The Dean Trust
Ashton on Mersey School

Year 10
Knowledge Organisers
Biology CB1-CB5

Knowledge Organiser: CB1 Key Concepts in Biology (1 of 2)

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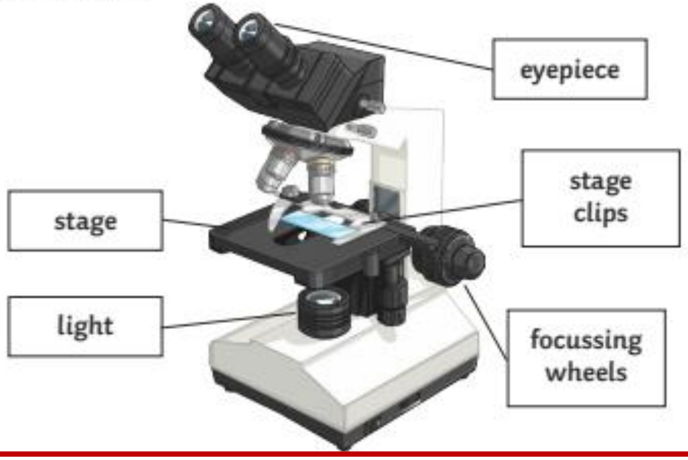
Key Learning

- Using a microscope
- Preparing slide (CP)
- Calculating magnification
- Labelling cells
- Role of cell parts
- Comparing prokaryotic and eukaryotic cells
- Movement of substances into and out of cells
- Investigating osmosis (CP)
- Role of enzymes in digestion
- Function of enzyme active site on specificity
- Effect of temp and pH on enzyme activity
- Investigating effect of pH on enzyme activity (CP)

Microscopy Required Practical

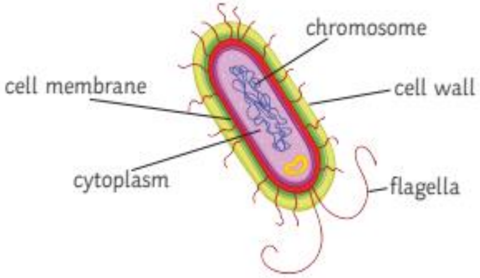
- Includes preparing a slide, using a light microscope, drawing any observations – use a pencil and label important observations.



	Prefix	Effect on unit	Example	
	milli-	÷ 1000	millimetres (mm)	
× 1000	micro-	÷ 1 000 000	micrometres (μm)	÷ 1000
× 1000	nano-	÷ 1 000 000 000	nanometres (nm)	÷ 1000
× 1000	pico-	÷ 1 000 000 000 000	picometres (pm)	÷ 1000

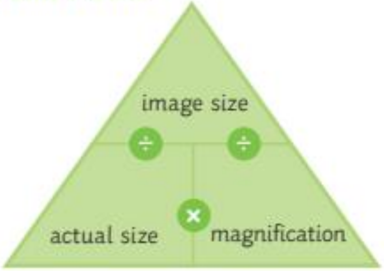
Bacterial Cells

Bacterial cells do not have a true nucleus, they just have a single strand of DNA that floats in the cytoplasm. They contain a plasmid.



Equations and Maths

Equation



Maths Skills

Conversions:

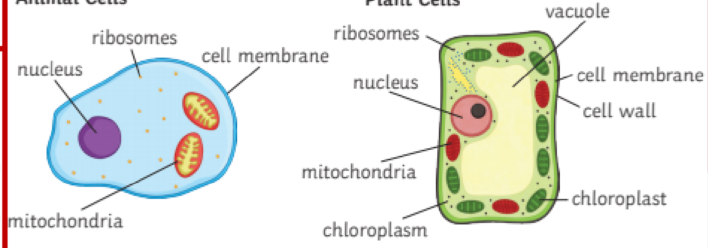
Micrometres to millimetres: divide by 1000.

Standard Form:

$0.003 = 3 \times 10^{-3}$

$5.6 \times 10^{-5} = 0.0056$

Prokaryotic and Eukaryotic Cells



Plant and animal cells have similarities and differences:

	Animal	Plant
nucleus	✓	✓
cytoplasm	✓	✓
chloroplast	X	✓
cell membrane	✓	✓
permanent vacuole	X	✓
mitochondria	✓	✓
ribosomes	✓	✓
cell wall	X	✓

Key Terms and definitions

Microscopes
Magnification
Specimen
Prefix
Prokaryote
Eukaryote
Enzymes
Denatured
Biological catalyst
Optimum
Diffusion
Osmosis
Active Transport

Context

Microbiology in covid-19 tests

Knowledge Organiser: CB1 Key Concepts in Biology (2 of 2)

Specialised Cells

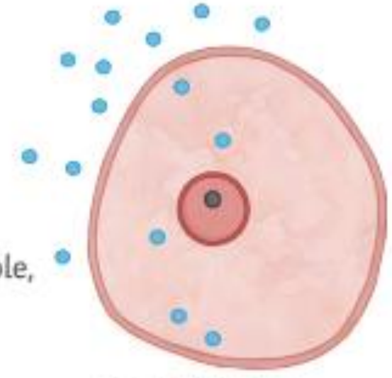
When a cell changes to become a specialised cell, it is called differentiation.

Specialised Cell	Function	Adaptation
sperm	To get the male DNA to the female DNA.	Streamlined head, long tail, lots of mitochondria to provide energy.
nerve	To send electrical impulses around the body.	Long to cover more distance. Has branched connections to connect in a network.
muscle	To contract quickly.	Long and contain lots of mitochondria for energy.
root hair	To absorb water from the soil.	A large surface area to absorb more water.
phloem	Transports substances around the plant.	Pores to allow cell sap to flow. Cells are long and joined end-to-end.
xylem	Transports water through the plant.	Hollow in the centre. Tubes are joined end-to-end.

Key Processes

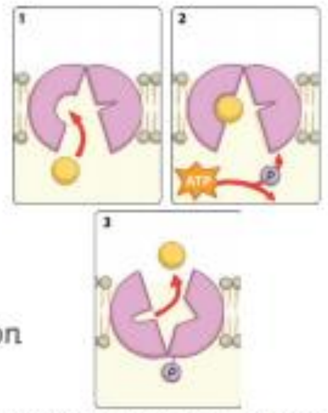
Diffusion is the spreading out of particles from an area of higher concentration to an area of lower concentration.

Cell membranes are semi-permeable, only small molecules can get through.


Cell Diffusion

Osmosis is the movement of water molecules across a partially permeable membrane from a region of higher concentration to a region of lower concentration.

Active transport is the movement of substances against the concentration gradient. This process requires energy from respiration.

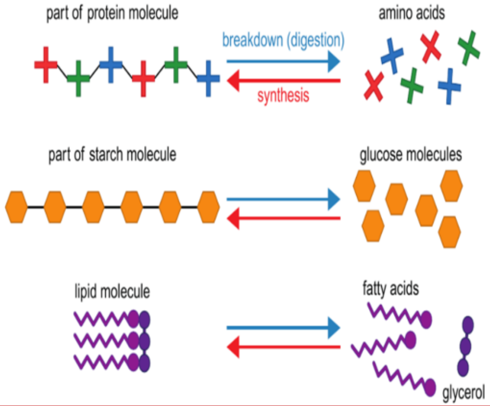


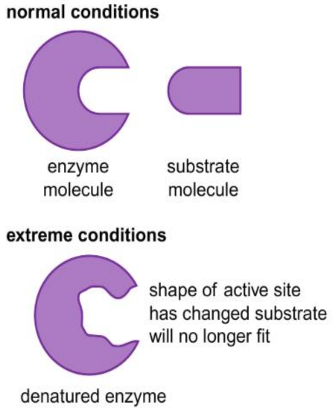
Active Transport in Cells

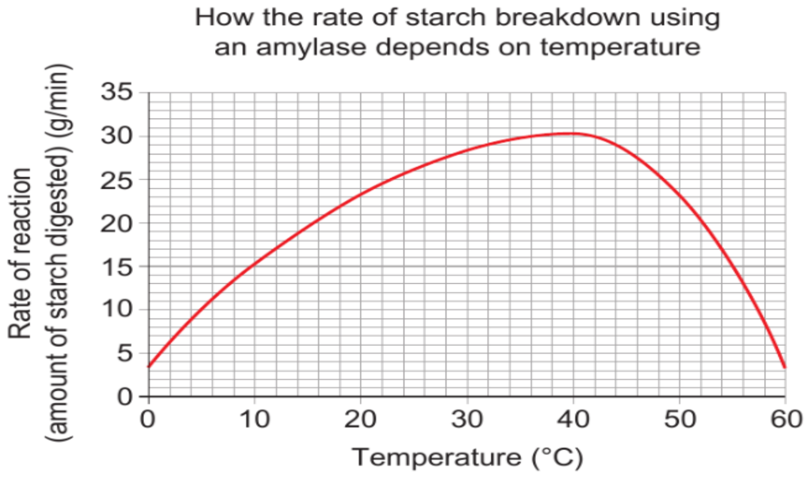
Osmosis and Potato Practical

- Independent variable – concentration.
- Dependent variable – change in mass.
- Control variable – volume of solution, temperature, time, surface area of the potato.

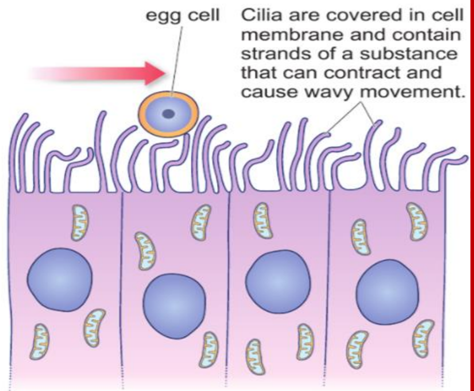
The potato in the sugar solution will lose water and so will have less mass at the end; the potato in the pure water solution will gain water.

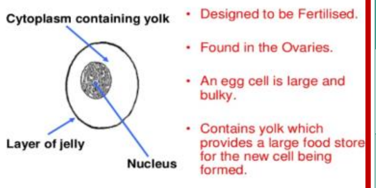


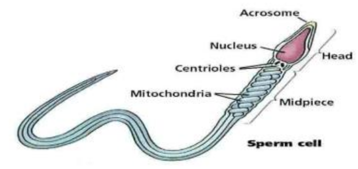




B the data in graph A shown as a rate of reaction graph







Enzyme name	Where found	Reaction catalysed
amylase	saliva and small intestine	breaking down starch to small sugars, such as maltose
catalase	most cells, but especially liver cells	breaking down hydrogen peroxide made in many cell reactions to water and oxygen
starch synthase	plant	synthesis of starch from glucose
DNA polymerase	nucleus	synthesis of DNA from its monomers

Knowledge Organiser: CB2 Cells and Control (1 of 2)

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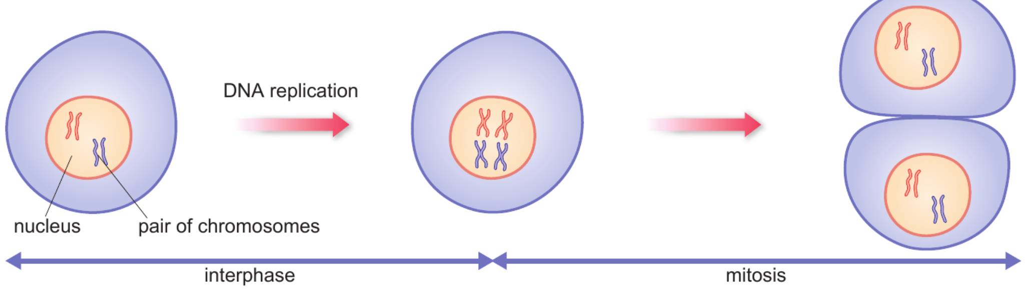
In multicellular organisms the process of **growth** and **repair** requires new cell. The **cell cycle** is a process that produces **two identical daughter cells**.

This diploid cell has two sets of chromosomes – one blue and one red in each set. (Chromosomes that are the same are shown in pairs.)

Each chromosome is copied and the copies remain attached, forming X-shapes.

The copies of the chromosomes separate and each daughter cell ends up with the same number of chromosomes as the parent cell.



Stages of **mitosis**

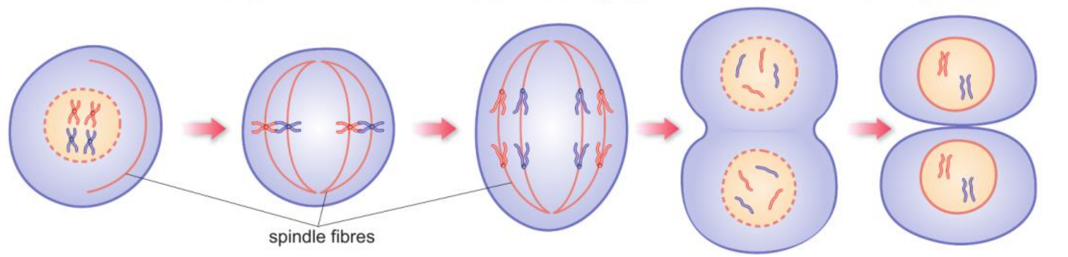
In **prophase** the nucleus starts to break down and **spindle fibres** appear.

By the end of **metaphase**, the chromosomes are lined up on the spindle fibres across the middle of the cell.

The chromosome copies are separated and moved to either end of the cell on the spindle fibres. This is **anaphase.**

In **telophase** a membrane forms around each set of chromosomes to form nuclei.

A cell surface membrane forms to separate the two cells during **cytokinesis.** Cell walls form in plant cells.



Asexual reproduction replies on **mitosis**

Some organisms can reproduce using just one parent. This **asexual reproduction** produces offspring that are **clones**, which means that their cells have the same chromosomes and the parent (they are **genetically identical**)

The nuclei of human body cells contain two copies of each of 23 types of chromosome, making 46 in all. Cells with two copies of each chromosome (two sets of chromosomes) are **diploid**. Gametes (sex cells) contain one copy of each type of chromosome and are **haploid**.

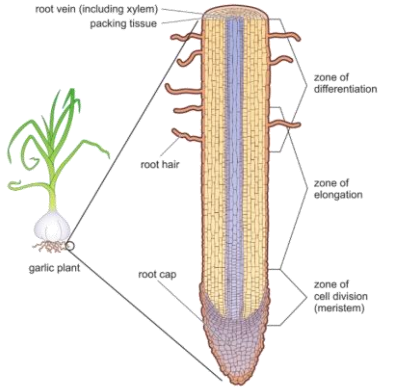
Uncontrolled cell division can result in cancer tumours

The rate at which a cell divides by mitosis is controlled by its genetic information. A mutation might alter a gene controlling cell division allowing cells to start dividing uncontrollably. This can result in the formation of a tumour.

Growth in animals and plants

Growth occurs in young animals by rapid cell division all over the body. As animals get older most cell division is simply to **replace** or **repair** damaged cells.

Growth in plants occurs by cell division of **meristems** at the root and shoot tips. Cells increase in size by cell **elongation**. Meristems allow plants to grow throughout their life.

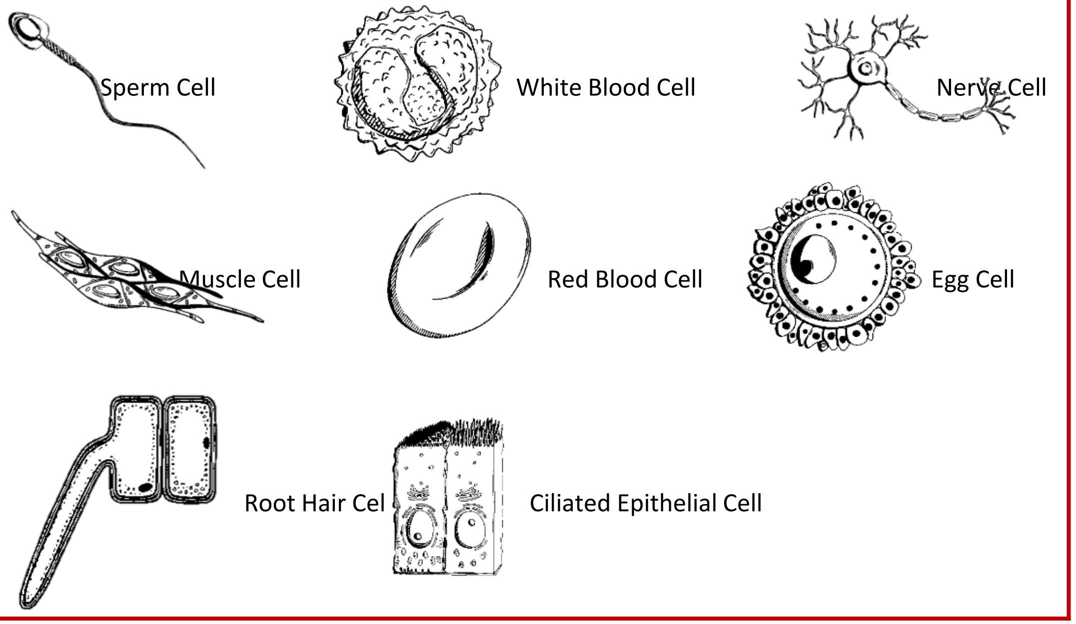


Cells that can divide repeatedly over a long period of time to produce cells that then differentiate are called **stem cells**. In plants, these cells are found in meristems (and are sometimes called **meristem cells**).

This is an example of a NHS percentile chart used to monitor growth of a baby girl from 6 months to 2 years. There are separate charts for length, mass and head circumference.

A 9 month old girl who weighs 7.5kg is on the 25th percentile. This means 75% of 9 month old girls are heavier and 25% are lighter. Further tests on the girl would occur if the mass fell below the bottom percentile line or was above the top line or an inconsistent pattern like low mass with large head circumference or the mass increased or decreased by two percentile lines over a short time.

Cell differentiation is when an unspecialised cell changes to become specialised for a function



There are many different ways of measuring growth in plants, including height, leaf surface area and mass.

Percentage changes are often worked out for these values and can be calculated using this formula.

$$\frac{\text{final value} - \text{starting value}}{\text{starting value}} \times 100\%$$

Knowledge Organiser: CB2 Cells and Control (2 of 2)

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Stem cells

Stem cells are cells that have not undergone differentiation. A cell which has not yet become specialised is called undifferentiated.

Stem cells can divide to produce new cells, which can then divide into different cell types. They therefore have the potential to be transplanted into patients to treat medical conditions and disease. They could be used to replace cells that have been damaged or destroyed, for example:

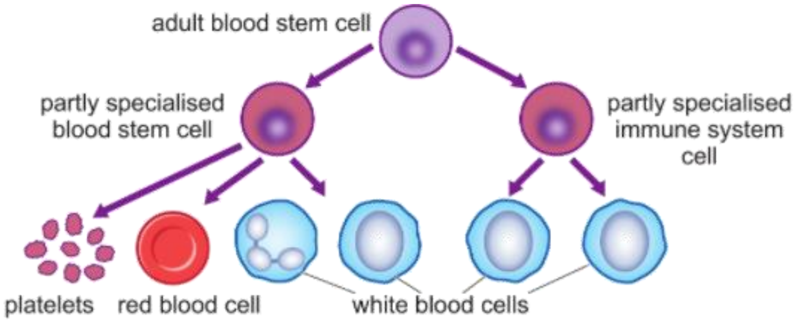
- in type 1 diabetes
- in cases of multiple sclerosis, which can lead to paralysis
- in cases of spinal cord or brain injury, which have led to paralysis

The stem cells used could be embryonic stem cells or adult stem cells.

Embryonic stem cells can differentiate into a wider range of cell types, but are difficult to obtain. The best source is the five-day-old embryo.

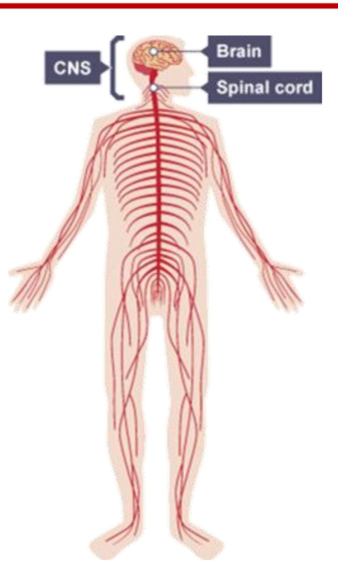
Adult stem cells will differentiate into a narrower range of cell types. Bone marrow transplants are an example of adult stem cell transplant. Bone marrow cells will differentiate into different types of blood cells. Bone marrow transplants are carried out:

- in cases of blood cell cancer, eg leukaemia and lymphoma
- when blood cells have been destroyed, eg during cancer treatment

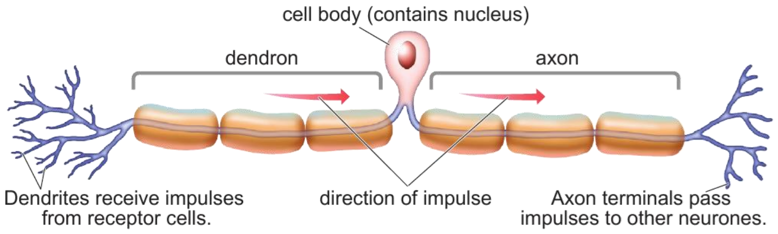


There are problems with using stem cells, which scientists are still trying to solve. For example, if stem cells continue to divide inside the body after they have replaced damaged cells, they can cause **cancer**. Another problem is that stem cells from one person are often killed by the immune system of other people that they are put into. This is called **rejection**.

The brain and **spinal cord** form the **central nervous system** (**CNS**), which controls your body. Nerves make up the rest of the **nervous system**. This organ system allows all the parts of your body to communicate, using electrical signals called **impulses**.



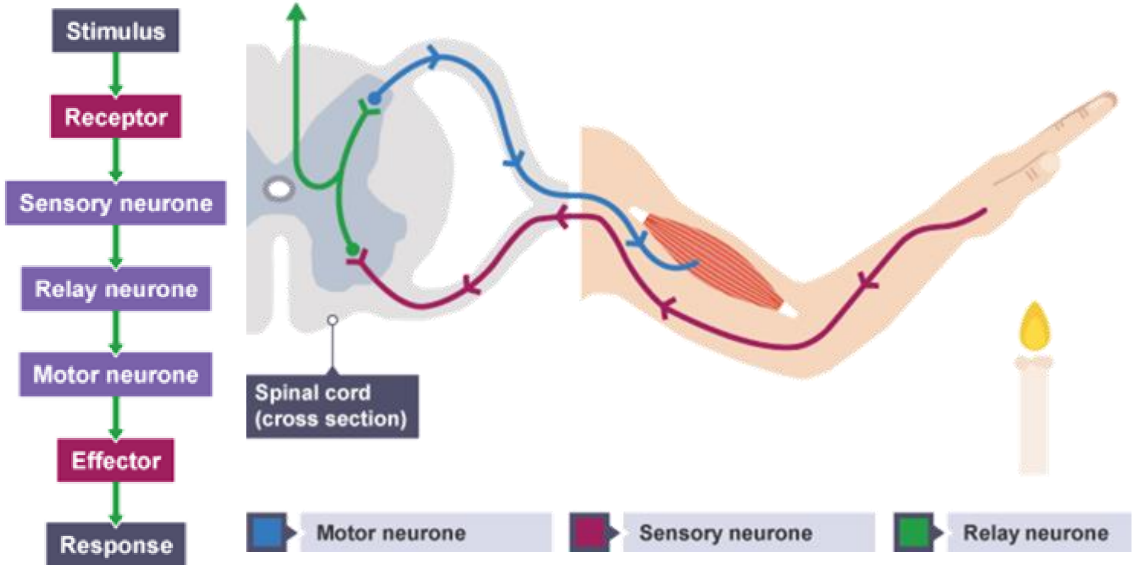
There are three main types of neurone: **sensory, relay and motor.**



Features of neurones:

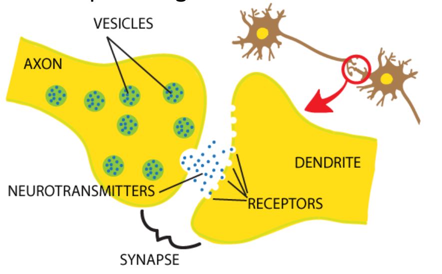
- cell body contains the **nucleus**, organelles and most of the **cytoplasm** of the neurone
- ≥1 **dendrons**, which carry nerve impulses towards the cell body
- **axon**, a single fibre that carries nerve impulses away from the cell body
- **myelin sheath**, insulates the neurone

The reflex arc produces a rapid response to a stimulus, which minimises any damage to the body from potentially harmful conditions, such as touching something hot.
A reflex action does not involve the conscious part of the brain, which makes it much quicker.



Neurotransmission

Sensory neurons carry impulses to the CNS. Motor neurones carry impulses to effectors (muscles or glands). Relay neurons link motor and sensory neurones.
A synapse is the gap where one neurone meets another.
When an impulse reaches an axon terminal, a neurotransmitter substance is released into the gap. This is detected by the next neurone where a new impulse is generated.



Knowledge Organiser: CB3 Genetics (1 of 2)

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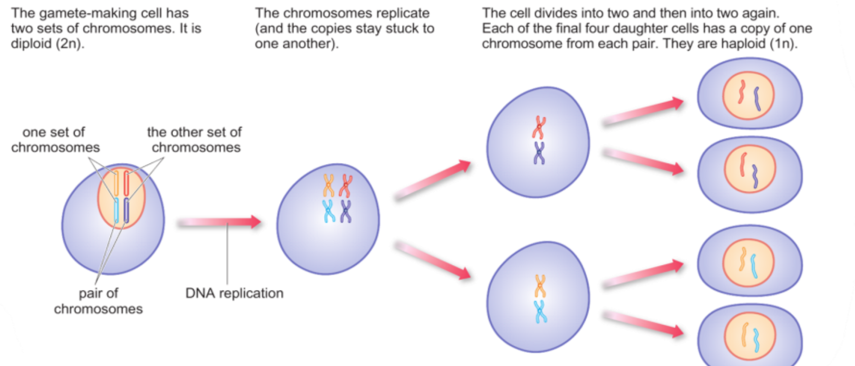
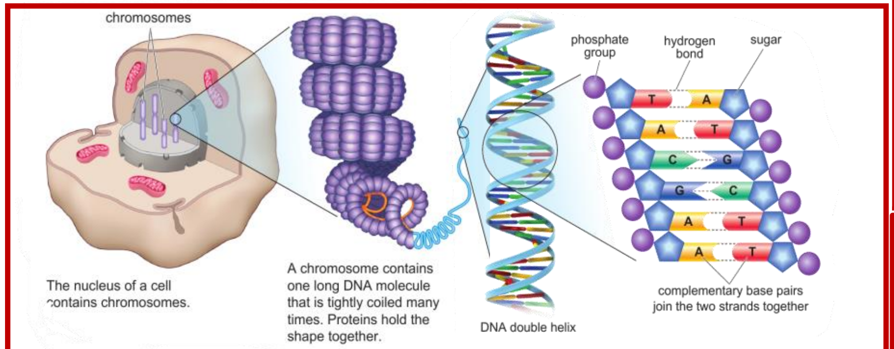
Humans start life as a single fertilised egg cell, a **zygote**. This is formed when two **gametes** (sex cells) fuse during **fertilisation**. The zygote then forms a ball of cells using a type of cell division called **mitosis**

The nuclei of human body cells contain two copies of each of 23 types of chromosome, making 46 in all. Cells with two copies of each chromosome (two sets of chromosomes) are **diploid**. Gametes (sex cells) contain one copy of each type of chromosome and are **haploid**.



meiosis (simplified to show just two different types of chromosome)



A molecule of DNA contains two strands, each of which forms a shape called a helix. The two strands are joined together by pairs of substances called **bases**, to form a **double helix**.

There are four bases in DNA: **adenine**, **thymine**, **cytosine** and **guanine**. To make things simpler, we often call them A, T, C and G. Diagram B shows how they are arranged. Notice that A always pairs with T and C always pairs with G. The matching bases are **complementary base pairs**.

Each base is attached to a sugar and each sugar is attached to a phosphate group. The sugars and phosphate groups form the backbone of the DNA strands. DNA is therefore made of many similar units joined in a chain, and so it is a polymer.

Extracting DNA

A) Dissolve 3g of salt in 100cm^3 of water. Add 10cm^3 of washing up liquid. The detergent breaks down the cell membranes.

B) Thoroughly mash up 50g of kiwi/any fruit. Add the solution to the mashed peas.

C) Place the beaker in a water bath at 60ºC for 15 minutes (this stage is optional).

D) Filter the mixture through a piece of muslin cloth into a boiling tube.

E) Tilt the boiling tube and slowly pour ice cold ethanol down the inside of the tube. DNA is insoluble in ethanol so forms a white precipitate that you can remove using a glass rod.

Probability

There are four possible combinations of gametes that offspring can inherit.

female genotype \ male genotype	A	a
A	AA	Aa
a	Aa	aa

One of these four has the genotype aa – that's $\frac{1}{4}$, 25% or 0.25.

The recessive phenotype has a ratio of 1:3 because only one combination will show the phenotype while the other three will not.

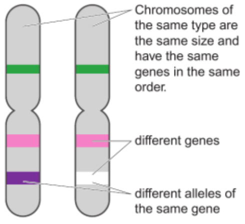
Sex Determination

dad \ mum	X	X	
X	XX	XX	female
Y	XY	XY	male

Females carry two X chromosomes.
Males carry one X and one Y chromosome.

Hydrogen bonding

Parts of DNA bases have very slight electrical charges. A slightly negatively charged part of one base attracts a slightly positively charged part of another base. This forms a weak force of attraction called a **hydrogen bond**. Cytosine and guanine form three hydrogen bonds between them. Adenine and thymine form two hydrogen bonds. This helps to explain why C only pairs with G, and A pairs with T.



B Each gene can exist in a number of different forms called alleles.

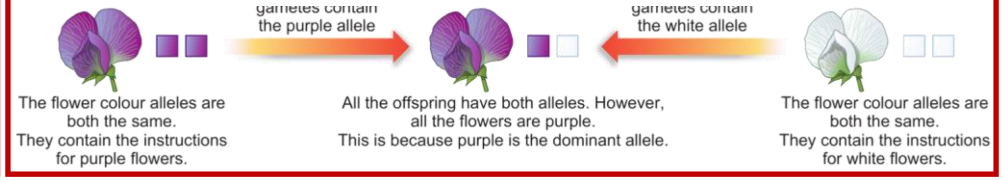
Genes for the same characteristic (e.g. eye colour) can contain slightly different instructions that create variations (e.g. brown, blue). Different forms of the same gene are called **alleles**.

Since there are two copies of every chromosome in a body cell nucleus, a body cell contains two copies of every gene. Each copy of a gene may be a different allele. There are many alleles for most of the 20 000 human genes, and the different combination of alleles in each person gives each of us slightly different characteristics (**genetic variation**).

chromosome	A structure found in the nuclei of cells. Each chromosome contains one long DNA molecule packed up with proteins.
daughter cell	A cell produced by another dividing cell.
diploid	A cell or nucleus that has two sets of chromosomes.
DNA	Deoxyribonucleic acid. A polymer made of sugar and phosphate groups joined to bases.
egg cell	The female gamete in humans.
fertilisation	Fusing of a male gamete with a female gamete.
gamete	A haploid cell used for sexual reproduction.
gene	Section of the long strand of DNA found in a chromosome, which often contains instructions for a protein.
genome	All the DNA in an organism. Each body cell contains a copy of the genome.
haploid	A cell or nucleus that has one set of chromosomes. Gametes are haploid.
meiosis	Form of cell division in which one parent cell produces four haploid daughter cells.
mitosis	Form of cell division in which one parent cell produces two diploid daughter cells.
polymer	A molecule made out of a chain of repeating similar units (called monomers).
replicate	When DNA replicates it makes a copy of itself.
sperm cell	The male gamete in humans.
zygote	Another term for 'fertilised egg cell'.

If both alleles for one gene are the same, an organism is **homozygous** for that gene. If the alleles are different, an organism is **heterozygous**.

Gametes have only one copy of each chromosome and so only contain one copy of each gene. In diagram C, gametes from the purple and white flowers fertilise and form a **zygote** that is heterozygous. However, in the offspring plant only the allele for purple flowers has an effect. It is said to be **dominant**. The white flower allele has no effect if the purple flower allele is there. This white flower allele is **recessive**.



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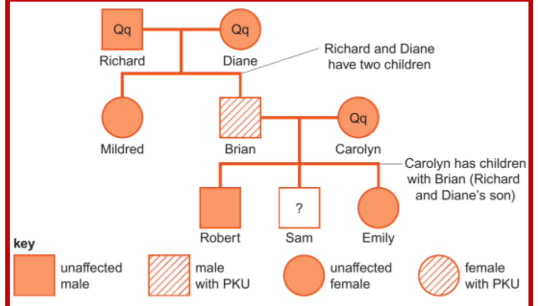
A family pedigree chart like the one below shows how genotypes and their resulting phenotypes are inherited in families.



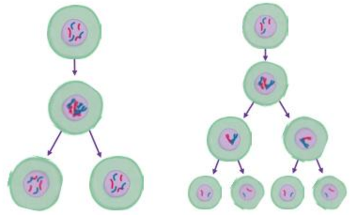
D Phenylketonuria (PKU) is a disorder caused by a recessive allele. People with PKU lack an enzyme called phenylalanine hydroxylase and can develop nerve problems unless they stick to a special diet.

Most genetic mutations have no effect on the **phenotype** (the characteristic expressed, what we can 'see') , some mutations have a small effect on the phenotype and, rarely, a single mutation will significantly affect the phenotype. This is how we get genetic variation.

The Human Genome Project

This was an international collaboration to find the sequence all of the genes in humans. It was started in 1990 and completed in 2003 and cost billions.

There are many medical benefits: such as knowing if someone carries the gene which causes some types of breast cancer (BRCA1 & 2)



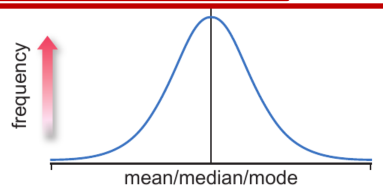
Mitosis	Meiosis
Produces two daughter cells.	Produces four daughter cells.
Daughter cells are genetically identical.	Daughter cells are not genetically identical.
The cell divides once.	The cell divides twice.
The chromosome number of the daughter cells is the same as the parent cells. In humans, this is 46 chromosomes.	The chromosome number is reduced by half. In humans, this is 23 chromosomes.
Used for growth and repair, and asexual reproduction.	Produces gametes for sexual reproduction.

adenine	One of four bases found in DNA. Often written as A.
base (in DNA)	Four substances that help make up DNA, often shown by the letters A, C, G and T. Pairs of bases form 'links' between two 'spines' formed of phosphate groups and a type of sugar.
complementary base pair	Two DNA bases that fit into each other and link by hydrogen bonds. There are two types of complementary base pair: A linking with T, and C linking with G.
double helix	Two helices joined together.
hydrogen bond	Weak force of attraction caused by differences in the electrical charge on different parts of different molecules.
allele	Most genes come in different versions, called alleles. So a gene for eye colour may have a version (allele) that can cause dark eyes and an allele that can cause pale eyes.
dominant	Allele that will always affect the phenotype (as opposed to a recessive allele, whose effect will not be seen if a dominant allele is present).

Some of the variation between individuals of the same species is the result of variation in their genes. **Genetic variation** is caused by the different alleles inherited during sexual reproduction. Different alleles are produced by mutations, some of which cause changes in the phenotype. However, many characteristics also show **environmental variation**, because they are affected by their surroundings. For example, how well a plant grows is affected by how much light, water and nutrients it gets.

Variation can be grouped into two types:

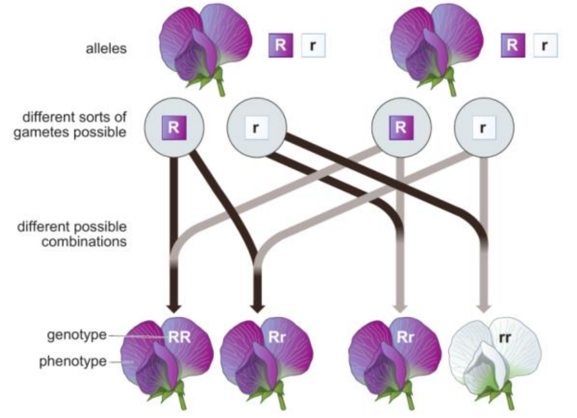
- **discontinuous variation** is where the data can only take a limited set of values
- **continuous variation** is where the data can be any value in a range.



E In a normal distribution curve, the **mean** value is the same as the **mode** (most common value) and the **median** (the middle value).

Continuous data for variation often forms a bell-shaped curve, known as a **normal distribution** (see graph E). It is called this because it is what is expected for a large amount of data for a characteristic where:

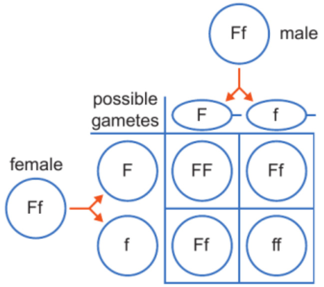
- the most common value is the middle value in the whole **range**
- the further a value is from the median, the fewer individuals have that value.



D A genetic diagram shows the possible combinations of alleles when two organisms breed. We use diagrams like this to explain the inheritance of one gene (**monohybrid inheritance**). We can also use these diagrams to predict the **ratios** of the phenotypes (purple and white phenotypes are in a 3:1 ratio in this example).

Cystic Fibrosis (CF) is a recessive genetic disease

People who inherit two recessive CF alleles (f) have the condition. People who inherit at least one dominant allele (F) do not have CF. This punnet square shows that if heterozygous parents have children, the percentage of children with CF is predicted to be 25%.



Inherited variation	Differences between organisms passed on to offspring by their parents in reproduction.
genotype	The alleles for a certain characteristic that are found in an organism.
heterozygous	When both the alleles for a gene are different in an organism.
homozygous	When both the alleles for a gene are the same in an organism.
monohybrid inheritance	The study of how the alleles of just one gene are passed from parents to offspring.
phenotype	The characteristics that a certain set of alleles produce.
recessive	Allele that will only affect the phenotype if the other allele is also recessive. It has no effect if the other allele is dominant.
family pedigree chart	A chart showing the phenotypes and sexes of several generations of the same family, to track how characteristics have been inherited.
probability	The likelihood of an event happening.
Punnett square	Diagram used to predict the different characteristics in the offspring of two organisms with known combinations of alleles.
sex chromosome	Chromosome that determines the sex of an organism.
Human Genome Project	The project that mapped the base pairs in one human genome.
mutation	A change to a gene, caused by a mistake in copying the DNA base pairs during cell division or by the effects of radiation or certain chemicals.
acquired characteristic	A characteristic that can change during life, due to a change in the environment.
continuous variation	Continuous data can take any value between two limits.
discontinuous variation	Data values that can only have one of a set number of options are discontinuous.

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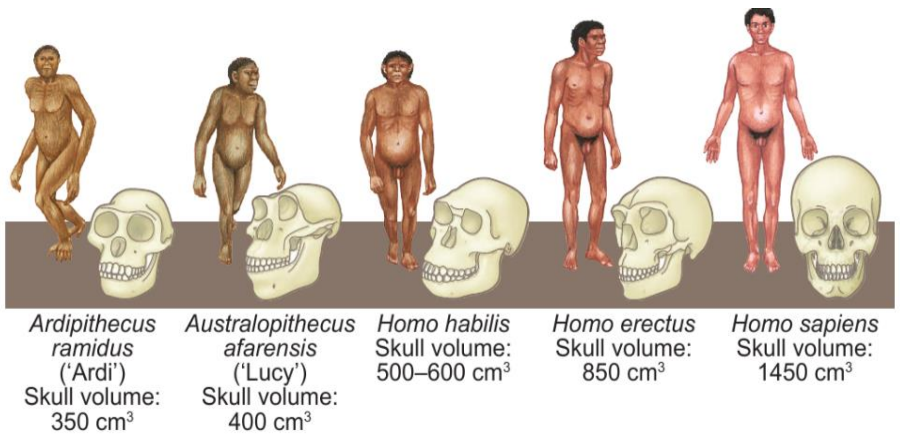
Knowledge Organiser: CB4 Natural Selection and Genetic Modification (1 of 3)

Key Learning

- Describe the evidence for human evolution from fossils and stone tools
- Describe how genetic analysis led the three domains
- Explain Darwin's theory of evolution including evolution of antibiotic resistant bacteria
- Describe genetic engineering (foundation) and the main stages (higher)
- Explain and describe selective breeding and the impact
- Evaluate the benefits and risks of genetic engineering

Evidence for evolution

Evolution is the gradual change in characteristics over time. Fossil and stone tools provide evidence that brain size increased and consequently so did intelligence. **'Ardi' and 'Lucy'** are 2 well known examples of fossils of early man.



The earliest evidence of human-like animals making tools is 3.3 million years old. Scientists can **work out the age of the rock** the stone tool is found in, and then they **assume the tool is about the same age** as the rock.

Key Terms

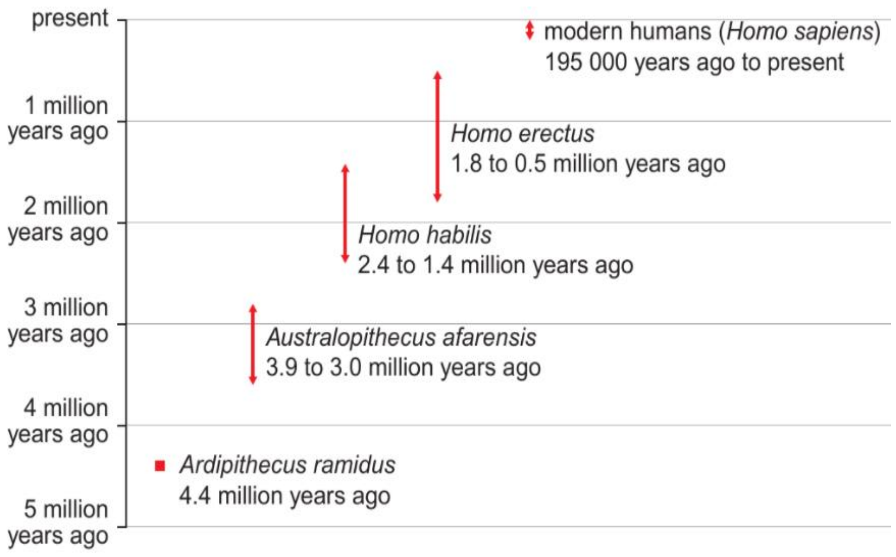
Evolution
Natural selection
Archaea
Kingdoms
Domains
Genetic variation
Competition
Environmental change
Selective breeding
Desired characteristics
Yield
Disease resistance
Herbicide (weed killer)
Plasmid
Restriction enzyme
Sticky ends
Ligase
Vector

Stone Tools

The earliest evidence of human-like animals using stone tools dates back to about 3.3million years ago. Scientists can work out the ages of different layers of rock. They then assume that a stone tool is about the same age as that layer of rock.

The oldest stone tools are very simple, but would have helped with skinning an animal or cutting up meat. Tools found in more recent rocks are more sophisticated.

D The stone tool in the upper photo is about 2 million years old. The lower one is about 13 000 years old.



C ages of human-like species fossils

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Knowledge Organiser: CB4 Natural Selection and Genetic Modification (2 of 3)

Classification

In 1735, **Carl Linneaus** published his **classification system** based on what animals looked like. Scientists used this basis to come up with the **5 kingdoms.**

Kingdom	Main charateristics
animals	multicellular (with cells arranged as tissues and organs), cells have nuclei, no cell walls
plants	multicellular (with cells arranged as tissues and organs), have chloroplasts for photosynthesis, cells have nuclei, cellulose cell walls
fungi	multicellular (apart from yeasts), live in or on the dead matter on which they feed, cells have nuclei, cell walls contain chitin (not cellulose)
protists	mostly unicellular (a few are multicellular), cells have nuclei, some have cell walls (made of different substances but not chitin)
prokaryotes	unicellular, cells do not have nuclei, flexible cell walls

Darwin's Theory of Evolution by Natural Selection

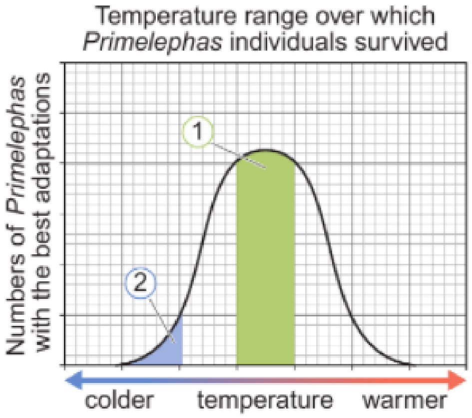
There are 4 key stages to evolution:

1 – There is **genetic variation** between individuals in the same species (we all look a little bit different).

2 - There is **competition** between organisms for food, due to **environmental change.**

3 - Some individuals survive and some don't **(Survival of the Fittest/Natural selection).**

4 – The survivors **breed** and **pass on their genes** to the offspring.



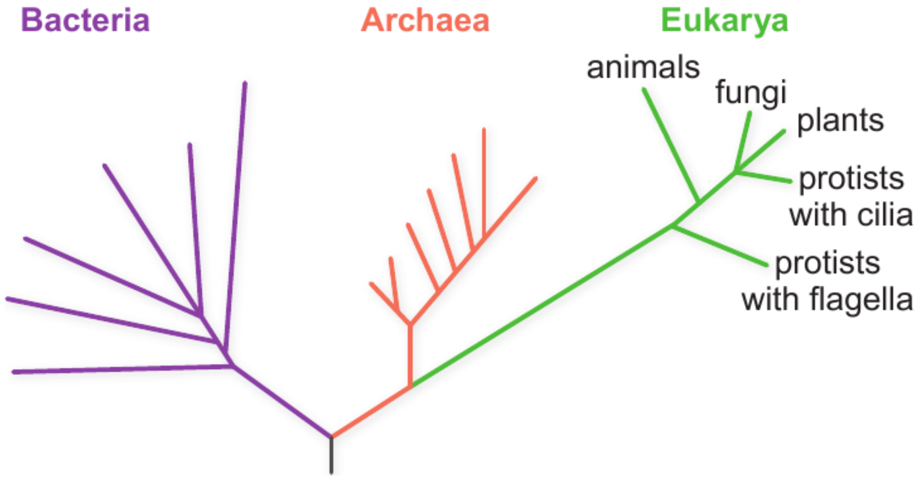
1. Most *Primelephas* were best adapted to medium temperatures. However, in conditions of medium temperature and ample resources, *all* the animals in the population could survive and reproduce.

2. Some *Primelephas* were better adapted to colder temperatures because they had more hair. When the area in which they were living became colder, more of these animals survived and reproduced.

B When conditions change, some individuals are better adapted to cope than others.

Then scientists discovered new single celled organisms called **Archaea** which they put in the prokaryote kingdom. However, they realised the archaea had **unused sections of DNA** like plants and animals. This led **Carl Woese** to propose 3 domains:

- Archaea
- Bacteria
- Eukarya



DNA changes slowly over time and so, by looking at these changes, scientists can work out how closely related two organisms are. The more DNA two organisms have in common, the more recently they evolved from a common ancestor and the more closely related they are. As DNA analysis gets faster and more precise, our classification system is updated to reflect new discoveries.

Knowledge Organiser: CB4 Natural Selection and Genetic Modification (3 of 3)

Selective Breeding (also known as artificial selection)

Human have bred animals for 8000 years for their own benefit. Those reasons are **disease resistance, yield, fast growth, taste and coping with certain environmental conditions**

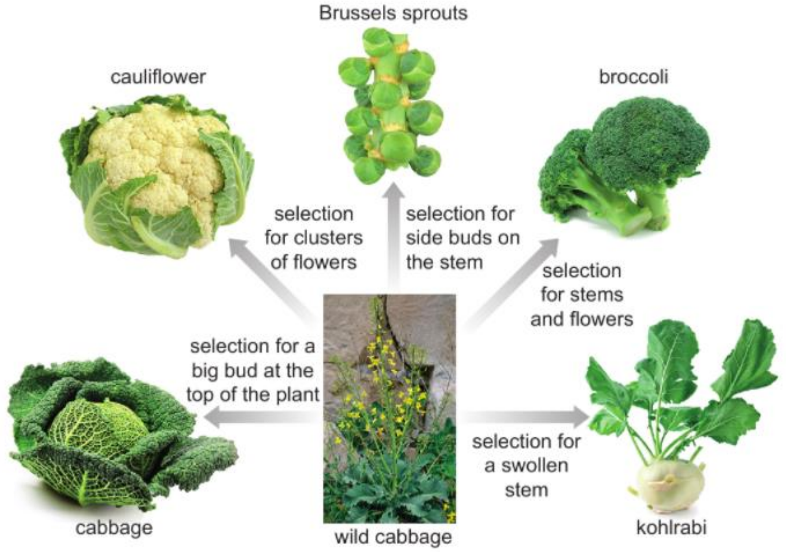
There are 4 simple stages:

1- Choose the animals with the **desired characteristics.**

2 – **Breed** them

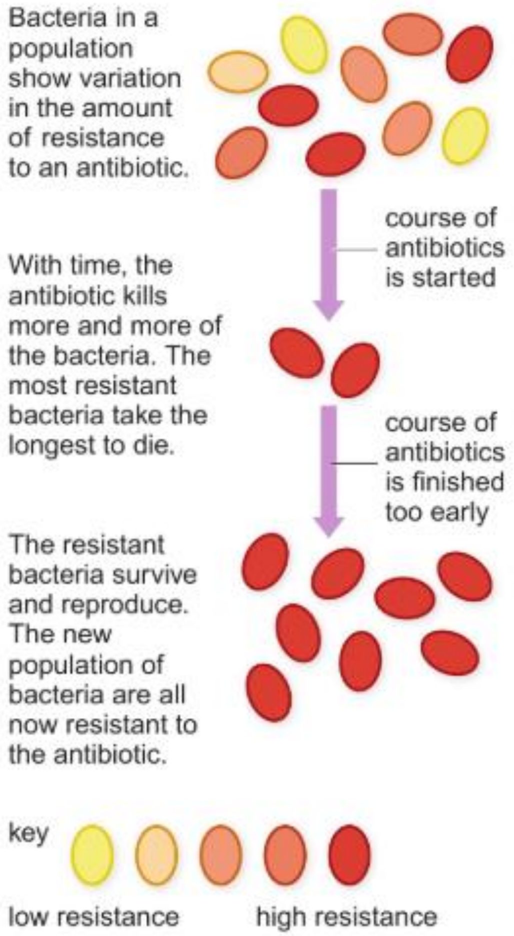
3 – Then **select the offspring with the desired characteristics** and **breed** them together

4 – **Repeat this process** over and over again.



B Selective breeding of wild cabbage has produced many vegetables – all varieties of the same species.

Evolution of antibiotic resistant bacteria



D Stopping an antibiotic early can cause resistance to develop in a species of bacterium.

Genetic Engineering

Genetic engineering involves **changing the DNA** of one organism by **inserting genes** from another. This creates genetically modified organisms (GMOs).

Benefits: GM crops can be made **resistant to herbicides** so you can spray herbicide which kill the weeds but not the crops.

Risks: People think the **resistant gene could end up in wild plants** which may have unknown consequences.

Stages of Genetic Engineering (higher tier only)

1 – **Restriction enzymes** cut DNA in a **bacterial plasmid**

2 – These enzymes do the same to **remove the gene from human DNA**

3 - Both the plasmid and the human gene now have the same **'sticky ends'**

4 – The **human gene is inserted into the bacterial plasmid** and the enzyme **ligase** is used to join the ends of DNA together

5 – The plasmids are inserted back into the bacteria, which can now make human insulin.

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Knowledge Organiser: Combined Science Biology Topic 5 Health, disease and the development of medicines

Key Learning

- Describe health
- Describe the difference between communicable and non-communicable diseases and what causes them
- Describe a pathogen
- Describe some common infections and explain how pathogens are spread and how to reduce this spread.
- Describe the process of developing new medicines
- Explain the role of the human immune system and the body's response to immunisations
- Evaluate different treatments for cardiovascular disease

Health definition

The World Health Organization (WHO) describes health as **a state of complete physical, mental and social well-being** and not merely the absence of disease or infirmity.

A **pathogen** is a micro-organism that causes a disease.

Communicable diseases are caused by pathogens and can be passed from infected person to another person. eg COVID 19

Non-communicable diseases are not passed from person to person and are caused by a fault in the body often due to lifestyle choices eg heart disease.

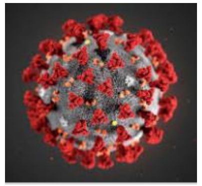
Common communicable diseases include:

Cholera	Caused by bacteria	Causes diarrhoea	Spread in water
Tuberculosis (TB)	Caused by bacteria	Causes lung damage	Spread through the air (droplets)
Chalara ash dieback (Plant disease)	Caused by fungi	Causes leaf loss and bark lesions	Spread through the air (wind)
Malaria	Caused by protists	Causes damage to blood and liver	Spread by animal vectors (mosquitos)
Chlamydia	Caused by bacteria	Can cause infertility	Sexually transmitted (STI)
HIV	Caused by a virus	Damages the immune system	Sexually transmitted (STI)

Key Terms and definitions

Pathogen
Antibiotics
Communicable
Non-communicable
Immune system
Antibodies
Antigens
Immunisation
Cardiovascular disease
Vaccine
Bacteria
Virus
Fungi and protist

Context



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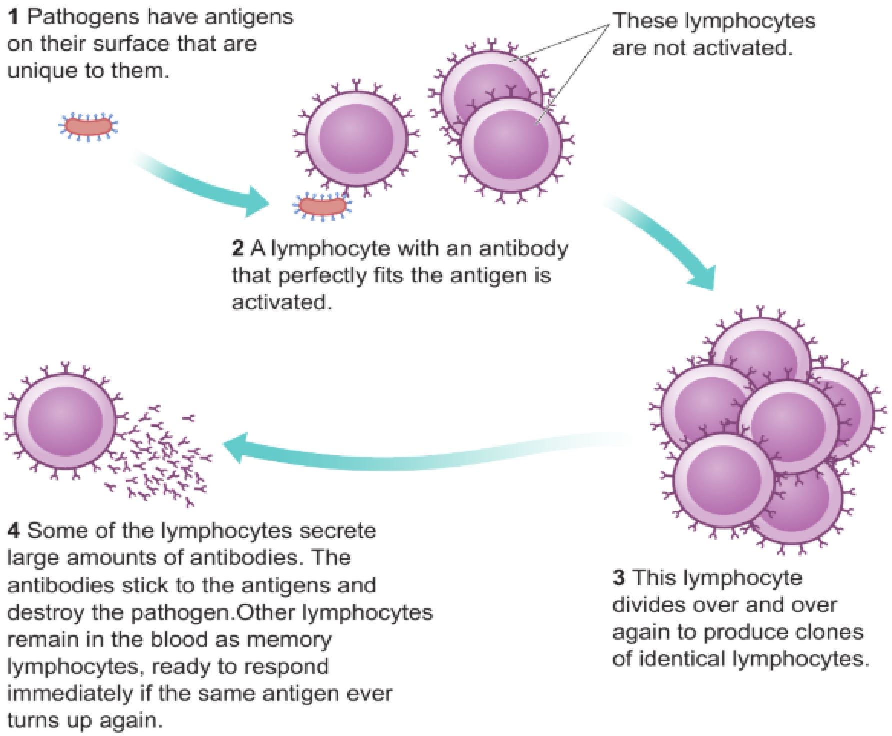
Knowledge Organiser: Combined Science Biology Topic 5 Health, disease and the development of medicines

How does the immune system work?



B how the immune system attacks a pathogen

Immunisations

Having a **vaccine** causes immunity artificially. The vaccine contains **weakened or dead pathogens** that include the **antigens,** so you get the same response as in the diagram above.

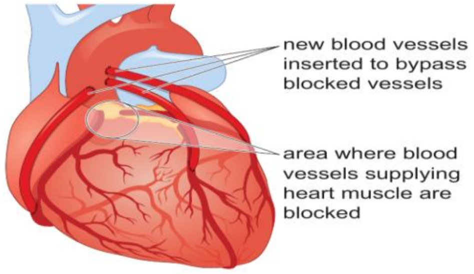
Treating and evaluating Cardiovascular disease

High blood pressure: treat with medication, exercise more, give up smoking

Narrow blood vessels: insert a small mesh tube called a **stent** to hold it open.

Problems: a relatively safe surgery, but complications can occur.

Blocked coronary arteries: Perform a bypass operation by inserting other blood vessels so the heart receives oxygen and other nutrients. **Problems:** High risk surgery and a lifetime of drugs to prevent heart attacks.



D Blocked blood vessels can be bypassed by inserting new blood vessels.

How to prevent the spread:

Being hygienic –

washing hands thoroughly.

Destroying vectors –

killing vectors by using insecticides or destroying their habitat.

Isolation –

isolating an infected person will prevent the spread.

Vaccination –

people cannot develop the infection and then pass it on.

Developing Drugs

There are three main stages in drug testing:

Pre-clinical testing:

1. Drugs are tested on human cells and tissues.
2. Testing carried out on living animals.

Clinical testing:

3. Tested on healthy human volunteers in clinical trials. Starts with a very low dose, then tested on people with the illness to find the optimum dose.

Placebo is a substance that is like the drug, but does not do anything.

Placebo effect is when the patient thinks the treatment will work even though their treatment isn't doing anything.

Blind trial is when the patient does not know whether they are getting the drug or the placebo.

Double-blind trial is when both the doctor and the patient do not know whether they are getting the drug.

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Year 10
Knowledge Organisers
Chemistry CC1-CC12

Knowledge Organiser: CC1 & CC2 States of Matter (1 of 4)

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Key Learning

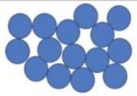
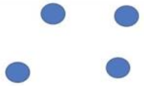
- Recall the names used for the interconversions between states of matter.
- Describe the arrangement, movement and relative energy of particles in a solid, liquid and gas.
- Interpret data to distinguish between pure substances and mixtures.
- Identify and describe appropriate experimental techniques to separate different types of mixture.
- Describe how ground and waste water can be made potable.
- Describe how sea water can be made potable.
- Interpret paper chromatograms.
- Explain the difference between the use of 'pure' in chemistry and everyday use.

The three states of matter are solid, liquid and gas. For example, water can exist in the solid state as ice, or as liquid water, or in the gas state as water vapour.

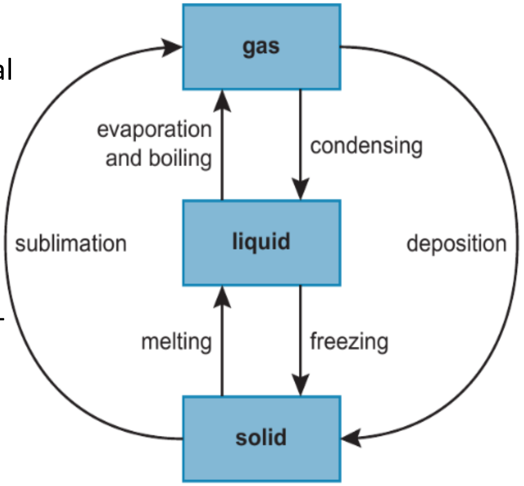
The particle model

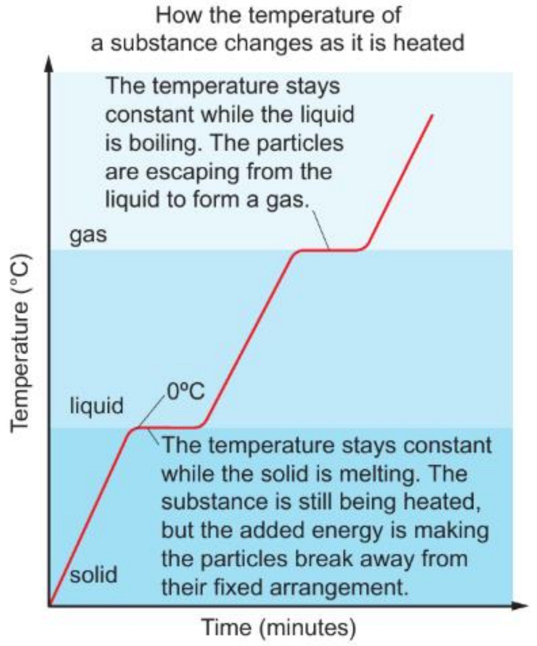
Some **particles** are large enough to see, like the dust on a computer screen. Others, like **atoms** and **molecules**, are far too small for you to see. When chemists discuss particles, they usually mean these very small particles.

The **particle model** explains state changes in a substance in terms of the arrangement, movement and energy stored in its particles.

State	Diagram of particles	Arrangement of particles	Relative distance between particles	Main movement of particles
Solid		Regular	Very close	Vibrate around fixed positions
Liquid		Random	Close	Move around each other
Gas		Random	Far apart	Move quickly in all directions

State changes are physical changes. They can be reversed, and the chemical properties of the substance do not change. This is because the particles themselves do not change – only their arrangement, movement and amount of stored energy.





Particles are attracted to one another by weak forces of attraction. There are many of these forces in a solid, some of these are overcome during melting. The remaining attractive forces between particles in a liquid are overcome during evaporation and boiling. For this to happen energy must be transferred from the surroundings to the particles.

Predicting the state of a substance.

You can predict the state of a substance if you know its temperature, and its melting and boiling points.
If the temperature is:

- below the melting point, the substance is a solid.
- between the melting and boiling points, the substance is a liquid.
- above the boiling point, the substance is a gas.

Key Terminology

Solid
Liquid
Gas
Particle model
Physical change
Evaporation
Condensation
Melting
Freezing
Sublimation
Deposition
Insoluble
Filtration
Crystallisation
Filtrate
Residue
Chromatography
Distillation
Potable
Precipitate

Context:

City of Manchester Distillery

Knowledge Organiser: CC1 & CC2 States of Matter (2 of 4)

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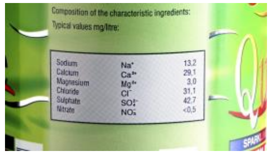
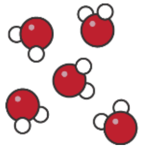
Pure chemical substances

Food and drink may be advertised as 'pure'. For example, you may see cartons of 'pure orange juice' or 'pure mineral water'. This means that nothing else was added to the orange juice or mineral water during manufacture. However, these substances are not pure to a scientist. In science, a pure substance contains only one element or compound.



Mineral water is mostly water, but there are other substances mixed with it. These are the ingredients that you see listed on the bottle's label.



Completely pure water would only contain water molecules, and nothing else

The composition (make-up) of a **pure** substance:

- cannot be changed
- is the same in all parts of a piece of the substance.

So, for example, pure gold contains only gold atoms.

Pure sucrose is always sucrose, no matter how finely it is ground down.

What is a Mixture?

A mixture contains two or more substances that are not chemically combined.

Mixtures are unlike chemical compounds, because:

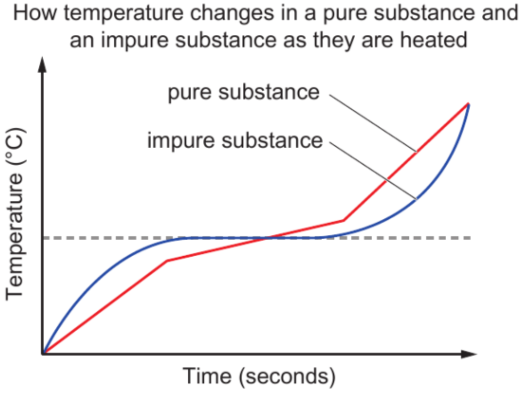
- The substances in a mixture can be separated using physical methods such as filtration, freezing, and distillation.
- There is little or no energy change when a mixture forms.
- Mixtures have variable compositions, while compounds have a fixed, definite formula.
- When mixed, individual substances keep their properties in a mixture, while if they form a compound their properties can change.

Melting points

When a solid melts, its particles gain enough energy to overcome the weak forces of attraction between them. They move further away from one another and the solid becomes a liquid. The temperature at which this happens is the **melting point**. This is an example of a **physical property** (how a substance responds to forces and energy).

A pure substance has the same composition in every part of it, and so its physical properties are the same in every part. So, all of a pure substance will melt at the same temperature until all the substance has changed state. The melting point of pure gold is 1063 °C and the melting point of oxygen is –218 °C.

A **pure substance** has a sharp **melting point** (**melts** at one temperature) and a sharp **boiling point**A **mixture melts** over a range of **temperatures** and boils over a range of **temperatures**.



heating curves for a pure substance and a mixture

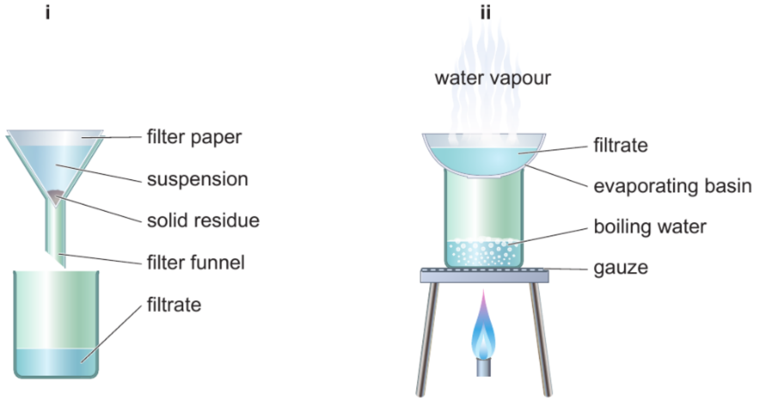
Filtration

Filters can be used to separate some mixtures. They let smaller pieces or liquids through but trap bigger pieces or **insoluble** substances.

Examples of **filtration** are to be seen all around us. Cars, vacuum cleaners and air-conditioning systems all have filters. Some whales use filters to feed. They open their mouths and take in water. When they close their mouths, they push out the water through filters. Small animals (such as krill) get stuck in the filters and are swallowed.

Filtration and crystallisation in the lab

To filter a solution in the laboratory, a filter funnel is lined with filter paper that has fine holes in it. The solvent and solute(s) pass through the fine holes to form the **filtrate**. Bits of insoluble substances cannot fit through the holes and so leave a **residue** in the filter paper. A Bunsen burner is then used to evaporate the filtrate carefully. Care must be taken not to overheat the solution once it is saturated, because hot crystals may spit out. Further heating may also cause crystals to change chemically.



Laboratory apparatus for (i) filtration and (ii) crystallisation.

In a **risk assessment**, the **hazards** of doing an experiment are identified. A hazard is something that could cause harm. Then ways of reducing the **risk** (chance) of a hazard causing harm are considered.

During crystallisation, the risks from spitting can be reduced by wearing eye protection, removing the Bunsen burner before the solution is completely dry and/or using steam to heat the evaporating basin gently

Knowledge Organiser: CC1 & CC2 States of Matter (3 of 4)

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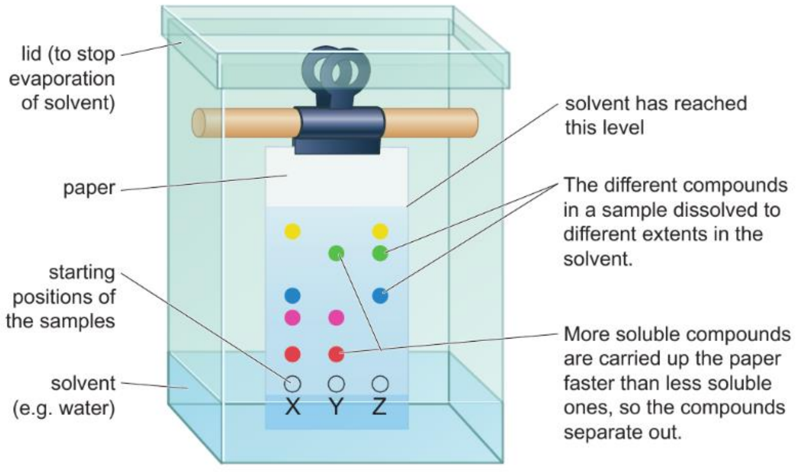
Paper chromatography

Paper **chromatography** is used to separate mixtures of **soluble** substances. These are often coloured substances such as food colourings, inks, dyes or plant pigments.



B paper chromatography

Interpreting a chromatogram

Separation by chromatography produces a **chromatogram**.
A paper chromatogram can be used to distinguish between **pure** and impure substances:
•a pure substance produces one spot on the chromatogram
•an impure substance produces two or more spots
A paper chromatogram can also be used to identify substances by comparing them with known substances. Two substances are likely to be the same if:
•they produce the same number of spots, and these match in colour
•the spots travel the same distance up the paper (have the same R_f value)

Calculating R_f Values

The **R_f value** is the distance the compound has risen divided by the distance the solvent has risen. Both measurements are made from the starting positions of the samples on the paper.

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

The R_f value of a particular compound does not change if the chromatography conditions used remain the same.

Worked example

In diagram B, the pink spots have moved 4 cm and the solvent has moved 10 cm along the paper. Calculate the R_f value of this pink compound:

$$R_f = \frac{4}{10} = 0.4$$

A compound never rises as fast as the solvent, so R_f values are always less than 1. If you calculate an R_f value bigger than 1, you've made a mistake.

Paper chromatography can be used to:

- distinguish between pure and impure substances
- identify substances by comparing the pattern on the chromatogram with the patterns formed by known substances
- identify substances by calculating their R_f values.

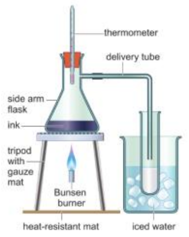
Real life uses of chromatography:

Pharmaceutical Company: to determine the amount of chemical found in a new product.
Environmental Agency: to determine the levels of pollutants in the water supply.
Law Enforcement: to compare samples found at a crime scene to samples from suspects.

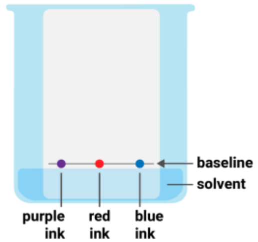
Chromatography can be used to help identify substances at crime scenes.

Core Practical: Investigating Ink

Ink is a mixture of coloured substances dissolved in a liquid solvent. Ink that appears to be a single colour, such as black, may contain two or more substances with different colours. Permanent inks do not run if the paper becomes wet, a useful property if you drop your homework in a puddle. Washable inks separate into their different colours if the paper gets wet, but may be removed if spilt on clothing.



separating ink using simple distillation



Method

Simple distillation

Wear eye protection.

- **A** Set up your apparatus so that the ink is in a flask, and its vapours can be led away to be condensed. Diagram B shows some typical apparatus but yours may be different.
- **B** Heat the flask of ink using a Bunsen burner, making sure the ink simmers gently and does not boil over into the delivery tube.
- **C** Continue heating until you have collected a few cm^3 of distillate (distilled solvent).
- **D** Note the maximum temperature obtained.

Paper chromatography

- **E** Draw a pencil line on a piece of chromatography paper, about 2 cm from the bottom.
- **F** Add a small spot of ink to the pencil line.
- **G** Add water to a container to a depth of about 1 cm.
- **H** Place the paper into the container. Make sure the paper is supported so that it does not slump into the water when it becomes damp. Allow the water to travel through the paper.
- **I** Take the paper out before the water reaches the top. Immediately mark the position of the solvent front using a pencil, then leave the paper to dry.
- **J** Measure the distance travelled by the water from the pencil line, and the distances travelled by each coloured substance.
- **K** Calculate the R_f value for each coloured substance.

Knowledge Organiser: CC1 & CC2 States of Matter (4 of 4)

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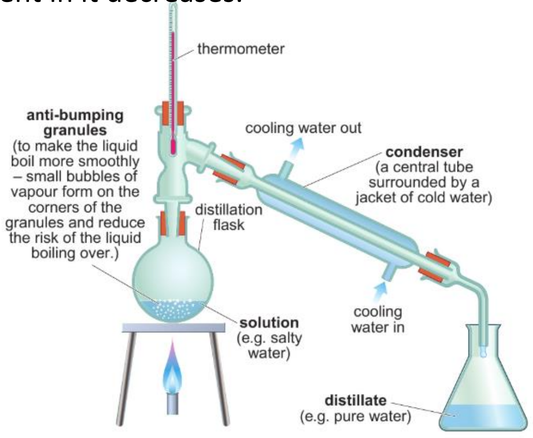
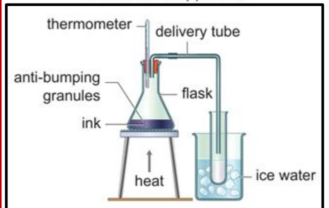
Simple distillation

Simple distillation is used to separate a solvent from a solution. It is useful for producing water from salt solution.
Simple distillation works because the dissolved solute has a much higher boiling point than the solvent. When the solution is heated, solvent vapour evaporates from the solution. The gas moves away and is cooled and condensed. The remaining solution becomes more concentrated in solute as the amount of solvent in it decreases.



C distillation apparatus

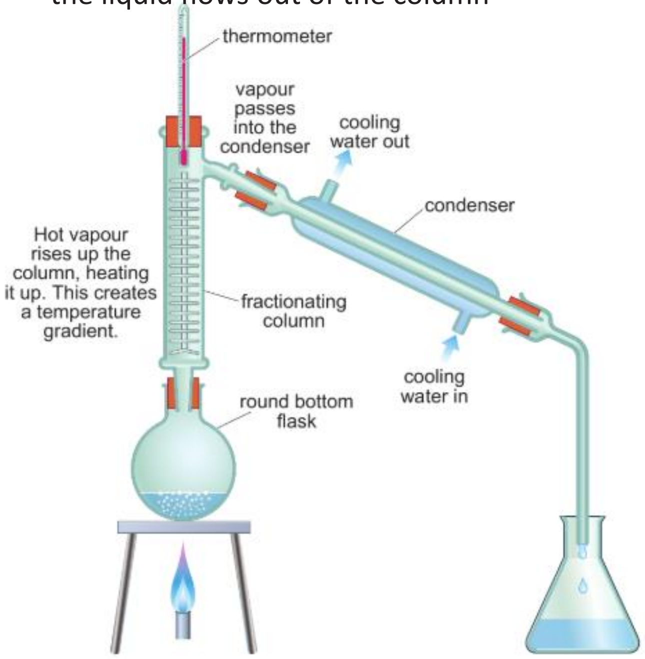


a simple still

Fractional distillation

Fractional distillation is used to separate different liquids from a mixture of liquids. It is useful for separating ethanol from a mixture of ethanol and water, and for separating different fractions from crude oil.
Fractional distillation works because the different liquids have different boiling points. When the mixture is heated:

- vapours rise through a column which is hot at the bottom, and cold at the top
- vapours condense when they reach a part of the column that is below the temperature of their boiling point
- the liquid flows out of the column



D distillation apparatus with a fractionating column

Purifying sea water

Water is separated from dissolved salts using simple distillation. A lot of energy is needed and this method is not suitable for producing large volumes of drinking water.

Water for chemical analysis.

Chemical analysis involves using chemical reactions or sensitive machines to identify and measure the substances in a sample. The water used for chemical analysis should not contain any dissolves salts, otherwise, incorrect results will be obtained. Tap water contains small amounts of dissolved salts, which may react and hide the correct results leading to incorrect conclusions.

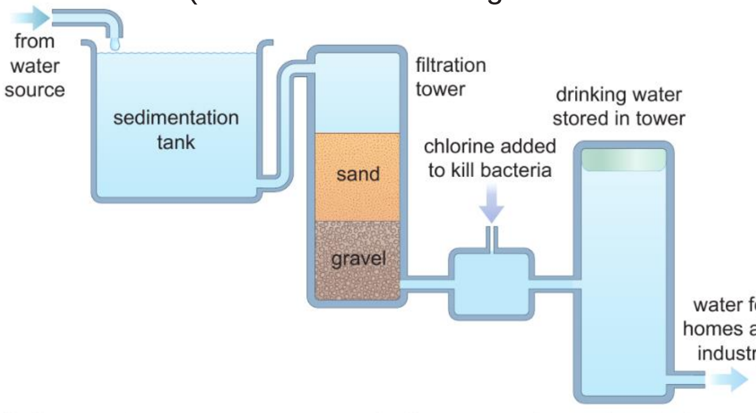
Water for drinking

In the UK, the water we drink comes from rivers, lakes or aquifers. These sources contain:

- Objects such as leaves and twigs
- Small insoluble particles such as grit and silt
- Soluble substances, including salts, pesticides and fertilisers
- Bacteria and other microorganisms. That may be harmful to health.

Different steps are needed to deal with these impurities.

1. Screening using a sieve
2. Sedimentation (small particles allowed to settle out)
3. Filtration
4. Chlorination (chlorine kills microorganisms in treated water)



D These are the main stages in treating fresh water to make it safe to drink.

Knowledge Organiser: CC3 Atomic Structure & CC4 The Periodic Table (1 of 2)

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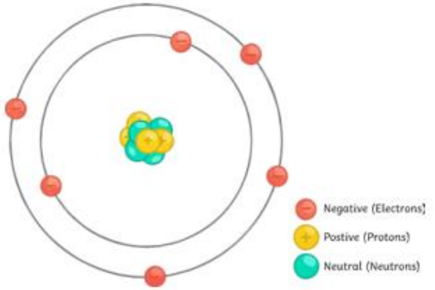
Atomic theory

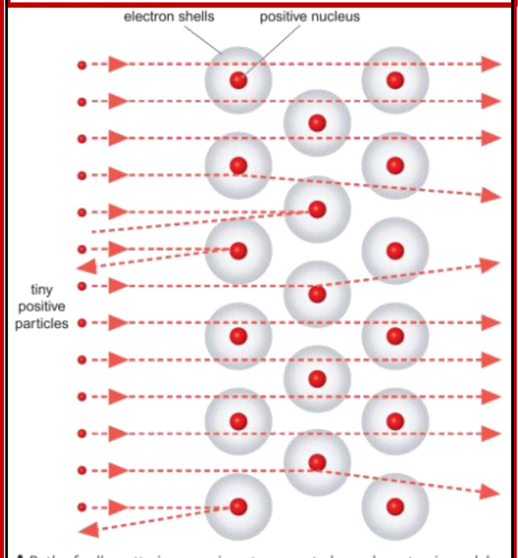
- all matter is made up of tiny particles called **atoms**
- atoms are tiny, hard spheres that cannot be broken down into smaller parts
- atoms cannot be created or destroyed
- the atoms in an **element** are all identical (but each element has its own type of atom).

Electronic Structure

Electrons are found in shells. A maximum of two in the most inner shell, then eight in the 2nd and 3rd shell. The inner shell is filled first, then the 2nd then the 3rd shell.



In 1909, Ernest Rutherford (1871–1937) was working with others to investigate the structure of atoms. In one experiment, tiny positive particles were fired at a thin gold foil. To everyone's surprise most of the particles passed straight through the gold foil, with a few being deflected and a very small number bouncing back. Rutherford explained this by suggesting that atoms are mostly empty space, with a small positive central nucleus that contains most of the mass



A Rutherford's scattering experiments suggested a nuclear atomic model.

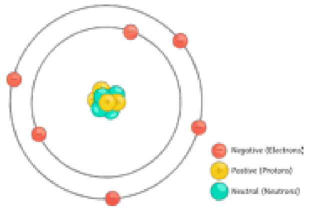
History of the atom

Scientist	Time	Discovery
John Dalton	start of 19th century	Atoms were first described as solid spheres.
JJ Thomson	1897	Plum pudding model – the atom is a ball of charge with electrons scattered.
Ernest Rutherford	1909	Alpha scattering experiment – mass concentrated at the centre; the nucleus is charged. Most of the mass is in the nucleus. Most atoms are empty space.
Niels Bohr	around 1911	Electrons are in shells orbiting the nucleus.
James Chadwick	around 1940	Discovered that there are neutrons in the nucleus.

Atoms

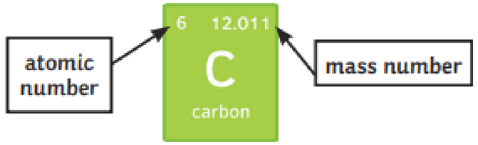
Contained in the nucleus are the **protons** and **neutrons**. Moving around the nucleus are the **electron** shells. They are negatively charged.

Particle	Relative Mass	Charge
proton	1	+1
neutron	1	0
electron	Very small	-1

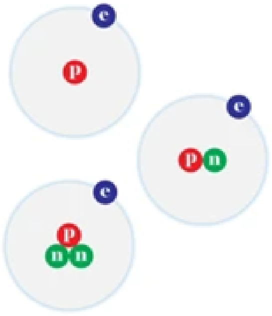


Overall, atoms have no charge; they have the same number of protons as electrons. An ion is a charged particle - it does not have an equal number of protons to electrons.

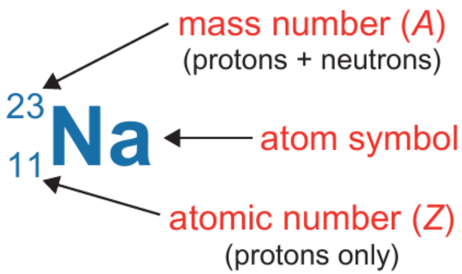
Atomic Number and Mass Number



An isotope is an element with the same number of protons but a different number of neutrons.
They have the same atomic number but different mass number.



Isotope	Protons	Electrons	Neutrons
$^{1}_{1}H$	1	1	1 - 1 = 0
$^{2}_{1}H$	1	1	2 - 1 = 1
$^{3}_{1}H$	1	1	3 - 1 = 2



The mass of an electron is described as 'negligible' – it is so small that it can be ignored. This explains why the nucleus of any atom contains nearly all its mass. For this reason the total number of protons and neutrons in an atom is called its **mass number**.

Knowledge Organiser: CC3 Atomic Structure & CC4 The Periodic Table (2 of 2)

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In the early 1800s, elements were arranged by atomic mass. The periodic table was not complete because some of the elements had not been found. Some elements were put in the wrong group.

Dimitri Mendeleev (1869) left gaps in the periodic table. He put them in order of **atomic mass**. The gaps show that he believed there was some undiscovered elements. He was right! Once found, they fitted in the pattern.

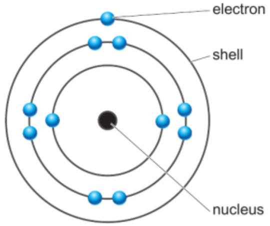
The Modern Periodic Table

Elements are in order of **atomic mass/proton number**. It shows where the metals and non-metals are. **Metals** are on the **left** and **non-metals** on the **right**. The **columns** show the **groups**. The **group number** shows the number of **electrons** in the **outer shell**. The rows are **periods** – each period shows another full shell of electrons.

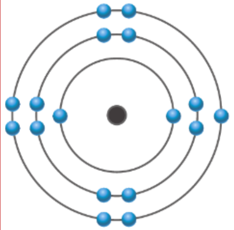
The periodic table can be used to predict the reactivity of elements.

Electronic configuration

In an atom, electrons occupy **electron shells** arranged around the nucleus. The shells can be modelled in diagrams as circles, with the electrons drawn as dots or crosses on each circle. The way in which an atom's electrons are arranged is called its **electronic configuration**.



The electronic configuration for sodium is 2.8.1

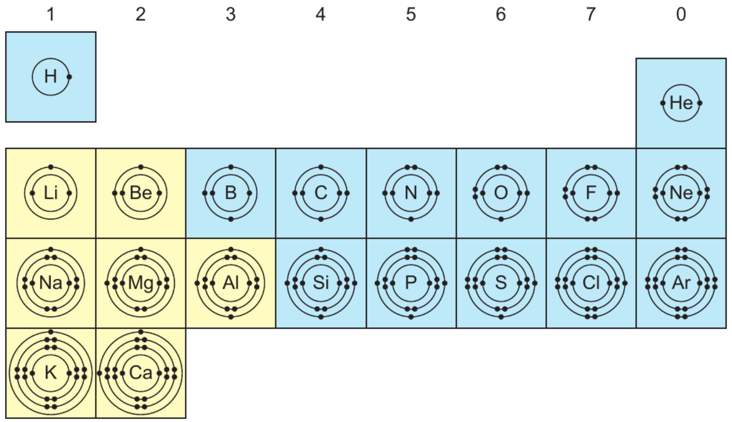


The electronic configuration for chlorine is 2.8.8

Connections with the periodic table

Diagram D shows the electronic configurations for the first 20 elements in the periodic table. The electronic configuration of an element is related to its position:

- the number of occupied shells is equal to the period number
- the number of electrons in the outer shell is equal to the group number (except for group 0 elements, which all have full outer shells).



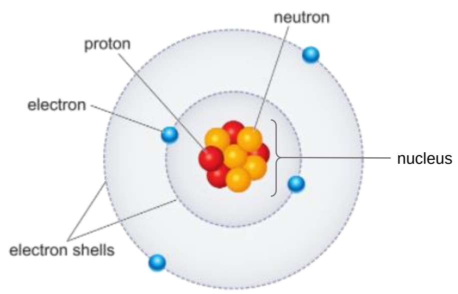
D These are the electronic configurations of the first 20 elements.

Unit glossary

atom	Atoms are small particles from which all substances are made. They are the smallest neutral part of an element that can take part in chemical reactions.
atomic number	The number of protons in the nucleus of an atom (symbol Z). Also known as the proton number.
chemical property	How a substance reacts with other substances.
electronic configuration	The arrangement of electrons in shells around the nucleus of an atom.
element	A simple substance made up of only one type of atom.
group	A vertical column of elements in the periodic table. Elements in the same group generally have similar properties.
relative charge	The electric charge of a subatomic particle compared to the charge on a proton.
relative mass	The mass of a subatomic particle compared to the mass of a proton.
subatomic particles	The smaller particles that make up atoms – protons, neutrons and electrons.
mass number	The total number of protons and neutrons in the nucleus of an atom (symbol A). Also known as the nucleon number.
isotopes	Atoms of an element with the same number of protons (atomic number) but different mass numbers due to different numbers of neutrons.
nuclear fission	The reaction in which the nucleus of a large atom, such as uranium, splits into two smaller nuclei.
relative atomic mass (RAM)	The mean mass of an atom relative to the mass of an atom of carbon-12, which is assigned a mass of 12. The RAM of an element is the mean relative mass of the isotopes in the element.
periodic table	An ordered list of all known elements.
physical property	A description of how a material behaves and responds to forces and energy. Hardness is a physical property.
prediction	What you think will happen in an experiment and why you think this.
relative atomic mass, Ar	The mean mass of an atom relative to the mass of one-twelfth of an atom of carbon-12, which is assigned a mass of 12. The Ar of an element is the mean relative mass of the isotopes in the element.

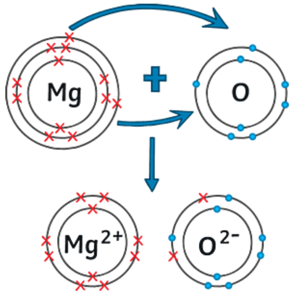
Knowledge Organiser: CC5/CC6/CC7 Ionic Bonding, Covalent Bonding & Types of Substance (1 of 4)

Atoms



Ionic compounds have high melting and boiling points

The electrostatic forces of attraction between oppositely charged ions are strong. A lot of energy is needed to overcome these forces in order to separate the ions and cause the substance to melt. This is why ionic compounds must be heated to high temperatures before they change state. They have high melting and boiling points.
Some ions have more than one charge such as Mg^{2+} and O^{2-}. These highly charged ions will attract other ions more strongly than ions with 1 charge. More energy will be needed to overcome the electrostatic forces of attraction and so the melting points will be higher.



Ions

Ions are charged particles. They can be either positively or negatively charged, for example Na^+ or Cl^-.

Atoms are neutral because they have an equal number of protons (positively charged subatomic particles) and electrons (negatively changed subatomic particles).

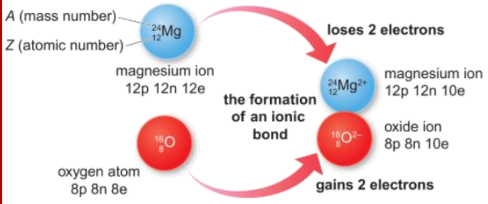
When an atom loses or gains electrons it becomes an ion.

Metals lose electrons to become positively charged ions called cations. Cations have more protons than electrons.

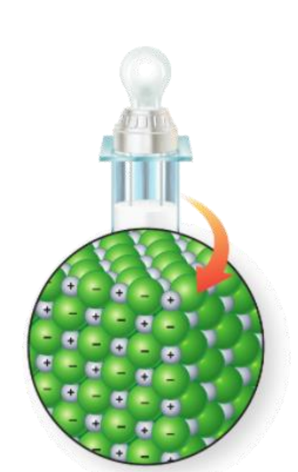
Non-metals gain electrons to become negatively charged ions called anions. Anions have more electrons than protons.

Charge of ions

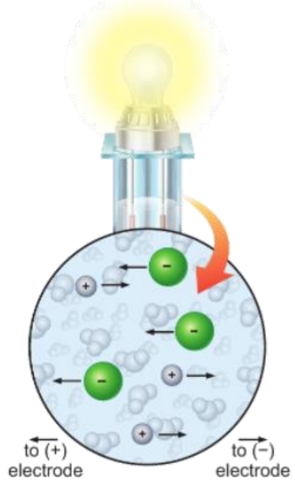
The charge of the ions formed by an atom depends on the elements position in the periodic table and its number of electrons. For example, magnesium is in group 2 which means It has 2 electrons in its outer shell. It needs to lose 2 electrons to be stable, therefore it forms an Mg^{2+} ion.



Ionic compounds conduct electricity when molten or dissolved



Positive and negative ions fixed in a solid do not conduct a current.



In solution, positive and negative ions move and conduct a current.

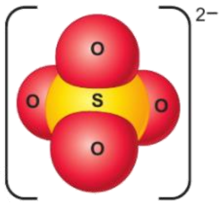
Ionic compounds conduct electricity when they are molten or dissolved in water.
They do not conduct electricity when they are in the solid state.
When an ionic compounds conduct electricity, it is the charged ions that carry the current.
Ionic compounds do not conduct electricity in the solid state as the ions and not free to move from place to place.
When the ionic compound is molten or an aqueous solution, the ions are free to move and so it does conduct electricity.
Most ionic compounds are **soluble** in water and form an aqueous solution.

Bonds

Bonds are **forces of attraction** that hold atoms together. When bonds form between atoms, energy is released from the atoms, making them more stable (less reactive).
The most stable atoms are those of the noble gases because they have a full outer shell of electrons.

Polyatomic ions

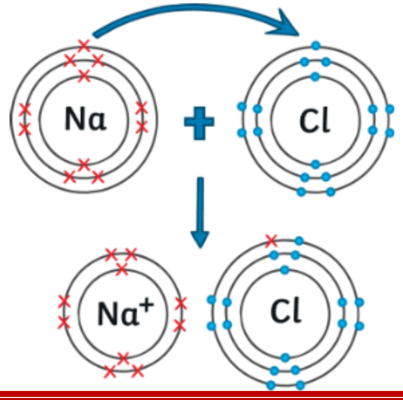
Some ions contain more than one atom. For example, the sulphate ion contains one sulphur atom bonded to four oxygen atoms with two added electrons. An ion name ending in '-ate' or '-ite' shows that the ion contains oxygen as well as another element.



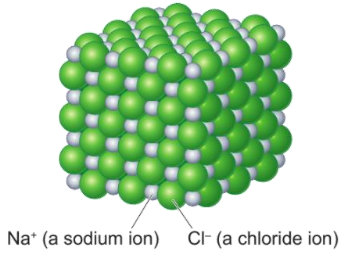
The formula of a sulfate ion is SO_4^{2-}.

Ionic Bonds

Atoms are more stable when they have a full outer shell of electrons like the noble gases. This can be achieved by the transfer of electrons between atoms, forming charged particles (ions)
Ionic bonding occurs between a **metal** and **non-metal**.
Metals lose electrons to become positively charged cations.
Non-metals gain electrons to become negatively charged anions.
Opposite charges are attracted by electrostatic force which hold the oppositely charged ions together, and form an ionic bond between them.



Ionic lattices

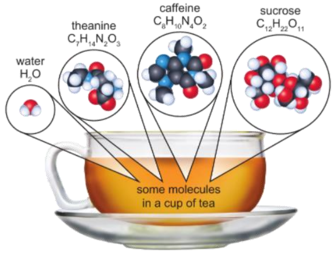


Ionic compounds held together by strong and a pro static forces of Attraction between oppositely charged ions. These strong ionic bonds allow billions of ions to be packed together in a regular repeating arrangement called a lattice structure. Ionic compounds will open from crystals when solid because of their regular lattice structure

Knowledge Organiser: CC5/CC6/CC7 Ionic Bonding, Covalent Bonding & Types of Substance (2 of 4)

Covalent bonds

Molecular substances contain groups of atoms that are held together by strong bonds called **covalent bonds**. The number of atoms of each element bonded together in a simple **molecule** is shown by its **molecular formula.**

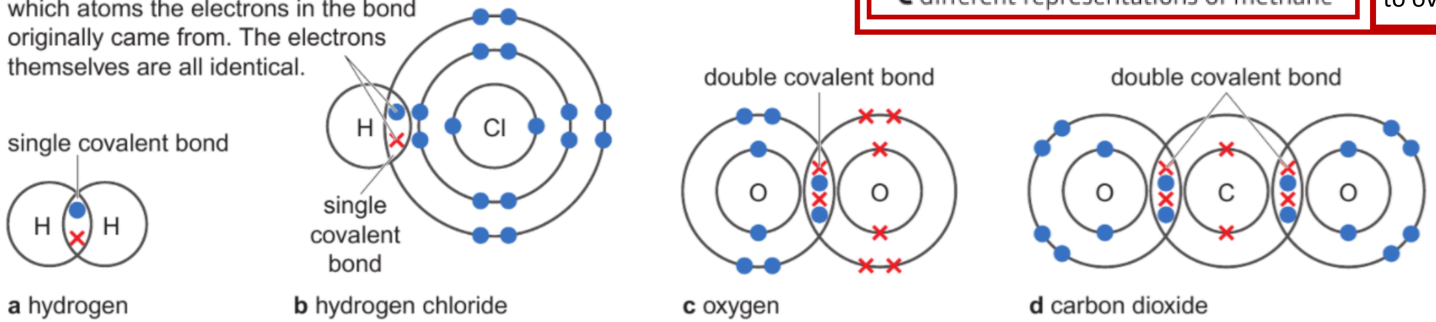


Most of the molecules in a cup of tea are water, which has the molecular formula H_2O.

Covalent bonds are usually formed between non-metal atoms and are produced by sharing pairs of electrons. By forming the bond the atoms become more stable, because they can use the shared electrons to complete their **outer electron shells**. The reason why noble gases are so stable is because they have full outer electron shells.

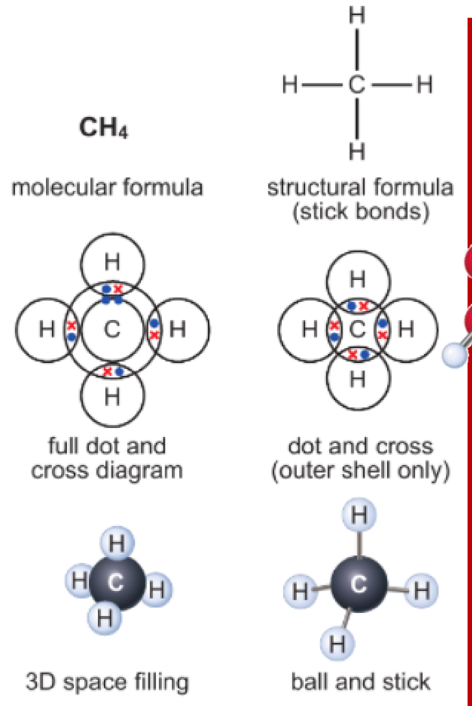
The **dot and cross diagrams** in diagram B show how covalent bonds are formed. Counting the shared electrons, each atom now has a complete outer shell of electrons. Sometimes atoms share more than one pair of electrons to fill their outer shells. In oxygen and carbon dioxide the atoms share two pairs of electrons, to form **double bonds**.

Dots show electrons from one atom and crosses show electrons from the other atom. This allows us to see which atoms the electrons in the bond originally came from. The electrons themselves are all identical.

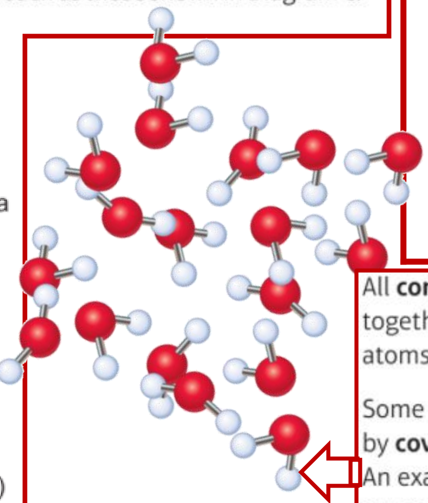


B Dot and cross diagrams can be used to explain how covalent bonds are formed.

The atoms in molecules are held together by strong **electrostatic forces** of attraction between the positive nuclei and the negative electrons in the bonded atoms. There are also some forces of attraction *between* molecules but these are very weak in comparison. Atoms and molecules are extremely small, about 10^{-10} metres across, so we represent them using models, such as those shown in Diagram C.



C different representations of methane



Working out molecular formulae

The numbers of covalent bonds formed by atoms of different elements are shown in table D. This is called the **valency** of the element. It is the same as the number of electrons needed to obtain a complete outer shell.

Group number	Examples	Outer electrons	Bonds formed	Valency
4	C and Si	4	4	4
5	N and P	5	3	3
6	O and S	6	2	2
7	F and Cl	7	1	1

All **compounds** contain atoms of more than one **element**, chemically joined together by **bonds**. The properties of a compound are influenced by its atoms and by its type of bonding.

Some compounds exist as molecules – distinct groups of atoms joined by **covalent bonds**. They have **covalent, simple molecular structures**. An example is water. One molecule of water always contains one atom of oxygen covalently bonded to two atoms of hydrogen.

Simple molecules have low melting and boiling points

The covalent bonds in a water molecule are strong forces of attraction. However, there are also weak forces of attraction between molecules- **intermolecular forces**. Intermolecular forces hold water molecules together and must be overcome when turning liquid water into a glass. Small, simple molecules such as water often have low melting and boiling points because it doesn't take much energy to overcome the weak intermolecular forces.

Simple molecules do not conduct electricity.

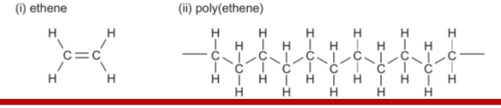
Simple molecules have no overall charge and so cannot carry an electrical current.

In a covalent bond, electrons are shared between atoms. The strong forces between the electrons and the positively charged nuclei mean that the electrons cannot flow.

Polymers

Monomers are small, simple molecules that can be joined in a chain to form a polymer.

Polymer molecules can have different lengths. Longer polymers have more intermolecular forces between them, and can also get tangled up with one another. Longer polymers have higher melting and boiling points.



Knowledge Organiser: CC5/CC6/CC7 Ionic Bonding, Covalent Bonding & Types of Substance (3 of 4)

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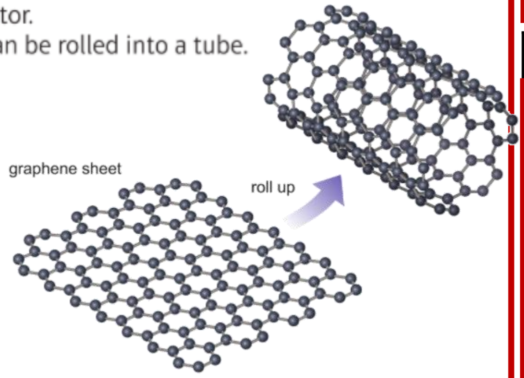
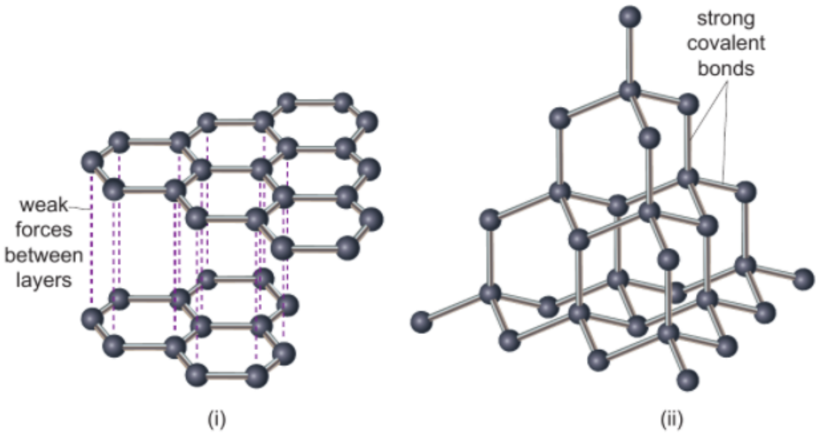
Allotropes of carbon

The element carbon can form a number of different molecules. Different structural forms of the same element are called **allotropes**. The structure and bonding in different allotropes influences their properties and uses.

Graphene

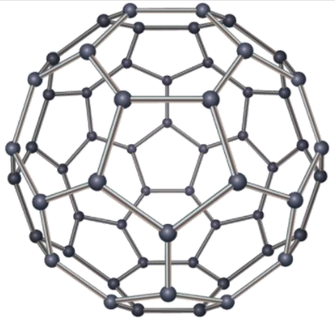
Graphene is similar to fullerenes but is not a simple molecule. It consists of a sheet of carbon atoms with no fixed formula. The sheet is just one atom thick, making it the lightest known material, but its covalent bonds make it extremely strong. It also allows free electrons to move across its surface and so is a good electrical conductor.
Graphene can be a sheet or can be rolled into a tube.





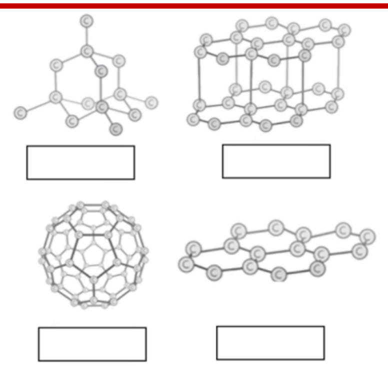
C small sections of (i) graphite and (ii) diamond to show the arrangements of atoms

Fullerenes



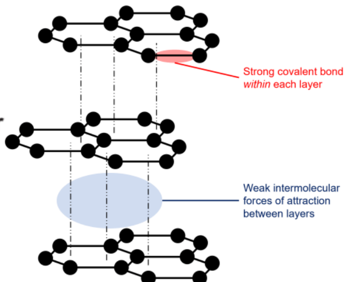
Carbon can form simple molecules called **fullerenes**, in which each carbon atom is covalently bonded to three other carbon atoms. Fullerenes are often tubular molecules (nanotubes) or spherical. An example is buckminsterfullerene (or 'bucky ball'), which has 60 carbon atoms that form a ball with the formula C_{60}.

Fullerenes have weak intermolecular forces between the molecules and so have low melting points (or sublimation points). These weak forces also make them soft and slippery. However, the molecules themselves are very strong due to their covalent bonding.



Giant structures of carbon

Diamond and graphite are two more allotropes of carbon that are not simple molecules. They are both examples of **covalent, giant molecular structures**, which have huge three-dimensional networks of carbon atoms linked by covalent bonds.



Graphite and diamond both have high melting points because of the many strong covalent bonds that need to be broken to melt the solids.

However, graphite has three covalent bonds for each carbon atom, whereas diamond has four. This gives graphite a layered structure and means that not all of its electrons are held in covalent bonds. These **delocalised electrons** are free to move and can carry an electrical current. Since graphite conducts electricity well and is cheap and not very reactive, it is used as electrodes (in electrolysis).

The sheets of carbon atoms in graphite are held together by weak forces of attraction (purple dashed lines in diagram C). These weak forces allow the layers to slide past each other, which makes graphite quite soft and useful as a **lubricant**.

Diamond is very hard because it has a rigid network of carbon atoms in a tetrahedral arrangement, joined by strong covalent bonds. This property makes diamond useful for tools to cut things. It is also an electrical insulator because it has no free charged particles.

Some key terms and definitions

anion	Negatively charged ion.
cation	Positively charged ion.
ion	Atom or group of atoms with an electrical charge.
ionic bond	Strong electrostatic force of attraction between oppositely charged ions.
covalent bond	The bond formed when a pair of electrons is shared between two atoms.
double (covalent) bond	The bond formed when two pairs of electrons are shared between the same two atoms.
element	A simple substance, made up of only one type of atom.
intermolecular force	A weak force of attraction between molecules.
polymer	A long-chain molecule made by joining many smaller molecules (monomers) together.
delocalised electron	An electron that is free to move and can carry an electrical current.
fullerene	A simple molecule in which each carbon atom is covalently bonded to three other carbon atoms
graphene	An allotrope of carbon consisting of a sheet that is one atom thick, with atoms arranged in a honeycomb shape.
lattice	An arrangement of many atoms or other particles that are bonded together in a fixed regular (grid-like) pattern.
malleable	A substance that can be hammered or rolled into shape without shattering.
metallic bonding	The type of bonding found in metals

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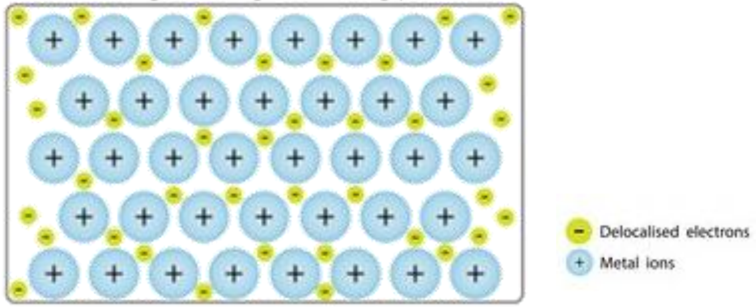
Metallic structure and bonding

The atoms in a metallic element are all the same size and are packed closely together in layers to form a giant **lattice**.

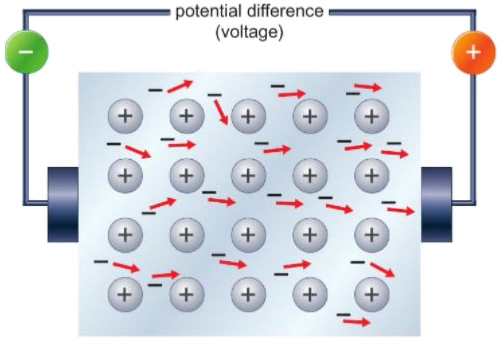
Metal atoms have one, two or three electrons in their outer shell. These outer shell electrons are lost from each atom and become free to move randomly throughout the metal. This leaves a giant lattice of positive metal ions surrounded by a 'sea' of delocalised electrons, which move randomly in all directions.

Metallic bonding is the electrostatic attraction between the positive metal ions and the negative delocalised electrons. This attraction is strong, so metals have high melting and boiling points.

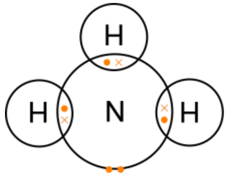
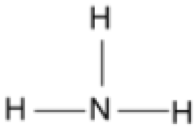
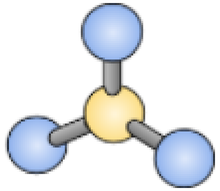


Metals conduct electricity

The delocalised electrons move randomly between the positive metal ions in all directions. When a potential difference (voltage) is applied between two points on a piece of metal, the electrons will flow towards the positive side. This flow of electrons transfers energy and forms an electrical current.



Bonding models

Dot and cross 	**Advantages** Can easily see where the electrons have come from Easy to draw **Weaknesses and limitations:** Don't show the relative sizes of the atoms Can't see the structure of the molecule i.e. how the atoms are arranged in space Suggest that the electrons in different atoms are different, when they are actually all the same
Displayed formula 	**Advantages** Quick and easy to draw (useful for large molecules) **Weaknesses and limitations:** Can't see how the atoms are arranged in space Can't see where the shared electrons have come from
3D ball and stick model 	**Advantages** They show which atoms are joined together They show the shape of the structure and the arrangement of molecules in space **Weaknesses and limitations:** difficult to draw and easily get confusing don't know where the electrons have come from Show the atoms being really far apart There are not really 'sticks' holding atoms together

Substances that conduct electricity better than others have a higher **electrical conductivity**. The electrical conductivity of the metals increases as the number of delocalised electrons increases. Each sodium ion has one positive charge, Na^+, and contributes 1 electron to the 'sea' of delocalised electrons. Each magnesium ion has two positive charges, Mg^{2+}, and contributes 2 electrons to the 'sea' of delocalised electrons, and so magnesium has a higher electrical conductivity than sodium.

Summary

Ionic

Where found: in most compounds containing metal and non-metal atoms.

Bonding: ionic bonds formed by the loss and gain of electrons to produce oppositely charged ions that attract one another.

Structure: billions of ions held together in a lattice structure.

Properties:
- high melting/boiling points
- many are soluble in water
- conduct electricity when liquid or in solution but do not when solid.

Simple molecular (covalent)

Where found: in most non-metal elements and compounds.

Bonding: covalent bonds formed when atoms share pairs of electrons.

Structure: small, distinct groups of atoms.

Properties:
- low melting/boiling points
- a few are soluble in water
- most do not conduct electricity.

Metallic

Where found: in all metals.

Bonding: metallic bonds are the electrostatic attraction between positive metal ions and negative delocalised electrons.

Structure: billions of ions held together in a giant lattice structure of positive ions in a 'sea' of negative delocalised electrons.

Properties:
- high melting/boiling points
- insoluble in water
- conduct electricity when solid or liquid.

Giant covalent

Where found: in a few non-metal elements and some compounds of non-metals.

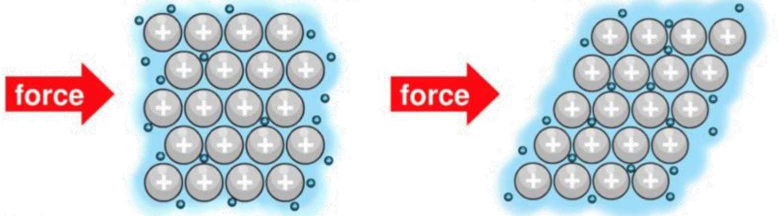
Bonding: covalent bonds formed when atoms share pairs of electrons.

Structure: billions of atoms held together in a lattice structure.

Properties:
- high melting/boiling points
- insoluble in water
- most do not conduct electricity (except in carbon as graphite).

Metals are malleable

Metals are **malleable**. This means that they can be hammered or rolled into shape without shattering. When you hit a metal, the layers of ions slide over each other. The 'sea' of electrons holds the ions together and so the metal changes shape instead of breaking.



Knowledge Organiser: CC8 Acids and Alkalis (1 of 2)

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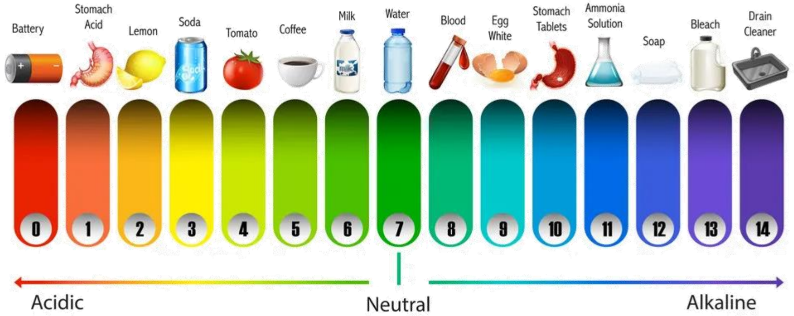
Acids and alkalis

- All aqueous solutions are either acidic, alkaline or neutral.
- When an acid is dissolved in water we get an acidic solution.
- When a base dissolves in water it is an alkali and makes an alkaline solution.
- If a solution is neither acidic nor alkaline it is neutral. Pure water is neutral.
- Some solutions (including neutral) can be hazardous, indicated by international hazard symbols.
- The acidity and alkalinity of a solution is measured on a pH scale.
- pH <7 = acidic
- pH 7 = neutral
- pH >7 = alkaline

pH scale



Neutralisation

acid + **alkali** → **salt** + **water**

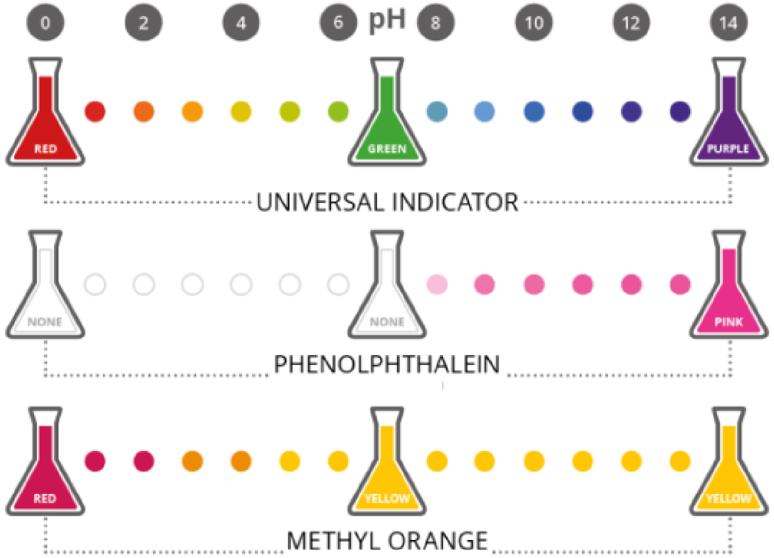
For example:

sodium hydroxide + hydrochloric acid → sodium chloride + water

copper oxide + sulfuric acid → copper sulfate + water

Indicators

- Indicators are substances that change colour when they are added to acidic or alkaline solutions.



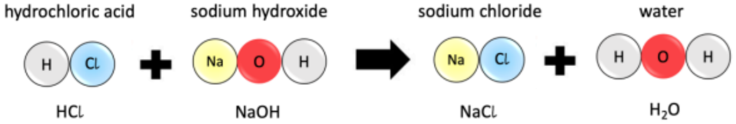
Neutralisation

A chemical reaction happens if you mix together an acid and a base. The reaction is called neutralisation. A neutral solution is made if you add just the right amount of acid and base together.

Naming salts

There are two parts to a salt name: The first word is a metal, taken from the alkali. The second word depends on the acid.

Acid used	Salt formed
Hydrochloric acid	Chloride
Nitric acid	Nitrate
Sulphuric acid	Sulphate

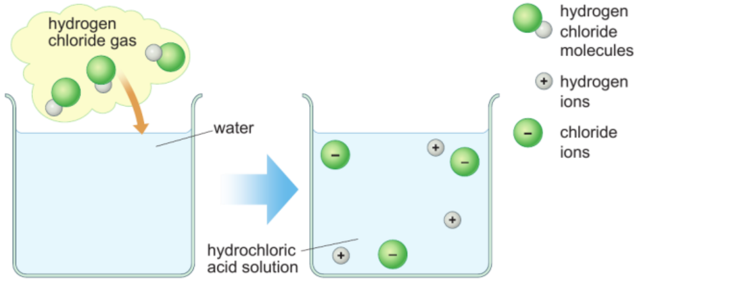


potassium hydroxide + **nitric** acid → *potassium* **nitrate** + water

sodium hydroxide + **sulfuric** acid → *sodium* **sulfate** + water

Acids

- Acids are a group of chemicals with similar properties. For example, they all taste sour. Acids have a pH of less than 7
- Substances with a pH of 0-3 are classified as strong acids. They turn Universal Indicator red. Weak acids have a pH of of 4-6, they turn Universal Indicator orange or yellow.
- Lemon juice, vinegar and milk are all acids.
- Common laboratory acids include hydrochloric acid (HCl), sulfuric acid, (H_2SO_4), nitric acid (HNO_3).
- Acids produce an excess of hydrogen ions (H^+) when they dissolve in water.

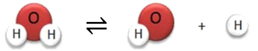


Bases and Alkalis

- Bases are chemically opposite to acids. When a **base** is dissolved in water, we call it an **alkali**. Alkalis have a pH of more than 7.
- Substances with a pH of 11-14 are classified as strong alkalis, they turn Universal Indicator purple. Weak alkalis have a pH of 8-10, they turn Universal Indicator dark green or blue.
- Alkalis all have similar properties, for example they feel soapy.
- Baking powder, soap and bleach are all alkalis.
- Common laboratory alkalis include sodium hydroxide (NaOH), potassium hydroxide (KOH) and ammonium hydroxide (NH_4OH).
- Alkalis produce excess hydroxide ions (OH^-) ions in water.

Neutral

- In pure water, there are always equal numbers of H^+ and OH^- , and the pH is defined to be neutral. In a neutralisation reaction, the H^+ ions from the acid and OH^- ions from the base react to form water.



Knowledge Organiser: CC8 Acids and Alkalis (2 of 2)

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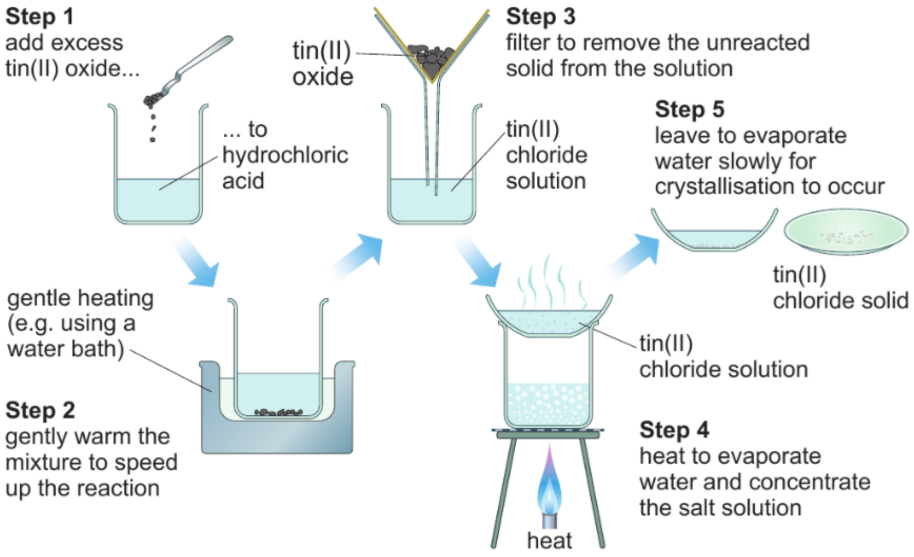
Preparing soluble salts

- The reaction between an acid and an insoluble metal oxide can be used to prepare samples of different soluble salts.



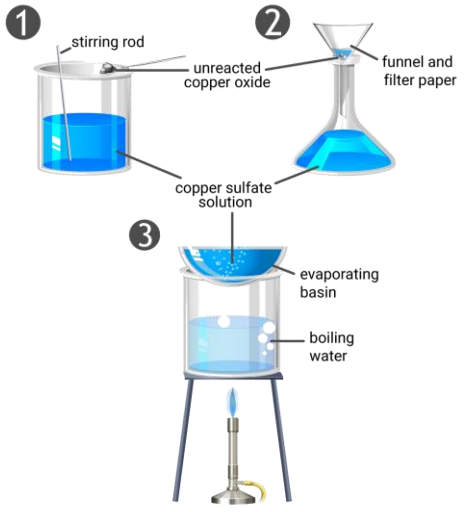
$SnO(s) + 2HCl(aq) \rightarrow SnCl_2(aq) + H_2O(l)$

tin(II) oxide + hydrochloric acid → tin(II) chloride + water

Balancing equations

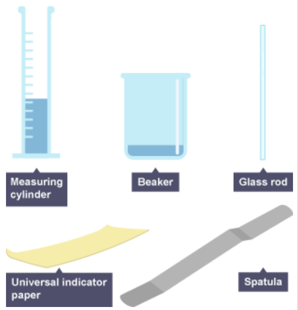
Check to see if there are equal numbers of atoms of each element on both sides. Here there aren't.	$N_2 + H_2 \rightarrow NH_3$
There are two nitrogen atoms on the left but only one on the right, so a big 2 is added to the left of the NH_3.	$N_2 + H_2 \rightarrow 2NH_3$
There are two hydrogen atoms on the left but (2 × 3) = 6 on the right, so a big 3 is placed in front of the H_2.	$N_2 + 3H_2 \rightarrow 2NH_3$
Check to see if there are equal numbers of each element of both sides.	2x N 6x H atoms on both sides ✓
Add the state symbols if they are requested.	$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

Core practical - making copper sulfate crystals



Core practical – investigating neutralisation

1. Use a measuring cylinder to add dilute hydrochloric acid to a beaker.
2. Dip a clean glass rod into the contents of the beaker. Use it to transfer a drop of liquid to a piece of universal indicator paper on a white tile. Wait 30 seconds, then match the colour to a pH colour chart. Record the estimated pH.
3. Add a level spatula of calcium hydroxide powder to the beaker.
4. Stir thoroughly, then estimate and record the pH of the mixture (as in step 2).
5. Repeat steps 3 and 4 until there are no more changes in pH.

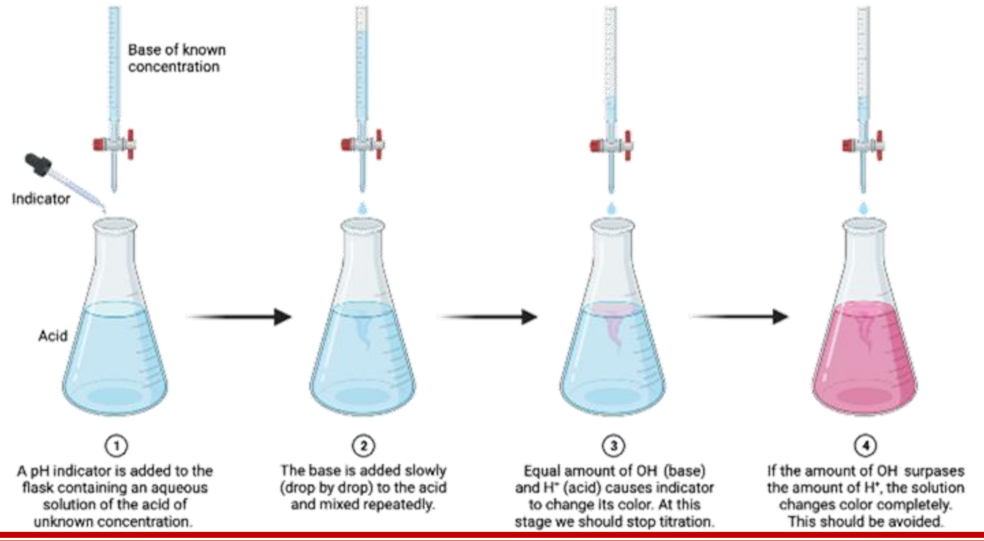


Titration

In a titration, acid is added from a burette to a fixed volume of alkali in a conical flask.

To make a pure, dry salt:

1. Carry out a titration
2. Note the exact volume of acid needed to neutralise the alkali
3. Use the burette to add the correct volume of acid without the indicator
4. Evaporate the water from the solution formed



Reaction of metals and metal carbonates with acid

Metal + acid → salt + hydrogen

Metal carbonate + acid → salt + water + carbon dioxide

To test for hydrogen, place a lighted splint in the test tube. A squeaky pop will be heard.

To test for carbon dioxide, bubble the gas through limewater. Limewater turns milky if carbon dioxide is present.

Precipitation

A precipitation reaction is one in which soluble substance in solutions case an insoluble precipitate to form.

All common sodium, potassium and ammonium salts and all nitrates are soluble. Most chlorides are soluble except silver and lead chlorides. Most sulphates are soluble except lead, barium, calcium sulphates are soluble. Most hydroxides and carbonates are insoluble except sodium, potassium and ammonium carbonates and hydroxides.

Knowledge Organiser: CC10/CC11/CC12 Electrolytic processes, Obtaining and using Metals, Reversible reactions and equilibria (1 of 3)

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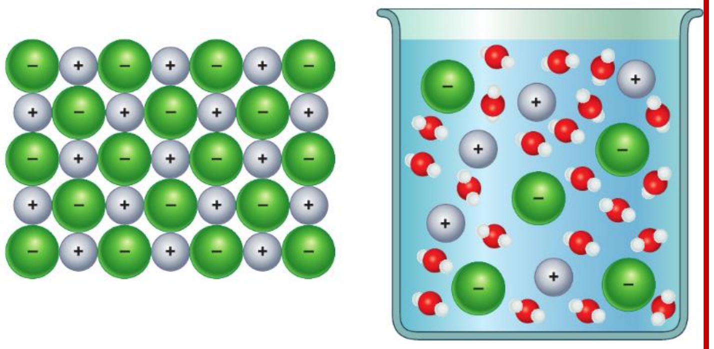
Electrolysis is used to break apart a compound using electricity.
The ionic substance with freely moving ions is called an electrolyte.
Cations are positive ions that are attracted to the negative cathode.
Anions are negative ions that are attracted to the positive anode.



A (a) The ions cannot move in the lattice structure of solid sodium chloride. (b) The ions can move when sodium chloride is dissolved in water.

HIGHER ONLY
At the anode, negative ions lose electrons (OXIDATION). At the cathode, positive ions gain electrons (REDUCTION)

Oxidation **I**s the **L**oss of electrons.

Reduction **I**s the **G**ain of electrons.

You can remember these by: OIL RIG.

These changes are represented by **half equations**, which show the change at each electrode.

Cathode reaction: $Zn^{2+} + 2e \rightarrow Zn$ reduction

Anode reaction: $2Cl^- \rightarrow Cl_2 + 2e$ oxidation

ReduCtion takes place at the Cathode.

OxidAtion takes place at the Anode.

Note that two Cl^- ions are needed to form one chlorine molecule.

Method

Using copper electrodes

Wear eye protection.

A Select two clean pieces of copper foil. Label one 'anode' and the other 'cathode'. Measure and record the masses of the two electrodes.

B Set up an electrolysis circuit as shown in diagram B.

C Turn on the power and adjust the variable resistor to give a current of about 0.2 A. Record the current and adjust the variable resistor to keep it constant. Leave the power on for 20 minutes.

D Turn off the power and remove the electrodes from the beaker. Gently wash the electrodes with distilled water then dip them into propanone. Lift the electrodes out and gently shake off the propanone. Allow the remainder of the propanone to evaporate.

E Measure and record the masses of the dry electrodes.

F Repeat the experiment using currents of 0.3 A, 0.4 A and 0.5 A.

During electrolysis molten or dissolved salts are used with inert (unreactive) electrodes. During electrolysis ions are discharged as atoms or molecules at the electrodes. The metal is formed at the cathode and the non-metal at the anode.

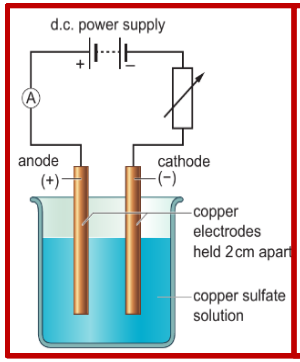
Core Practical: Electrolysis of copper sulfate solution. This practical investigates the effect that changing the current has on the mass of product formed. This practical begins with copper electrodes and with inert graphite electrodes.

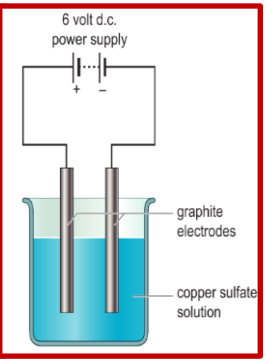
Ions attracted to electrode	Electrode reaction
H^+ and ions from an unreactive metal e.g. Cu^{2+} or Ag^+	Metal ions gain electrons so copper or silver is formed at the cathode.
H^+ and ions from a reactive metal e.g. Na^+ or Mg^{2+}	H^+ ions gain electrons so hydrogen gas is formed at the cathode.
OH^- and halide ions i.e. Cl^-, Br^- and I^-	Halide ions lose electrons so Cl_2, Br_2 or I_2 is formed at the anode.
OH^- and SO_4^{2-} or NO_3^-	Hydroxide ions lose electrons so oxygen is formed at the anode.

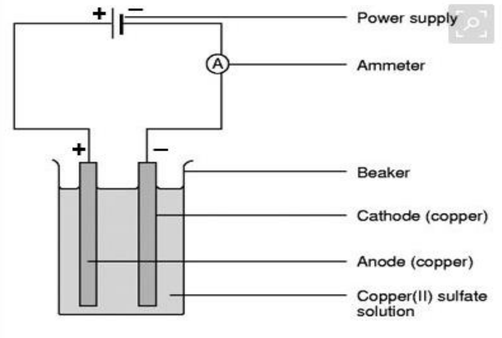
H

Cathode reaction: $Pb^{2+}(l) + 2e \rightarrow Pb(l)$

Anode reaction: $2Br^-(l) \rightarrow Br_2(g) + 2e$







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Metal	Reaction with water	Reaction with dilute acid	Tendency of metal atoms to form cations
potassium	react with cold water to form hydrogen and a metal hydroxide	react violently	increasing ability of metal atoms to form positive ions
sodium			
calcium		react to form hydrogen and a salt solution	
magnesium	react very slowly, if at all, with cold water but react with steam to form hydrogen and a metal oxide		
aluminium			
zinc			
iron			
copper	do not react with cold water or steam	do not react	
silver			
gold			

You can use the reactivity series to predict whether reactions will take place. Displacement reactions are when a more reactive metal will displace (kick out) a less reactive metal from its compound.

$$Zn(s) + CuSO_4(aq) \rightarrow Cu(s) + ZnSO_4(aq)$$

This is a **displacement reaction**. The zinc has displaced the copper.

H

Displacement reactions are also redox reactions. The reaction between zinc and copper sulfate can be written as an ionic equation:

$$Zn + Cu^{2+} \rightarrow Cu + Zn^{2+}$$

The sulfate ions have been left out as they do not change and are called **spectator ions**. The zinc atoms lose electrons to form zinc ions. This can be shown in a **half equation**. 2e represents the two electrons.

$Zn \rightarrow Zn^{2+} + 2e$ This is **oxidation** – the loss of electrons.

The copper ions gain electrons to form copper atoms:

$Cu^{2+} + 2e \rightarrow Cu$ This is **reduction** – the gain of electrons.

A reaction in which one substance is oxidised and another is reduced is called a **redox reaction**.

Very unreactive metals e.g gold are found naturally in their native state. More reactive metals are found reacted to other metals. They need to be extracted from these compounds.

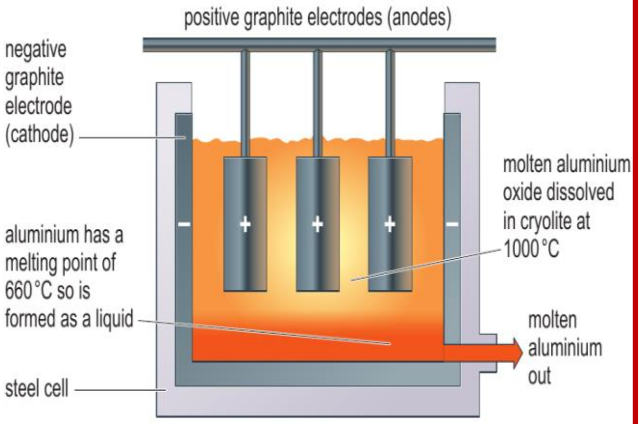
An ore is a rock that contains enough of a compound to extract a metal for profit. The method used for extraction depends on how reactive the metal is

increasing reactivity

Metal	Method of extraction
potassium	electrolysis of a molten compound
sodium	
calcium	
magnesium	
aluminium	
(carbon)	
zinc	heat an ore with carbon
iron	
copper	
silver	found as the uncombined element
gold	

HIGHER ONLY:
Biological methods of metal extraction include bioleaching and phytoextraction

Process	Advantages	Disadvantages
both bioleaching and phytoextraction	no harmful gases (e.g. sulfur dioxide) are produced causes less damage to the landscape than mining conserves supplies of higher grade ores	very slow
bioleaching	does not require high temperatures	toxic substances and sulfuric acid can be produced by the process, and damage the environment
phytoextraction	can extract metals from contaminated soils	more expensive than mining some ores growing plants is dependent on weather conditions



B the electrolysis cell used to extract aluminium

Corrosion happens when a metal reacts with oxygen, making the metal weaker over time. The metal gains oxygen so is oxidized. The corrosion of iron requires water as well as oxygen is called rusting. The more reactive a metal is, the more rapidly it corrodes.

D The iron in the Angel of the North has reacted with oxygen and water.

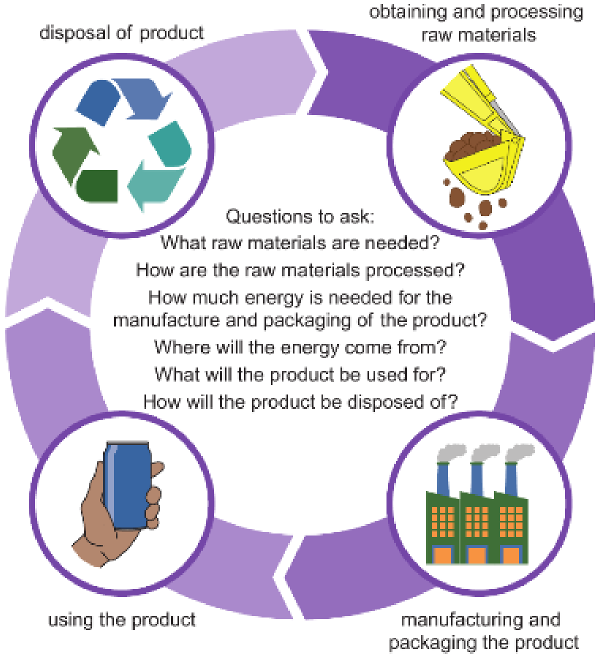
Knowledge Organiser: CC10/CC11/CC12 Electrolytic processes, Obtaining and using Metals, Reversible reactions and equilibria (3 of 3)

Recycling metals has lots of advantages

- Natural reserves of metal ores will last longer.
- The need to mine ores is reduced. Mining can damage the landscape as well as create noise and dust pollution.
- Less pollution may be produced. For example, sulfur dioxide is formed when some metals are extracted from metal sulfide ores.
- Many metals need less energy to recycle them than to extract new metal from the ore.
- Less waste metal ends up in landfill sites.

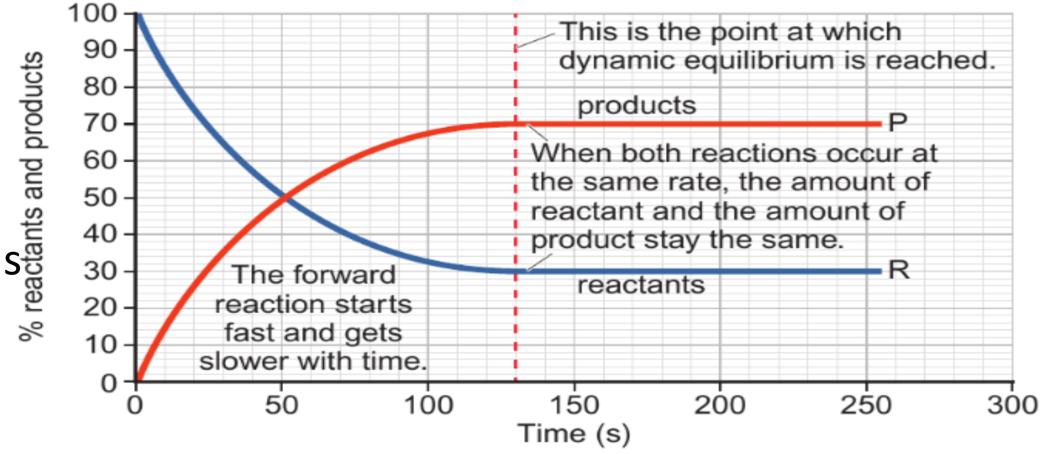
Life cycle Assessment

LCA can be carried out to work out the environmental impact of a product. The LCA helps people decide whether it is worthwhile to manufacture and recycle a product.



C stages in an LCA

Dynamic equilibrium is a reversible reaction that is still occurring (dynamic) but the substances remain in balance (equilibrium). Reversible means the forward and backward reactions occur at the same time



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Equilibrium positons can be altered by changes in temperature, pressure and concentration. In general, the equilibrium position shifts to reduce the effects of any changes to the system.

The Haber process involves a reversible reaction between nitrogen (from the air) and hydrogen (from natural gas). The conditions are at temperature of 450 oC, a pressure of 200 atmospheres and the use of an iron catalyst.

$$\underset{\text{nitrogen}}{N_2(g)} + \underset{\text{hydrogen}}{3H_2(g)} \rightleftharpoons \underset{\text{ammonia}}{2NH_3(g)}$$

Change by . . .	Equilibrium position shifts . . .
increasing temperature	in the **endothermic** direction (transferring energy from the surroundings, cooling them down)
decreasing temperature	in the **exothermic** direction (transferring energy to the surroundings, heating them up)
increasing gas pressure	in the direction that forms fewer gas molecules (as this reduces pressure)
decreasing gas pressure	in the direction that forms more gas molecules (as this increases pressure)
increasing a concentration	in the direction that uses up the substance that has been added
decreasing a concentration	in the direction that forms more of the substance that has been removed

Year 10
Knowledge Organisers
Physics CP1-CP8

Knowledge Organiser: CP1 Motion (1 of 2)

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A **scalar** quantity has **magnitude** only. Examples include temperature or mass.

A **vector** quantity has both **magnitude** and **direction**. Examples include velocity.

Speed is the scalar magnitude of **velocity**.

A vector quantity can be shown using an **arrow**. The size of the arrow is relative to the magnitude of the quantity and the direction shows the associated direction.

A change in velocity is called acceleration. Acceleration is a vector quantity – it has a size (magnitude) and a direction. If a moving object changes its velocity or direction, then it is accelerating.
Acceleration is calculated using the following equation:

$$\text{acceleration (m/s}^2) = \frac{\text{change in velocity (m/s)}}{\text{time taken (s)}}$$

This can also be written as:

$$a = \frac{v - u}{t}$$

where a is the acceleration

v is the final velocity

u is the initial velocity

t is the time taken for the change in velocity.

Acceleration does not always mean getting faster. An acceleration can also cause an object to get slower. This is sometimes called a **deceleration**, and the acceleration will have a negative value.

Acceleration can be related to initial velocity, final velocity and distance travelled by this equation:

$$(\text{final velocity})^2 - (\text{initial velocity})^2 = 2 \times \text{acceleration} \times \text{distance}$$

(m/s)^2 (m/s)^2 (m/s^2) (m)

This can also be written as $v^2 - u^2 = 2 \times a \times x$, where x represents distance.

Examples of scalar and vector quantities

Scalar	Vector
Distance, speed, mass, energy, density, power, length, area, volume, time, temperature, work	Displacement, velocity, weight, acceleration, force, pressure, momentum, gravity

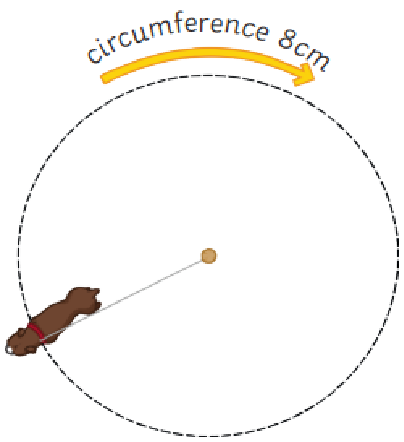
Distance is a **scalar** quantity. It measures how far something has moved and does not have any associated direction.

Displacement is a **vector** quantity. It measures how far something has moved and is measured in relation to the direction of a straight line between the starting and end points.

E.g. A dog is tethered to a post. It runs 360° around the post three times. Each 360° lap is 8m

distance = 8 × 3 = 24m

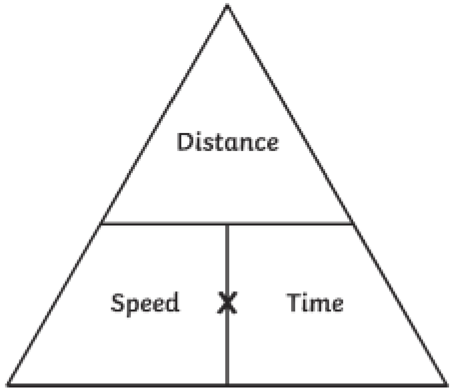
displacement = 0m (The dog is in the same position as when it started.)



Acceleration due to gravity

An object in free fall moves downwards due to the force of gravity acting on it. The acceleration due to gravity is constant close to the Earth's surface. If no other forces (such as air resistance) act on the object, the acceleration towards the Earth is therefore a constant 9.8 m/s^2. This value is known as the acceleration due to gravity. It is represented by the symbol g and is often rounded to 10 m/s^2 in calculations.

speed = distance ÷ time



Worked example:

John runs 5km. It takes him 25 minutes. Find his average speed in metres per second.

Step 1: convert the units

km → m (×1000) = 5000m

min → s (×60) = 1500s

Step 2: calculate s = d ÷ t

s = 5000 ÷ 1500

s = 3.33m/s

Worked example 2:

Zi Xin has driven along the motorway. Her average speed is 65mph. She has travelled 15 miles. How long has her journey taken? Give your answer in minutes.

Step 1: calculate t = d ÷ s

t = 15 ÷ 65

t = 0.23 (hours)

Step 2: convert units

hr → min (×60) = 13.8 minutes

Knowledge Organiser: CP1 Motion (2 of 2)

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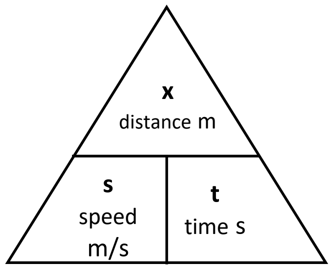
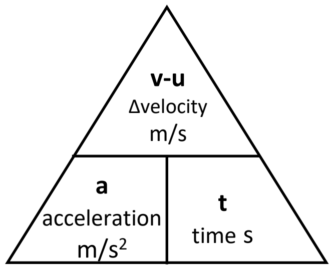
Glossary

Word	Meaning
acceleration	A measure of how quickly the velocity of something is changing.
displacement	The distance travelled in a particular direction. Displacement is a vector quantity.
distance	How far something has travelled. Distance is a scalar quantity, and has no direction.
force	At the simplest level a force is a push, pull or twist. Forces acting on an object can cause it to accelerate. Force is a vector quantity.
magnitude	The size of something
mass	A measure of the amount of material that there is in an object.
scalar quantity	A quantity that has a magnitude (size) but not a direction e.g. mass, distance, energy and speed.
speed	The distance an object travels in a given time
vector quantity	A quantity that has both a size and a direction e.g. force, velocity, displacement, momentum and acceleration.
velocity	The speed of an object in a particular direction. Velocity is a vector quantity.
weight	The force acting on an object due to gravity.
average speed	The speed worked out from the total distance travelled divided by the total time taken for a journey. speed = distance travelled /time
distance/time graph	A graph of the distance travelled against time for a moving object. The gradient of a line on a distance/time graph gives the speed.
instantaneous speed	The speed at one particular moment in a journey.
gradient	A way of describing the steepness of a line on a graph in numbers.
deceleration	When an object is slowing down.
velocity/time graph	A graph of velocity against time for a moving object. The gradient of a line on the graph gives the acceleration and the area under the graph gives the distance travelled.

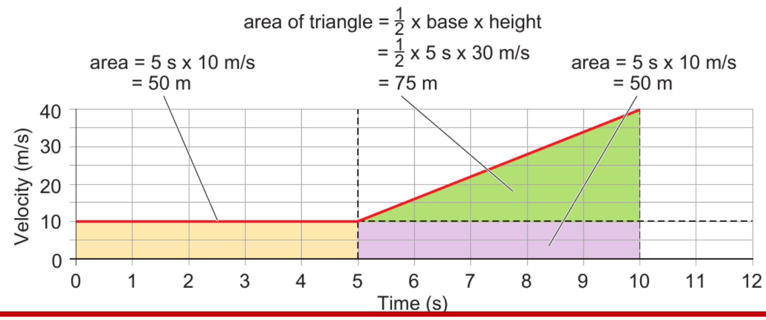
Equation triangles

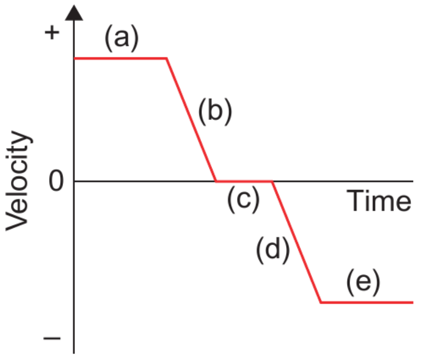




Calculating distance travelled from a graph

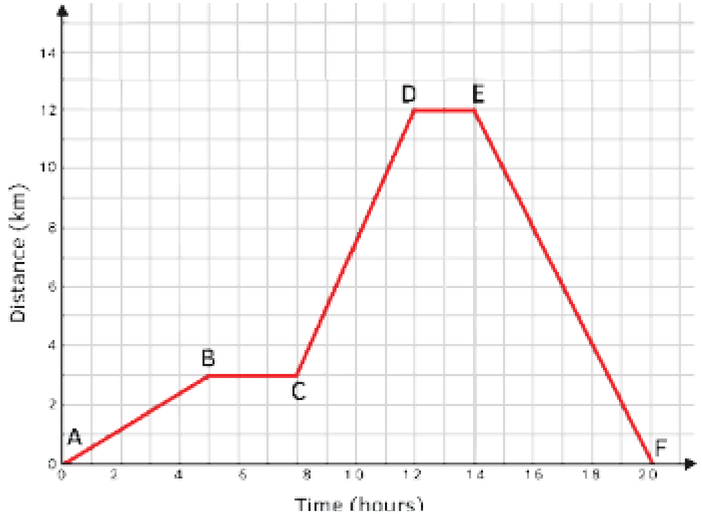
The area under a velocity/time graph is the distance the object has travelled





B The graph shows a lift moving up at a constant speed (a), slowing to a stop (b) and waiting at a floor (c) then accelerating downwards (d) and then travelling downwards at a constant speed (e).

When an object travels in a **straight line**, we can show the distance which has been covered in a **distance-time graph**.



You should be able to understand what the features of the two types of graph can tell you about the motion of an object.

Graph Feature	Distance-Time Graph	Velocity-Time Graph
x-axis	time	time
y-axis	distance	velocity
gradient	speed	acceleration (or deceleration)
plateau	stationary (stopped)	constant speed
uphill straight line	steady speed moving away from start point	acceleration
downhill straight line	steady speed returning to the start point	deceleration
uphill curve	acceleration	increasing acceleration
downhill curve	deceleration	increasing deceleration
area below graph		distance travelled

Knowledge Organiser: CP2 Forces & Motion (1 of 2)

A **scalar** quantity has **magnitude** only. Examples include temperature or mass.

A **vector** quantity has both **magnitude** and **direction**. Examples include velocity.

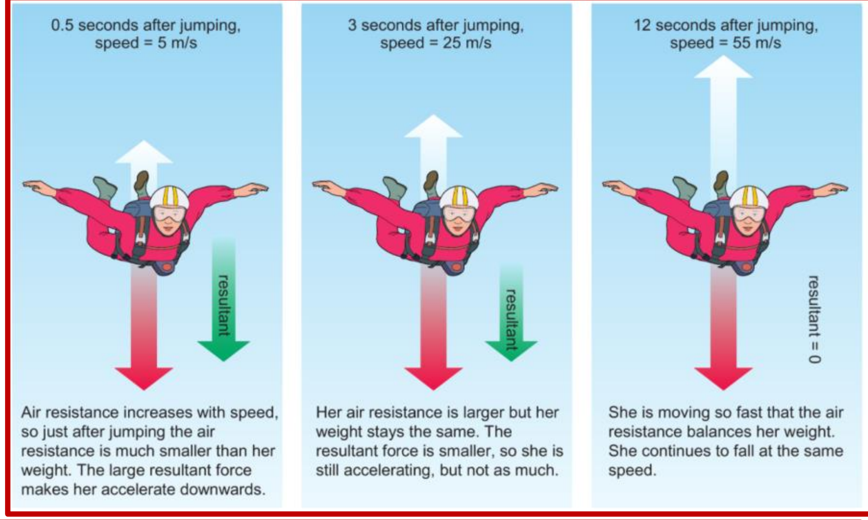
Speed is the scalar magnitude of **velocity**.

A vector quantity can be shown using an **arrow**. The size of the arrow is relative to the magnitude of the quantity and the direction shows the associated direction.

When an object changes its velocity, it is accelerating. As **acceleration** is a change in a vector quantity (velocity), acceleration is also a vector.

Examples of scalar and vector quantities

Scalar	Vector
Distance, speed, mass, energy, density, power, length, area, volume, time, temperature, work	Displacement, velocity, weight, acceleration, force, pressure, momentum, gravity



Resultant Forces

A number of forces acting on an object may be replaced by a single force that has the same effect as all the original forces acting together. This single force is called the resultant force.

When two forces act in a line the resultant force is the vector addition of the two vectors. Remember the direction is important.

R = 16 N to the right **R = 4 N to the right**

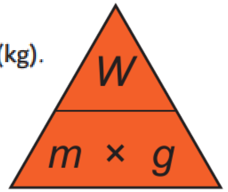
If the resultant of all the forces on an object is zero, we say the forces are **balanced**. If there is a non-zero resultant force on an object, the forces are **unbalanced**.

Gravity is the natural phenomenon by which any object with mass or energy is drawn together.

- The **mass** of an object is a scalar measure of how much matter the object is made up of. Mass is measured in **kilograms (kg)**.
- The **weight** of an object is a vector measure of how gravity is acting on the mass. Weight is measured in **newtons (N)**.

weight (N) = mass (kg) × gravitational field strength (N/kg)

(The gravitational field strength will be given for any calculations. On earth, it is approximately 9.8N/kg).



Newton's First Law of motion can be written as:

- a moving object will continue to move at the same speed and direction unless an external force acts on it
- a stationary object will remain at rest unless an external force acts on it.

It is the overall resultant force that is important when you are looking at how the velocity of an object changes. Balanced forces (zero resultant force) will not change the velocity of an object. Unbalanced forces (non-zero resultant force) will change the speed and/or direction of an object.

The acceleration of an object is a measure of how much its velocity changes in a certain time. Sir Isaac Newton's Second Law of Motion describes the factors that affect the acceleration of an object.

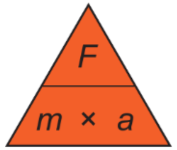
The acceleration in the direction of a resultant force depends on:

- the size of the force (for the same mass, the bigger the force the bigger the acceleration)
- the mass of the object (for the same force, the more massive the object the smaller the acceleration).

The force needed to accelerate a particular object can be calculated using the equation:

force = mass × acceleration
(N) (kg) (m/s^2)

This is often written as $F = m \times a$

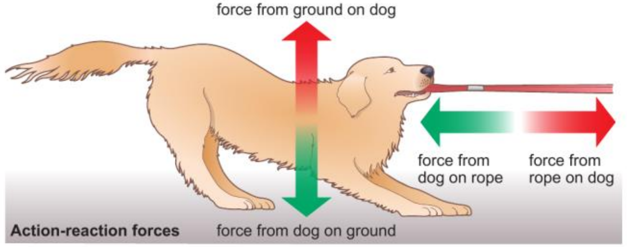


1 newton is the force needed to accelerate a mass of 1 kg by 1 m/s^2.

Newton's Third Law is about the forces on two different objects when they interact with each other. This interaction can happen:

- when objects touch, such as when you sit on a chair
- at a distance, such as the gravitational attraction between the Earth and the Moon.

There is a pair of forces acting on the two interactive objects, often called **action–reaction forces**. The two forces are always the same size and in opposite directions. They are also the same type of force.



Knowledge Organiser: CP2 Forces & Motion (2 of 2)

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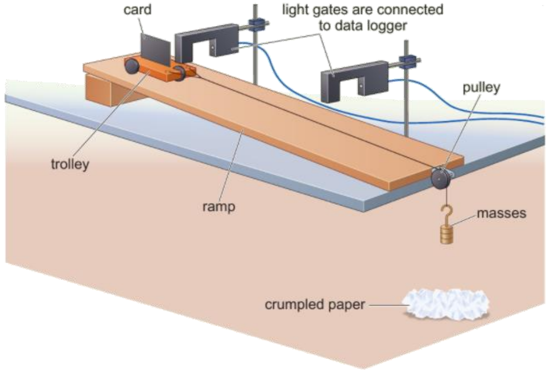
acceleration	A measure of how quickly the velocity of something is changing.
balanced forces	When the forces in opposite directions on an object are the same size so that there is a zero resultant force.
resultant force	The total force that results from two or more forces acting upon a single object.
scalar quantity	A quantity that has a magnitude (size) but not a direction.
speed	How fast something is moving.
unbalanced forces	When the forces in opposite directions on an object do not cancel out, so there is a non-zero resultant force.
vector quantity	A quantity that has both a size and a direction.
velocity	The speed of an object in a particular direction.
mass	A measure of the amount of material there is in an object.
weight	The force pulling an object downwards. It depends upon the mass of the object and the gravitational field strength.
gravitational field strength	A measure of how strong the force of gravity is somewhere.
action–reaction forces	Pairs of forces on interacting objects. Action–reaction forces are always the same size, in opposite directions, and acting on different objects.
thinking distance	The distance travelled by a vehicle while the driver reacts.
braking distance	The distance travelled by a vehicle while the brakes are working to bring it to a halt.
stopping distance	The distance in which a car stops; sum of the thinking & braking distances.
reaction time	The time taken to respond to a stimulus.
stimulus	A change that can be detected by the body
response	The way the body reacts to a stimulus.

Required practical



Aim: investigate the effect of varying the force on the acceleration on an object of constant mass, and the effect of varying the mass of an object on the acceleration produced by constant force.

Something is a **fair test** when **only** the independent variable has been allowed to affect the dependent variable.

The independent variable was **force**.

The dependent variable was **acceleration**.

The control variables were:

- **same total mass**
- **same surface/glider/string/pulley (friction)**
- **same gradient if you used a ramp**

When a driver sees a problem ahead, their vehicle will travel some distance while the driver reacts to the situation. This is called the **thinking distance**. The vehicle will then go some distance further while the brakes are working to bring it to a halt. This is called the **braking distance**. The overall **stopping distance** for any road vehicle is the sum of the thinking and braking distances.

stopping distance = thinking distance + braking distance

A **reaction time** is the time between a person detecting a **stimulus** (such as a flashing light or a sound) and their **response** (such as pressing a button or applying the brakes in a car). Response times can be measured using computers or electric circuits that measure the time between a stimulus and a response.

The typical reaction time to a visual stimulus, such as a computer screen changing colour, is about 0.25 seconds. However this time can be much longer if the person is tired, ill or has been taking drugs or drinking alcohol. Distractions, such as using a mobile phone, can also increase reaction times.

The **braking distance** is the distance travelled by a vehicle once the **brakes are applied** and until it reaches a full stop.

Braking distance is affected by:

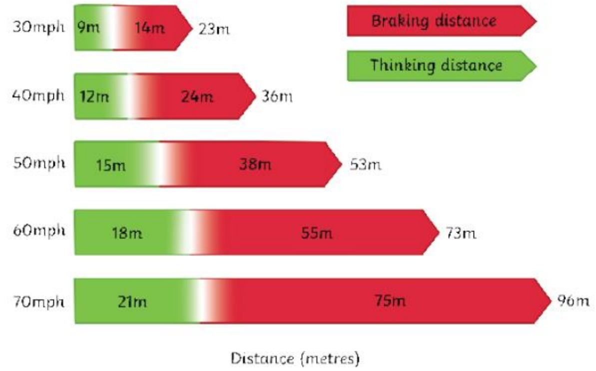
- **adverse weather conditions** (wet or icy)
- **poor vehicle condition** (brakes or tyres)

When **force** is applied to the brakes, **work is done** by the **friction** between the car wheels and the brakes.

The work done reduces the **kinetic energy** and it is transferred as **heat** energy, increasing the **temperature** of the brakes.

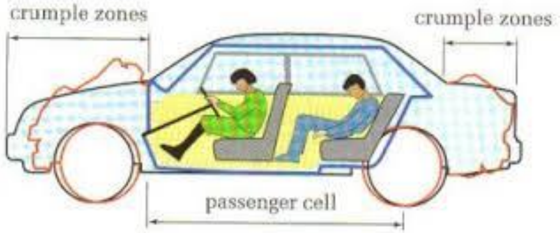
increased speed = increased force required to stop the vehicle

increased braking force = increased deceleration



In a car crash, the vehicles involved come to a stop very quickly. Slowing down is a **deceleration** (or a negative acceleration). The force needed for any kind of acceleration depends on the size of the acceleration and on the mass of the object.

Modern cars have lots of safety features built into them to help to reduce the forces on the occupants in a collision. **Crumple zones** are built into the front (and sometimes the back) of cars. If the car hits something it takes a little time for this crumpling to happen, so the deceleration of the car is less and the force on the car is also less than if it had a more solid front.



Knowledge Organiser: CP3 Conservation of Energy (1 of 2)

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1. Energy stores

- **Chemical energy** – stored in food, fuels and batteries
- **Kinetic energy** – stored in moving objects
- **Thermal energy** – stored in hot objects
- **Elastic potential energy** – stored in stretched, compressed or twisted objects
- **Gravitational potential energy** – stored in objects in high position
- **Nuclear energy** – stored in the nuclei of atoms

2. Energy transfers

There are five ways in which energy can be transferred from one store to another:

- <u>S</u>ound
- <u>H</u>eating
- <u>E</u>lectricity
- <u>L</u>ight
- <u>F</u>orces

Use the acronym **SHELF** to help you remember these!

3. Law of conservation of energy

Energy cannot be created or destroyed. It can only be transferred from one store to another.

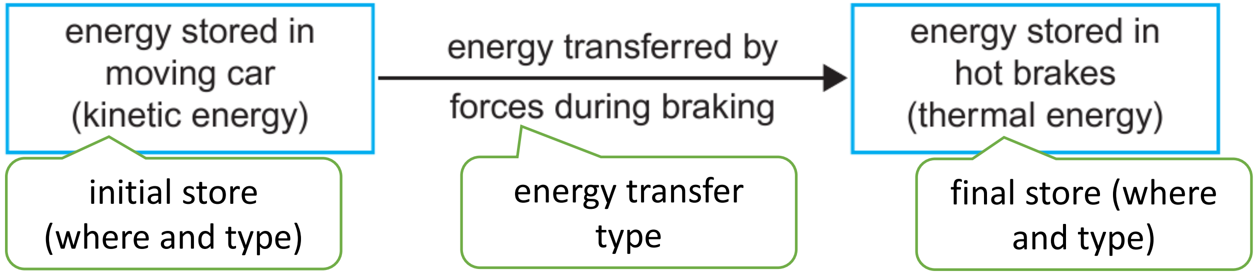
<u>Note</u>: energy is always conserved, but it isn't always transferred into forms that are useful.

Wasted energy is usually transferred to the surroundings – it is **dissipated** (spread out).

Friction in a machine causes energy to be transferred by heating (wasted). **Lubrication** can be used to reduce this.

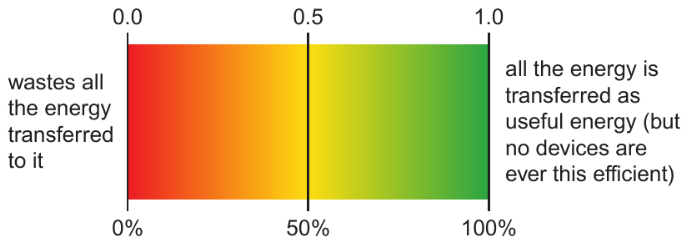
4. Energy diagrams

These are use to represent energy stores and transfers.
e.g. the energy transfers when a car brakes



5. Efficiency

How good a device is at transferring energy into useful forms. It is given as a number between 0 and 1.



6. Calculating efficiency of a device

$$\text{efficiency} = \frac{\text{(useful energy transferred by the device)}}{\text{(total energy supplied to the device)}}$$

<u>Note</u>: efficiency has no units as it is a ratio. It is always less than 1

7. Units of energy

Energy is measured in **joules (J)**. 1 kilojoule (kJ) = 1000J

Knowledge Organiser: CP3 Conservation of Energy (2 of 2)

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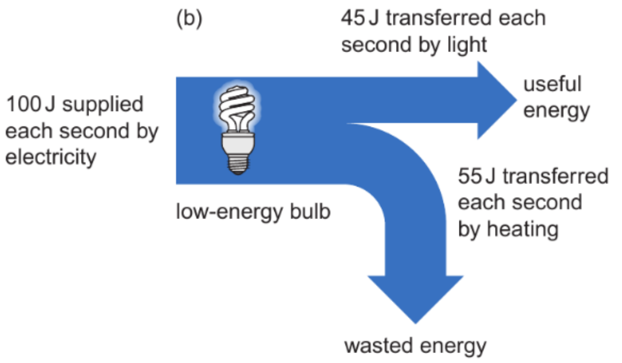
8. Sankey diagrams

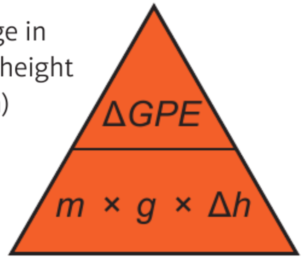
These show the amount of energy transferred by a device e.g.



9. Calculating gravitational potential energy

change in gravitational potential energy (J) = mass (kg) × gravitational field strength (N/kg) × change in vertical height (m)

$$\Delta GPE = m \times g \times \Delta h$$

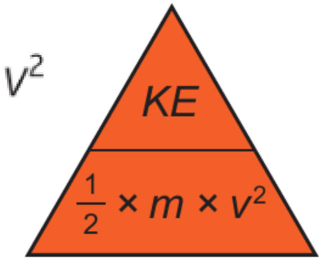


<u>Note</u>: the gravitational field strength on Earth is approximately 10N/Kg.

10. Calculating kinetic energy

kinetic energy (J) = $\frac{1}{2}$ × mass (kg) × (speed)^2 (m/s)^2

$$KE = \frac{1}{2} \times m \times v^2$$



11. Transfers by heating

Energy can be transferred by heating by:

- **Conduction** – vibrations are passed on between particles in a solid
- **Convection** – part of a fluid that is warmer than the rest rises and sets up a convection current
- **Radiation (infrared)** – can be transferred through a vacuum. Can pass through gases and some solids. Absorbed and emitted best by dull, dark surfaces.

12. Controlling transfers

The rate at which energy is transferred though a material by heating depends on:

- **thickness**
- **temperature difference**
- **thermal conductivity**

Energy transfers by heating can be reduced by:

- Using **thicker insulating materials**
- Use **materials with low thermal conductivity** (i.e. good insulators)

Materials that contain trapped air (e.g. fur or feathers) are good insulators. This is because air has poor thermal conductivity and it cannot form convection currents when trapped.

13. Renewable/non-renewable

Non-renewable energy resources will run out one day. Renewable energy resources will not run out.

14. Renewable & non-renewable energy resources

Energy	Energy store	Renewable?	Uses	Power output	Impact on environment
Fossil fuels (oil, coal, gas)	Chemical	No	Transport, heating, electricity generation	High	Releases CO_2 (causes global warming)
Nuclear fuels	Nuclear	No	Electricity generation	Very high	Radioactive waste (needs to be disposed of safely)
Biofuel	Chemical	Yes	Transport, heating, electricity generation	Medium	Carbon-neutral so low impact
Wind	Kinetic	Yes	Electricity generation	Very low	Take up large areas that could be used for farming, people say windmills spoil their view
Hydroelectricity	GPE	Yes	Electricity generation	Medium	Local habitats are affected by the large areas that need to be flooded to build dams
Geothermal	Thermal	Yes	Electricity generation, heating	Medium	Very low
Tides	Kinetic	Yes	Electricity generation	Very high but hard to harness	Tidal barrages can block sewage which needs to go out to sea
Sun	Nuclear	Yes	Electricity generation	Very high, but hard to harness	Very little
Water waves	Kinetic	Yes	Electricity generation	Low	Very low

Knowledge Organiser: CP4/SP4 Waves (1 of 2)

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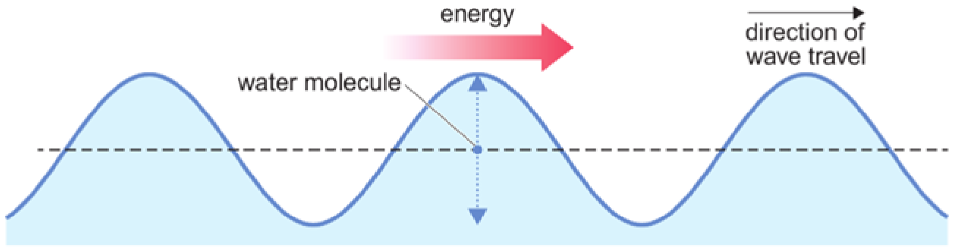
1. Transverse waves

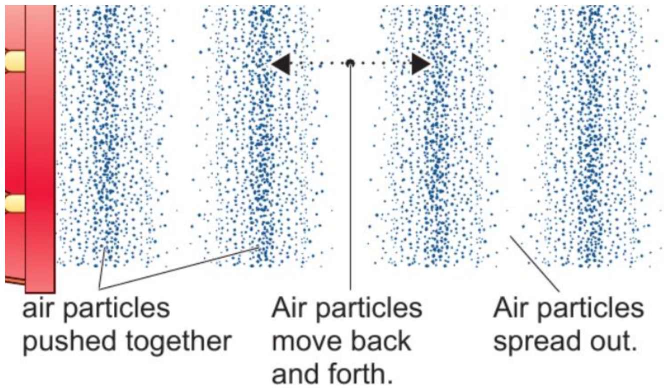
In transverse waves the vibrations are at right angles to the direction the wave is travelling.



Examples: water waves, electromagnetic waves, S waves (type of seismic wave).

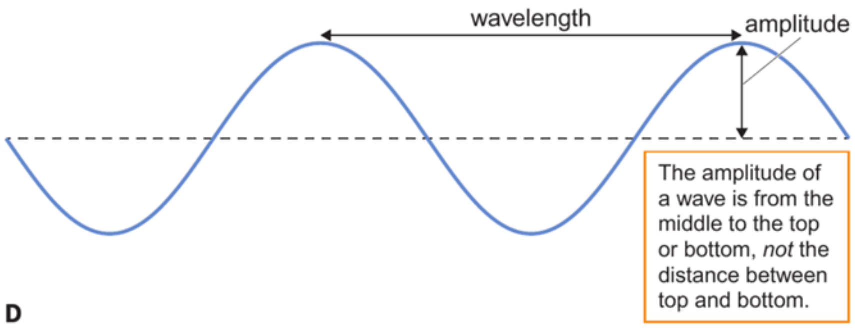
2. Longitudinal waves

In longitudinal waves the vibrations are back and forth parallel to the direction the wave is travelling.



Examples: sound waves,
P waves (type of seismic wave)

3. Describing waves

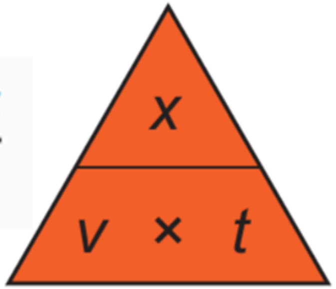


Frequency: the number of waves in one second. Units are Hertz (Hz). One hertz is one wave per second.
Period: the time taken for one complete wave to pass a point. Units are seconds (s).
Wavelength: the distance between a point on one wave and the same point on the next wave. Units are metres (m).
Amplitude: the maximum distance a particle moves away from its resting position when a wave passes. Units are metres (m).
Wave velocity: the speed of a wave in the direction it is travelling. Unites are metres per second (m/s)

4. Calculating wave speed

$$\text{speed (m/s)} = \frac{\text{distance (m)}}{\text{time (s)}}$$

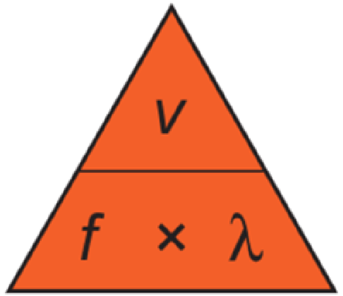
$$v = \frac{x}{t}$$



$$\text{wave speed (m/s)} = \text{frequency (Hz)} \times \text{wavelength (m)}$$

$$v = f \times \lambda$$

(Note: λ is the symbol for wavelength)



Knowledge Organiser: CP4/SP4 Waves (2 of 2)

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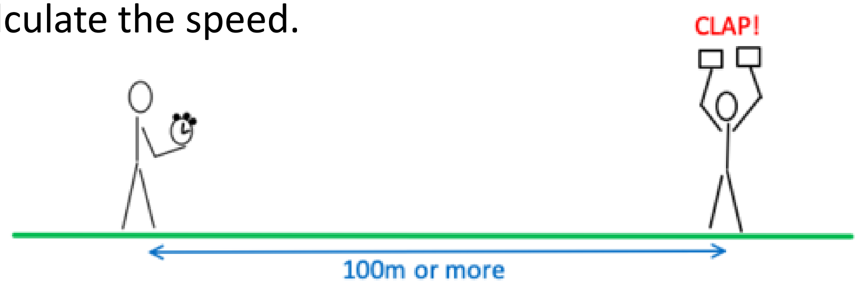
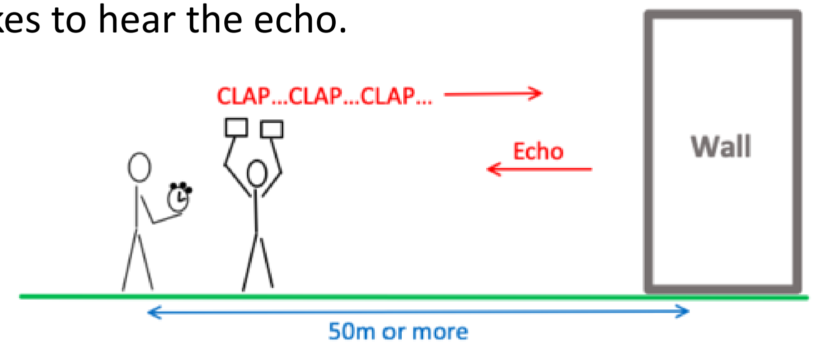
5. Determining the speed of a wave

We can measure the speed of sound my measuring how long it takes a noise to travel a certain distance. Then use the speed, distance, time equation to calculate the speed.



An alternative method is to make a sound facing a wall or cliff, recording the total distance and the time it takes to hear the echo.

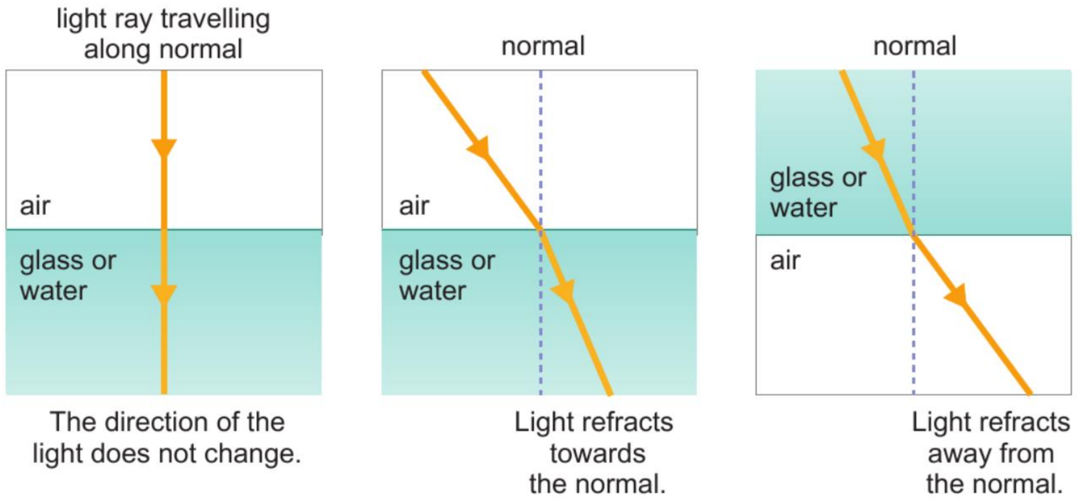


We can use a similar method to measure the speed of waves on water. Measure a suitable distance e.g. between two buoys in the sea, then time how long it takes a wave to travel from one to the other. Use the speed, distance, time equation to calculate the speed

6. Refraction

Refraction is the change in direction of a light ray when it passes the **interface** (boundary) from one **medium** (material) to another.

Refraction happens because light travels at different speeds in different media. Light travels more slowly in glass and water than it does in air.



The normal is an imaginary line drawn at right angles to the surface of the glass or water where the ray of light crosses the interface.

As a ray of light passes from air to glass it slows down and refracts towards the normal. As it passes from glass to air, it speeds up and refracts away from the normal.

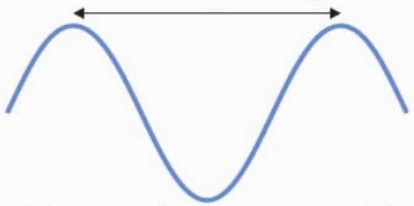
A good way to remember this is **F.A.S.T.**

Faster **A**way, **S**lower **T**owards

Key Learning

- Electromagnetic waves
- The Electromagnetic spectrum
- Refraction
- Using the longer waves
- Using the shorter waves
- EM radiation dangers

The distance from a point on one wave to a point in the same position on the next wave is the **wavelength**.



The number of waves passing a point each second is the frequency.

B Electromagnetic waves are transverse waves.

Electromagnetic waves

We see things when light travels from a source and is reflected by an object into our eyes. The light transfers energy from the source to our eyes. Light is a type of **electromagnetic wave**.

Using the long wavelengths

Visible light

Visible light is the part of the electromagnetic spectrum that our eyes detect. Light bulbs are designed to emit visible light, while cameras detect it and record images.

Infrared

Infrared radiation can be used for communication at short ranges, such as between computers in the same room or from a TV to its remote control unit. The information sent along optical fibres is also sent using infrared radiation.

Microwaves

Microwaves are used for communications and satellite transmissions, including mobile phone signals. In a microwave oven, microwaves transfer energy to the food, heating it up.

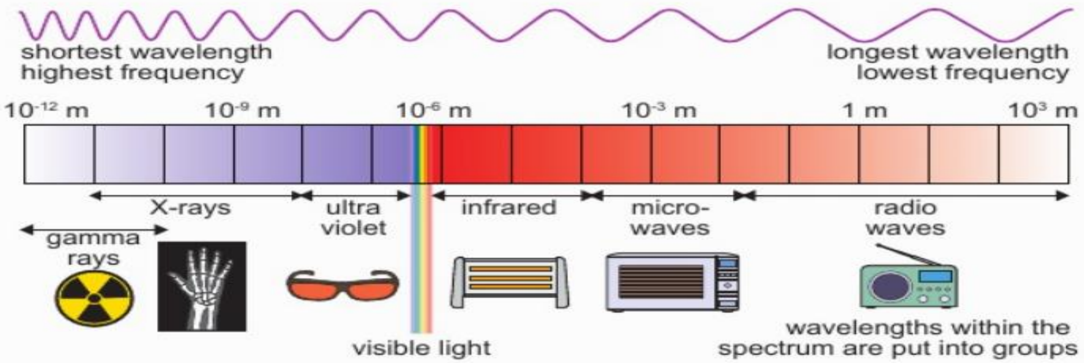
Radio waves

Radio waves are used for transmitting radio broadcasts and TV programmes as well as other communications. Some radio communications are sent via satellites. Controllers on the ground communicate with spacecraft using radio waves.

B Pilots communicate with each other and with ground controllers using radio waves.

The electromagnetic spectrum

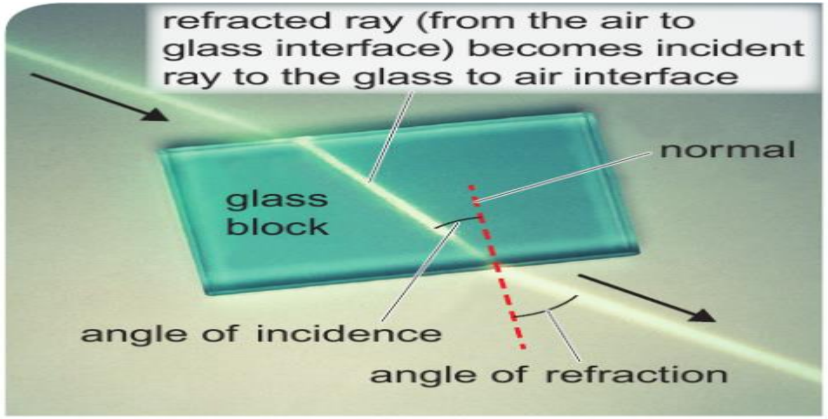
The full range of electromagnetic waves is called the **electromagnetic spectrum**. The spectrum is continuous, so all values of frequency are possible. Higher frequency waves have shorter wavelengths, and lower frequency waves have longer wavelengths. It is convenient to group the spectrum into seven wavelength groups, as shown in diagram B.



B the electromagnetic spectrum (not to scale)

Core practical – Investigating refraction

Electromagnetic waves travel at different speeds in different materials. Light slows down when it goes from air into glass or water. If the light hits the interface at an angle, it changes direction. This is called refraction.



Knowledge Organiser: CP5 Light and the Electromagnetic spectrum (2 of 2)

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Using the short wavelengths

Ultraviolet

Ultraviolet radiation transfers more energy than visible light. It is absorbed by most of the same materials that absorb visible light, including our skin. The energy transferred can be used to disinfect water by killing microorganisms in it.

Did you know?

Obtaining clean drinking water is a problem in many parts of the world. Microorganisms in water can be killed by putting the water in clear plastic bottles and leaving them in sunshine for several hours. Infrared energy from the sun heats up the water and the high temperature and the ultraviolet radiation both help to kill microorganisms.

A

X-rays

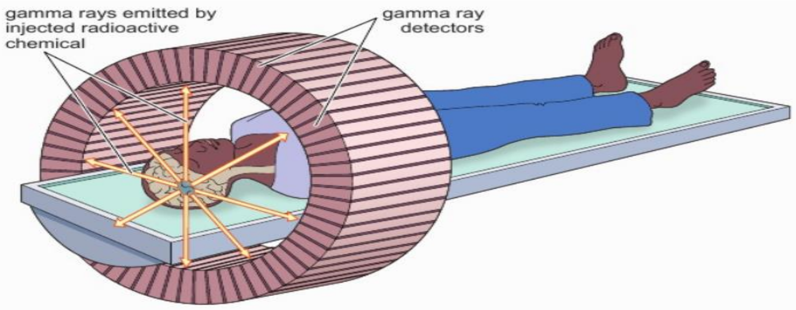
X-rays can pass through many materials that visible light cannot. For example, they can pass through muscles and fat easily but bone absorbs some X-rays. This means X-rays can be used in medicine to make images of the inside of the body. X-rays can also be used to examine the insides of metal objects and to inspect luggage in airport security scanners.

C This X-ray image shows that the dog has swallowed a toy duck.

Gamma rays

Gamma rays transfer a lot of energy, and can kill cells. For this reason, they are used to sterilise food and surgical instruments by killing potentially harmful microorganisms.

Gamma rays are used to kill cancer cells in **radiotherapy**. They can also be used to detect cancer. A chemical that emits gamma rays is injected into the blood. The chemical is designed to collect inside cancer cells. A scanner outside the body then locates the cancer by finding the source of the gamma rays. Gamma rays can pass through all the materials in the body.



D a gamma ray medical scanner

EM radiation dangers

All waves transfer energy. A certain microwave frequency can heat water and this frequency is used in microwave ovens. This heating could be dangerous to people because our bodies are mostly water and so the microwaves could heat cells from the inside. Mobile phones use different microwave frequencies. Current scientific evidence tells us that, in normal use, mobile phone signals are not a health risk.

A Mobile phone transmitters use different frequencies of microwaves compared with microwave ovens.

Infrared radiation is used in grills and toasters to cook food. Our skin absorbs infrared, which we feel as heat. Too much infrared radiation can damage or destroy cells, causing burns to the skin.

C Sunburn is caused by too much ultraviolet radiation being absorbed by the skin.

Higher-frequency waves transfer more energy than low-frequency waves and so are potentially more dangerous. Sunlight contains high frequency ultraviolet radiation, which carries more energy than visible radiation. The energy transferred by ultraviolet radiation to our cells can cause sunburn and damage **DNA**. Too much exposure to ultraviolet radiation can lead to **skin cancer**. We can help to protect our skin by staying out of the strongest sunshine, covering up with clothing and hats, and using sun cream with a high SPF (sun protection factor).

The ultraviolet radiation in sunlight can also damage our eyes. Skiers and mountaineers can suffer temporary 'snow blindness' because so much ultraviolet radiation is reflected from snow. We can protect our eyes using sunglasses.

X-rays and gamma rays are higher frequency than ultraviolet radiation and so transfer more energy. They also can penetrate the body. Excessive exposure to X-rays or gamma rays may cause **mutations** in DNA that can kill cells or cause cancer.

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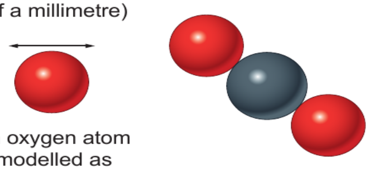
Key Learning

- Atomic models
- Inside atoms
- Electrons and orbits
- Background radiation
- Types of radiation
- Radioactive decay
- Half-life
- Dangers of radioactivity

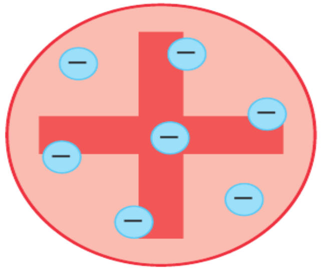


A Atoms and molecules are often modelled as spheres.

Atomic models

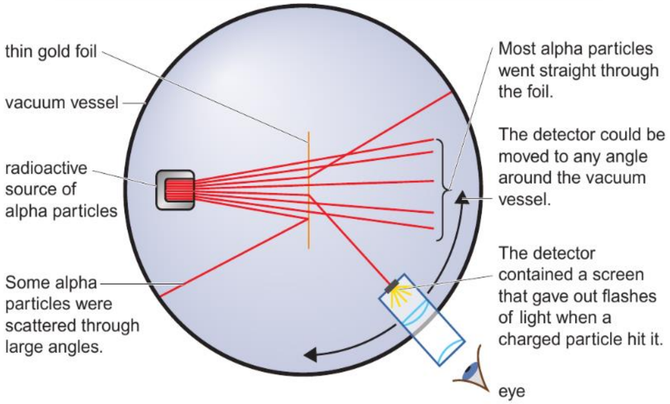
J.J. Thomson (1856–1940) carried out some experiments that showed that atoms contain much smaller **subatomic particles** called **electrons**. These had a negative charge and hardly any mass.

In the 1900s, Thomson supported using a new model for atoms that could explain this new evidence. This new model described the atom as a 'pudding' made of positively charged material, with negatively charged electrons (the 'plums') scattered through it.



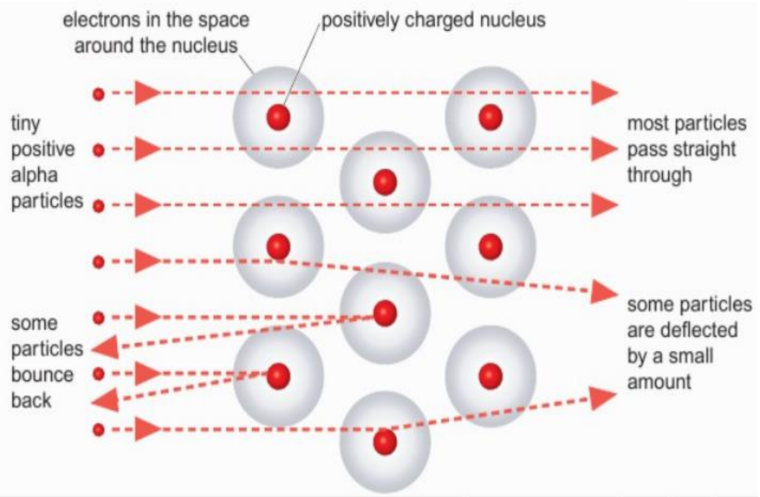
B the plum pudding model of the atom

Between 1909 and 1913, a team of scientists led by Ernest Rutherford (1871–1937) carried out a series of experiments that involved studying what happened when positively charged subatomic particles, called **alpha particles**, passed through various substances (such as gold foil).



C the design of one of Rutherford's experiments

Rutherford suggested that atoms were mostly empty space, with most of their mass in a tiny central **nucleus** with a positive charge and electrons moving around the nucleus. Figure D shows how this model of the atom explains the results.



E If an atom had the same diameter as the dome of the O2, its nucleus would be the size of this dot ●.

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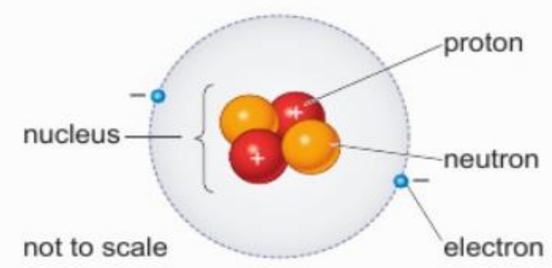
Inside atoms



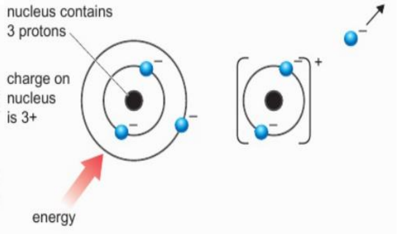
A the structure of an atom

Subatomic particle	Location in atom	Relative charge	Relative mass
proton	nucleus	+1 (positive)	1
neutron	nucleus	0	1
electron	around nucleus	−1 (negative)	$\frac{1}{1835}$ (negligible)

B The mass of an electron is so small that it is usually ignored when talking about the mass of an atom.

Ionisation

Sometimes an atom gains so much energy that one or more of the electrons can escape from the atom altogether. An atom that has lost or gained electrons is called an **ion**. Radiation that causes electrons to escape is called **ionising radiation**.



D ionisation of a lithium atom

Types of radiation

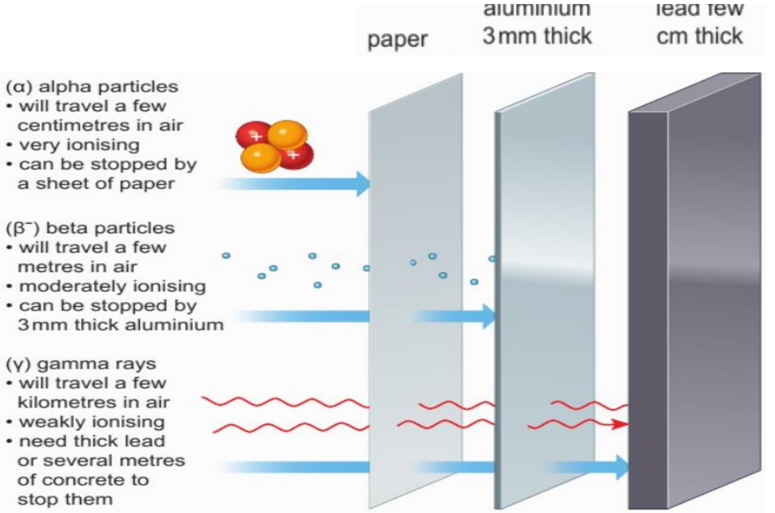
Alpha particles contain two protons and two neutrons, just like the nucleus of a helium atom. They have a relative mass of 4. They have no electrons and so have a charge of +2. They can be written as **α** or $^{4}_{2}\mathbf{He}$.

Beta particles are high-energy, high-speed electrons. They have a relative mass of $\frac{1}{1835}$ and a charge of −1. They can be written as β^- or $^{0}_{-1}\mathbf{e}$.

This number represents charge.

Gamma-rays (γ) are high-frequency electromagnetic waves (they travel at the speed of light). They do not have an electric charge.

Neutrons can also be emitted from an unstable nucleus. They have a relative mass of 1 and no electric charge.

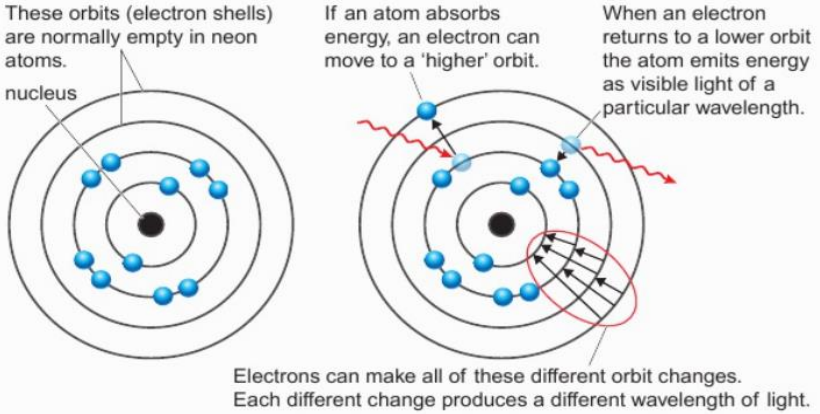


C the penetrating properties of alpha, beta and gamma radiation

Isotopes

Two atoms of the same element will always have the same atomic number, but they can have different mass numbers if they contain different numbers of neutrons. Atoms of a single element that have different numbers of neutrons are called **isotopes**.

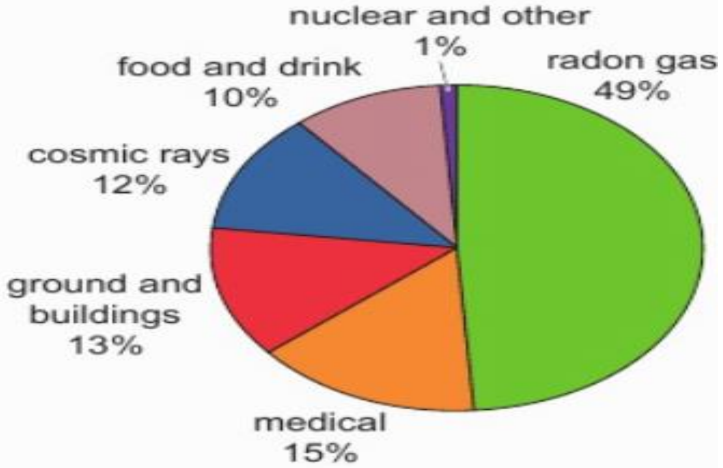
Electrons and orbits



B electronic configuration and energy level changes for neon

Background radiation

We are constantly being exposed to ionising radiation at a low level, from space and from naturally radioactive substances in the environment. This is called **background radiation**.



B sources of background radiation in the UK

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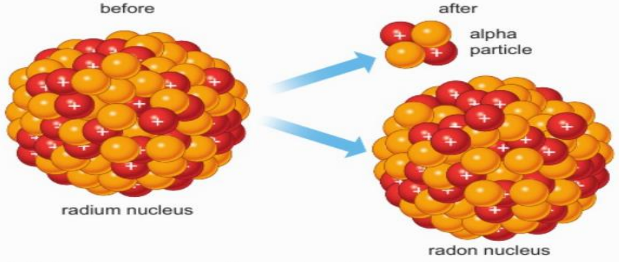
Radioactive decay

When an unstable nucleus changes and emits particles, the atomic number can change. If this happens, the atom becomes a different element. For example, when an alpha particle is emitted, the mass number of the nucleus goes down by 4 and the atomic number goes down by 2.

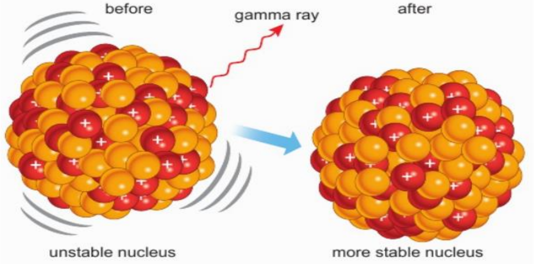


A Alpha decay turns a radium nucleus into a radon nucleus.

During β^- decay, a neutron changes into a proton and an electron. The electron is ejected from the atom. The atomic number increases by 1 but there is no change to the mass number.

In β^+ decay a proton becomes a neutron and a positron. The atomic number goes down by 1 but the mass number does not change.

Nuclei may also lose energy as gamma radiation when the subatomic particles in the nucleus are rearranged. This helps to make them more stable.



B gamma radiation

Half-life

The **half-life** is the time taken for half the unstable nuclei in a sample of a radioactive isotope to decay. This is shown in diagram B. We cannot predict the decay of an individual nucleus because it is a random process. However, the half-life does allow us to predict the activity of a large number of nuclei. The half-life is the same for any mass of a particular isotope. Some half-lives are shown in table C.

Isotope	Half-life
uranium-235	700 million years
carbon-14	5730 years
caesium-137	30 years
radon-222	3.8 days

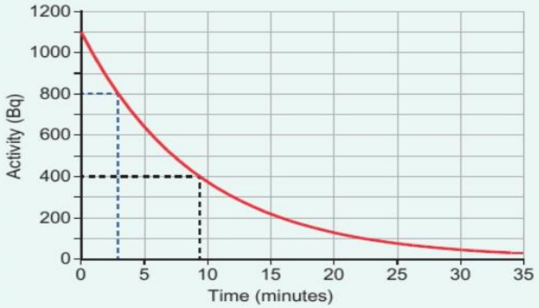
C half-lives of some isotopes

After decaying, a nucleus may become stable. The more stable nuclei a sample of a substance contains, the lower its activity. The half-life of an isotope is therefore also a measure of how long it takes for the activity to halve. It can be found by recording the activity of a sample over a period of time.

Worked example

In figure D, the activity at 3 minutes is 800 counts per second. After one half-life the count rate will have decreased to 400 counts per second.

This occurs at 9.5 minutes, so the half-life is 9.5 – 3 = 6.5 minutes.



D graph of activity against time for a radioactive substance

Dangers of radioactivity

Small amounts of ionising radiation over long periods of time can damage the DNA inside a cell. This damage is called a **mutation**. DNA contains the instructions controlling a cell, so some mutations can cause the cell to malfunction and may cause cancer. Gene mutations that occur in gametes can be passed on to the next generation. However, not all mutations are harmful and cells are often capable of repairing the damage if the radiation **dose** is low.

A This patient has radiation burns. He was among the first emergency personnel on the scene after the Chernobyl nuclear power plant disaster on 26 April 1986.

Radiation in hospital

Medical staff working with radioactive sources have their exposure limited in a number of ways, including increasing their distance from the source, shielding the source and minimising the time they spend in the presence of sources. Their exposure is also closely monitored using dosimeter badges (see CP6d).

Some patients may be exposed to a dose of radiation for medical diagnosis or treatment (such as detecting and treating cancer). This is only done when the benefits are greater than the possible harm the radiation could cause, and the minimum possible dose is used.

Nuclear accidents

Occasionally there is an accident in a nuclear power station, allowing radioactive materials to escape into the environment. Accidents such as this cause a hazard, as they may lead to people being irradiated or contaminated.

D These workers are cleaning up after an accident at a nuclear reactor. The overalls stop their clothing becoming contaminated.

Dangers in perspective

It is important to understand that the dangers of radiation from medicine, industry and power generation are small compared with many other aspects of our modern lives. However, many people are concerned that accidents may happen in nuclear power stations.

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Knowledge Organiser: Physics – CP7 Energy - Forces Doing Work (1 of 2)

Key Learning

- Energy stores and transfers
- E = F x d
- Calculate energy changes
- $\Delta GPE = m \times g \times \Delta h$
- $KE = \frac{1}{2} \times m \times v^2$
- Wasted energy
- $P = \frac{E}{t}$
- Efficiency $= \frac{Useful\ energy\ transferred}{Total\ energy\ supplied}$

Equations

Work done can be calculated using the equation:

work done (J) = force (N) x distance moved in the direction of the force (m)

E= F x d

Note: Energy transferred (joule, J) is equal to work done (joule, J)

Work Done Calculations

A box is pushed 3 m across the floor with a force of 120 N.

Work out the work done in moving the box.

Solution

Equation: work done = force x distance travelled

Substitution: work done = 120 x 3

Work done = 360 J

A man with a mass of 70 kg gets onto a moving escalator.
The escalator moves 15 m horizontally and 8 m vertically.
Calculate the work done by the motor against gravity.

Take g = 10 N/kg.

Solution
Gravity acts downwards, so the distance moved against gravity is 8 m.
Since W = mg; the weight of the man is 700 N.

Using: work done = force x distance travelled
work done = 700 x 8
work done = 5600 J

Equations

When an object is raised above ground level it gains **gravitational potential energy** (GPE). This **stored energy** can be released if the object is allowed to **fall**.

A pile driver is a machine that lifts a heavy weight then drops it on a post to drive it into the ground.

Recall and use the equation to calculate the change in gravitational PE when an object is raised above the ground:

change in G.P.E (J) = mass (kg) x gravitational field strength (N/kg) x change in height (m)

$\Delta GPE = m \times g \times \Delta h$

GPE Calculation

Recall and use the equation to calculate the change in gravitational PE when an object is raised above the ground:

change in G.P.E (J) = mass (kg) x gravitational field strength (N/kg) x change in height (m)

$\Delta GPE = m \times g \times \Delta h$

The pile driver hammer has a mass of 120 kg and it is raised to a height of 4 m above the ground. How much G.P.E will it have?

$\Delta GPE = m \times g \times \Delta h$

$\Delta GPE = 120 \times 10 \times 4$

The G.P.E gained is: $\Delta GPE = 4800$ J

Kinetic Energy

Moving objects have kinetic energy.
The long-jumper is using her **kinetic energy** to carry her body as far as possible. The more kinetic energy she has, the longer her jump will be. Her kinetic energy depends on her mass (which she can not change) and her velocity (she can run faster!).

Equations

Recall and use the equation to calculate the amounts of energy associated with a moving object:

kinetic energy (J) = ½ × mass (kg) × speed² (m/s)

$$KE = \frac{1}{2} \times m \times v^2$$

KE Calculation

If her mass is 46 kg and she is travelling at 8 m/s, her kinetic energy during her jump will be:

$KE = \frac{1}{2} m v^2$

$KE = \frac{1}{2} \times 46 \times 8^2$

The energy transferred in the jump is: $KE = 1472$ J

Knowledge Organiser: Physics – CP7 Energy – Forces Doing Work (2 of 2)

Work Done Against Frictional Forces

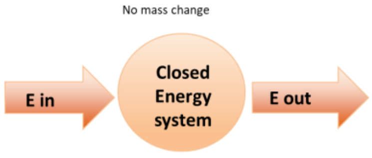
When **work** is done against **frictional forces** on an object there is a **temperature increase** of the object.

A bicycle pump gets hot in use as work is done in compressing the gas, causing the pump to get hotter.

Energy Transfers in a System

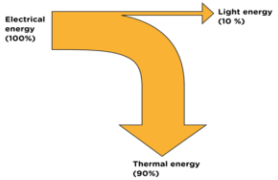
Energy can be stored, transferred or dissipated - but can not be created or destroyed.

In a closed energy system there can be transfer of energy but not mass. There is **no change to the total energy in the system.**



In a **closed energy system** all the energy can be accounted for even when energy stores change.

The diagram shows the energy transfer for a light bulb. All the **electrical energy** store can be accounted for as **light energy** and **thermal energy**.
The thermal energy is not useful in this case and can be
considered to be **dissipated** or "waste" energy.



Energy Transfers in a System

The F1 car below shows that eventually all the chemical energy (fuel) put in the car ends up as <u>unwanted</u> thermal energy which is dissipated to the surroundings. **Unwanted** energy is often described as being **'wasted'**

Chemical →  → Kinetic → Thermal; → Sound → Thermal; → Thermal

Kinetic energy is dissipated by the tyres, brakes and air resistance to become <u>unwanted</u> thermal energy stores.
Sound energy is absorbed by materials and becomes **thermal** energy.
Thermal energy is produced by the engine as fuel is burnt.

Oil is used in the engine, gearbox and other moving parts as a **lubricant** to reduce friction and **reduce unwanted thermal energy** in these parts.

Key Terminology

Power - the rate at which energy is transferred
the rate at which work is done (rate means "how quickly")
Power is measured in joules per second   1 J/s = 1 Watt

An object which transfers energy does so at a certain rate.
The metal filament in this light bulb transfers the electrical energy store into heat and light.
This bulb transfers 2400 joules of energy in 60 seconds.

Power Equation and Calculation

Power can be calculated using the following equation:

$$\text{power (W)} = \frac{\text{work done (J)}}{\text{Time taken (s)}}$$

$$P = \frac{E}{t} \qquad P = 2400 / 60 = 40\ J/s$$

So this is a **40 Watt** light bulb.

Power = work done / time

The crane lifts the 2000 kg container through a height of 5.4m in 30s.
The power of the crane is:
Power = work done / time   But: Work done = force x distance
= 20 000 N x 5.4 m = 108 000 J

Power = 108 000 J / 30 s

The Power of the crane is 3600 J/s   or 3600 Watts

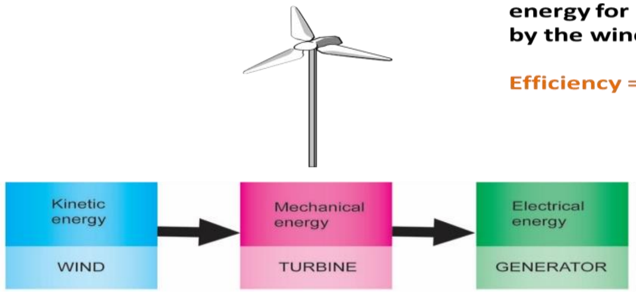
Efficiency

The amount of useful energy you get from an energy transfer, compared to the energy put in, is called the **EFFICIENCY**

$$\text{Efficiency} = \frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}}$$

This calculation will result in a decimal value which can be multiplied by 100 to give a percentage efficiency.

A wind turbine energy transfer



The wind turbine produces 120 MW of electrical energy for every 500 MW of kinetic energy provided by the wind.

$$\text{Efficiency} = \frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}}$$

$$= \frac{120}{500} = 0.24 \text{ efficient}$$

or 0.24 x 100 = 24 % efficient

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Knowledge Organiser: Physics – CP8 Forces and their Effects (1 of 2)

Key Learning

- Vector and Scalar Quantities
- Vector Diagrams (H)
- Free Body Diagrams (H)
- Resultant Forces(H)

Contact and Non-Contact Forces

Forces can be placed into two groups. There are forces that act on contact and there are forces that act at a distance.

Contact Forces	Non-Contact Forces
Air Resistance	Gravity
Friction	Magnetism
Tension	Electrical Force
Normal Force	Nuclear Force

Vector and Scalar Quantities

Scalars	Vectors
Direction	Displacement
Speed	Velocity
Mass	Forces (including weight)
Temperature	Acceleration
Energy	Momentum

Higher Tier ONLY!

Vector and Scalar Quantities

Materials in a classroom can be grouped into two groups – metals and non-metals.

Things we measure can be put into two groups as well – scalars and vectors.

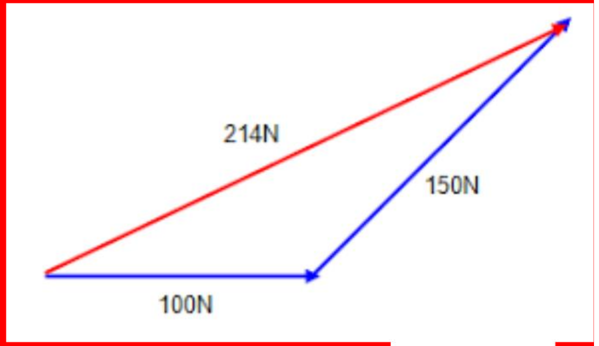
Scalars: Things that we measure that have a magnitude (size) only are scalars.

Vectors: Things that we measure that have both magnitude and direction are vectors.

Sometimes direction is really important. In a crash the direction, as well as the speed, of the vehicles will determine how much damage is caused.

Vectors can be shown by arrows.

The length of the arrow shows the size, or magnitude, of the force.



The direction of the arrow shows the direction of the force.

The vector arrows can be added together to show the resultant of two of more vectors.

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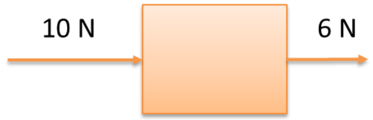
Knowledge Organiser: Physics – CP8 Forces and their Effects (2 of 2)

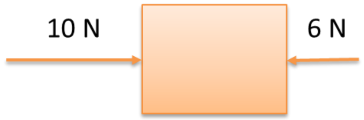
Resultant Forces

A number of forces acting on an object may be replaced by a single force that has the same effect as all the original forces acting together. This single force is called the resultant force.

When two forces act in a line the resultant force is the vector addition of the two vectors. Remember the direction is important.



R = 16 N to the right

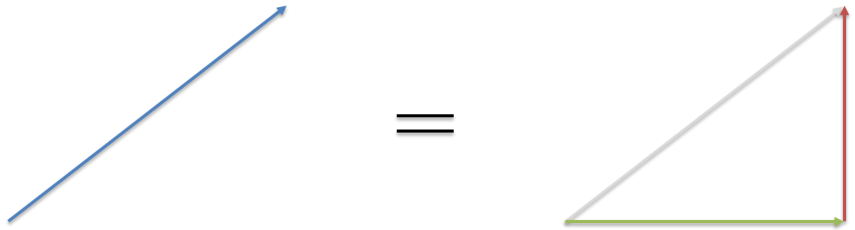


R = 4 N to the right

HIGHER TIER ONLY!

Calculating Resultant Force… continued

A single force can be resolved into two components acting at right angles to each other. The two component forces together have the same effect as the single force.



Calculating Resultant Force

Example 1:

A box is pushed along the floor with a force of 120 N. There is a resistive force of 30 N. Work out the resultant force on the box.

Solution:

Resistive forces act in the opposing direction to motion.

Addition of the forces gives:

120 N + -30 N = 90 N in direction of 120 N force

Example

A pendulum has a weight of 0.5 N.

On a windy day the pendulum is hung outside and the pendulum now hangs at an angle of 45º.

Assuming the wind hits the pendulum moving horizontally, draw a free body diagram to represent the forces acting.

Solution