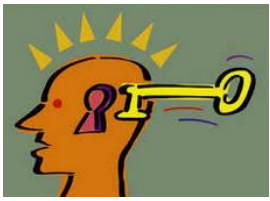
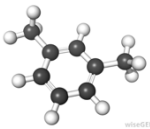
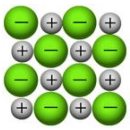


Science
Crucial Knowledge




Chemistry

Paper 1

Topic C1	Atomic Structure & Periodic Table
Topic C2	Bonding
Topic C3	Quantitative Chemistry
Topic C4	Chemical Changes
Topic C5	Energy Changes

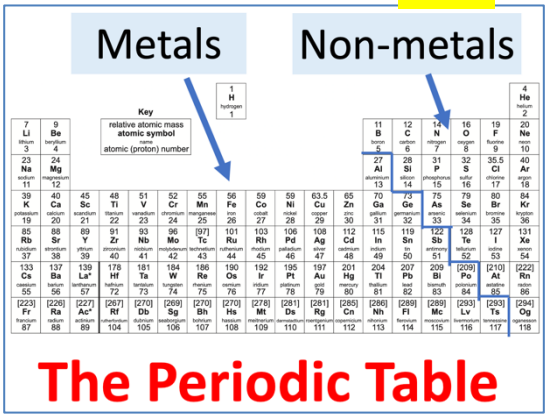
Paper 2

Topic C6	Rates of Reaction
Topic C7	Organic Chemistry
Topic C8	Chemical Analysis
Topic C9	Chemistry of the Atmosphere
Topic C10	Using Resources

Chemistry is the study of how substances interact

Chemistry C1 Atomic Structure and the Periodic Table

C1



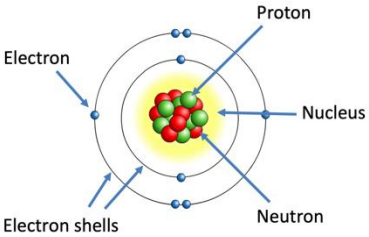
Atoms, elements, molecules, compound

- Atoms make up everything
- An element is made up of only one type of atom
- A molecule is made up of two or more atoms
- A compound is made up of two or more different atoms
- A mixture is a group of chemicals not bonded together
- Mixtures can be separated by physical processes – filtration, crystallization, distillation, chromatography

Atomic models

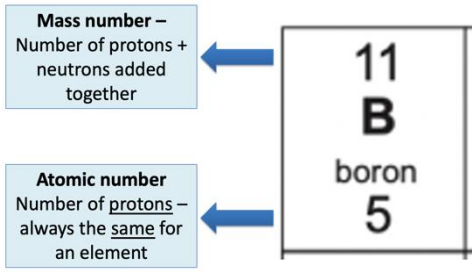
- Plum pudding model – negative electrons embedded throughout the atom, rest of atom is positive
- Nuclear model – most of the mass of an atom in the nucleus, most of the atom is empty space

Structure of the atom



Subatomic particle	Mass	Charge	Position in the atom
Proton	1	+1	Nucleus
Neutron	1	0	Nucleus
Electron	Very small	-1	Electron shells

- Atomic number – the number of protons in an atom
- Atomic mass – number of protons + neutrons added together
- Electrons fill the shells 2,8,8
- Isotopes are atoms of the same element with a different number of neutrons



Periodic table

- Mendeleev left gaps and predicted existence of new elements

Group 1 – Alkali metals

- More reactive going down the group
- Single outer electron feels less electrostatic attraction from the nucleus as we go down the group
- Alkali metal + water → metal hydroxide + hydrogen
- All have 1 electron in the outer shell

Group 7 – The halogens

- More reactive at the top of the group
- Further down the group the outer electron shell feels less attractive force from the nucleus due to electron shielding
- All have 7 electrons in the outer shell

Group 0 – Noble gases

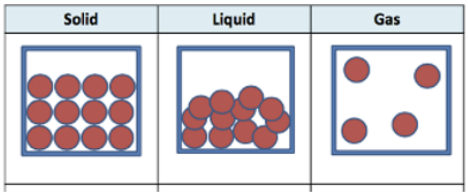
- Have a full outer shell so don't react with anything

Chemistry C2 Bonding C2

States of matter and state symbols

State symbol	Meaning	Example
(s)	Solid	Iron oxide$_{(s)}$
(l)	Liquid	Water$_{(l)}$
(g)	Gas	Carbon dioxide$_{(g)}$
(aq)	Aqueous, dissolved in water	Sodium chloride solution$_{(aq)}$

States of matter particle diagrams



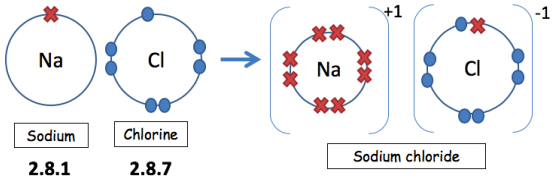
Ions

- Atoms that have lost or gained one or more electrons
- Metal atoms form positive ions. Examples: Li^+ Ca^{2+}
- Non-metal atoms form negative ions. Examples: Cl^- O^{2-}

Ionic bonding

- Happens between metal and non-metal
- The metal atom transfers electrons to the non-metal atom
- Positive and negative ions attract
- Strong electrostatic force holds the ions together

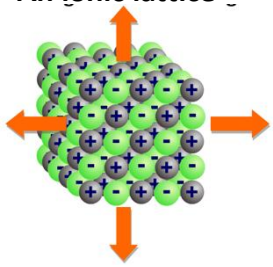
Ionic bonding



Ionic compounds

- Ions arranged in layers in a giant lattice structure
- Requires a lot of energy to break the bond so ionic compounds have a high melting and boiling point
- Cannot conduct electricity when solid as the ions cannot move
- Can conduct electricity when molten or dissolved as the ions can move

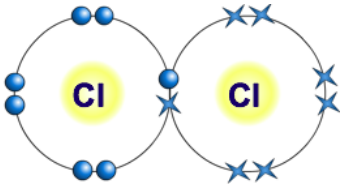
An ionic lattice



Covalent bonding

- Happens between non-metals
- The atoms share a pair of electrons to get a full outer shell

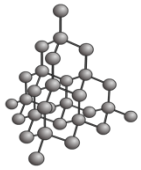
Covalent bond dot and cross diagram



Simple covalent molecules

- Made of only a few atoms
- Weak forces between molecules means low boiling and melting points
- Examples – H_2O, CO_2, O_2, CH_4

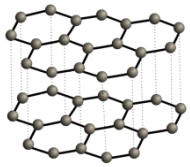
Structure of diamond



Giant covalent structures

- Made of billions of atoms
- Examples - Diamond, graphite, silica
- Strong covalent bonds between atoms means they have a high melting and boiling point
- Graphite has free electrons that can move so can conduct electricity

Structure of graphite

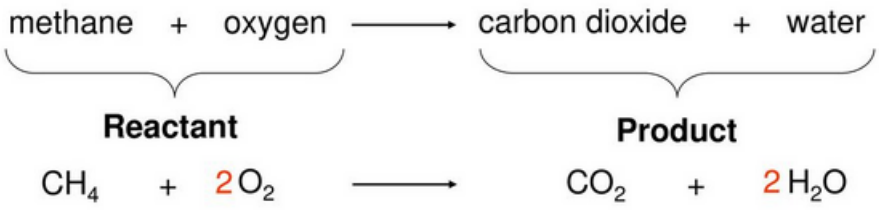


Metallic bonding – metals only

- Atoms arranged in layers
- Delocalised electrons can move so metals can conduct electricity and heat
- Atoms in a pure metal arranged in layers so the metal can be bent and shaped
- Alloys are stronger – layers of atoms disrupted by different sized atoms

Word equations

- Reactants are the substances on the left, that are reacting
- Products are the substance on the right, that are made in the reaction
- The arrow shows a reaction has taken place



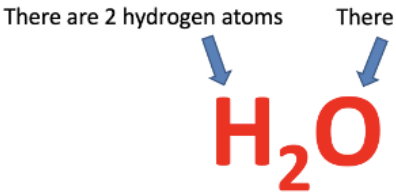
Law of conservation of mass

- In any chemical reaction the total mass of the reactants is the same as the mass of the products
- Mass of products = mass of reactants

Relative formula mass

How to work out **relative formula mass**

- Take the relative atomic mass of each element from the periodic table
- Add them up

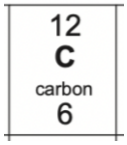


Relative atomic mass of hydrogen = 1
Relative atomic mass of oxygen = 16

Relative formula mass of H_2O : 1 + 1 + 16 = **18**

Moles (Higher only)

- A mole is just a number: 6.02×10^{23}
- In 1 mole of any substance there are 6.02×10^{23} particles
- The mass of one mole of a substance in grams is equal to its relative atomic mass or formula mass.
  Example: the atomic mass of carbon is 12
  1 mole of carbon = 12g
  12g of carbon contains 6.02×10^{23} atoms



$$\text{number of moles of substance} = \frac{\text{mass of substance (g)}}{A_r \text{ or } M_r}$$

A_r = relative atomic mass (top number on the periodic table)
M_r = relative atomic mass of a molecule (top numbers all added together)

Concentration

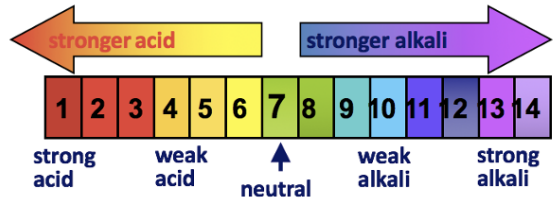
- To convert cm^3 into dm^3 you divide by 1000
- $cm^3 \div 1000 = dm^3$

$$\text{Concentration of solution} = \frac{\text{mass of solute (g)}}{\text{volume of solution (dm}^3\text{)}}$$

Neutralisation

- Acid + alkali → salt + water
- Bases are insoluble metal hydroxides and metal oxides that neutralise acids
- Alkalis are soluble metal hydroxides
- All acids contain H^+ ions
- All alkalis contain hydroxide ions OH^-
- The neutralisation equation: $H^+ + OH^- \rightarrow H_2O$

The pH scale



Strong and weak acids (Higher only)

- A strong acid is completely ionized in aqueous solution
- A weak acid is only partially ionized in aqueous solution
- As pH decreases by one, the H^+ concentration in solution increases by a factor of 10

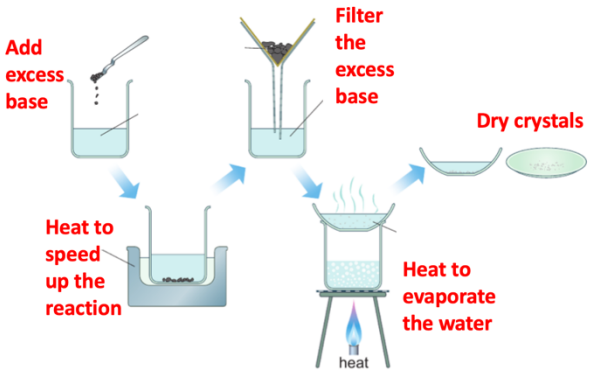
Acid + metal

- Acid + metal → salt + hydrogen
- Hydrogen gas test – lit splint makes a squeaky pop

Acid + carbonates

- Acid + metal carbonate → salt + carbon dioxide + water
- Carbon dioxide test – limewater turns cloudy

Making soluble salts



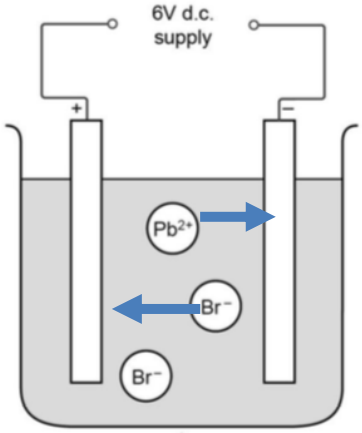
Making soluble salts – core practical

- Mix excess (too much) base with acid
- Add excess base to neutralize all of the acid
- Heat the solution to speed up the reaction
- Filter off the excess oxide
- Evaporate the water to leave crystals of salt

Extraction of metals

- Unreactive metals like gold are found unreacted in the ground
- Metals less reactive than carbon can be extracted from their oxides by reduction with carbon
- Metals more reactive than carbon can be extracted by electrolysis
- OILRIG – oxidation is the loss of electrons, reduction is the gain of electrons

Electrolysis



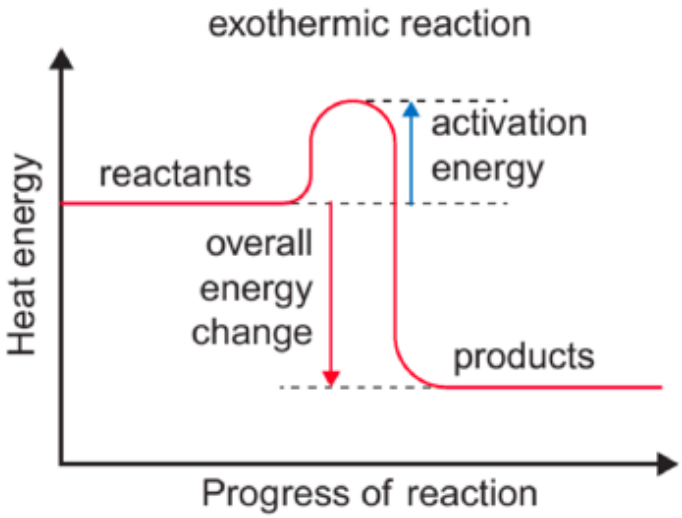
Electrolysis

- Splitting a compound using electricity
- Solid ionic compounds cannot conduct electricity as there are no free ions
- Ionic compounds can conduct electricity when molten or dissolved as the ions can move
- Positive ions move to negative electrode (cathode)
- Negative ions move to positive electrode (anode)
- $Cu^{2+} + 2e \rightarrow Cu$
- $2Cl^- \rightarrow Cl_2 + 2e$

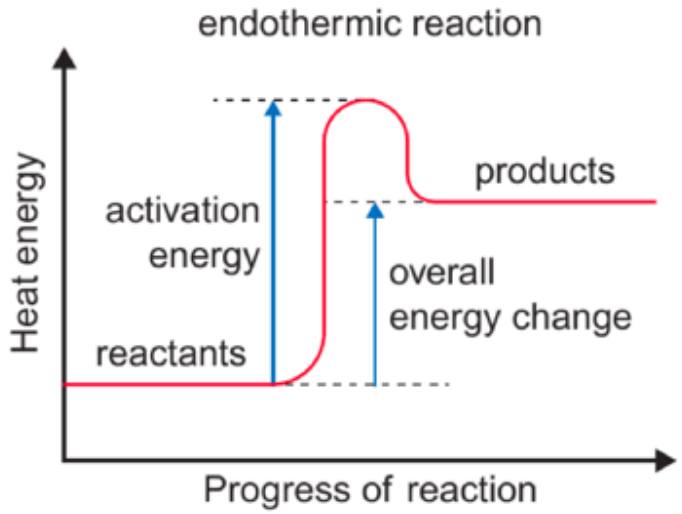
Exothermic reactions
- Transfers energy to the surroundings. Give OUT energy
- Temperature of the surroundings goes up
- Combustion, neutralisation and displacement reactions are exothermic

Endothermic reactions
- Takes in energy from the surroundings. Takes IN energy
- Temperature of the surroundings decreases
- Thermal decompositions and photosynthesis are endothermic

Activation energy
- The energy needed for a reaction to occur



Energy profile for an exothermic reaction
- The reactants have more energy than the products

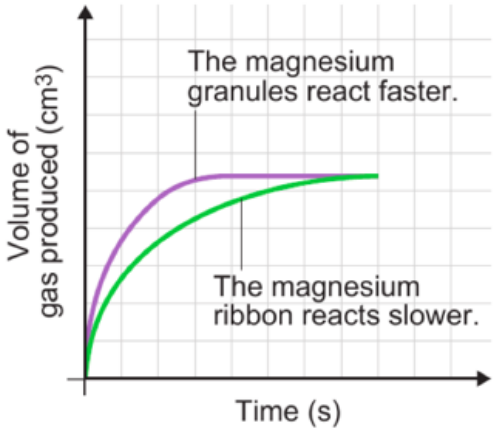


Energy profile for an endothermic reaction
- The reactants have less energy than the products

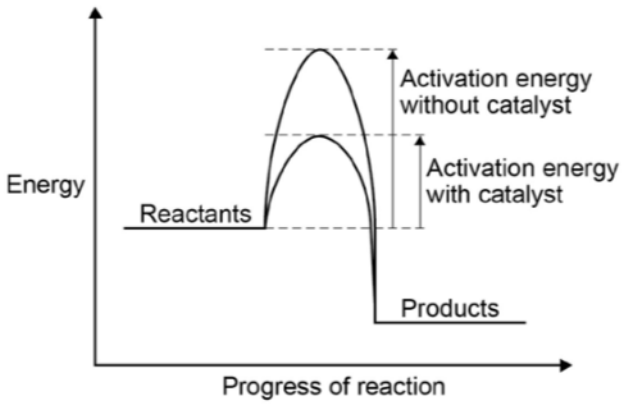
Collision theory
- Chemical reactions only occur when particles collide
- Particles have to collide with enough energy
- The minimum amount of energy needed for particles to react is called the activation energy

Factors affecting rate of reaction
- Increasing surface area increases rate of reaction – more collisions between particles
- Increasing temperature increases rate of reaction – particles move faster and collide more often
- Increasing concentration increases rate of reaction – there are more particles so more collisions

Rate of reaction
- A steeper line shows a faster rate of reaction
- On this graph the blue line shows a faster rate



Catalysts
- Catalysts speed up the rate of reaction but are not used up
- Catalysts increase the rate of reaction by lowering the activation energy
- A reaction profile for a catalyst is:



Reversible reactions
- In some reactions, the products of the reaction can react to produce the original reactants
- Symbol for a reversible reaction: ⇌

Equilibrium
- Equilibrium is reached when the forward and reverse reactions occur at exactly the same rate

Crude oil

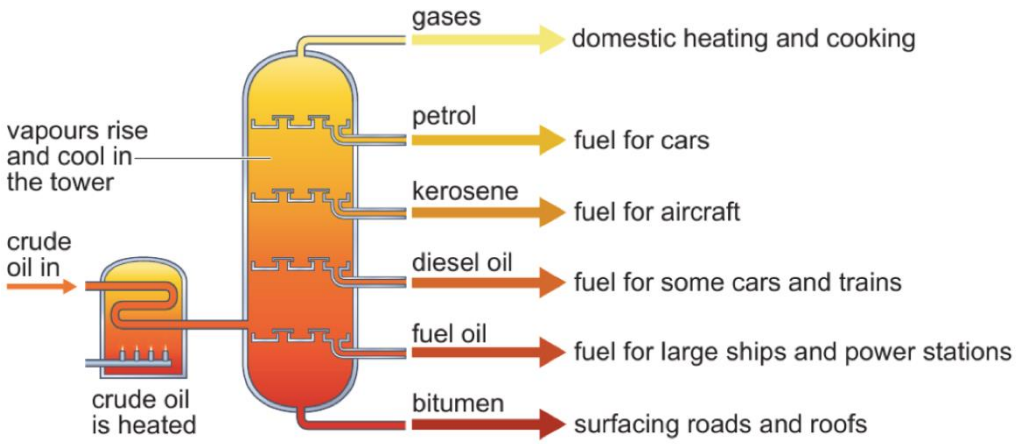
- Crude oil is made from the remains of plankton (small sea creatures) buried in mud under the sea
- Crude oil is a mixture of hydrocarbons

Hydrocarbons

- Molecules made of hydrogen and carbon only

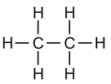
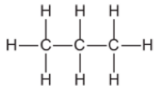
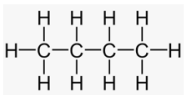
Fractional distillation

- Crude oil needs to be separated into useful fuels by fractional distillation
- Crude oil is heated and evaporates
- Gases rise up a fractionating column, cool down and condense
- They condense at different points depending on the boiling point
- Most viscous (thick and not runny) at the bottom of the column
- Highest boiling point at the bottom of the column



Alkanes

- A group of hydrocarbons with similar properties
- General formula C_nH_{2n+2}
- React with oxygen to produce carbon dioxide and water
- The first four alkanes and their structure

Name	Structural formula	Chemical formula
Methane		CH_4
Ethane		C_2H_6
Propane		C_3H_8
Butane		C_4H_{10}

Cracking

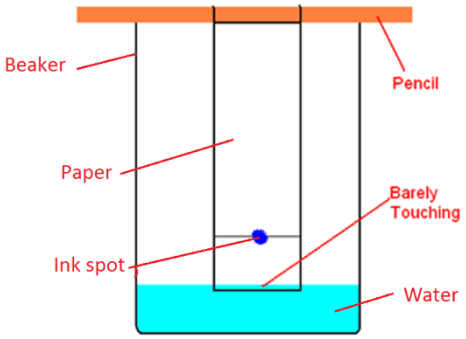
- Cracking is breaking down longer hydrocarbons into smaller, more useful molecules
- Conditions needed for cracking: high temperatures and high pressure
- A product of cracking is an alkene
- Test for alkenes: bromine water turns from orange to colourless

Pure substances
- A single element or compound not mixed with any other substance
- Will melt at specific temperatures

Formulations
- A mixture that has been designed as a useful product
- Formulations include fuels, cleaning agents, paints, medicines, alloys, fertilisers and foods

Chromatography
- Used to separate mixtures
- Stationary phase – the chromatography paper
- Mobile phase – the solvent moving
- More soluble dyes move further up the paper
- A pure compound will produce a single spot in all solvents

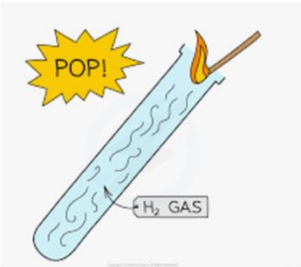
$$R_f = \frac{\text{distance moved by substance}}{\text{distance moved by solvent}}$$



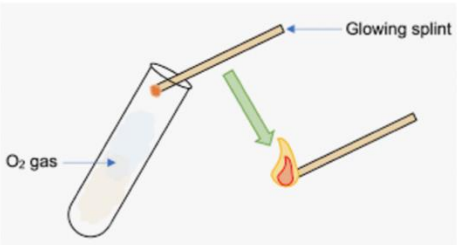
Test for pure water
- Boils at 100°C

Gas tests

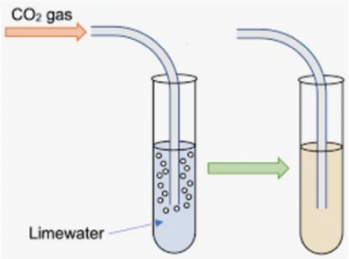
Test for hydrogen gas H_2
- Lit splint
- Squeaky pop



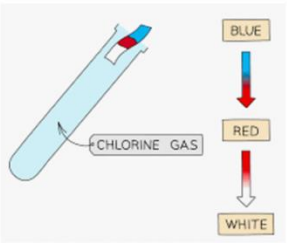
Test for oxygen gas O_2
- Glowing splint
- Re-lights



Test for carbon dioxide gas CO_2
- Limewater
- Turns cloudy



Test for chlorine gas Cl_2
- Damp blue litmus paper
- Turns red then white



The early atmosphere
- Volcanoes released gases – water vapour, nitrogen, methane, ammonia, carbon dioxide
- No oxygen
- Water vapour condensed and rained to form the oceans
- Carbon dioxide dissolved into the oceans

How carbon dioxide decreased
- Dissolved into the oceans
- Formation of sedimentary rocks and fossil fuels
- Algae and plants used CO_2 for photosynthesis

How oxygen increased
- Algae and plants produced O_2 by photosynthesis

The atmosphere today
- About 80% nitrogen
- About 20% oxygen
- Small proportions of carbon dioxide, water vapour and noble gases

Greenhouse gases
- Water vapour, carbon dioxide and methane are greenhouse gases
- Greenhouse gases maintain a temperature on Earth to support life

How human activities increase greenhouse gases
- Deforestation and burning fossil fuels increases the amount of carbon dioxide
- Farming increases the amount of methane

Effects of climate change
- Greenhouse gases trap heat energy in the atmosphere, causing climate change
- Sea levels rise leading to flooding
- More extreme weather
- Extinction of wildlife

Carbon footprint
- The total amount of carbon dioxide and other greenhouses gases over the full life cycle of a product
- Can be reduced by reducing emissions of carbon dioxide and methane

Atmospheric pollutants
- Combustion of fuels produces pollutants
- Carbon monoxide is a toxic gas
- Sulfur dioxide and oxides of nitrogen cause respiratory problems in humans and acid rain
- Soot particles cause health problems and global dimming

Chemistry C10 Using Resources

C10

Potable water
- Water that is safe to drink
- Potable water is NOT pure. It will still have dissolved minerals and ions in it

Test for pure water
- Boils at 100°C

Desalination
- Making sea water or salty water safe to drink
- Can be done by distillation
- Requires large amounts of energy

Waste water treatment
- Screening and grit removal – to remove large pieces of unwanted substances
- Sedimentation – to allow smaller pieces to settle
- Anaerobic digestion of sewage sludge, using bacteria
- Aerobic biological treatment of effluent, using bacteria

Methods of extracting metals (Higher only)
- Phytomining – uses plants to absorb metal compounds from the ground. Plants are then burnt to produce ash that contains metal compounds
- Bioleaching – uses bacteria to produce solutions with metal compounds

Life cycle assessment: 4 stages
- Extracting and processing raw materials
- Manufacturing and packaging
- Use and operation
- Disposal

Reusing and recycling
- Obtaining raw materials from the Earth by quarrying and mining causes environmental impacts
- Glass bottles can be crushed and melted to make different glass products
- Metals can be recycled by melting

Advantages of recycling	Disadvantages of recycling
• Conserves finite oil resources • Saves energy • Reduces need for mining • Reduces waste disposed of in landfill • Less pollution • Cheaper to recycle than mine new ores	• Costs of collecting, sorting and melting metals • Some metals more expensive to recycle