Chemistry Revision Notes

FOR AQA GCSE (9-1)

SIMPLE, CLEAR & MEMORABLE

PAPER 2

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USING THIS BOOK

This is **Higher Tier** only material – this means you will only need to revise this if you are sitting the higher tier Biology paper.

This is **Chemistry (separate science)** only material – this means you will only need to revise this if you are sitting the triple award separate science Biology paper (**8462**).

This is **Higher Tier <u>and</u> Chemistry (separate science)** only material – this means you will only need to revise this if you are sitting the higher tier Biology paper (**8462**).

THIS IS A SPECIFICATION CHAPTER

1.1 THIS IS A SPECIFICATION TOPIC

1.1.1 This is a specification subtopic

THE PERIODIC TABLE

← This is an identical copy of the periodic table provided in the AQA GCSE Chemistry exams

Key

Key
relative atomic mass **atomic symbol** name atomic (proton) number

1	2											3	4	5	6	7	0
							1 **H** hydrogen 1										4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4											11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9	20 **Ne** neon 10
23 **Na** sodium 11	24 **Mg** magnesium 12											27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17	40 **Ar** argon 18
39 **K** potassium 19	40 **Ca** calcium 20	45 **Sc** scandium 21	48 **Ti** titanium 22	51 **V** vanadium 23	52 **Cr** chromium 24	55 **Mn** manganese 25	56 **Fe** iron 26	59 **Co** cobalt 27	59 **Ni** nickel 28	63.5 **Cu** copper 29	65 **Zn** zinc 30	70 **Ga** gallium 31	73 **Ge** germanium 32	75 **As** arsenic 33	79 **Se** selenium 34	80 **Br** bromine 35	84 **Kr** krypton 36
85 **Rb** rubidium 37	88 **Sr** strontium 38	89 **Y** yttrium 39	91 **Zr** zirconium 40	93 **Nb** niobium 41	96 **Mo** molybdenum 42	[98] **Tc** technetium 43	101 **Ru** ruthenium 44	103 **Rh** rhodium 45	106 **Pd** palladium 46	108 **Ag** silver 47	112 **Cd** cadmium 48	115 **In** indium 49	119 **Sn** tin 50	122 **Sb** antimony 51	128 **Te** tellurium 52	127 **I** iodine 53	131 **Xe** xenon 54
133 **Cs** caesium 55	137 **Ba** barium 56	139 **La*** lanthanum 57	178 **Hf** hafnium 72	181 **Ta** tantalum 73	184 **W** tungsten 74	186 **Re** rhenium 75	190 **Os** osmium 76	192 **Ir** iridium 77	195 **Pt** platinum 78	197 **Au** gold 79	201 **Hg** mercury 80	204 **Tl** thallium 81	207 **Pb** lead 82	209 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111	[285] **Cn** copernicium 112	[286] **Nh** nihonium 113	[289] **Fl** flerovium 114	[289] **Mc** moscovium 115	[293] **Lv** livermorium 116	[294] **Ts** tennessine 117	[294] **Og** oganesson 118

* The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Relative atomic masses for **Cu** and **Cl** have not been rounded to the nearest whole number.

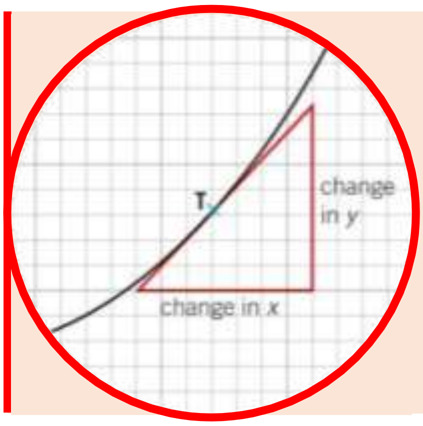
6 THE RATE AND EXTENT OF CHEMICAL CHANGE

6.1 RATE OF REACTION

6.1.1 Calculating rates of reactions

mean rate of reaction = $\dfrac{\textbf{quantity of product formed}}{\textbf{time taken (s)}}$

- When drawing a graph showing the rate of reaction, time is always shown on the x-axis and quantity of product formed is on the y-axis.



- To calculate the rate of a reaction at a specific time on a curve, you must draw a tangent to the curve and calculate the gradient of the slope.

6.1.2 Factors which affect the rates of chemical reactions

- Factors affecting rate of reaction:
  - **concentration** of reactants (concentrated vs. dilute)
  - **pressure** of reacting gases (high vs. low pressure)
  - **surface area** of solid reactants (many pieces vs. one)
  - **temperature** (high vs. low)
  - **catalysts** (present vs. absent)

6.1.3 Collision theory and activation energy

- Collision theory is the idea that particles must collide with enough energy to react.

- <u>Concentration / Pressure / Surface area</u>
- Increasing the concentration, pressure or surface area:
    - increases frequency of collisions
    - increases rate of reaction

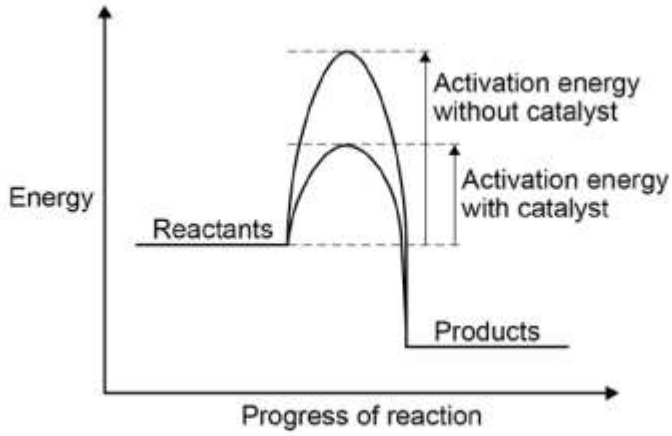
- <u>Temperature</u>
- Increasing the temperature:
    - increases frequency of collisions
    - increases energy of collisions
    - increases rate of reaction

6.1.4 Catalysts

- Catalyst:
    - a substance that increases the rate of a reaction by providing an alternative reaction pathway that has a lower activation energy
    - does not get used up
    - is reaction-specific

- Using a catalyst means a higher proportion of reactant particles will have enough energy to react.

- Catalysts are **not** included in chemical equations of reactions.



6.2 REVERSIBLE REACTIONS AND DYNAMIC EQUILIBRIUM

6.2.1 Reversible reactions

- In reversible reactions, the products of the reaction can react to produce the original reactants.

- Equation format: $A + B \rightleftharpoons C + D$

- The direction of reversible reactions can be changed by changing the conditions e.g.

  ammonium chloride $\underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}}$ ammonia + hydrogen chloride

6.2.2 Energy changes and reversible reactions

- If a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction.
- The same amount of energy is transferred in each case.

  hydrated copper sulfate (blue) $\underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}}$ anhydrous copper sulfate (white) + water

6.2.3 Equilibrium

- When a reversible reaction occurs in an apparatus which prevents the escape of reactants and products, equilibrium is reached when the forward and reverse reactions occur at exactly the same rate.

6.2.4 The effect of changing conditions on equilibrium

- If a system is at equilibrium and a change is made to any of the conditions, then the system responds to counteract the change.
- The relative amounts of all the reactants and products at equilibrium depend on the conditions of the reaction.
- Le Chantelier's Principle allows for predictions about the effect of changing conditions on a system at equilibrium.

6.2.5 The effect of changing concentration

- If the concentration of one of the reactants/products is changed:
    - the system is no longer at equilibrium
    - the concentrations of all the substances will change until equilibrium is reached
    - if the concentration of a reactant is increased, more products will be formed until equilibrium is reached again
    - if the concentration of a product is increased, more reactants will be formed until equilibrium is reached again

6.2.6 The effect of temperature changes on equilibrium

- If the temperature of a system at equilibrium is increased:
    - relative product yield increases for an endothermic forward reaction
    - relative product yield decreases for an exothermic forward reaction

- If the temperature of a system at equilibrium is decreased:
    - relative product yield decreases for an endothermic forward reaction
    - relative product yield increases for an exothermic forward reaction

6.2.7 The effect of pressure changes on equilibrium

- If the pressure of a system at equilibrium is increased:
    - equilibrium shifts towards side with smaller number of molecules as shown by symbol equation to decrease total number of molecules
- If the pressure of a system at equilibrium is decreased:
    - equilibrium shifts towards side with larger number of molecules as shown by symbol equation to increase total number of molecules

7 ORGANIC CHEMISTRY

7.1 CARBON COMPOUNDS AS FUELS AND FEEDSTOCK

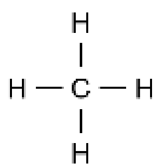
7.1.1 Crude oil, hydrocarbons and alkanes

- Crude oil is a finite resource found in rocks.
- It is an ancient biomass consisting mainly of plankton that was buried in mud.

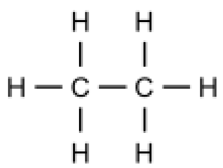
- It is a mixture of many compounds, mainly hydrocarbons.
- Hydrocarbons are made up of hydrogen and carbon atoms only.

- Most of the hydrocarbons in crude oil are alkanes, with the general formula **C_nH_{2n+2}.**
- Alkanes are saturated hydrocarbons with only single C–C bonds.

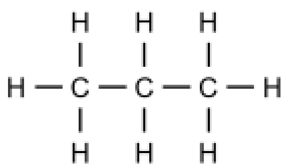
- The first four alkanes are:
    - methane, CH_4



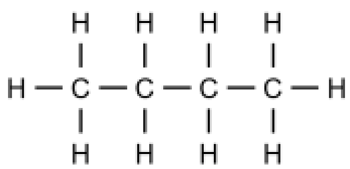
    - ethane, C_2H_6



    - propane, C_3H_8



    - butane, C_4H_{10}



7.1.2 Fractional distillation and petrochemicals

- Crude oil can be separated into fractions with similar number of carbon atoms by fractional distillation.
- The fractions can be processed to produce fuels and feedstock for the petrochemical industry.
- The fractions produced include petrol, diesel, kerosene, petroleum gases, as well as solvents, lubricants, polymers and detergents.

7.1.3 Properties of hydrocarbons

- As molecular size of hydrocarbons increases:
    - boiling point increases
    - viscosity increases
    - flammability decreases

- Combustion of hydrocarbon fuels involves oxidation and releases energy.
- Hydrocarbon + oxygen → carbon dioxide + water
- E.g. $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
- E.g. $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$

7.1.4 Cracking and alkenes

- Hydrocarbons can be cracked (broken down) to produce smaller, more useful molecules.
- There is a high demand for fuels with smaller molecules so cracking is necessary to meet the high demands.

- In catalytic cracking, the fraction is heated and passed over a hot catalyst where thermal decomposition occurs.
- In steam cracking, the fraction is heated, mixed with steam and further heated.

- Cracking produces alkanes and alkenes.
- Alkenes are unsaturated hydrocarbons with one or more double C=C bonds.

- Test for alkenes:
    - react with bromine water (orange to colourless)

- Alkenes are used:
    - to produce polymers
    - as starting materials for certain chemicals

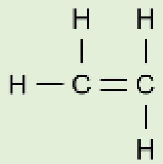
7.2 REACTIONS OF ALKENES AND ALCOHOLS

7.2.1 Structure and formulae of alkenes

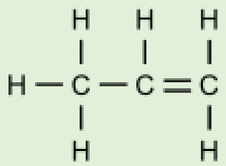
- Alkenes are hydrocarbons with a C=C (double) bond.
- The general formula for the homologous series of alkenes is $\mathbf{C_nH_{2n}}$.

- Alkenes are unsaturated because they contain two fewer hydrogen atoms than alkanes with the same number of carbon atoms.

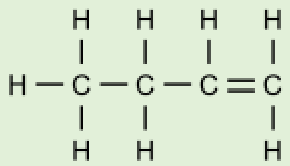
- The first four alkenes are:
  - **ethene,** C_2H_4



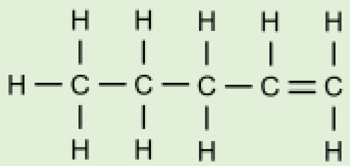
  - **propene,** C_3H_6



  - **butene,** C_4H_8



  - **pentene,** C_5H_{10}



7.2.2 Reactions of alkenes

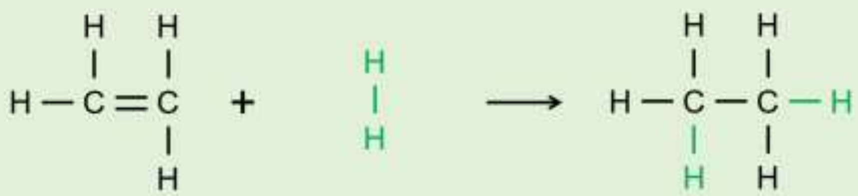
- A functional group is a characteristic that defines a homologous series.
- Alkenes are hydrocarbons containing the functional group C=C.

- Alkenes react with oxygen in <u>incomplete</u> combustion reactions, so they burn with smoky flames containing carbon particulates.
- When reacting with hydrogen, water and the halogens, alkenes lose their double C=C bond to form a single C–C bond, adding atoms across the bond:

- For an alkene to react with hydrogen, water or a halogen:
    - H_2O must be in gas form (steam)

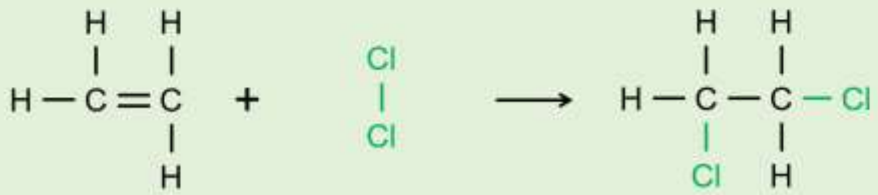
- **alkene + hydrogen → alkane**

Ethene, C_2H_4 + Hydrogen, H_2 ⟶ Ethane, C_2H_6



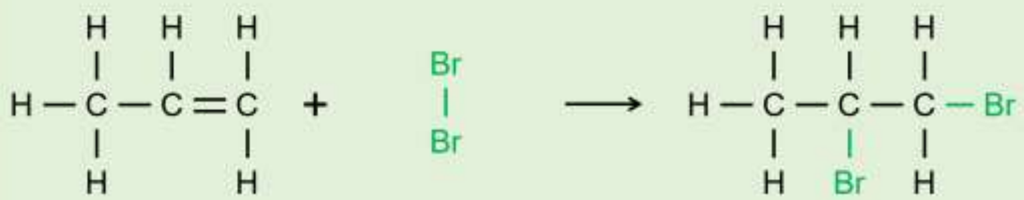
- **alkene + chlorine → dichloroalkene**

Ethene, C_2H_4 + Chlorine, Cl_2 ⟶ Dichloroethane, $C_2H_4Cl_2$



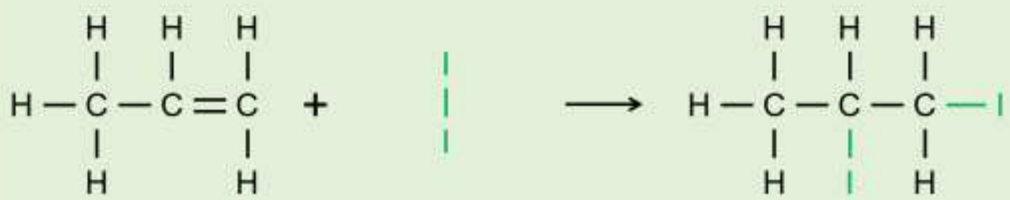
- **alkene + bromine → dibromoalkane**

Propene, C_3H_6 + Bromine, Br_2 ⟶ Dibromopropane, $C_2H_5Br_2$

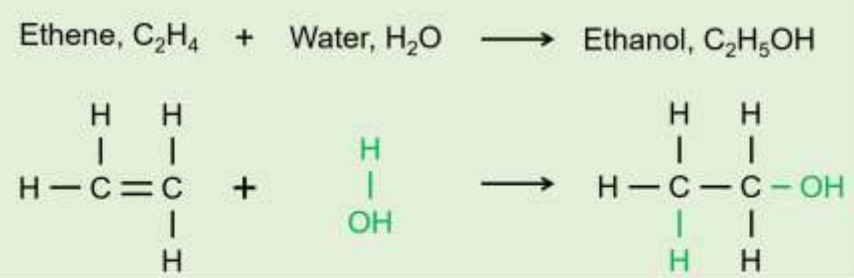


- **alkene + iodine → diiodoalkane**

Propene, C_3H_6 + Iodine, I_2 ⟶ Diiodopropane, $C_2H_5I_2$



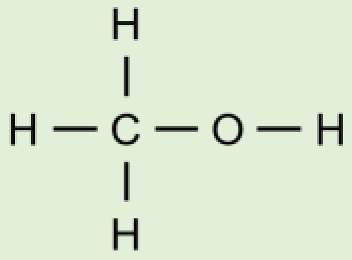
- **alkene + water → alkanol**



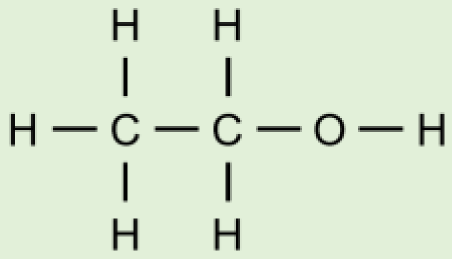
7.2.3 Alcohols

- Alcohols contain the functional group –OH.

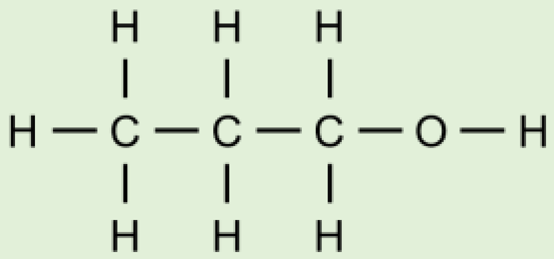
- The first four alcohols are:
  - **methanol,** CH_3OH



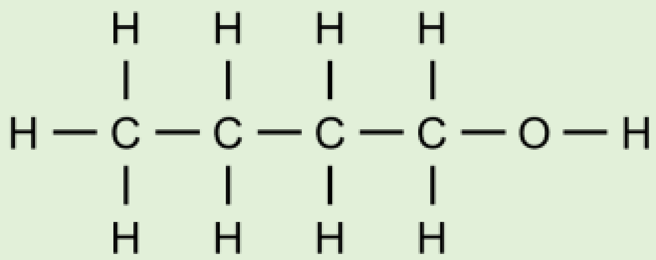
  - **ethanol,** CH_3CH_2OH or C_2H_5OH



  - **propanol,** $CH_3CH_2CH_2OH$ or C_3H_7OH



  - **butanol,** $CH_3CH_2CH_2CH_2OH$ or C_4H_9OH



Chapter 7 – Organic Chemistry

- Uses of alcohols:
  - **alcoholic drinks:** ethanol
  - **solvents:** in perfumes and aftershaves
  - **fuels:** ethanol + oxygen → carbon dioxide + water

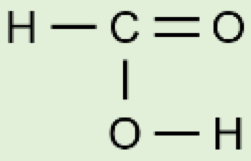
- Reactions of alcohols:
  - **with sodium:** sodium ethoxide + hydrogen (for ethanol)
  - **burn in air:** carbon dioxide + water
  - **added to water:** dissolve to form neutral solution
  - **react with oxidising agent:** methanoic acid + water (for methanol)

- Fermentation:
  - glucose $\xrightarrow{\text{yeast}}$ ethanol + carbon dioxide
  - required conditions:
    - cotton to let CO_2 out but stop air coming in
    - high temperature (25 – 35 °C)
    - presence of yeast in sugar solution

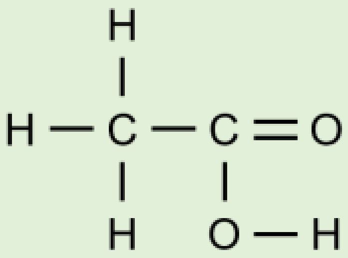
7.2.4 Carboxylic acids

- Carboxylic acids contain the functional group –COOH.

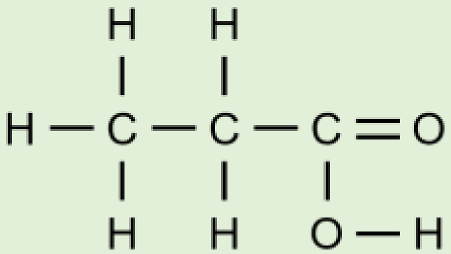
- The first four carboxylic acids are:
  - **methanoic acid,** HCOOH



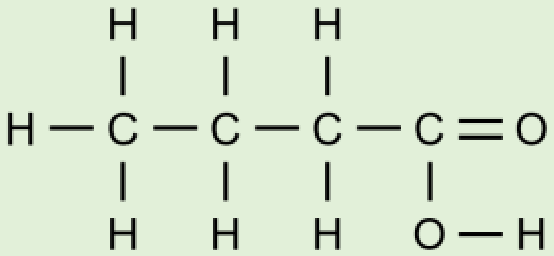
  - **ethanoic acid,** CH_3COOH



  - **propanoic acid,** C_2H_5COOH



  - **butanoic acid,** C_3H_7COOH



- Carboxylic acids are weak acids because they:
  - have a higher pH
  - only partially ionise in a solution (H^+ ions and ethanoate$^-$ ions)

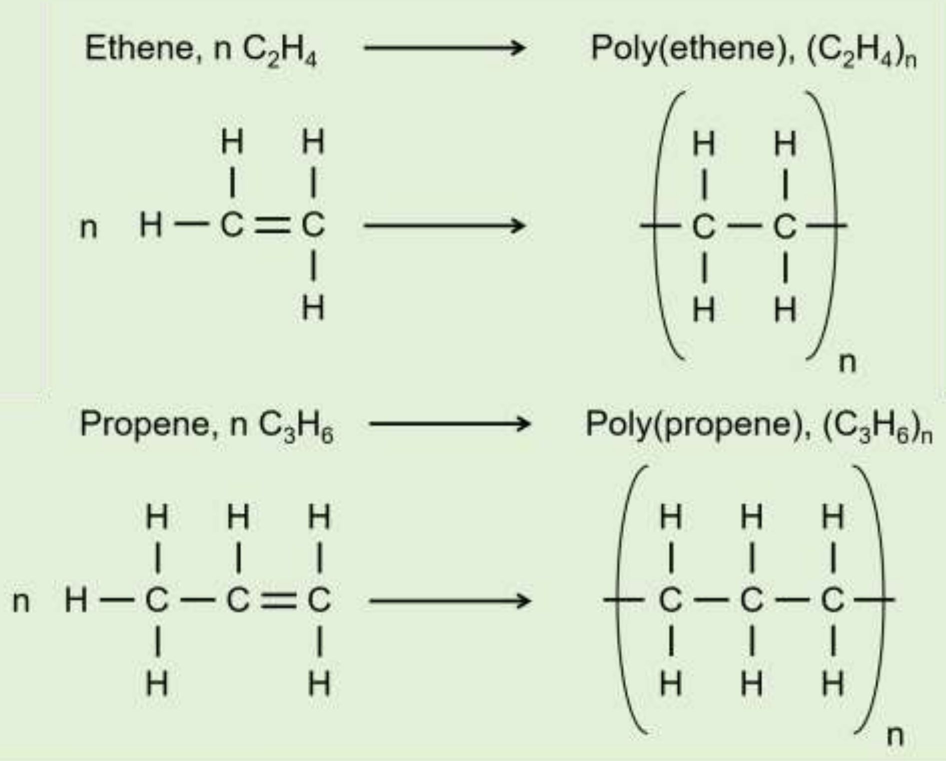
- Reactions of carboxylic acids:
  - **react with carbonates:** sodium ethanoate + water + carbon dioxide
  - **dissolve in water:** partial ionisation, weak acidic solution
  - **react with alcohols:** ester (ethyl ethanoate) + water

7.3 SYNTHETIC AND NATURALLY OCCURING POLYMERS

7.3.1 Addition polymerisation

- In addition polymerisation reactions, many small molecules (monomers) join together to form very large molecules (polymers).
- Alkenes, e.g. ethene, join to make polymers, e.g. poly(ethene).
- The repeating unit (of the polymer) has the same atoms as the monomer because no other molecule is formed in the reaction, except the double C=C bond becomes a single one.

- Addition polymerisation reactions:

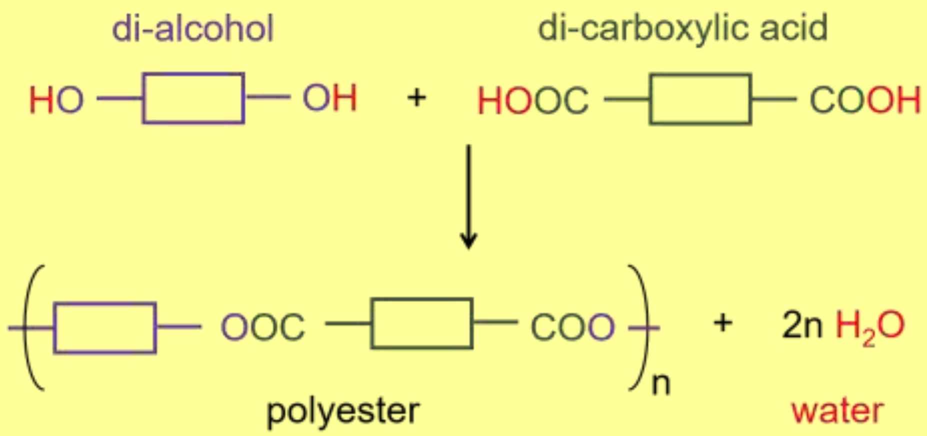


7.3.2 Condensation polymerisation

- In condensation polymerisation reactions, monomers, each with two of the same functional group, join together, usually losing small molecules such as water.

- A di-alcohol reacts with a di-carboxylic acid to form a polyester.

- E.g. ethane diol + hexanedioic acid → polyethylene terephthalate
  n $C_2H_6O_2$ + n $C_6H_{10}O_4$ → $(C_{10}H_8O_4)_n$



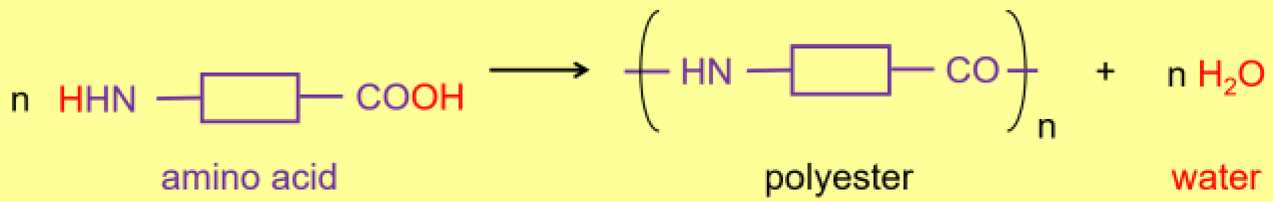
- In condensation polymerisation reactions:
  - di-alcohol loses two hydrogen atoms
  - di-carboxylic acid loses two hydroxide molecules
  - two molecules of water form (typically)
  - the remaining reactants join together, with a repeating unit as shown above

7.3.3 Amino acids

- Amino acids have two different functional groups in a molecule:
  - amine group (–NH_2)
  - carboxylic acid group (–COOH)

- Amino acids react by condensation polymerisation to produce polypeptides.

- E.g. glycine → poly(glycine) + water
- E.g. NH_2CH_2COOH → $(–HNCH_2COO–)_n$ + n H_2O



- Different amino acids can be combined into one chain to produce proteins.

7.3.4 DNA (deoxyribonucleic acid) and other naturally occurring polymers

- DNA is a large molecule essential for life.
- DNA encodes genetic instructions for the development and functioning of living organisms and viruses.
- Most DNA molecules are two polymer chains, each made from four different monomers called nucleotides, in the form of a double helix.

- Other naturally occurring polymers include:
    - **proteins** (made of amino acids)
    - **starch** (made of monosaccharides)
    - **cellulose** (made of glucose)

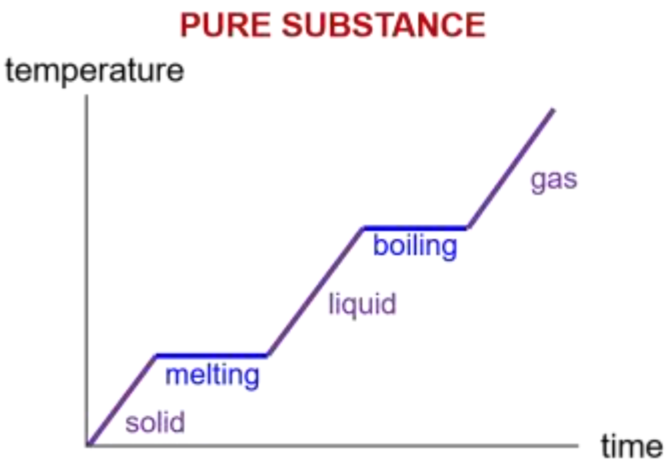
8 CHEMICAL ANALYSIS

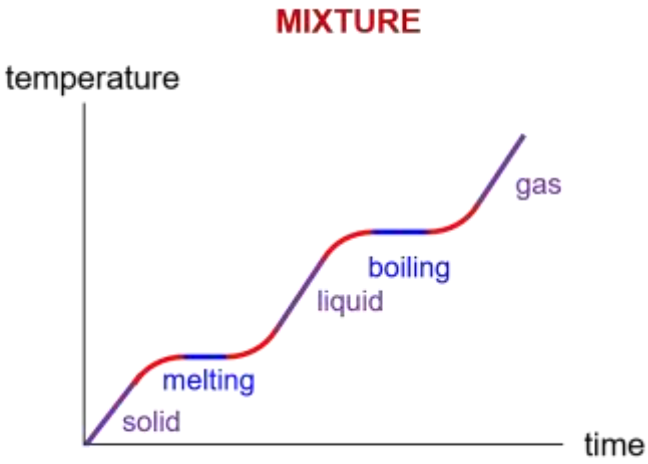
8.1 PURITY, FORMULATIONS AND CHROMATOGRAPHY

8.1.1 Pure substances

- A pure substance is a single element or compound, not mixed with any other substance.
- Pure elements and compounds melt and boil at specific temperatures.
- Mixtures melt and boil over a range of temperatures.

- Melting and boiling point data can be used to distinguish pure substance from mixtures.





- In everyday language, a pure substance is a substance with nothing added to it, so it is unadulterated and in its natural state, e.g. pure milk.

8.1.2 Formulations

- A formulation is a mixture that has been designed as a useful product.

- Many products are complex mixtures in which each chemical has a particular purpose.
- Formulations are made by mixing the components in carefully measured quantities to ensure that the product has the required properties.
- Formulations include:
    - fuels
    - cleaning agents
    - paints
    - medicines
    - alloys
    - fertilisers
    - foods

8.1.3 Chromatography

- Chromatography can be used to separate mixtures and can give information to help identify substances.

- Chromatography involves a stationary phase and a mobile phase.
- Separation depends on the distribution between the phases.

- Stationary phase: the part of the apparatus that does not move, i.e. chromatography paper
- Mobile phase: the moving part, i.e. solvent

- A substance with stronger forces of attraction to the mobile phase than to the stationary phase will be carried a greater distance in a given time.

- The R_f (retention factor) value of a substance represents the ratio of the distance moved by a compound (centre of spot from origin) to the distance moved by the solvent.

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

- Different compounds have different R_f values in different solvents, which can be used to identify the compounds.

- A pure compound will produce a single spot in all solvents.
- A mixture will separate into different spots depending on the solvent.

8.2 IDENTIFICATION OF COMMON GASES

8.2.1 Test for hydrogen

- **Apparatus:** a <u>burning splint</u> held at the open end of a test tube of the gas
- **Test:** hydrogen burns rapidly with a <u>pop sound</u>

8.2.2 Test for oxygen

- **Apparatus:** a <u>glowing splint</u> inserted into a test tube of the gas
- **Test:** splint <u>relights</u>

8.2.3 Test for carbon dioxide

- **Apparatus:** mixing gas with <u>lime water</u> (calcium hydroxide solution)
- **Test:** lime water turns <u>milky</u> (cloudy)

8.2.4 Test for chlorine

- **Apparatus:** <u>litmus paper</u> inserted into a test tube of the gas
- **Test:** litmus paper <u>bleached and turns white</u>

8.3 IDENTIFICATION OF IONS BY CHEMICAL AND SPECTROSCOPIC MEANS

8.3.1 Flame tests

- Flame tests can be used to identify some metal ions (cations).

Cation	Symbol	Colour of flame
Lithium	Li^{+}	crimson
Sodium	Na^{+}	yellow
Potassium	K^{+}	lilac
Calcium	Ca^{2+}	orange-red
Copper	Cu^{2+}	green

How to conduct a flame test:

- dip nichrome loop in acid then heat in blue Bunsen flame until there is no colour (clean)
- dip loop into acid then sample
- hold loop in Bunsen flame and observe

- If a sample containing a mixture of ions is used some flame colours can be masked.

8.3.2 Metal hydroxides

- Sodium hydroxide solution can be used to identify some metal ions (cations).
- These ions react to form insoluble metal hydroxides.

Cation	Symbol	Colour of precipitate	Further test
Aluminium	Al^{3+}	white	soluble in excess sodium hydroxide solution
Calcium	Ca^{2+}		insoluble in excess sodium hydroxide solution
Magnesium	Mg^{2+}		insoluble in excess sodium hydroxide solution
Copper(II)	Cu^{2+}	blue	
Iron(II)	Fe^{2+}	green	
Iron(III)	Fe^{3+}	brown	

- E.g. aluminium sulfate + sodium hydroxide → sodium sulfate + aluminium hydroxide
  $Al_2(SO_4)_{3\ (aq)} + NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + Al(OH)_{3\ (s)}$

- E.g. iron(II) chloride + sodium hydroxide → sodium chloride + iron hydroxide
  $FeCl_{2\ (aq)} + 2NaOH_{(aq)} \rightarrow 2NaCl_{(aq)} + Fe(OH)_{2\ (s)}$

- E.g. magnesium iodide + sodium hydroxide → sodium iodide + magnesium hydroxide
  $MgI_{2\ (aq)} + 2NaOH_{(aq)} \rightarrow 2NaI_{(aq)} + Mg(OH)_{2\ (s)}$

8.3.3 Carbonates

- Carbonates react with dilute acids to form carbon dioxide gas.
- Carbon dioxide turns limewater cloudy.

8.3.4 Halides

- Halide ions in solution react with silver nitrate solution *in the presence of dilute nitrate acid* to produce precipitates.

Precipitate	Symbol	Colour
Silver chloride	$AgCl_2$	white
Silver bromide	$AgBr_2$	cream
Silver iodide	AgI_2	yellow

8.3.5 Sulfates

- Sulfate ions in solution react with barium chloride solution *in the presence of dilute hydrochloric acid* to produce a white precipitate.

8.3.6 Instrumental methods

- Elements and compounds can be detected and identified using instrumental methods.

Advantages	Disadvantages
- accurate - sensitive - rapid	- expensive equipment - requires special training to use - comparison with data from known substances is required to produce a result

8.3.7 Flame emission spectroscopy

- Flame emission spectroscopy is an example of an instrumental method used to analyse metal ions in solutions.

- Process of flame emission spectroscopy:
    - sample is put into flame
    - light given out is passed through spectroscope
    - output is a line spectrum
    - line spectrum is analysed and compared to that of known metal ions
    - metal ions are identified
    - their concentrations can be measured by the intensity of the light with the wavelength of that metal ion's spectrum

9 CHEMISTRY OF THE ATMOSPHERE

9.1 THE COMPOSITION AND EVOLUTION OF THE EARTH'S ATMOSPHERE

9.1.1 The proportions of different gases in the atmosphere

- For the last 200 million years, the proportions of different atmospheric gases have been about the same:
  - 78% nitrogen
  - 21% oxygen
  - 1% other gases (carbon dioxide, water vapour, noble gases)

9.1.2 The Earth's early atmosphere

- Evidence for early atmosphere is limited because of the 4.6 billion year timescale.

- The common theory:
  - during the first billion years of existence, the Earth's atmosphere may have been like that of Venus and Mars, consisting of mainly carbon dioxide
  - there was intense volcanic activity which released:
    - **nitrogen** and small proportions of methane and ammonia which built up the atmosphere
    - **water vapour** which condensed to form the oceans
  - carbon dioxide dissolved in the oceans' water forming carbonates which took in carbon dioxide from the atmosphere

9.1.3 How oxygen increased

- Algae and plants existed 2.7 billion years ago
- They released oxygen by photosynthesis.
- Eventually enough oxygen was in the atmosphere for animals to exist.

- **carbon dioxide** + water $\xrightarrow[\text{chlorophyll}]{\text{light}}$ glucose + **oxygen**

- $6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$

9.1.4 How carbon dioxide decreased

- Algae and plants also took in carbon dioxide by photosynthesis.
- The formation of sedimentary rocks and fossil fuels took in carbon dioxide which decreased the amount in the atmosphere.

- Formation of sedimentary rocks and fossil fuels:
    - **limestone:** precipitation of carbonates in oceans
    - **coal:** compression of decayed plant material
    - **crude oil:** compression of decayed plankton remains
    - **natural gas:** compression of decayed plankton remains

9.2 CARBON DIOXIDE AND METHANE AS GREENHOUSE GASES

9.2.1 Greenhouse Gases

- Greenhouse gases in the atmosphere maintain temperatures on Earth high enough to support life.
- Examples of greenhouse gases include:
    - carbon dioxide
    - methane
    - water vapour

- The greenhouse effect:
    - greenhouse gases act as a ‘blanket’ around the Earth
    - they let short wavelength radiation from the Sun in
    - the Earth produces long wavelength radiation which is absorbed by the greenhouse gases
    - the more greenhouse gas molecules there are, the more long wavelength radiation they absorb, and the warmer the atmosphere gets

9.2.2 Human activities which contribute to an increase in greenhouse gases in the atmosphere

- Human activities increase the following greenhouse gases in the atmosphere:
    - **carbon dioxide** by:
        - combustion of fossil fuels (which contain carbon)
        - deforestation (trees release their carbon dioxide)
    - **methane** by:
        - pastoral farming (cattle)
        - arable farming (paddy rice fields)
        - biomass combustion (incomplete combustion of biomass)

- Peer-review refers to the approval of scientific research by other experts before it is published and agreed upon.
- Theories cannot be given authority unless peer-reviewed.
- Based on peer-reviewed evidence, many scientists believe that human activities will cause global climate change where temperature will increase at the surface.

- Problems with predicting the future:
    - it is difficult to model such complex systems
    - simplified models, speculation and opinion may be biased towards certain evidence
    - there is no hard evidence linking carbon dioxide levels and global climate change
    - contrasting evidence causes confusion

9.2.3 Global climate change

- Global climate change refers to an increase in average global temperature.

- Effects of global climate change:
  - **rising sea levels** due to melting glaciers and warmer ocean expansion
  - **increasingly common extreme weather events** such as storms
  - **changes in rainfall patterns** can affect crop yield (too wet/dry)
  - **changes of distribution of wildlife species**, e.g. extinction of polar bears

- Discussing the scale, risk and environmental implications:
  - temperature increases globally
  - rising sea levels lead to permanent flooding
  - low crop yields can lead to famine
  - extinction of species

9.2.4 The carbon footprint and its reduction

- The carbon footprint is the total amount of carbon dioxide or other greenhouse gases emitted over the full life cycle of a product, service or event.

- The carbon footprint can be reduced by:
  - **using solar power** reduces use of electricity from fossil fuels
  - **cycling to work** does not release CO_2 like driving
  - **using insulation** reduces the amount of energy to heat property
  - **carbon capture and storage** does not release CO_2 into atmosphere
  - **recycling waste** reduces landfill and CH_4/CO_2 release

- Problems with reducing the carbon footprint:
  - solar panels are expensive
  - cycling will not suffice for long distance commutes
  - incomplete international cooperation
  - affects developing countries

9.3 COMMON ATMOSPHERIC POLLUTANTS AND THEIR SOURCES

9.3.1 Atmospheric pollutants from fuels

- The combustion of fuels is a major source of atmospheric pollutants.
- Most fuels contain carbon, hydrogen or sulfur.

- Release of atmospheric pollutants by combustion:
    - **carbon dioxide**: complete combustion of fossil fuels
    - **carbon monoxide:** incomplete combustion of fossil fuels
    - **carbon particulates:** combustion of some long chain hydrocarbons
    - **sulfur dioxide:** combustion of fuels with sulfur impurities
    - **nitrogen oxides:** oxidation of N_2 gas in air at high temperatures

- propane + oxygen → carbon dioxide + water *(complete)*
- ethane + oxygen → carbon monoxide + water *(incomplete)*
- methane + oxygen → carbon + water *(incomplete)*
- sulfur + oxygen → sulfur dioxide
- nitrogen + oxygen → nitrogen dioxide

9.3.2 Properties and effects of atmospheric pollutants

- Effects of atmospheric pollutants:
    - **carbon dioxide** absorbs infrared radiation
    - **carbon monoxide** is a toxic gas that reduces the blood’s oxygen carrying capacity; is colourless and odourless so is not easily detected
    - **carbon particulates** cause global dimming and lung damage
    - **water vapour** increases humidity
    - **sulfur dioxide** causes acid rain and respiratory problems
    - **nitrogen oxides** cause acid rain and triggers asthma
    - **unburned hydrocarbons** are a waste of fuel

10 USING RESOURCES

10.1 USING THE EARTH'S RESOURCES AND OBTAINING POTABLE WATER

10.1.1 Using the Earth's resources and sustainable development

- Humans use the Earth's resources to provide:
    - warmth
    - shelter
    - food
    - transport

- **Natural resources:** supplemented by agriculture and provide:
    - food
    - timber
    - clothing
    - fuels

E.g. wood, rubber, cotton, wool, silk, linseed oil etc.

- **Finite resources:** from the Earth, oceans and atmosphere, processed to provide:
    - energy
    - resources

E.g. metal ores, coal, oil, gas, limestone etc.

- The role of chemistry in resource management:
    - plays an important role in improving agricultural and industrial processes
    - this provides new products through sustainable development

- **Sustainable development:** development that meets the needs of current generations without compromising the ability of future generations to meet their own needs.

10.1.2 Potable water

- Water of appropriate quality is essential for life.
- For humans, drinking water should have sufficiently low levels of dissolved salts and microbes.
- **Potable water:** water that is safe to drink (not pure water).

- Methods to produce potable water depend on available supplies of water and local conditions.

- In the UK, rain provides water with low levels of dissolved substances (fresh water) that collects in the ground and in lakes and rivers.
- Most potable water is produced by:
    - choosing an appropriate source of fresh water *(not polluted etc.)*
    - passing the water through filter beds *(to remove large particles)*
    - sterilising *(to kill microbes)*
- Sterilising agents used for potable water include:
    - chlorine
    - ozone
    - ultraviolet light

- If supplies of fresh water are limited, desalination of salty water or sea water may be required.
- Desalination can be done by:
    - distillation or
    - processes that use membranes, e.g. reverse osmosis
- These processes require large amounts of energy.

10.1.3 Waste water treatment

- Urban lifestyles and industrial processes produce large amounts of waste water that require treatment before releasing into the environment.

- Sewage and agricultural waste water requires removal of **organic matter** and **harmful microbes.**
- Industrial waste water may require removal of **organic matter** and **harmful chemicals**.

- Sewage treatment includes:
    - **screening and grit removal:** removing large particles by passing through a grid
    - **sedimentation:** sewage settles to produce sludge (solids) and effluent (liquid)
    - **anaerobic digestion of sewage sludge:** microbes break down organic material in the absence of oxygen
    - **aerobic biological treatment of effluent:** microbes break down dissolved organic material in the presence of oxygen (by bubbling air through the water)

10.1.4 Alternative methods of extracting metals

- Copper ores are becoming scarce and new ways of extracting copper from low-grade ores do not involve traditional mining (digging, mobbing and disposing large amounts of rock).

- **Phytomining:**
    - plants grow and absorb metal compounds
    - plants are harvested
    - plants are burnt to produce ash that contains metal compound

- **Bioleaching:**
    - bacteria feed on low-grade metal ores
    - a solution of copper ions (leachate solution) is formed

- After phytomining or bioleaching:
    - metal compounds are processed to obtain the metal
    - e.g. copper can be obtained from solutions of copper compound by displacement using scrap iron or by electrolysis

10.2 LIFE CYCLE ASSESSMENT AND RECYCLING

10.2.1 Life cycle assessment

- Life Cycle Assessments (LCAs) are carried out to assess the environmental impact of products in each of these stages: (including transport and distribution at each stage)
    - **extracting** and **processing** raw materials
    - **manufacturing** and **packaging**
    - **use** and **operation** during its lifetime
    - **disposal** at the end of its useful life

- LCA is not a purely objective process because:
    - while allocating numerical values to pollutant effects is less straightforward and requires value judgements
    - use of water, resources, energy sources and production of some wastes can be fairly easily quantified

- Selective or abbreviated LCAs can be devised to evaluate a product but these can be misused to reach pre-determined conclusions, e.g. in support of claims for advertising.

LCA stage	Plastic shopping bags	Paper shopping bags
raw materials	crude oil is finite extraction requires lots of energy transport requires fuel (polluting)	trees are renewable resources habitats destroyed from deforesting transport requires fuel (polluting)
manufacturing	energy needed for separating fractions, cracking and polymerisation	water needed to produce pulp uses harmful chemicals that could leak
use and operation	distribution requires fuel (polluting)	distribution requires fuel (polluting)
disposal	melting requires energy	relatively easy to recycle

10.2.2 Ways of reducing the use of resources

- The reduction in use, reuse and recycling of materials by end users:
    - **reduces the use of limited resources**
    - **reduces the use of energy resources**
    - **adds to waste** produced
    - **has environmental impacts**

- Metals, glass, building materials, clay ceramics and most plastics are produced from limited raw material.
- Much of the energy for the processes comes from limited resources.
- Obtaining raw material from the Earth by quarrying and mining causes environmental impacts.

- Some products, such as glass bottles, can be reused.
- Glass bottles can be crushed and melted to make different glass products.
- Other products cannot be reused and so are recycled for a different use.

- Metals can be recycled by melting and recasting or reforming into different products.
- The amount of separation required for recycling depends on the material and the properties required of the final product.
- For example, some scrap steel can be added to iron in a blast furnace to reduce the amount of iron that needs to be extracted from iron ore.

10.3 USING MATERIALS

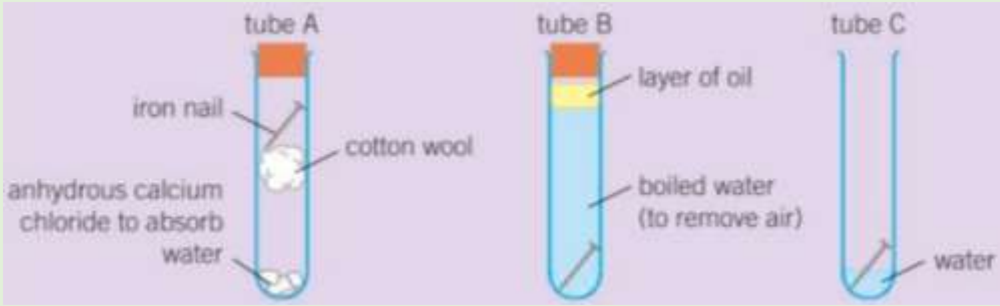
10.3.1 Corrosion and its prevention

- Corrosion is the destruction of materials by chemical reactions with substances in the environment.
- Rusting is the corrosion of iron, which requires both air and water.

- Corrosion can be prevented by applying a coating that acts as a barrier:
    - **greasing**
    - **painting**
    - **electroplating**
- Aluminium has an oxide coating that protects the metal from further corrosion.

- Sacrificial protection:
    - some coatings are reactive
    - they contain a more reactive metal than the one being protected
    - as the coating is relatively more reactive, it corrodes instead of the other metal
    - e.g. zinc is used to galvanise iron

- Experiments to show that both air and water are needed for rusting:



10.3.2 Alloys as useful materials

- Most materials in everyday use are alloys:
    - **bronze:** copper and tin (used in musical instruments)
    - **brass:** copper and zinc (used in door handles and plates of switches/sockets)
    - **gold:** gold, silver, copper and zinc (used as jewellery)
    - **steels:** alloys of iron that contain specific amounts of carbon and other metals
        - ***high carbon steel:*** *strong but brittle (used for car frames)*
        - ***low carbon steel:*** *softer and more easily shaped (used for saws)*
        - ***stainless steels:*** *contain chromium and nickel and are hard and resistant to corrosion (used for medical tools)*
    - **aluminium:** low density (used for aircrafts)

- The proportion of gold in a gold alloy is measured in carats.
    - 24 carat is 100% gold (pure gold)
    - 18 carat is 75% gold
    - 12 carat is 50% gold

10.3.3 Ceramics, polymers and composites

- Types of **glass**:
    - **soda-lime:** made by heating a mixture of sand, sodium carbonate and limestone
    - **borosilicate:** made from sand and boron trioxide; has higher melting point

- **Clay ceramics**, including pottery and bricks, are made by shaping wet clay then heating in a furnace.

- The properties of polymers depend on:
    - what monomers they are made from
    - the conditions under which they are made

- Types of polymers:
    - **thermosoftening:** melt when heated as they have tangled chains with weak intermolecular forces
    - **thermosetting:** do not melt when heated as they have cross-links between the chains which form strong bonds
- Types of poly(ethene):
    - **low density (LD):** formed at lower temperature and pressure
    - **high density (HD):** formed at higher pressures which enable cross-links to form
    - different catalysts are used to stimulate different types of reaction

- A composite is made from two or more materials, e.g. reinforced concrete, plywood etc.
- Most composites are made of two materials:
    - **matrix or binder:** surrounds and binds together the reinforcement
    - **reinforcement:** fibres or fragments of other material

10.4 THE HABER PROCESS AND THE USE OF NPK FERTILISERS

10.4.1 The Haber process

- The Haber process is used to make ammonia, which can be used to produce nitrogen-based fertilisers.
- The raw materials for the Haber process are:
    - **nitrogen:** from the air
    - **hydrogen:** from natural gas

nitrogen + hydrogen $\underset{\text{heat}}{\overset{\text{cool}}{\rightleftharpoons}}$ ammonia

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

- The Haber process:
    - the **purified gases are passed over a catalyst of iron** at a **high temperature (450˚C)** and a **high pressure (200 atmospheres)**
    - some hydrogen and nitrogen **reacts to form ammonia**
    - the **reaction is reversible** so **some of the ammonia produced breaks down** into nitrogen and hydrogen
    - on cooling, the **ammonia liquifies and is removed**
    - the **remaining hydrogen and nitrogen are recycled**

- Reasons for conditions:
    - **450˚C:** enough to reach activation energy yet low enough for decent yield (equilibrium shifts to ammonia at lower temperatures)
    - **200 atm:** high enough to shift equilibrium to ammonia
    - **iron catalyst:** lowers activation energy and increases rate of reaction

- Commercially used conditions for the Haber process are related to:
    - **availability/cost of raw materials:** pressure is kept as high as economically viable
    - **availability/cost of energy supplies:** moderate pressure/temperature for profits
    - **control of equilibrium position:** lower temperature and higher pressure needed
    - **rate of reaction:** iron catalyst is used to increase the rate of reaction

10.4.2 Production and uses of NPK fertilisers

- Compounds of nitrogen, phosphorus and potassium are used as fertilisers to improve agricultural productivity.
- NPK fertilisers contain compounds of all three elements.

- Industrial production of NPK fertilisers can be achieved using a variety of raw materials in several integrated processes.
- NPK fertilisers are formulations of various salts containing appropriate percentages of the elements.

- Potassium chloride, potassium sulfate and phosphate rock are obtained by mining, but phosphate rock cannot be used directly as a fertiliser.
- Ammonia can be used to manufacture ammonium salts and nitric acid.

- Phosphate rock is treated with nitric acid or sulfuric acid to produce soluble salts that can be used as fertilisers.

  phosphate rock + nitric acid → calcium nitrate + phosphoric acid
  phosphate rock + sulfuric acid → calcium sulfate + phosphoric acid
  phosphate rock + phosphoric acid → calcium phosphate

CHEMISTRY PAPER 2

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