Cells

Nucleus
Controls cell

Ribosomes
Protein synthesis

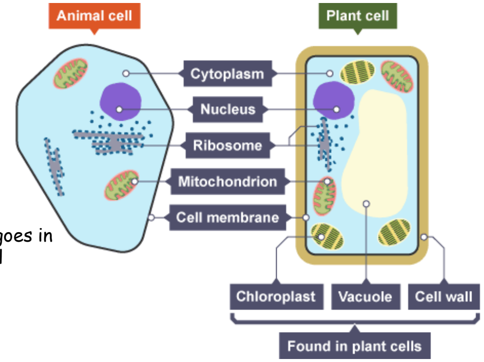
Cell Membrane
Controls what goes in and out the cell

Mitochondria
Respiration

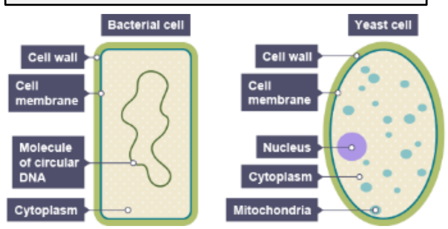
Chloroplast
Photosynthesis

Cytoplasm
Where chemical reactions occur

Eukaryotic cells



Prokaryotic cells – no membrane bound organelles (loose DNA)

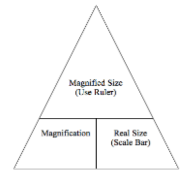


Magnification

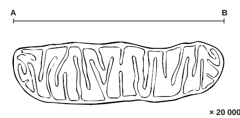
Fraction of a metre	Unit	Symbol
One thousandth = 0.001 = 1/1000 = 10^{-3}	millimetre	mm
One millionth = 0.000001 = 1/1000 000 = 10^{-6}	micrometre	µm
One thousand millionth = 0.000 000 001 = 1/1000 000 000 = 10^{-9}	nanometre	nm

To calculate actual size:

1. Measure the organelle with a ruler.
2. Multiply this by 1000 to get a value in micrometres
3. Divide this by the magnification



e.g. The diagram below is a drawing of an organelle from a ciliated cell as seen with an electron microscope.



Calculate the actual length of the organelle as shown by the line AB in the diagram. Express your answer to the nearest micrometre (µm).

1. Measure it in mm = 40mm
2. Multiply by 1000 = 40000µm
3. Divide by magnification 40000 / 20000 = 2µm

Magnification is the number of times larger an image is compared with the real size of the object.

Resolution is the ability to distinguish between 2 separate points.

Specialised Cells – Cells that have differentiated

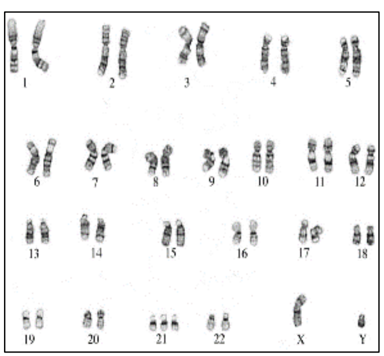
Neurone		• Long and thin. • Have a myelin sheath to prevent loss of impulse. • Form connections with other neurones. • Can carry electrical impulses in one direction.
Sperm		• Contain digestive enzymes for breaking down the outer layer of an egg cell. • Many mitochondria. • Have long tail.
Red Blood		• Large surface area. • Small diameter. • No nucleus. • Contain haemoglobin.
Root Hair		• Found close to xylem • Thin membrane. • Large surface area.
Cone Cells		• Outer segment filled with visual pigment that changes chemically in coloured light. • Lots of mitochondria so that you constantly see in colour. • Specialised synapses connecting to the optic nerve.

Chromosomes

Humans have 23 pairs of chromosomes (46 in total) in all adult cells.

Chromosomes 23 = sex chromosomes (XY = male XX = female)

Karyotype – visual appearance of our chromosomes.



What are the differences?

1. 47 instead of 46
2. Extra chromosome 21 (called Trisomy-21 (Down's Syndrome))
3. Normally 21 should be 2 chromosomes

Bacteria multiply by binary fission.

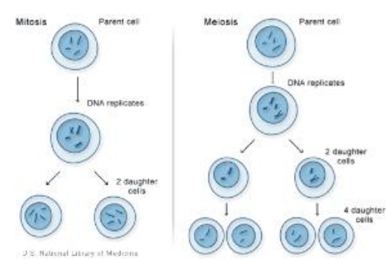
Growth is exponential i.e. 1 → 2 → 4 → 8 → 16 → 32 → 64…

Mitosis and Meiosis – cell division

Mitosis (in humans)

- Occurs all over the body
- Makes new cells with 23 pairs of chromosomes
- Cells divide once
- Makes new body cells.

Interphase: DNA copies



Different stages of mitosis:

Prophase – chromosomes condense

Metaphase – chromosomes line up in the middle

Anaphase – chromosomes pulled apart by spindle fibres

Telophase – 2 new nuclei form

Meiosis (in humans)

- Occurs in testes and ovaries
- Makes cells with 23 chromosomes
- Cells divide twice
- Makes gametes (sperm and egg)

Stem Cells - These are undifferentiated cells

- Embryonic – can make any type of cell
- Tissue-specific – can only make cells from specific parts of the body

Advantages:

- Treat blindness
- Organ transplants
- Treat paralysis

Disadvantages:

- Ethical issues with embryos
- Religious issues

Diffusion

Movement of particles from a high concentration to a low concentration (down a concentration gradient)

To increase rate of diffusion:

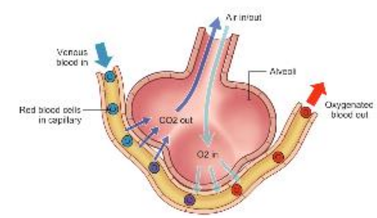
- Increase temperature
- Increase surface area
- Increase concentration gradient
- Shorten distance

Large organisms have a small surface area:volume so require specialised exchange surfaces with large surface area so diffusion is fast enough.

Small Intestine: Villi increase surface area
Blood flow maintains conc. Gradient
Thin wall 1 cell thick

Lungs:
Alveoli increase surface area

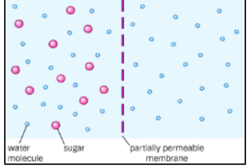
Blood flow and thin walls like the villi



Osmosis

Water travels from a ***dilute solution*** (high water concentration) to a ***more concentrated solution*** (low water concentration).

The water moves across a **partially permeable membrane**.

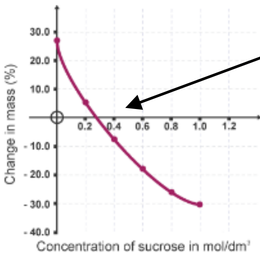


Isotonic means the amount of dissolved solutes is the same on the outside of the cell as the inside, so there is no difference in concentration of water.

Hypotonic means there are more solutes inside the cell than outside, therefore inside the cell has a lower concentration of water.

Hypertonic means there are more solutes on the outside of the cell than on the inside. So there is a lower concentration of water on the outside of the cell.

- **Turgid** – When a cell fills with water (plant cell wall protects cell from bursting)
- **Flaccid** – When a cell loses water



The solution is isotonic where the line crosses the x-axis i.e. 0.3 mol/dm^3.

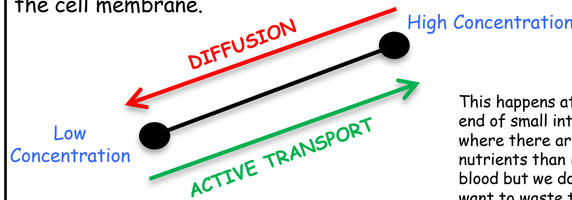
Potato gains mass in a hypotonic solution but loses mass in a hypertonic solution.

Active Transport

This is the opposite of diffusion.

Substances move from an area of low concentration to high concentration, **against the concentration gradient**.

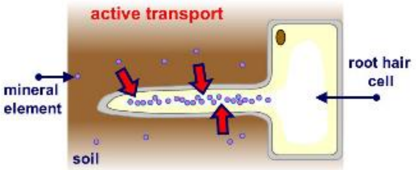
It requires ATP (energy) – this means it need mitochondria. The ATP is used to change the shape of protein channels in the cell membrane.



This happens at the end of small intestine where there are less nutrients than in the blood but we don't want to waste them.

Root hair cells have more minerals than the soil but still needs them. Active transport is used for uptake of these minerals.

Root hair cells therefore have lots of mitochondria.

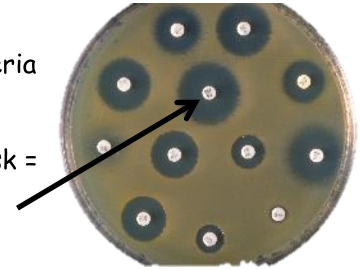


REQUIRED PRACTICAL: Growing Bacteria

- Flame the loop – sterilises it
- Lift lid slightly – prevent airborne bacteria getting into it
- Seal with 2 bits of tape – allows air to get in but keeps lid on for safety
- Incubate at 25°C – prevents pathogens growing

Antibiotics on bacteria on the jelly.

Big space around disk = most bacteria killed



Pathogens – microorganisms that cause disease

	Bacteria	Virus	Fungi
Size	1000nm	20-40nm	2-10µm
Method of reproduction	Grow then divide in two	Invade host cells and tell nucleus to make copies	They release spores which travel through the air
How they make you feel ill	Produce toxins that travel around the body	Make cells burst open	Produce toxic chemicals

Malaria

Caused by a protist called **Plasmodium**. Vector = mosquito

1. Mosquito bite injects sporozoites into blood.
2. Sporozoites invade liver cells.
3. Sporozoites turn into merozoites and burst open liver cells.
4. Merozoites invade red blood cells, digest haemoglobin, replicate and burst open red blood cells.
5. Merozoites taken back up into mosquito.

Prevention:

- Eggs laid in stagnant water – drain pools, spray them with insecticide, spray with oil to prevent oxygen getting to the eggs,
- Mosquito nets and repellant spray.
- Chloroquine

Name of disease	Type of pathogen	Transmission/how to prevent spread	Symptoms	Treatments
Salmonella	Bacteria	Uncooked poultry, dirty work surfaces Cook food thoroughly	Nausea, diarrhoea	Antibiotics
Gonorrhoea	Bacteria	Unprotected sex Wear condoms	Discharge, painful genitals	Antibiotics
Malaria	Protist	Mosquito bites Mosquito nets, drain pools, chloroquine	Tired, headache, vomiting	N/A
HIV	Virus	Blood contact, exchange of bodily sexual fluids, sharing needles Condoms, don't do heroin	Symptoms from various diseases caused by developing AIDs	N/A
Measles	Virus	Droplet infection, sneezes MMR vaccine	Red rash on skin	Painkillers to reduce the symptoms

White Blood Cells

- Phagocytes – Engulf (phagocytosis, non-specific)
- Lymphocytes - Make antibodies (specific proteins that bind to antigens)
- Lymphocytes - Make antitoxins (counteract toxins made by bacteria)

Vaccines

Contain dead or inactive pathogens

1. White blood cells make **antibodies**
2. Antibodies remove dead/inactive pathogen
3. If exposed to real pathogen, antibodies are made **quickly** before they can multiply.

MMR Vaccine = Measles, Mumps and Rubella

Drug Trials

Stage 1: Tested on animals, cells and tissue
Check for toxicity
Stage 2: Tested on human volunteers
Check dosage and side effects
Stage 3: Tested on patients to see if it is effective

Double blind - no one knows who gets the real drug
- no bias
Placebo – fake drug (looks same, taken same way) It is a control.

Thalidomide

- Tested as sleeping pill
- Not tested on pregnant women
- Given to pregnant women for morning sickness
- Babies have limb deformities
- Only given now for leprosy

Medicines

Medicines - A drug is a chemical that alters how the body works. They alter the normal chemical reactions in the body.

Antibiotics – kill bacteria or prevent them from multiplying.
THEY DON"T KILL VIRUSES because viruses live inside cells.

Painkillers – relieve the symptoms only

Antivirals – target specific viruses and slow down replication.

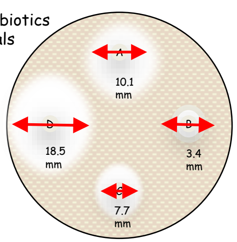
Antibiotic Resistance

1. Mutation occurs when bacteria multiply
2. Mutation makes bacteria resistant to antibiotic
3. Antibiotic kills all the others
4. No competition for food or space
5. New colony of resistant bacteria grows

e.g. MRSA

Causes: Incorrect use of antibiotics
Not completing the full course of antibiotics
Over-sterile environments e.g. hospitals

To calculate clear zone: πr^2



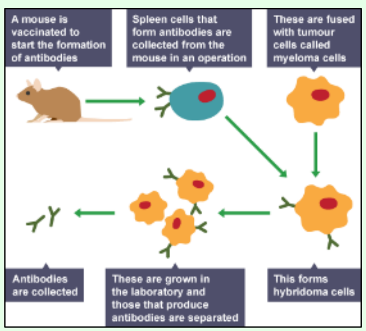
Resistant: 6mm or less
Intermediate: 7-11 mm
Susceptible: 12 mm or more

Monoclonal Antibodies

TRIPLE ONLY

Monoclonal antibodies are identical copies of antibodies that have been made in laboratories.

- **Pregnancy test kits** to identify the small levels of a hormone called hCG, which is present in the urine of pregnant women.
- **Locate blood clots** as they bind to clots.
- **Diagnose and then treat some cancers**. They can bind to the cancerous cells and help the person's immune system attack them.



Advantages: Monoclonal antibodies only bind to the specific cancer cells that need treatment. Healthy cells are not affected at all. In contrast conventional drug treatment is carried all around the body in the blood and can have a devastating effect on healthy cells as well as cancer cells.

Disadvantages: Monoclonal antibodies create more side effects, the most common being an allergic reaction to the drug. An allergic reaction can include these symptoms: chills, fever, an itchy rash, feeling sick, breathlessness, wheezing, headaches, flushes and faintness, changes in blood pressure.

Plant Diseases

TRIPLE ONLY

Some plant diseases are caused by bacteria, fungi and also by vectors e.g. aphids.

Name of disease	Type of pathogen	How it is spread	Symptoms	Prevention/ Treatment
Tobacco Mosaic Virus	Virus	Direct contact with diseased plant material and by insects	Mosaic pattern damaging cells preventing photosynthesis	Field hygiene and pest control
Rose Black Spot	Fungi	Spores carried by wind and spread by rain from leaf to leaf	Purple spots on leaves, dead leaves, poor flowers	Remove and burn affected leaves, fungicides

Aphids – penetrate phloem and take products of photosynthesis. Also act as vectors transferring pathogens to the plants.

Mineral Deficiencies – Soil lacking nitrates = less protein so less growth.
- Soil lacking magnesium = chlorosis = less chlorophyll so less photosynthesis – yellow leaves

Detecting Diseases

- Fast detection – discoloration, visible pests, stunted growth.
- Compare growth with normal plants or data online
- DNA analysis to identify pathogens (monoclonal antibodies)

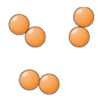
Elements, Mixtures and Compounds

Rule 1 – If two identical elements combine then the name doesn't change

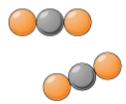
Rule 2 – When two elements join the end is usually ________ide.

Rule 3 – When three or more elements combine and one of them is oxygen the ending is ______ate

An element is just a pure substance, for example oxygen (O_2)

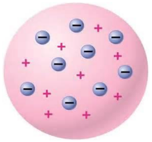


A compound is a material that is made up of more than one type of atom chemically bonded together, for example Carbon Dioxide (CO_2)



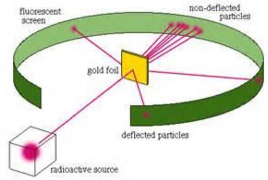
A mixture contains two or more different types of compounds or elements that are not chemically bonded together

Atomic Structure



1. In 1901 JJ Thompson suggested the **plum pudding model – this was an atom** that the atom is a ball of positive charge with negative electrons embedded in it.

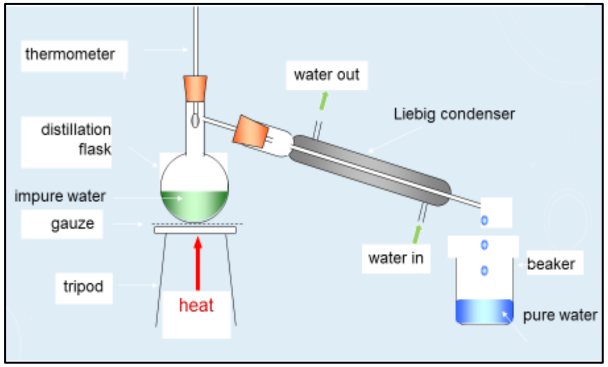
2. In 1909 Rutherford changed the accepted model using his alpha scattering experiment. The results from the alpha particle scattering experiment led to the conclusion that the mass of an atom was concentrated at the centre (nucleus) and that the nucleus was charged. This nuclear model replaced the plum pudding model.



3. Niels Bohr adapted the nuclear model by suggesting that electrons orbit the nucleus at specific distances.

4. 20 years later, James Chadwick provided the evidence to show the existence of neutrons within the nucleus.

Distillation



Distillation can be used to separate liquids from a mixture, if they have different boiling points. Distillation is the process in which evaporation of a liquid is followed by condensation

The Atom

Mass Number	12
	C
Atomic Number	6

Name of particle	Relative charge	Relative mass
Proton	+1	1
Neutron	0	1
Electron	–1	Very small

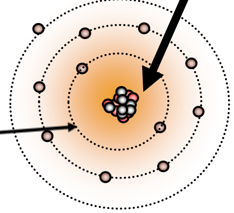
Atoms are very small, having a radius of about 0.1 nm (1 x 10^{-10} m).

The radius of a nucleus is less than 1/10 000 of that of the atom (about 1 x 10^{-14} m).

The mass number tells us the number of protons + neutrons.

The number of protons in an atom is known as its atomic number, this is also the number of electrons

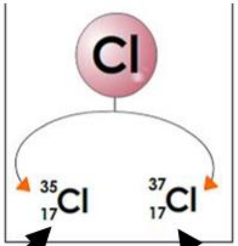
The Nucleus
a dense core of protons and neutrons containing nearly all the mass of the atom



'Shells' of electrons
electrons are really very very tiny so the atom is mostly empty space.

Relative Atomic Mass

RAM is the average mass of all the stable isotopes of that element and includes the relative abundance.



Chlorine - 35

Chlorine - 37

Element	Relative mass of isotope	Relative abundance
Chlorine	35	3
	37	1

$$R.A.M. = \frac{(35 \times 3) + (37 \times 1)}{3 + 1} = 35.5$$

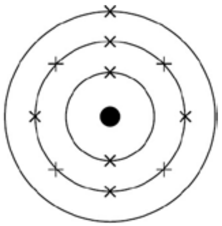
Electronic Structure

The electrons in an atom occupy the lowest available energy levels (innermost available shells).

The electronic structure of an atom can be represented by numbers or by a diagram.

Up to two electrons can occupy the lowest energy level, up to eight in the second energy level and up to eight in the third energy level.

For example, the electronic structure of sodium is 2,8,1.



Development of the Periodic Table


Newlands

Before the discovery of protons, neutrons and electrons, scientists attempted to classify the elements by arranging them in order of their atomic weights.

The early periodic tables were incomplete and some elements were placed in inappropriate groups if the strict order of atomic weights was followed.


Mendeleev

Mendeleev overcame some of the problems by leaving gaps for elements that he thought had not been discovered and in some places changed the order based on atomic weights.

Elements with properties predicted by Mendeleev were discovered and filled the gaps. Knowledge of isotopes made it possible to explain why the order based on atomic weights was not always correct.

Transition Metals (Triple Only)

The transition elements are metals with similar properties. Their properties are different from those found in Group 1. Lots of transition metals are used as catalysts.

Properties of transition metals;
- High melting + boiling point
- Form positive ions
- Good electrical conductors
- High thermal conductivity
- Malleable
- Form colored compounds

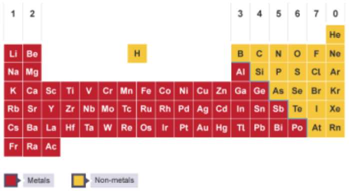
Copper Good conductor of heat and electricity	**Iron** Alloys are very strong	**Manganese** Resistant to corrosion
Cobalt Strong when alloyed with other metals	**Chromium** Can speed up reactions (Catalyst)	**Nickel** Alloys are resistant to corrosion

Metals and non-metals

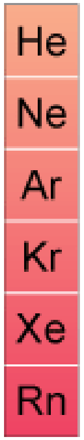
Elements that react to form positive ions are metals.
Elements that do not form positive ions are non-metals.

The formation of ions can be worked out using the Periodic Table:
- Group 1 elements form 1+ ions, group 2 elements form 2+ ions and group 3 elements form 3+ ions.
- Group 5 elements form 3- ions, group 6 elements form 2- ions and group 7 elements form 1- ions.
- Group 0 do not form ions due to having a stable structure/full outer shell.

The majority of elements are metals. Metals are found to the left and towards the bottom of the periodic table. Non-metals are found towards the right and top of the periodic table.



Group 0

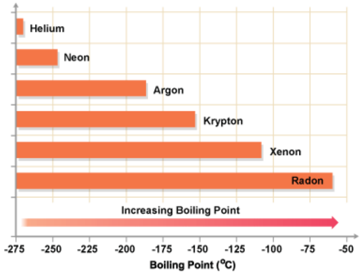


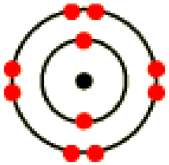
The elements in Group 0 of the periodic table are called the noble gases.

They are unreactive and do not easily form molecules because their atoms have stable arrangements of electrons.

The noble gases have eight electrons in their outer shell, except for helium, which has only two electrons.

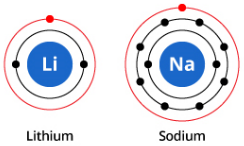
The boiling points of the noble gases increase with increasing relative atomic mass (down the group).

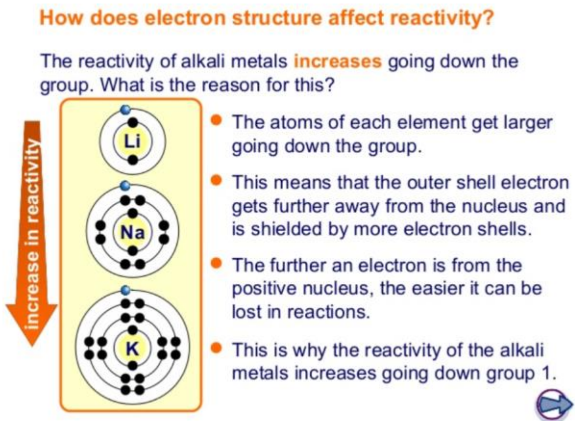




Group 1

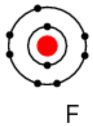
The elements in Group 1 of the periodic table are known as the alkali metals and have characteristic properties because of the single electron in their outer shell.



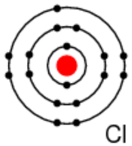


Group 7

The elements in Group 7 of the periodic table are known as the halogens and have similar reactions because they all have seven electrons in their outer shell.



The halogens are non-metals and consist of molecules made of pairs of atoms.



In Group 7, the further down the group an element is the higher its relative molecular mass, melting point and boiling point.

In Group 7, the reactivity of the elements decreases going down the group.

A more reactive halogen can displace a less reactive halogen from an aqueous solution of its salt.

Displaced is just a chemist's word for pushed out.

chlorine + sodium bromide → sodium chloride + bromine

$Cl_2 + 2NaBr \rightarrow 2NaCl + Br_2$

Chemical bonds

There are three types of strong chemical bonds: ionic, covalent and metallic.

IONIC	COVALENT	METALLIC
For ionic bonding the particles are oppositely charged ions. Ionic bonding occurs between metals and non-metals.	For covalent bonding the particles are atoms which share pairs of electrons. Covalent bonding occurs in non-metals.	For metallic bonding the particles are atoms which share delocalised electrons. Metallic bonding occurs in metallic elements and alloys.

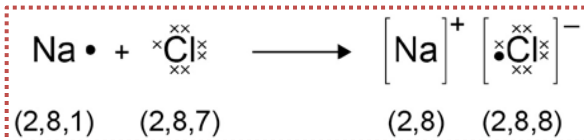
Ionic bonding

When a metal atom reacts with a non-metal atom electrons in the outer shell of the metal atom are transferred.

Metal atoms lose electrons to become positively charged ions.

Non-metal atoms gain electrons to become negatively charged ions.

The ions produced by metals in Groups 1 and 2 and by non-metals in Groups 6 and 7 have the electronic structure of a noble gas (Group 0).



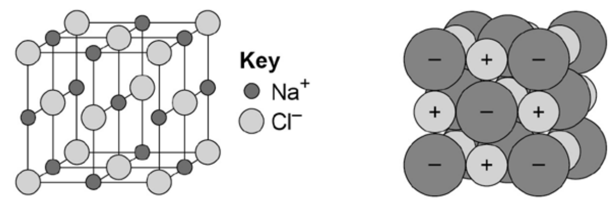
Ionic compounds

Ionic compounds are held together by strong electrostatic forces of attraction between oppositely charged ions.

These forces act in all directions in the lattice and this is called ionic bonding.

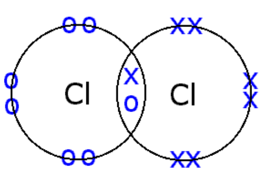
They have high melting and boiling points due to the strong forces of attraction in all directions holding the ions together.

They also conduct electricity when molten or dissolved in water as the ions are free to move so the charge can flow.

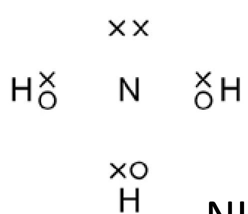


Covalent Bonding

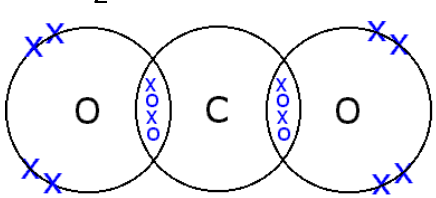
Covalent bonds happen where two or more non-metal elements make a bond. These bonds share electrons, therefore completing the outer shell for all the atoms.



Cl_2

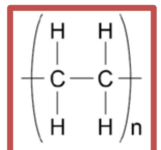


NH_3



CO_2

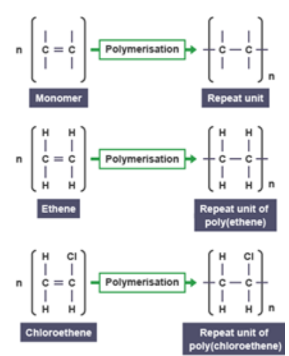
Polymers



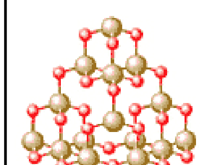
poly(ethene)

Polymers have very large molecules, with the atoms in polymer molecules linked to other atoms by strong covalent bonds. They are ,made by joining thousands of small identical molecules together (monomers). The monomers are often alkene molecules (e.g. ethene). The intermolecular forces between polymer molecules are relatively strong so they are solid at room temperature

By changing the monomer used, we can change the properties of the polymer formed.



Giant Covalent Structures 1

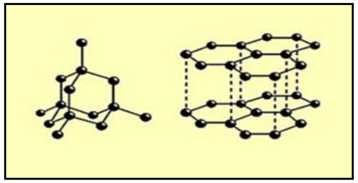


Silicon dioxide (silica)

Each silicon atom is covalently bonded to four oxygen atoms. Each oxygen atom is covalently bonded to two silicon atoms. This means that, overall, the ratio is two oxygen atoms to each silicon atom, giving the formula SiO_2.

Silicon dioxide is very **hard**. It has a very **high melting point** (1,610 °C) and **boiling point** (2,230 °C), is insoluble in water, and does not conduct electricity. These properties result from the very strong covalent bonds that hold the silicon and oxygen atoms in the giant covalent structure.

Giant Covalent Structures 2



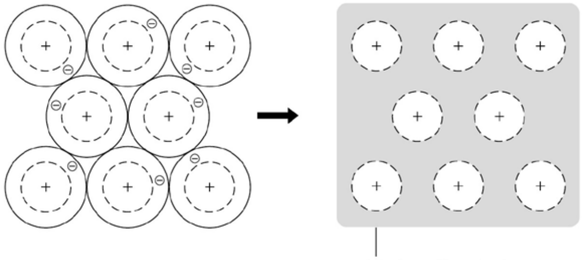
Diamond and graphite are both allotropes of carbon.

In Diamond each carbon atom is bonded to four other carbon atoms by very strong covalent bonds and therefore has no free electrons. The four strong covalent bonds give diamond a very high melting point.

In Graphite each carbon is bonded to 3 carbon atoms with weak intermolecular forces between the layers, which allows the layers to easily slide over each other. They also have a delocalised electron which allows graphite to conduct electricity. Graphite is used in lubricants as the layers can slide.

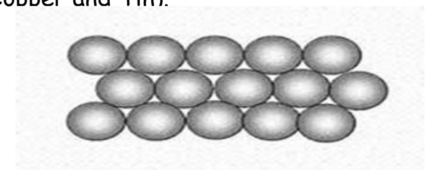
Metallic Bonding

Metals consist of giant structures of atoms arranged in a regular pattern. The electrons in the outer shell of metal atoms are delocalised and so are free to move through the whole structure. The sharing of delocalised electrons gives rise to strong metallic bonds.



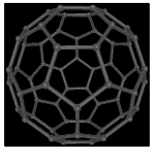
Giant Metallic Structures

Metals also form alloys. In alloys they contain at least two different types of atom which distorts the rigid regimented structure of the metal. As the layers are unable to slide over each other this causes metal alloys to be much stronger than the pure metals. Examples of alloys include Bronze (Copper and tin), Steel (Iron and Carbon) and Bronze (Copper and Tin).



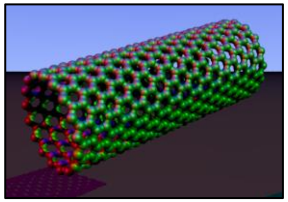
Giant Covalent Structures 3

Fullerenes are molecules of carbon atoms with hollow shapes, based on hexagonal rings of carbon atoms but they may also contain five or seven carbon atoms. Buckminsterfullerene C_{60} was the first to be discovered.



Carbon nanotubes are cylindrical fullerenes with high length to diameter ratios, this makes them useful for nanotechnology, electronics and materials.

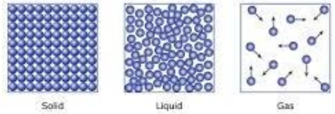
Fullerenes are often good lubricants due to their ability to roll.



Particle Model

The particles in a solid are tightly packed together and can only vibrate. They cannot be pushed any closer together.

The particles in a liquid are in contact with each other, but are arranged randomly. They can roll over each other, that is why a liquid can be poured.



The particles in a gas can move around freely. There are large spaces between the particles, so they can be pushed closer. This is why a gas can be compressed

In melting and boiling the strength of the forces between particles becomes less due to the increased kinetic energy, resulting in more space between the particles and more random arrangement

Nanoparticles (TRIPLE)

Unit name	Unit symbol	Meaning
gigametre	Gm	one billion metres
megametre	Mm	one million metres
kilometre	km	one thousand metres
metre	m	one metre
millimetre	mm	one thousandth of a metre
micrometre	μm	one millionth of a metre
nanometre	nm	one billionth of a metre

Nanoscience refers to structures that are 1^{-100} nm in size, of the order of a few hundred atoms.

Nanoparticles, are smaller than fine particles (PM2.5), which have diameters between 100 and 2500 nm (1×10^{-7} m and 2.5×10^{-6} m).

Coarse particles (PM10) have diameters between 1×10^{-5} m and 2.5×10^{-6} m. Coarse particles are often referred to as dust.

Nanoparticles may have properties different from those for the same materials in bulk because of their high surface area to volume ratio. It may also mean that smaller quantities are needed to be effective than for materials with normal particle sizes.

As the side of cube decreases by a factor of 10 the surface area to volume ratio increases by a factor of 10.

Conservation of mass

Mass is never lost or gained in chemical reactions. We say that mass is always **conserved**. In other words, the total mass of products at the end of the reaction is equal to the total mass of the reactants at the beginning.

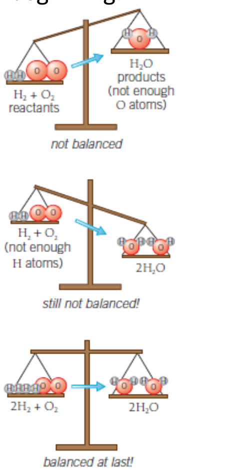


Figure 1 *Balancing an equation*

Balancing equations rules

- Never change the chemical formula
- Total number of reactants must equal total number of products
- Never put a small number yourself
- The big number in front applies to all the atoms in the compound/element
- The small number behind an element applies to that element only
- Use big numbers only and start with 2

Relative formula mass M_r

Mass number = number of protons + number of neutrons
Atomic number = number of protons
Neutron number = mass number – atomic number

The mass of a molecule is called the relative formula mass, M_r. This is calculated by adding up the relative atomic masses of all the atoms in the molecule.

What is the M_r (Relative Formula Mass) of carbon dioxide?

Formula for carbon dioxide	CO_2

Element	Number of atoms in compound		Mass Number (A_r)		Relative atomic mass of atom(s) in compound
C	1	x	12	=	12
O	2	x	16	=	+ 32
Relative Formula Mass (M_r) of carbon dioxide (CO_2) is....					44

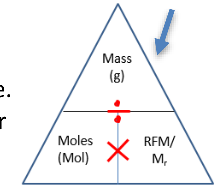
Examples of M_r below:

H_2SO_4 → M_r = (1x2=2) + 32 + (16x4=64) = 98
$Ca(OH)_2$ → M_r = 40 + (16 x 2=32) + (1 x 2=2) = 74
$Mg(HCO_3)_2$ → M_r = 24 + (1x2=2) + (12x2=24) + (16x6=96) = 146
$Al_2(SO_4)_3$ → M_r = (27x2=54) + (32x3=96) + (16x12=192) = 342

Moles and Reacting Masses

One mole of a substance contains the same number of the stated particles, atoms, molecules or ions as one mole of any other substance. The number of atoms, molecules or ions in a mole of a given substance is the Avogadro constant which is 6.02×10^{23} per mole.

Formula to calculate moles



The rules for working out **reacting masses** & example:

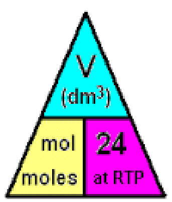
If 28 g of iron reacts with copper sulphate solution, what mass of copper will be made?

- **Step 1.** Write down the balanced symbol equation.
  Fe (28g) + $CuSO_4$ → Cu (?) + $FeSO_4$
- **Step 2.** Write down the relative atomic/formula masses.
  Fe = 56   Cu = 64
- **Step 3.** Write down the ratio of reactants and products.
  Fe : Cu = 1 : 1
- **Step 4.** Convert to ratio of reacting masses.
  Fe : Cu = 1 : 1 = 56 g : 64 g
- **Step 5.** Calculate the scale factor and apply this to the ratio of reacting masses.
  scale factor = 28 g / 56 g = 0.5
  mass of Cu made = 64 g x 0.5 = 32 g

Limiting Reactant (LR)
Is the reactant that gets used up first in a reaction. This is the reactant that is NOT in excess. Therefore, the amounts of product formed in a chemical reaction are determined by the LR

Volume of Gases

One mole of any gas has a volume of 24 dm³ or 24,000 cm³ at rtp (room temperature (20°C) and pressure (1 atmosphere)). This volume is called the molar volume of a gas.



Concentrations

The **concentration** of a solution is usually expressed as the amount of **solute (mol)** dissolved in a given **volume (dm³)** of solution.

Figure 1 *The orange squash is getting less concentrated going left to right (the darker colour indicates more squash is in the same volume of its solution)*

Figure 2 *Volumetric flasks are used to make up solutions. They have a graduation mark around their narrow necks. Water is added to the solute until the bottom of its meniscus (the curve at the surface of the solution when viewed from the side) is level with the mark*

Concentration continued…

The equations to calculate concentration:

$$\text{concentration (g/dm}^3) = \frac{\text{amount of solute (g)}}{\text{volume of solution (dm}^3)}$$

If you are working in centimetres cubed (cm³), convert the volume to dm³ by dividing it by 1000, and use the equation above. Alternatively, substitute your data in cm³ into the following equation:

$$\text{concentration (g/dm}^3) = \frac{\text{amount of solute (g)}}{\text{volume of solution (cm}^3)} \times 1000$$

*** to convert cm³→ dm³, divide by 1000 (0.001 dm³)**
*** to convert dm³→ cm³, multiply by 1000 (1000 cm³)**

You can increase the concentration of an aqueous solution by:

- adding more solute and dissolving it in the same volume of its solution
- evaporating off some of the water from the solution so you have the same mass of solute in a smaller volume of solution.

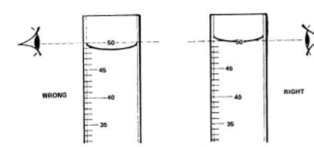
Titrations (TRIPLE ONLY)

Measuring the EXACT volumes of acid and alkali that are needed to react together. **What is this reaction called?** NEUTRALISATION

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

You can measure the exact volumes of acid and alkali needed to react with each other using a technique called **titration**. The point at which the acid and alkali have reacted completely is called the **end point** of the reaction. You judge when the end point has been reacted using an acid/base indicator.

Measuring to the meniscus

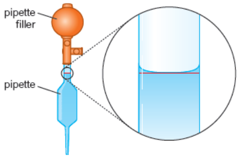


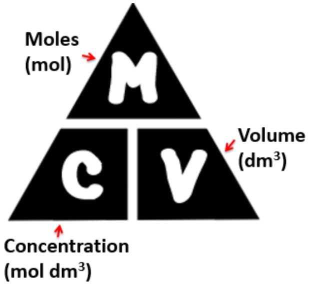
such as **Phenolphthalein Indicator**. It turns colourless in an neutral solution and pink in an alkaline solution.

Titrations continued…Carrying out a titration

1. First wash the pipette with distilled water, then with some alkali. Empty alkali into a conical flask.
2. Add a few drops of indicator to the conical flask. Swirl
3. Rinse a **burette** with distilled water and then with some acid. Acid added to burette, starting volume of acid is read accurately.
4. Record the reading on the burette. Open tap to release a bit of acid into flask, swirl.
5. Repeat step 4 until acid in burette has almost run in, then add one drop at a time. Neutralisation occurs. The volume of acid recorded.
6. Repeat 3 times. Discard anomalous results. Repeat the titrations until two results are within of 0.1 cm^3 each other. These precise results are called **concordant**. Calculate a mean.
7. Calculate the concentration of the acid or alkali.

- A volumetric pipette is used to accurately measure a volume of an alkali.
- A pipette filler is used to draw solution into the pipette safely.
- Neutralisation is a change in colour when acid and alkali have been mixed = titration is complete.
- Titre is the volume recorded from a burette





Percentage yield and Atom economy (TRIPLE)

$$\% \text{ yield} = \frac{\text{mass of product obtained}}{\text{maximum theoretical mass of product}} \times 100$$

- The reaction may be reversible – as products form they react to re-form the reactants again. You show reversible reactions using this symbol ⇌ instead of the normal arrow between reactants and products. Chemists can manipulate reversible reactions by the conditions they choose in the reaction vessels in chemical plants.
- Some reactants may react to give unexpected or unwanted products in alternative reactions.
- Some of the product may be lost in handling or left in the apparatus.
- The reactants may not be pure (as in the case of the lime kiln).
- Some of the desired product may be lost during its separation from the reaction mixture.

$$\text{Atom economy} = \frac{\text{mass of wanted product from equation}}{\text{total mass of products from equation}} \times 100$$

Yield Industrial processes –
Industrial processes need as high a percentage yield as possible, because this:
1) Reduces the waste of reactants
2) Reduces the cost of the process

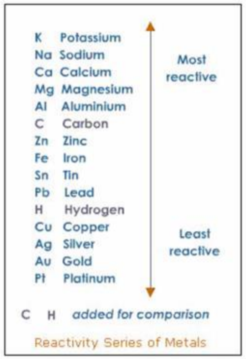
Atom Industrial processes –
Industrial processes need as high an atom economy as possible, because this:
1) Reduces the production of unwanted products
2) Makes the process more *sustainable*
3) Conserve the Earth's resources and minimise pollution

Extraction of Metals + Metal Oxides

Metals react with oxygen to form metal oxides

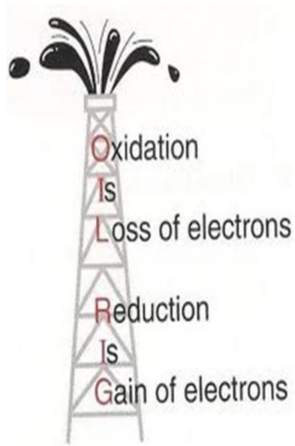
Chromium + Oxygen → Chromium oxide
Iron + Oxygen → Iron oxide
Copper + Oxygen → Copper oxide

Many metals are found in the ground as metal compounds. The metal needs to be extracted. For metals that are below carbon in the reactivity series this can be done by heating the metal compound with carbon The carbon removes the oxygen from the metal oxide.



1. Copper oxide + Carbon → Carbon dioxide + Copper
2. Lead oxide + Carbon → Carbon dioxide + Lead
3. Iron oxide + Carbon → Carbon dioxide + Iron

Oxidation and Reduction



Oxidation is the gain of oxygen and the loss of electrons, reduction is the loss of oxygen and gain of electrons.

A chemical reaction where both oxidation and reduction occur is called a redox reaction.

The equation below shows a word equation, a balanced symbol equation, ionic and half equations which show the movement of electrons.

Zinc + copper sulphate → zinc sulphate + copper
$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$
Zn - oxidised Cu^{2+} - reduced
$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$
$Zn - 2e^- \rightarrow Zn^{2+}$ or $Zn \rightarrow Zn^{2+} + 2e^-$
$Cu^{2+} + 2e^- \rightarrow Cu$

Metals + Acids and Metal Carbonates + Acid

Metal + Acid → Metal salt + Hydrogen

Calcium + Hydrochloric acid → Calcium chloride + Hydrogen
$Ca + 2HCl \rightarrow CaCl_2 + H_2$

Zinc + Hydrochloric acid → Zinc chloride + Hydrogen
$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

Metal Carbonate + Acid → Metal salt + Carbon Dioxide + Water

Calcium Carbonate + Hydrochloric acid → Calcium chloride + Carbon Dioxide + Water
$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

Potassium Carbonate + Nitric acid → Potassium nitrate + Carbon Dioxide + Water
$K_2CO_3 + 2HNO_3 \rightarrow 2KNO_3 + CO_2 + H_2O$

Acid + Alkali → Metal salt + Water

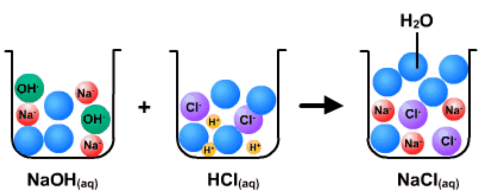
Hydrochloric acid + Sodium hydroxide → Sodium chloride + Water
$2HCl + NaOH \rightarrow NaCl_2 + H_2O$

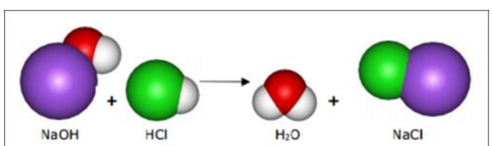
Sulphuric acid + Potassium hydroxide → Potassium Sulphate + Water
$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

Neutralisation

The acid used will determine the salt produced in a neutralisation reaction:

- hydrochloric acid produces chlorides
- nitric acid produces nitrates
- sulfuric acid produces sulfates





Soluble salts (Required practical)

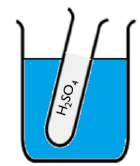
Soluble salts can be made from acids by reacting them with solid insoluble substances, such as metals, metal oxides, hydroxides or carbonates.

The solid is added to the acid until no more reacts and the excess solid is filtered off to produce a solution of the salt.

Salt solutions can be crystallised to produce solid salts.

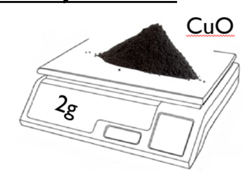
Soluble salts (Required practical): Method

1



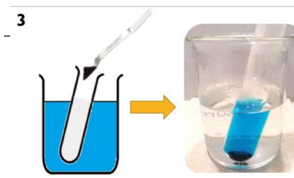
Sulfuric acid is warmed in a water bath

2



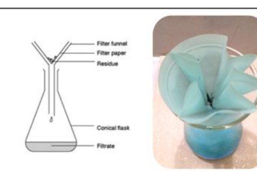
Weigh 2g of black copper oxide powder

3



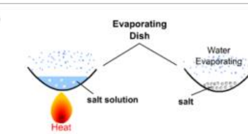
Add copper oxide to the sulphuric acid until a blue solution is formed and excess copper oxide sinks to the bottom of the tube.

4



Filter the unreacted copper oxide from the solution and collect the filtrate

5

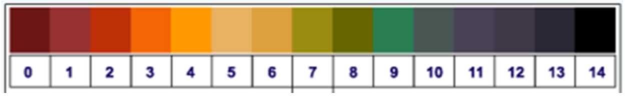


Transfer the solution to an evaporating dish and heat gently

6

Leave to cool, copper sulfate crystals will form. Remove and dry crystals.

pH and Acids + Alkalis



Acids produce H^+ (as H_3O^+) ions in water and they taste sour. They also corrode metals and have a pH of less than 7. They also turns blue litmus paper to red.

Alkalis produce OH^- ions in water and they taste bitter with a pH greater than 7. Alkalis turns red litmus paper to blue.

A solution is defined as an acid if the concentration of H^+ ions is greater than the concentration of OH^- ions. $[H^+] > [OH^-]$

A solution is defined as alkali/base if the concentration of hydrogen ions is less than the concentration of hydroxide ions. $[H^+] < [OH^-]$

Strong and weak acids

A strong acid is completely ionised in aqueous solution. $HCl + H_2O \rightarrow H^+ + Cl^-$

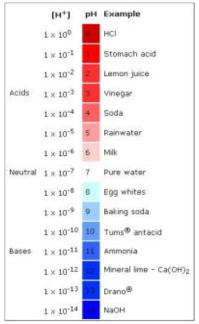
Examples of strong acids are hydrochloric, nitric and sulfuric acids.

A weak acid is only partially ionised in aqueous solution. $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H^+$

Examples of weak acids are ethanoic, citric and carbonic acids.

For a given concentration of aqueous solutions, the stronger an acid, the lower the pH.

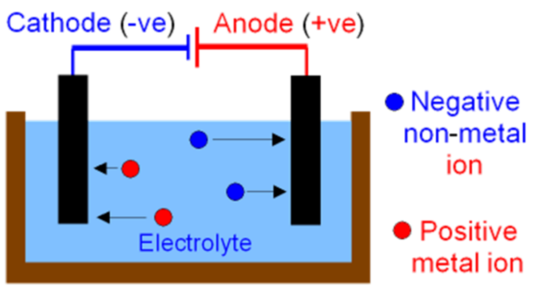
As the pH decreases by one unit, the hydrogen ion concentration of the solution increases by a factor of 10.



	$[H^+]$	pH	Example
	1×10^{0}	0	HCl
	1×10^{-1}	1	Stomach acid
	1×10^{-2}	2	Lemon juice
Acids	1×10^{-3}	3	Vinegar
	1×10^{-4}	4	Soda
	1×10^{-5}	5	Rainwater
	1×10^{-6}	6	Milk
Neutral	1×10^{-7}	7	Pure water
	1×10^{-8}	8	Egg whites
	1×10^{-9}	9	Baking soda
	1×10^{-10}	10	Tums® antacid
Bases	1×10^{-11}	11	Ammonia
	1×10^{-12}	12	Mineral lime - $Ca(OH)_2$
	1×10^{-13}	13	Drano®
	1×10^{-14}	14	NaOH

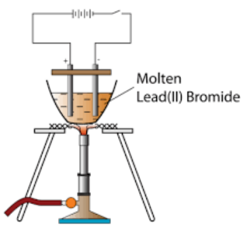
Electrolysis

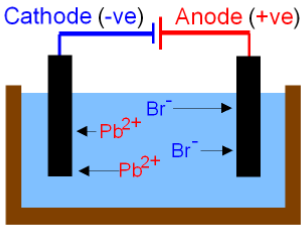
When an ionic compound is melted or dissolved in water, the **ions** are free to move about within the liquid or solution. These liquids and solutions are able to conduct electricity and are called electrolytes. Passing an electric current through electrolytes causes the ions to move to the electrodes. Positively charged ions move to the negative electrode (the cathode), and negatively charged ions move to the positive electrode (the anode).



Electrolysis of molten ionic compounds

When a simple ionic compound (eg lead bromide) is electrolysed in the molten state using inert electrodes, the metal (lead) is produced at the cathode and the non-metal (bromine) is produced at the anode.





Cathode (-ve electrode)

$Pb^{2+} + 2e^- \rightarrow Pb$

Anode (+ve electrode)

$2Br^- - 2e^- \rightarrow Br_2$

OR $2Br^- \rightarrow Br_2 + 2e^-$

Electrolysis Extended

At the negative electrode, hydrogen is produced if the metal is more reactive than hydrogen.
At the positive electrode oxygen is produced unless the solution contains halide ions when the halogen is produced.

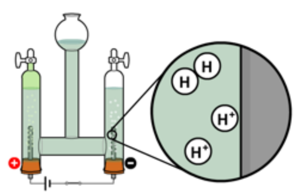
This is due to water molecules breaking down in aqueous solution to form hydrogen and hydroxide ions.

At the cathode positively charged ions gain electrons, whereas as the negatively charged ions lose electrons at the anode. These are both examples of oxidation and reduction. These can be represented as half equations.

$2H+ + 2e- \rightarrow H_2$

$4OH- \rightarrow O_2 + 2H_2O + 4e-$

$4OH- - 4e- \rightarrow O_2 + 2H_2O$



At the cathode

Whether hydrogen or a metal is produced at the cathode depends on the position of the metal in the metal **reactivity series**:

- the metal is produced at the cathode if it is less **reactive** than hydrogen
- hydrogen is produced at the cathode if the metal is more reactive than hydrogen

Rules for determining products

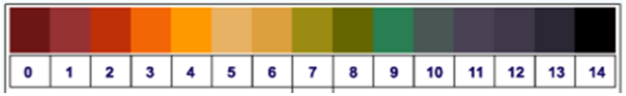
At the anode

Oxygen is produced (from hydroxide ions), unless **halide** ions (chloride, bromide or iodide ions) are present. In that case, the negatively charged halide ions lose electrons and form the corresponding **halogen** (chlorine, bromine or iodine).

The table summarises the product formed at the anode during the electrolysis of different **electrolytes** in solution.

Negative ion	Element given off at anode
Chloride, Cl^-	Chlorine, Cl_2
Bromide, Br^-	Bromine, Br_2
Iodide, I^-	Iodine, I_2
Sulfate, SO_4^{2-}	Oxygen, O_2
Nitrate, NO_3^-	Oxygen, O_2

pH and Acids + Alkalis



Acids produce H^+ (as H_3O^+) ions in water and they taste sour. They also corrode metals and have a pH of less than 7. They also turns blue litmus paper to red.

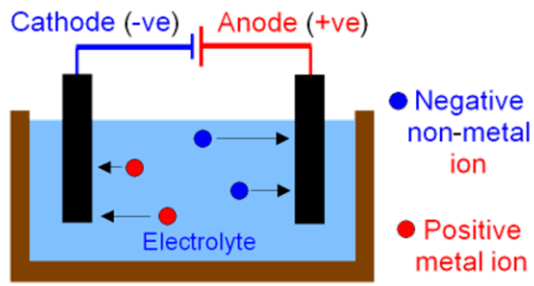
Alkalis produce OH^- ions in water and they taste bitter with a pH greater than 7. Alkalis turns red litmus paper to blue.

A solution is defined as an acid if the concentration of H^+ ions is greater than the concentration of OH^- ions. $[H^+] > [OH^-]$

A solution is defined as alkali/base if the concentration of hydrogen ions is less than the concentration of hydroxide ions. $[H^+] < [OH^-]$

Electrolysis

When an ionic compound is melted or dissolved in water, the **ions** are free to move about within the liquid or solution. These liquids and solutions are able to conduct electricity and are called electrolytes. Passing an electric current through electrolytes causes the ions to move to the electrodes. Positively charged ions move to the negative electrode (the cathode), and negatively charged ions move to the positive electrode (the anode).



Electrolysis Extended

At the negative electrode, hydrogen is produced if the metal is more reactive than hydrogen.
At the positive electrode oxygen is produced unless the solution contains halide ions when the halogen is produced.

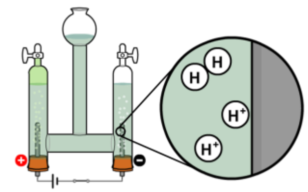
This is due to water molecules breaking down in aqueous solution to form hydrogen and hydroxide ions.

At the cathode positively charged ions gain electrons, whereas as the negatively charged ions lose electrons at the anode. These are both examples of oxidation and reduction. These can be represented as half equations.

$2H^+ + 2e^- \rightarrow H_2$

$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$

$4OH^- - 4e^- \rightarrow O_2 + 2H_2O$

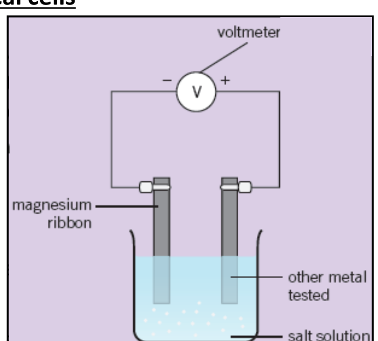


Cells and batteries continued…

- Metals lose electrons and form positive ions.
- When 2 metals are dipped in a salt solution and joined by a wire, the more reactive metal will donate electrons to the less reactive metal. This forms a simple electrical cell.
- The greater the difference in reactivity between the 2 metals, the higher the voltage produced by the cell.

Investigating chemical cells

This apparatus is used to investigate the voltage produced by different metals paired with magnesium ribbon. You can compare magnesium against zinc, iron, copper & tin in your electrical cells.



Fuel Cells

Scientists are developing hydrogen as a fuel.

Hydrogen + Oxygen → Water

$2H_2 + O_2 \rightarrow 2H_2O$

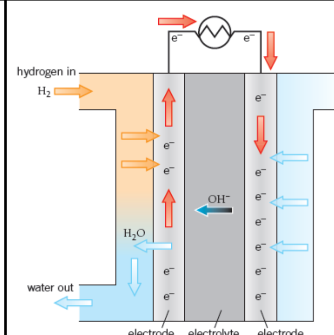
- The world relies on fossil fuels. However, they are non-renewable and they cause pollution.
- Hydrogen is one alternative fuel. It can be burned in combustion engines or used in fuel cells to power vehicles.
- Hydrogen gas is oxidised and provides a source of electrons in the hydrogen fuel cell, in which the only waste product is water.

Hydrogen gas is supplied as a fuel to the negative electrode. It diffuses through the graphite electrode and reacts with hydroxide ions to form water and provides a source of electrons to an external circuit.

$$2H_2(g) + 4OH^-(aq) \rightarrow 4H_2O(l) + 4e^-$$

Oxygen is supplied to the positive electrode. It diffuses through the graphite and reacts to form hydroxide ions, accepting electrons from the external circuit.

$$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$$



A hydrogen fuel cell which has an alkaline electrolyte, such as potassium hydroxide. Only waste product is water.

Advantages of hydrogen fuel cells –
1) Do not need to be electrically recharged
2) No pollutants are produced
3) Can be a range of sizes for different uses

Disadvantages of hydrogen fuel cells–
1) Hydrogen is highly flammable
2) Hydrogen is sometimes produced for the cell by non-renewable sources
3) Hydrogen is difficult to store

Exothermic and endothermic reactions

Exothermic reactions **release** thermal energy (heat) into their surroundings. They can occur spontaneously and some are explosive. Most chemical reactions are exothermic. Temperature **increases**.

What are some examples?

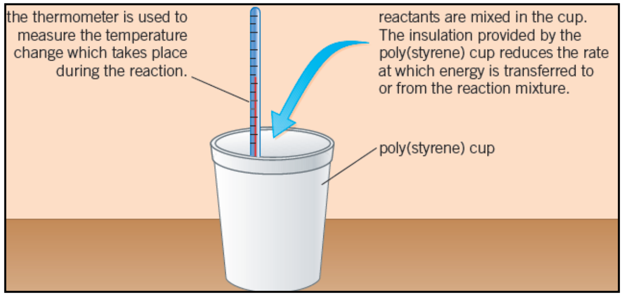
- combustion
- respiration
- neutralization of acids with alkalis
- reactions of metals with acids
- $Mg (s) + HCl (aq) \rightarrow MgCl_2 (aq) + H_2 (g)$
- the Thermite Process.
- Endothermic reactions absorb thermal energy, and so cause a **decrease** in temperature.

What are some examples?

- thermal decomposition, e.g. calcium carbonate in a blast furnace
- photosynthesis
- some types of electrolysis
- Sherbet
- $NH_4NO_3 (s) + H_2O (l) \rightarrow NH_4^+ (aq) + NO_3^- (aq)$

Investigating temperature changes

Record the initial temperatures of any solutions, and the maximum and minimum temperatures reached in the course of the reaction.



Using energy transfers from reactions

- Exothermic changes can be used in hand warmers and self heating cans. Crystallisation of the supersaturated solution is used in reusable warmers. However, disposable, one-off hand warmers heat up the surrounding for longer.
- Endothermic changes can be used in instant cold packs for sports injuries.

Reaction profiles and Activation energy

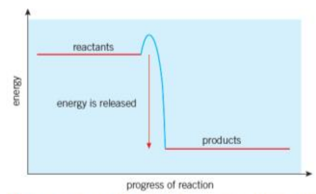


Figure 1 *The reaction profile for an exothermic reaction*

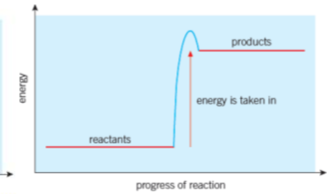


Figure 2 *The reaction profile for an endothermic reaction*

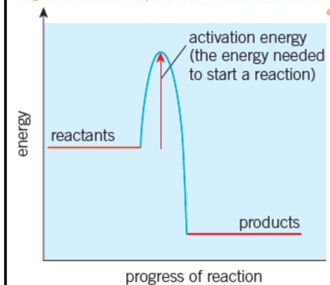


Figure 3 *This reaction profile shows the activation energy for an exothermic reaction*

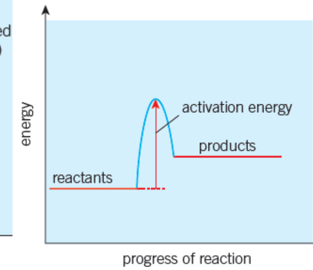


Figure 4 *This reaction profile shows the activation energy for an endothermic reaction*

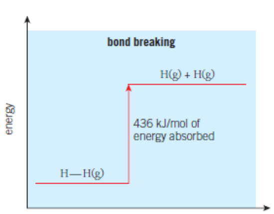
Bond breaking is endothermic whereas bond making is exothermic.

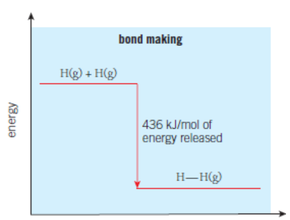
Bond energy calculations

The energy needed to break a bond between 2 atoms is called the **bond energy** for that bond. They are measured in KJ/mol.

Table 1 *Common bond energies*

Bond	Bond energy in kJ/mol	Bond	Bond energy in kJ/mol
C—C	347	H—Cl	432
C—O	358	H—O	464
C—H	413	H—N	391
C—N	286	H—H	436
C—Cl	346	O═O	498
Cl—Cl	243	N≡N	945



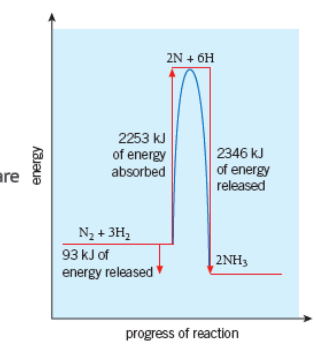


Breaking and making a particular bond always involves the same amount of energy

The formation of ammonia. The energy released, 93KJ, is from the formation of 2 moles of ammonia (see balanced equation below). So if you wanted to know the energy change for the reaction per mole of ammonia formed, it would release exactly half this, i.e. 46.5kJ/mol.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

- In chemical reactions, energy must be supplied to break the bonds between atoms in the reactants.
- When new bonds are formed between atoms in a chemical reaction, energy is released.
- In an exothermic reaction, the energy released when new bonds are formed is greater than the energy absorbed when bonds are broken.
- In an endothermic reaction, the energy released when new bonds are formed is less than the energy absorbed when bonds are broken.
- You can calculate the overall energy change in a chemical reaction using bond energies.



Cells and batteries

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

The sulfate ions do not change in the displacement reaction above. They are spectator ions.

So you can leave them out of the equation and write an ionic equation:

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

You can think of this redox reaction as two half equations.

One will represent reduction:

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

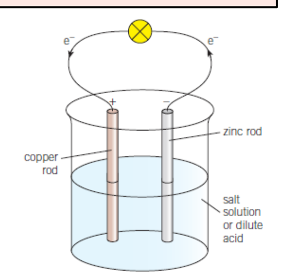
The Cu^{2+} ions are reduced to Cu.

The other will be an oxidation reaction:

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$

The Zn atoms are oxidised to Zn^{2+} ions.

An electrical cell made from zinc and copper → The electrons flow from the more reactive metal (zinc) to the less reactive metal (copper). So zinc acts as the negative terminal of the cell, providing electrons to the external circuit.



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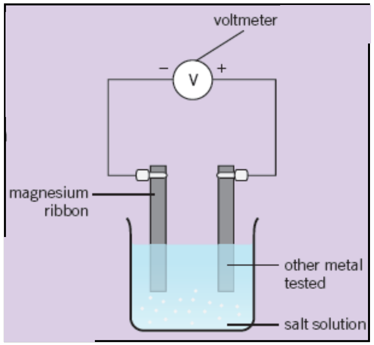

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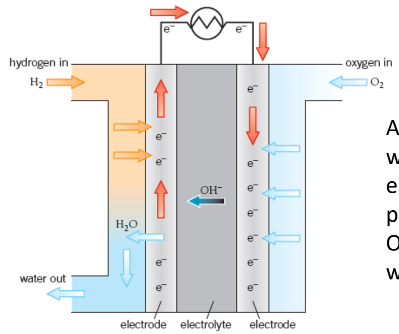

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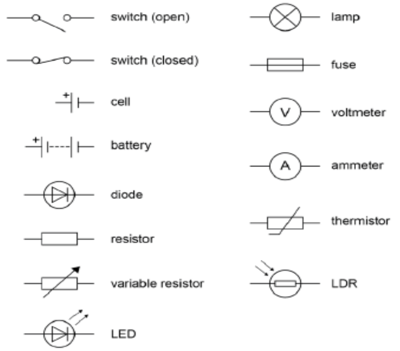
Static Electricity (Triple only)

Examples: Hair standing up after taking a jumper off, rubbing a balloon on your hair.

Static electricity is a build up of negative charges (electrons) which are then released. An object is charged if electrons are added or removed.

Circuit Symbols

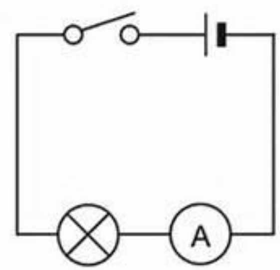


Current

Current is the flow of charge (electrons) around a circuit.

* It is measured in Amps (A)
* It is measured using an Ammeter
* In a series circuit the current is the same everywhere.
* In a parallel circuit the current splits at each branch. The current through the cell is equal to the current through all the branches added together.

The ammeter must be placed in the circuit to take a reading.

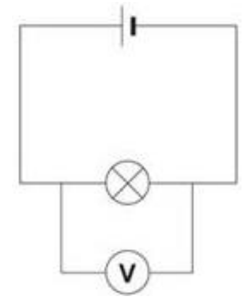


Potential Difference (Voltage)

Potential Difference is the amount of energy transferred to a component by each unit of charge.

* It is measured in Volts (V)
* It is measured using a Voltmeter
* In a series circuit the PD of the cell is shared between all the components. The component with the highest resistance receives the most PD.
* In a parallel circuit each branch receives the same PD as the cell.

The voltmeter must be placed in parallel with a component in order to measure the PD across it.



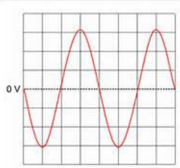
Resistance

Resistance is the measure of how hard it is for current to pass through a component.

* It is measured in Ohms (Ω)
* It is calculated using R=V/I
* If you add resisters in series the resistance increases, if you add resistance in parallel the resistance decreases.

AC & DC

* Alternating Current (AC) the current changes direction. UK mains supply is 230V and 50Hz.

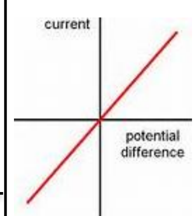


* Direct Current (DC) flows in the same direction. DC comes from a battery or from a AC supply which has passed through a diode.

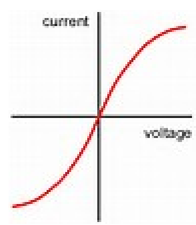
* The trace works like a graph, with time on the x-axis and voltage on the y-axis.

I-V Curves (Current-Voltage curves)

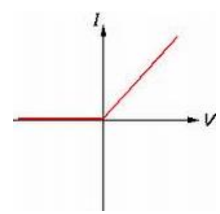
Fixed Resistor



Filament Bulb



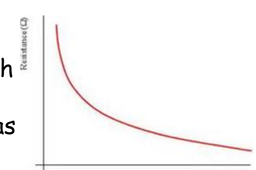
Diode



* Fixed Resistor – Straight line shows it is a constant resistance. The steeper the line the lower the resistance.
* Filament Bulb – Resistance increases as the bulb heats up and ions vibrate more.
* Diode – Only allows current to flow in one direction.

Thermistors and LDR's

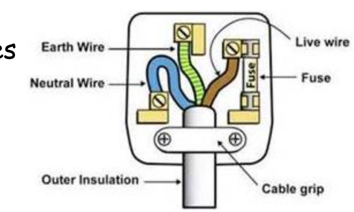
They have the same shaped graph



* LDR's – Street lighting, cameras
* Thermistors – Ovens, fridges, central heating

Electrical Safety

The plug and wires are coated in plastic which doesn't conduct electricity.

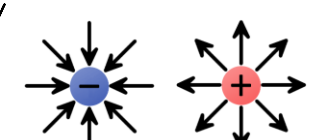


Safety Devices

* Earth Wire – Only needed for devices with a metal casing. Provides a safe route for the current if the live wire touches the casing.

Electrical fields (Triple only)

Field lines travel away from the positive and towards the negative.

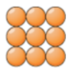


The closer you are to the charge, the stronger the electrical field

Density:

Density = Mass (kg) / Volume (m^3)
(kg/m^3)

Calculating the density of an irregular shape, can be done using a Eureka can and measuring the volume of water displaced.

State of matter	Diagram of structure	Movement of particles	Can it be compressed?	Density
Solid		Vibrate around a fixed position. They don't have enough energy to move apart	No, the particles have no space between them to move into.	High, there are lots of particles in a unit of area.
Liquid		They have enough energy to move from place to place but are still attracted to each other	No, the particles have no space between them to move into.	Quite high, there are lots of particles in a unit of area.
Gas		The have so much energy that they are not attracted to each other. Collisions with containers cause pressure.	Yes, the particles have lots of space between them to move into.	Low, there are few particles in a unit of area.

Internal Energy

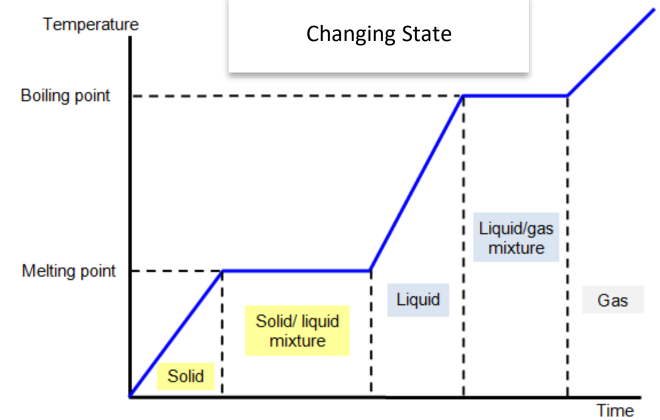
The energy in a substance is stored in its particles, this is called internal energy.

Internal energy = kinetic energy + potential energy.

Temperature: This is linked to the kinetic energy of the gas. The higher its temperature the higher its kinetic energy. If the temperature remains constant so does the kinetic energy of the particles.

Changing State

When a material changes state (melting or boiling) its internal energy increases, but its temperature does not. This means that its kinetic energy remains constant until it has changed state.



Specific Latent Heat

The specific latent heat of a substance is the energy needed to change 1kg of the substance with no change in state.

Energy = Mass x Specific Latent Heat
(J) (kg) (J/kg)

$E = m \times L$

Specific heat of fusion: when turning from a solid into a liquid
Specific heat of vapourisation: when turning from a liquid into gas

Pressure and volume

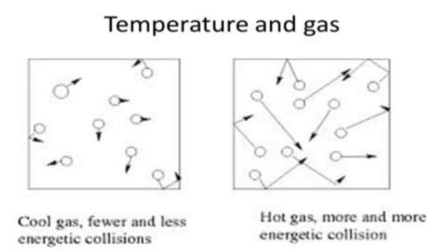
Pressure x Volume = constant
(Pa) (m^3)

so $P_1 \times V_1 = P_2 \times V_1$

Increasing the volume of a gas (making the container bigger) whilst keeping the temperature constant will decrease the pressure of the gas.

Temperature and pressure

Increasing the temperature of a gas increases the kinetic energy of the gas particles, this increases the number of collisions with the surface, this increases the pressure acting on the sides of the container.



Particles move in different directions with a range of speeds.

As the particles hit the side of the container they create a net force which acts at right angles to the wall of the container.

Atoms

$$^{12}_{6}C$$

12 ← Mass Number (Protons + Neutrons)

6 ← Atomic Number (Protons and electrons)

Number of Neutrons =
Mass Number – Atomic number (12 - 6 = 6)

Isotopes: An isotope is an atom with the same number of protons but different number of neutrons.

Ions: An atom that has gained (positive ion) or lost (negative ion) electrons.

Some atoms are radioactive, they give out radiation from the nucleus. This is measured in Becquerels (Bq)

Alpha, Beta & Gamma

Name	What it is	What is its charge	What is its mass	Ionising Power	Absorbed by
Alpha	Helium nucleus	+2	+4	High	Paper/ air
Beta	Electron	-1	Tiny	Medium	Thin steel
Gamma	EM Wave	0	0	Low	Thick Lead

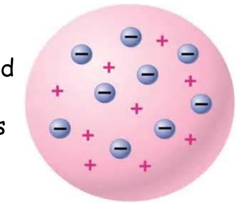
Alpha Decay (Atomic number -2, mass number -4)

$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}\alpha$$

Beta Decay (Atomic number +1, mass number 0)

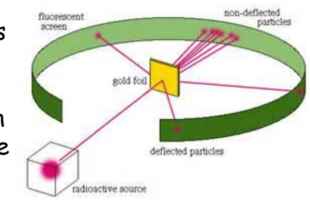
$$^{14}_{6}C \longrightarrow ^{14}_{7}N + ^{0}_{-1}\beta$$

Atomic Structure



1. In 1901 JJ Thompson suggested the '**plumb pudding**' model for the atom. With negative particles stuck in the middle of positive charge

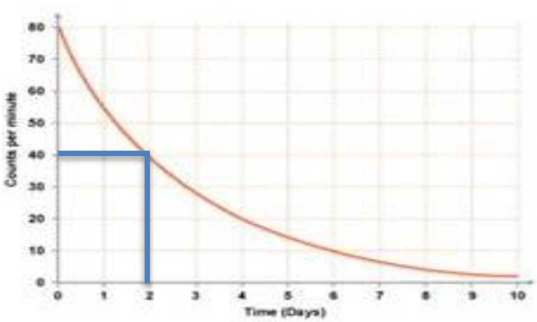
2. In 1909 Rutherford changed the accepted model using his alpha scattering experiment.



3a. He fired alpha particles at a sheet of gold foil.
3b. He expected them all to pass straight through
3c. Rarely one would bounce back
3d. This proved that the center of the atom was very small, held most of the mass and had a positive charge.
3e. The current model of the atom that we use today was born.

Half-life

The half-life of a radioactive source is **the time taken for half the material to decay.**



The half-life of the material above is 2 days.
The starting count was 80 half of it = 40
The time to get to 40 was 2 days.

In this example it would take: 2 days to get to get to 50%, 4 days to 25%, 6 days to get to

Nuclear fission (Triple Only)

1. Large radioactive atoms split in half (fission) because they are unstable.
2. When this happens a huge amount of energy is released.
3. Neutrons are released which hit and split more atoms, this is called a **chain reaction**.
4. This is the source of a nuclear power station or nuclear bomb's energy
5. Unfortunately a lot of radioactive waste is produced which stays radioactive for 1000's of years.

Nuclear Fusion (Triple Only)

1. Small light nuclei are forced together under huge heat and pressure – such as in the **core of the sun**.
2. The nuclei repel each other as they are both positively charged so it is hard to get them to fuse.
3. If the temperatures and pressures are large enough the nuclei will fuse to create a larger nuclei
4. A huge amount of energy is released
5. Fusion doesn't produce any radioactive waste
6. Scientists are yet to develop the technology to allow fusion to be used to produce electricity.

Radioactivity (Triple Only)

Radioactive atoms decay and release ionizing particles (alpha, beta and gamma)

There is a constant level of naturally occurring radiation all around us, this is known as **'background radiation'**. This is random when measured.

Background radiation comes from rocks, the air, our food and the sun. Very little comes from man-made devices such as powerstations.

Radiation is **ionizing**, this means it can damage your DNA and in large doses can cause cancer. It can also be used to kill cancerous cells.

Professionals working with radioactive sources protect themselves using lead glass.

Contamination is when the source is inside you
Irradiation is when the source is outside you