the **sum** of the resistance of each component (see equation). So, adding more resistors in series *increases* the total resistance.	The total resistance of two components in parallel is always **less** than the smallest resistance of the components. As a result, adding **more** resistors in parallel actually *decreases* the overall resistance.

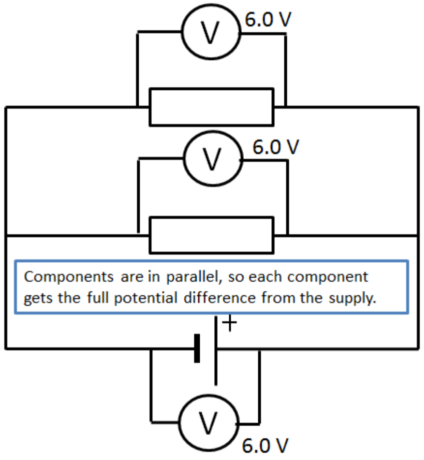
Key Terms	Definitions
series	Components connected one after another in a closed loop.
parallel	Components connected in different loops of a circuit.
resistor	An electrical component that regulates current in a circuit. Bear in mind, all electrical components have **resistance**, so are resistors in some sense, as well as being e.g. bulbs.

Equation	Meanings of terms in equation
for series circuits: $R_{total} = R_1 + R_2$ *	R_{total} = *total resistance (ohms, Ω)* R_1 = *resistance of first component (Ω)* R_2 = *resistance of next component (Ω) – and so on*









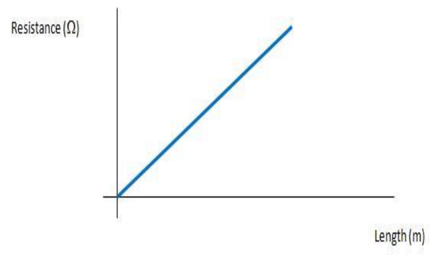
Practical Methods Knowledge Organiser
Topic 15: How length of a wire affects resistance

Equipment List

- Power supply
- Ammeter
- Voltmeter
- Two crocodile clips
- Resistance wires, with a range of diameters
- Meter ruler
- Connecting leads (wires)

Method

1. Connect the circuit. It may be helpful to start at the positive side of the battery or power supply. This may be indicated by a red socket.
2. Connect a lead from the red socket to the positive side of the ammeter.
3. Connect a lead from the negative side of the ammeter to the crocodile clip at the zero end of the ruler.
4. Connect a lead from the other crocodile clip to the negative side of the battery. The main loop of the circuit is now complete. Use this lead as a switch to disconnect the battery between readings.
5. Connect a lead from the positive side of the voltmeter to the crocodile clip the ammeter is connected to.
6. Connect a lead from the negative side of the voltmeter to the other crocodile clip.
7. Record the length of the wire between the crocodile clips, and the readings on the ammeter and voltmeter in a suitable table. You will need just four columns in total.
8. Move the crocodile lip and record the new ammeter and voltmeter readings. Note that the voltmeter reading may not change. Repeat this to obtain several pairs of meter readings for different lengths of wire.
9. Calculate and record the resistance for each length of wire using the equation: $V=IR$
10. Plot a graph of resistance in ohms against length.



Expected Results

The longer the wire, the lower the current when mains voltage remain unchanged. To obtain the resistance of the wire under different lengths, the equation $V=IR$ is rearranged so that resistance of different lengths of wires can be calculated by $R = V/I$. The expected results should show an increase in resistance as the test wire used is longer. You should be able to draw a straight line of best fit although it may not go through the origin, because the connecting leads have some resistance.

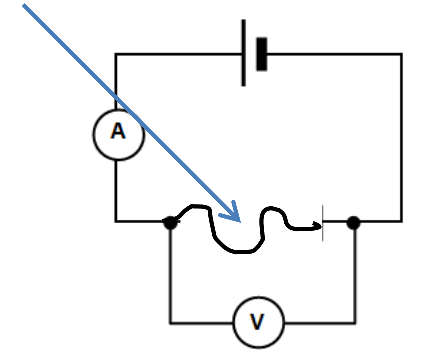
Key Terms	Definitions
resistance	Quantity that determines the size of a current for a particular potential difference.
Ohm's law	The equation that links voltage, resistance and current. The equation is $V=IR$.
ammeter	A device that measures current in Amps. It must be connected in series with all other components.
voltmeter	A device that measure voltage across two points. It must be connected in parallel.

Experimental variables

In the practical, the independent variable was the length of the test wire. The dependent variable was the current flowing through the wire.
The control variable is the voltage / p.d. of the power supply.

Circuit diagram

Piece of wire being tested.



Conclusions and explanation

Resistance of wire increases with its length. This is the best way to explain it:

- Any length of wire has some resistance. So if we divide the wire up into little portions (e.g. 1 cm each), we have more portions, each with a bit of resistance.
- A long piece of wire is made of more portions than a short piece of wire.
- Resistance of components in series adds up, so the more portions we have, the more total resistance we have.

Practical Methods Knowledge Organiser
Topic 15: IV Characteristics of Electrical Components

Equipment List

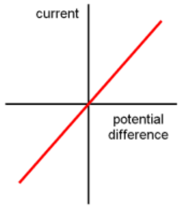
- Power supply
- ammeter and milliammeter,
- voltmeter or multimeter
- lamp
- resistor, for example 100 Ω, 1 W
- diode and protective resistor (eg 10 Ω)
- Variable resistor eg 10Ω, 5A
- connecting leads

Method

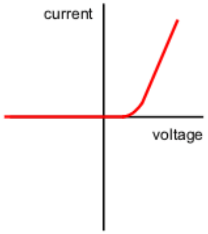
1. Set up the circuits as shown in the diagrams. Ensure the voltmeter is connected in parallel
2. Connect a lead from the negative side of the voltmeter to the other side of the resistor.
3. Record the readings on the ammeter and voltmeter in a suitable table.
4. Adjust the variable resistor and record the new ammeter and voltmeter readings. Repeat this to obtain several pairs of readings.
5. Swap the connections on the battery so that the ammeter is now connected to the negative terminal and variable resistor to the positive terminal. The readings on the ammeter and voltmeter should now be negative.
6. Continue to record pairs of readings of current and potential difference with the battery reversed.
7. Plot a graph of current in A against potential difference in V. As the readings include negative values the origin of your graph will be in the middle of the graph paper.
8. You should be able to draw a straight line of best fit through the origin. This is the characteristic of a resistor.

Expected Results- You need to remember the shapes of these graphs

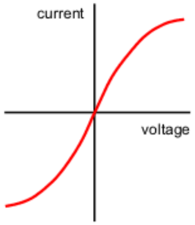
Fixed resistor



Diode

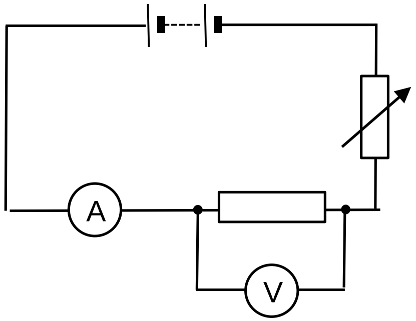


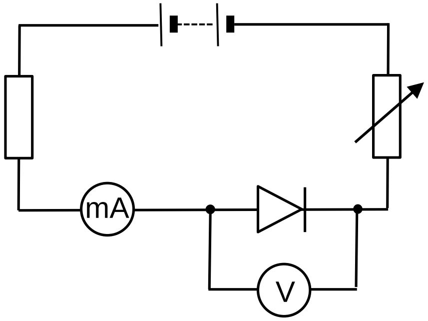
Filament Lamp

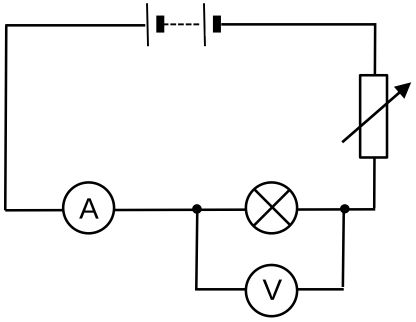


Key Terms	Definitions
diode	A component which allows current to flow in one direction
fixed resistor	A resistor that has the same resistance regardless of the current flowing through it
variable resistance	A resistor whose resistance can be changed, allowing current in the circuit to be changed

Circuit Diagrams







Conclusions

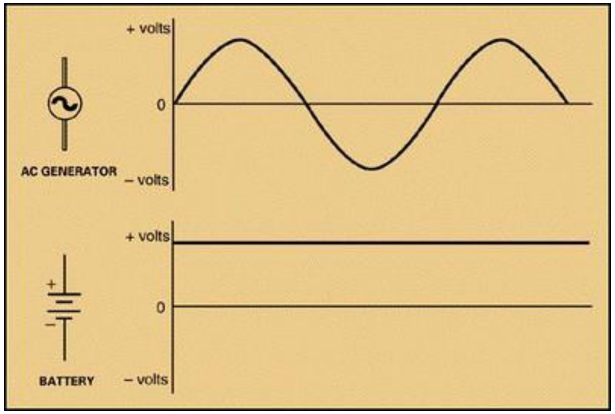
In a fixed resistor, the relationship between current and voltage is directly proportional as the resistance is constant. A diode will only allow current to flow in one direction and therefore in one direction the current will always be 0. The filament lamp is the most complicated, as the current increases the temperature increases and therefore the resistance increases. This causes the graph to form an ‘s’ shape.

Combined Science Physics Knowledge Organiser
Topic 15: Electricity

Key Terms	Definitions
direct p.d.	A supply where the potential difference is fixed at a certain value, so the current flows in one direction only
alternating p.d.	A supply where the p.d. switches between positive a negative, reversing the direction of the current frequently.
frequency	The number of times the p.d. reverses direction every second. Measured in Hertz (Hz).

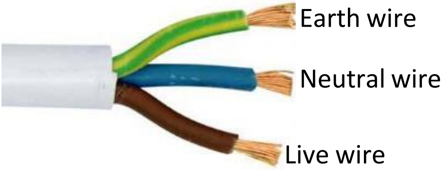
Direct and alternating potential difference

The flow of charge (current) in a circuit can travel in one direction around the circuit only. This is due to a **direct** supply of potential difference, also known as dc. Cells and batteries provide a direct potential difference. However, it is possible for the direction of the current to change back and forth in a circuit. This happens when there the supply provides an **alternating** potential difference – also known as ac. This means the p.d. is constantly switching from positive to negative, which you can see if you measure the p.d. and produce an image of is on an **oscilloscope**, as the diagram shows. The rate at which the p.d. switches from positive to negative is called the frequency of the supply. The bottom image, since the supply is a battery, shows a direct potential difference.



Three-core cables

We connect most electrical appliances to the mains with a three-core cable. The three pins on a plug are just the three ends, or terminals, of the three wires in the cable. Each wire in insulated in a different colour.



Mains electricity

Mains electricity (the supply into your house/school etc. that comes through the plugs) is an ac supply. In the UK, we have a supply with a p.d. of about 230V, and the frequency is 50 Hz.

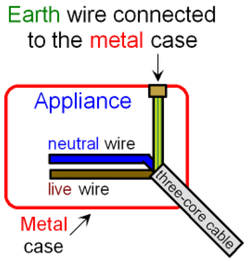
Wire in three-core cable	Colour code of the insulation	Function
Live wire	Brown	Carries the alternating p.d. from the supply to the appliance
Neutral wire	Blue	Completes the circuit. The neutral wire is at 0 V (earth potential).
Earth wire	Yellow and green stripes	Earth wires are at 0 V. They are safety wires, and only carry a current if there is a fault and the appliance has become live (electrified).

The national grid

The national grid connects power stations to consumers of the power – like you. It consists of a network of cables (i.e. power lines) and **transformers**. There are two types of transformers; together they improve the efficiency of the energy transfer from power station to homes and schools etc.:

1. Step-up transformers ***increase*** the p.d. from the power station to the transmission cables. This reduces the current so less energy is lost as heat.
2. Step-down transformers ***decrease*** the p.d. from the cables to a much lower value (230V, generally) for domestic use. This increases the current to suit electrical appliances used at home.

DANGER (and safety)



The earth wire carries current to the ground (literally, earth). This makes circuits safer because if there is a fault, it conducts the current to the ground rather than making the appliance 'live'. Appliances become live if the live wire touches the case. This is particularly a problem with metal-cased appliances, like cookers or toasters.

The live wire is the most dangerous one, since it is at 230 V. it should never touch the earth wire (unless the insulation is between them, of course!), because this would make a complete circuit from your mains supply to the ground (earth). A shock or fire would be highly likely.

Even if a circuit is switched off (i.e. the switch is **open**), the live wire can still be dangerous. If you touch it, you may complete a circuit between the live wire and the earth (because you'll be standing on the floor), so you get a shock.

Combined Science Physics Knowledge Organiser
Topic 15: Electricity

Power

You should recall that power is **the rate of energy transfer**, or the rate at which work is done. In electrical components, including any electrical appliance, the power relates to the potential difference across the component and the current through it. If either p.d. or current increases, the power increases. In other words, the rate of energy transfer increases. This should be clear from the first equation.

The second equation also finds the power. The equation comes from substituting in $V = IR$. The second equation is useful if you don't know the p.d. across a component.

Energy transfers in electrical appliances

The whole point of electrical appliances is to transfer energy. The electrical potential energy from the supply is transferred to something useful – such as light and sound in your TV. The other way of saying this is that **work is done** when **charge flows** in a circuit.

Some examples of energy transfers in electrical appliances:
- In your mobile phone, electrical potential energy from the dc supply (the battery) is transferred to light, sound and thermal energy. This means the energy from the battery is **dissipated** to the surroundings.
- A washing machine transfers electrical potential energy from the ac mains supply to kinetic energy in the electric motor (that's why it spins), along with heat. Eventually, all the energy of the input is dissipated to the surroundings.
- An electric heater transfers the electrical potential energy of the supply to thermal energy. The energy stored in the supply ends up stored in the air, the walls, the floor and so on around the heater: stored in the heat of the materials.

The amount of energy transferred by an appliance depends on the **power** of the appliance and the **time** it is switched on for. To find the amount of energy transferred, simply multiply the power of the appliance by the time it is on for (see third equation).

Furthermore, since p.d. is a measure of how much work is done per coulomb of charge, you can find out how much work is done (aka energy transferred) by a circuit by multiplying the charge flow by the p.d. (see fourth equation).

Key Terms	Definitions
power	The rate of energy transfer. In electrical components, the power is found by multiplying p.d. by current.
work	Transfer of energy.
appliance	Any device that transfers electrical energy to other forms. The supply of electrical energy can be a cell, battery, or the mains ac supply.

Equation	Meanings of terms in equation
$P = V\,I$ *	*P = power (watts, W)* *V = potential difference (volts, V)* *I = current (amps, A)*
$P = I^2\,R$ *	*P = power (watts, W)* *I = current (amps, A)* *R = resistance (ohms, Ω)*
$E = P\,t$ *	*E = energy transferred (joules, J)* *P = power (watts, W)* *t = time (seconds, s)*
$E = Q\,V$ *	*E = energy transferred (joules, J)* *Q = charge flow (coulombs, C)* *V = potential difference (volts, V)*

Interpreting the power of an electrical appliance

The power of an appliance determines how much energy it transfers in a given length of time. If an appliance has a high power (e.g. a washing machine), it transfers lots of energy in a given time. If it has a low power (e.g. a lamp), it doesn't transfer much energy in a given time, in comparison.

The other way of looking at it is how long the appliance takes to transfer a given amount of energy, e.g. 1000 J. A washing machine will transfer the energy in a very short length of time, whereas a lamp will take much longer to transfer this energy.

Combined Science Physics Knowledge Organiser
Topic 17: Nuclear Physics

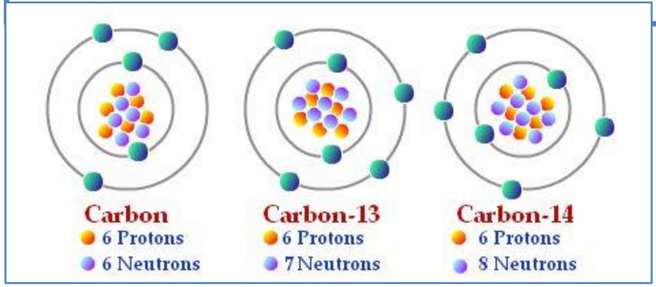
The structure of the atom and isotopes

Atoms are made of a small, dense central nucleus (made of protons and neutrons) surrounded by electrons, arranged in shells.

The shells, or energy levels, where electrons are found can *change*:

- Electrons move *up* an energy level with the **absorption** of a specific wavelength of EM radiation
- Electrons move *down* an energy level by **emitting** a specific wavelength of EM radiation.

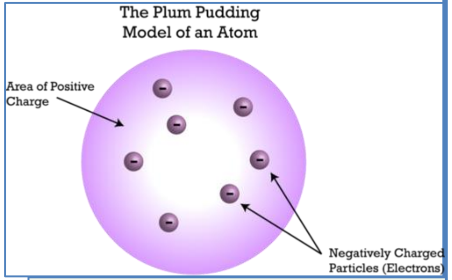
Atoms of a particular element always have the same number of protons (the atomic number in the periodic table). However, the number of *neutrons* can vary in atoms of the same element. **Isotopes** of an element have the same number of protons but different numbers of neutrons. Look at the diagram for the example of three isotopes of carbon.

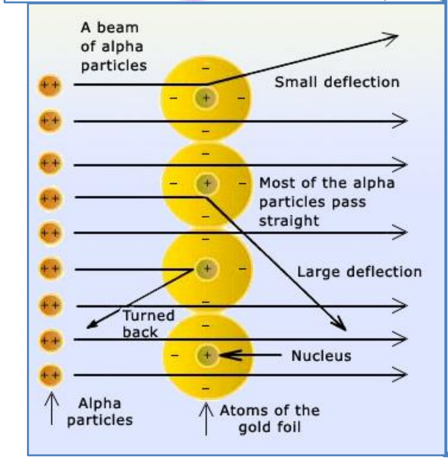


Radioactive decay

Some atomic nuclei are **unstable**, or **radioactive**. The nucleus will spontaneously and randomly change to become more stable. When the nucleus does this, it gives out (emits) nuclear radiation.

Since it is a random process, it is impossible to predict which particular nucleus will decay next. However, with a huge number of them, it is possible to measure the rate at which the whole source of radiation is decaying. This rate is measured in number of decays per second: the unit is the **becquerel (Bq).** One Bq = 1 decay per second. This can be measured with a detector called a Geiger-Muller tube – in this case, 1 Bq = 1 count per second.





Key Terms	Definitions
isotope	An atom with a specific number of protons and neutrons in the nucleus.
energy level	The other name for electron 'shells'. Each energy level is a specific distance from the nucleus and holds a limited number of electrons.
radioactive decay	The process of an unstable nucleus becoming stable and giving out nuclear radiation in the process.
nuclear radiation	Types of radiation that come from the nuclei of atoms during decay. Four types: alpha, beta, gamma, and neutrons.

How the modern model of the atom was developed

The model of the atom that you know all about has changed over time. Here's a brief timeline:

1. Before electrons were discovered, atoms were thought of as simply **tiny, hard spheres** that couldn't be divided into smaller particles.
2. **Electrons** were discovered (which are smaller than atoms!), so the model was modified. The **plum pudding** model of the atom was described: the atom as a ball of positive charge with negative electrons embedded in it like pieces of fruit in a pudding (see diagram).
3. A famous experiment by the scientists **Rutherford** and **Marsden** showed that the plum pudding model was wrong. Particles named **alpha particles** (more on these later) were fired at a sheet of atoms and some rebounded, some were deflected and others went straight through (see diagram). This showed that atoms have a hard, very small concentration of mass in the centre – which was named the **nucleus**. It also showed that the nucleus was positively charged, and we now know that is due to the protons in the nucleus. This model is sensibly called the **nuclear model** of the atom.
4. The nuclear model was further developed to include the idea that electrons orbit at specific distances from the nucleus: in energy levels. The key scientist presenting this model was **Niels Bohr**.
5. Next, the nucleus was investigated further. It was found that the nucleus can be split up, producing particles with an equally-sized positive charge. These particles are named 'protons' – of course!
6. Then, in 1932, a scientist named **James Chadwick** proved that there were also uncharged particles in the nucleus. He called these particles 'neutrons' as they are neutral: no charge. This was about 20 years after the nucleus had already been accepted as the right idea about atoms.

Combined Science Physics Knowledge Organiser
Topic 17: Nuclear Physics

Types of nuclear radiation

The rate of decay of a nucleus is measured in Bq, or can be measured as the **count rate** in Bq. What it actually 'counts' is the amount of radiation hitting the detector each second. The radiation emitted from the nucleus thanks to radioactive decay can be:

- An **alpha particle** (symbol: α). An alpha particle is made of two protons and two neutrons (making it identical to the nucleus of helium atoms). Since there are four subatomic particles in one alpha particle, it has a mass number of 4. Since there are two protons in an alpha particle, it has a proton number of 2.
- A **beta particle** (symbol: β). A beta particle is a high speed electron. Beta particles are emitted during a type of radioactive decay where a neutron turns into a proton and an electron, and electrons aren't 'allowed' in nuclei, so it gets fired out – emitted.
- A **gamma ray** (symbol: γ). Yes, the same wave as in the electromagnetic spectrum. It has a very high frequency and very short wavelength.
- A **neutron** (symbol: n). An uncharged particle.

Alpha, beta and gamma

As well as being different in form, alpha, beta and gamma are also different in terms of how they behave after emission from a nucleus.

Type of nuclear radiation	Range in air	Penetrating power	Ionising power
Alpha	A few centimet-res	Not very penetrating at all: absorbed by a thin sheet of paper.	Strongly ionising (as alpha particles are large and have a +2 charge)
Beta	A few metres	Fairly penetrating: completely absorbed by a sheet of aluminium 5mm thick.	Moderately ionising (as not as big as alpha particles and their charge is smaller, -1)
Gamma	Enormous distances	Penetrates most materials. Absorbed only by several metres of concrete or a thick sheet of lead.	Only weakly ionising.

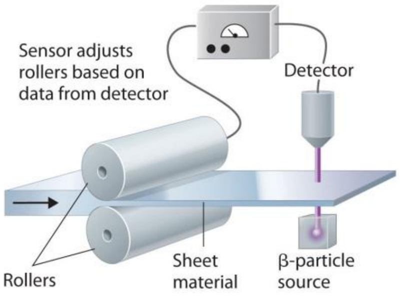
Key Terms	Definitions
emission	Releasing or giving out. Nuclear radiation is **emitted** during radioactive decay.
penetration	Passing through a material. Different types of nuclear radiation can penetrate different materials, and are absorbed by certain materials.
ionisation	The process of making an ion by 'knocking off' electrons. Ionising radiation causes this, and can break up molecules into ions which go on to react with other chemicals. This is very dangerous in living organisms.

Using nuclear radiation

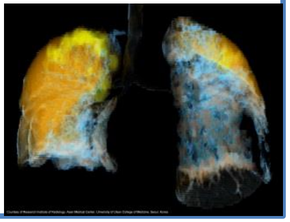
Nuclear radiation can be very useful. Here are some examples to know; notice that the type of nuclear radiation used depends on exactly what you need it for, so it links to the properties in the table opposite.

Radiotherapy: this is a treatment for cancer, using gamma rays. Gamma rays easily penetrate body tissues, so they can reach a tumour e.g. in the brain. The gamma rays can kill the cancer cells. However, since gamma rays are dangerous to healthy tissue, they use beams of gamma rays from many angles to the tumour, so healthy cells between source and tumour are not affected too badly.

Monitoring thickness of paper in a factory: As the diagram shows, a beta source is used. This is because beta will pass through materials such as paper. The detector on the other side of the sheet will measure a lower count rate if the sheet gets too thick, and a higher count rate if it gets too thin. The rollers can be automatically adjusted to fix this.



Medical diagnosis: sources of radiation can be taken into the body and the nuclear radiation monitored from the outside to give information about body function. Obviously, alpha is NOT suitable for this as it won't penetrate body tissues to get to the detector! For example, a radioactive xenon isotope can be inhaled to check lung function. On the image, the left lung isn't getting much air to the bottom parts.



Combined Science Physics Knowledge Organiser
Topic 17: Nuclear Physics

Nuclear equations

To show what happens to an atom when it radioactively decays, we use nuclear equations. In these equations, we represent alpha and beta particles as shown in the key terms table.

Recalling that an alpha particle is 2 protons and 2 neutrons, it is clear that a nucleus going through alpha decay loses 4 subatomic particles (so the mass number has to **decrease** by *four*). Two of those are *protons*, so the *atomic number* must decrease by 2. This changes the element. Here's an example:

$$ {}^{219}_{86}\text{radon} \longrightarrow {}^{215}_{84}\text{polonium} + {}^{4}_{2}\text{He} $$

Beta decay results in a beta particle, and happens because a neutron turns into a proton and an electron. The electron is ejected from the nucleus. Since neutrons and protons have the same mass, the mass number does not change. However, there is an *extra proton*, so the atomic number must increase by one (therefore the charge of the nucleus increases by 1). This changes the element. Here's an example:

$$ {}^{14}_{6}\text{carbon} \longrightarrow {}^{14}_{7}\text{nitrogen} + {}^{0}_{-1}\text{e} $$

This shows that the carbon nucleus decays to produce a nitrogen nucleus and a beta particle.

NB: emission of a gamma ray DOES NOT cause any change to the mass or atomic number, so it does not change the element.

Radioactive contamination

Being exposed to nuclear radiation DOES NOT make something radioactive! We say the exposed material/object has been **irradiated**.

On the other hand, **radioactive contamination** means getting unwanted radioactive materials onto other objects. For instance, spilling a powdered radioactive source onto clothes. This is dangerous because the radioactive material keeps on emitting nuclear radiation through nuclear decay, so it can keep on irradiating the thing it is on.

The hazards due to irradiation or contamination mean that *precautions* must be taken. For instance, the radioactive materials (e.g. uranium) used in nuclear power plant is only transferred, stored and used in containers that nuclear radiation can't penetrate. There is ongoing research by scientists into the effects of nuclear radiation on human health. Like all scientific findings, this research should be **published** and receive **peer review** – where other scientists check the methods and analysis performed, to make sure it is right!

Key Terms	**Definitions**
mass number	The total number of subatomic particles in the nucleus of an atom (protons + neutrons).
atomic number	The number of protons in the nucleus of an atom. In other words, the number of positive (+1) charges in the nucleus.
alpha particle	A form of nuclear radiation made from 2 protons and 2 neutrons that be represented with the symbol: ${}^{4}_{2}\text{He}$
beta particle	A form of nuclear radiation made of a high-speed electron that be represented with the symbol: ${}^{0}_{-1}\text{e}$
half-life	The half-life of a radioactive isotope is the time it takes for the number of radioactive nuclei in a sample to halve.

Half life

Radioactive decay is **random** – so you don't know which nucleus will decay next. However, with a <u>large number</u> of radioactive nuclei, the time it takes for <u>HALF</u> of them to decay *is* predicable. This differs depending on the particular isotope involved. This length of time is called a **half-life**. Plotting the number of radioactive nuclei OR the count rate against time makes half-life easy to find. Read off the time it takes for the number on the y-axis to decrease by a half. So, in this example, we can see that the half-life of carbon-14 is 5.5 thousand years, whereas the half-life of plutonium-239 is 24 thousand years.

The y-axis could also show count rate (Bq) – the shape of the graph would be identical