

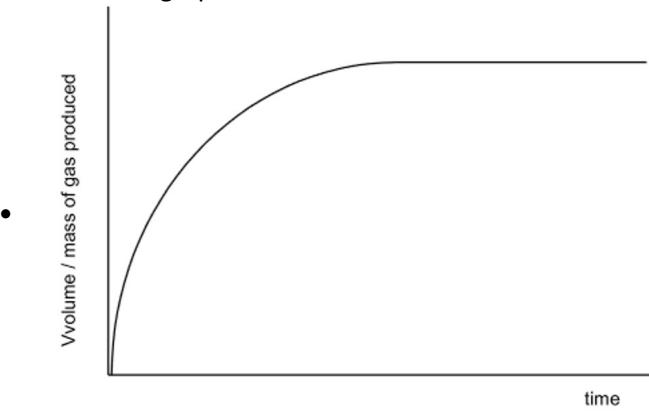
6.1 Rate of reaction

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6.1.1 Calculating rates of reactions

- Rate of reaction
 - Tells how quickly a reactant is used up / how quickly a product is produced
 - mean rate of reaction =
$$\frac{\text{quantity of reactants used}}{\text{time taken}} = \frac{\text{quantity of product formed}}{\text{time taken}}$$
 - Unit: amount = Moles, grams, cm³; time = seconds, minutes, hours, days
- Rate of reaction graph



- Fastest at the beginning
- Rate decreases as reaction goes on
 - Decreases more slowly as time increases
- Level off at last when the reaction finish (rate of reaction = 0)

6.1.2 Factors which affect the rates of chemical reactions

- Factors
 - Temperature
 - Concentration of a solution
 - Volume of a gas (pressure of gas)
 - Surface area of a solid
 - Presence of catalysts

6.1.2 Required practical 4

- Measuring by gas volume produced
 - e.g. $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$
 - Use a measuring cylinder to measure out 50 cm³ of HCl into the conical flask
 - Attach the conical flask to a bung and a delivery tube
 - Measuring gas produced
 - Place the delivery tube into a container filled with water
 - Place an overturned measuring cylinder also filled with water over the delivery tube
 - Alternative = connect to gas syringe
 - Add magnesium strip into the HCl, quickly seal the flask with bung and start the timer
 - H₂ produced is trapped in the measuring cylinder
 - Measure the volume of H₂ produced every 10 / 30 seconds until no more H₂ is produced
 - (Repeat with different HCl concentration)
- Measuring by colour change
 - e.g. sodium thiosulfate solution + hydrochloric acid $\rightarrow \text{sulfur}_{(\text{s})}$
 - Use a measuring cylinder to measure out 10 cm³ of sodium thiosulfate solution into the conical flask
 - Place the conical flask on a printed black cross
 - Add 10 cm³ of HCl into the conical flask
 - Swirl the solution and start a stopwatch

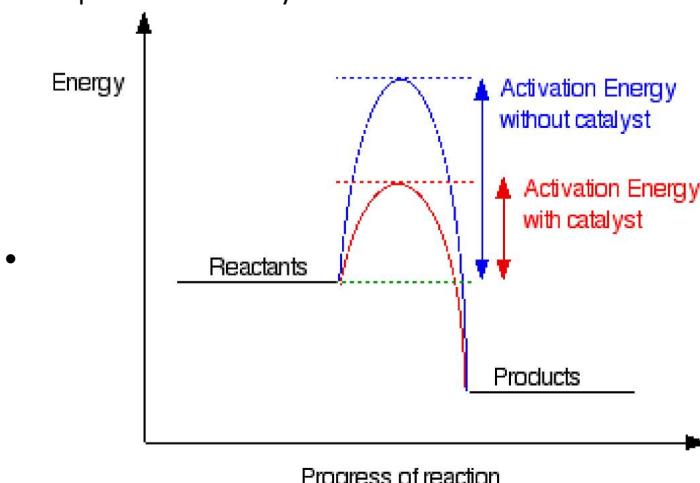
- Look down through the top of the flask
- Measure the time taken for the solution to become too cloudy to see the cross
- Repeat with different sodium thiosulfate concentration
- 3 repeats for each concentration + calculate mean time

6.1.3 Collision theory and activation energy

- Collision theory
 - For two particles to be able to react they must:
 - Collide with enough energy (meet activation energy)
 - Collide with the correct orientation
- Activation energy (E_a)
 - The minimum amount of energy that particles must have to react
- Temperature
 - Temperature increase = particles have more (kinetic) energy so they move faster
 - Particles collide more frequently
 - Particles collide with more force (energy)
 - Colliding particles are more likely to have enough energy to be able to react (meet activation energy)
 - More successful collisions per unit time
- Concentration
 - Concentration increase = more particles in the same volume
 - More collisions per unit time
- Pressure
 - Pressure increase = more particles in the same volume
 - More collisions per unit time
 - Gas only
- Surface area of solids
 - Only the particles on the surface of a solid can react
 - Only they can collide with other particles
 - Smaller particles = larger surface area to volume ratio, using smaller particles = more surface area
 - More particles can react as more particles are on the surface and can collide with other particles
 - More collisions per unit time

6.1.4 Catalysts

- How catalysts increase the rate of reaction
 - Providing an alternative pathway of lower activation energy
 - Particles only have to collide with each other will less energy / force to be able to react
 - Do not get used up during the reaction (can be reused)
 - Different reactions need different catalysts
 - Enzymes = biological catalysts
- Reaction profile with catalysts



6.2 Reversible reactions and dynamic equilibrium

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6.2.1 Reversible reactions

- Reversible reaction
 - Definition
 - In some chemical reactions, the products of the reaction can react to produce the original reactants
 - Presented as $A + B \rightleftharpoons C + D$
- Changing direction
 - The direction of a reversible reaction can be changed by changing the conditions
 - e.g. $\text{NH}_4\text{Cl}_{(s)} \rightleftharpoons \text{NH}_3_{(g)} + \text{HCl}_{(g)}$
 - Goes forward when it is heated
 - Backward when it is cooled down

6.2.2 Energy changes and reversible reactions

- Energy transfer
 - If a reversible reaction is exothermic in one direction, it must be endothermic in the opposite direction
 - The same amount of energy is transferred in each case
 - e.g. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}_{(s)} \rightleftharpoons \text{CuSO}_4_{(s)} + 5\text{H}_2\text{O}_{(l)}$
 - When water is added to anhydrous copper(II) sulfate exactly the same amount of heat energy is released as absorbed in the forward reaction
 - The mixture gets hotter

6.2.3 Equilibrium

- Equilibrium
 - In a reversible reaction carried out in a closed system
 - Closed system = an apparatus that prevents the escape of reactants and products
 - The point where the forward and backward reactions happen at the same rate is the equilibrium
 - Concentration / amount of the reactants and products remain constant

6.2.4-7 The effect of changing conditions on equilibrium

- Effect of change in condition
 - The relative amount of reactants and products at equilibrium depends on the conditions of the reaction
 - Le Chatelier's principle
 - For a reaction in equilibrium:
 - If the condition of one of the reactants or products is changed
 - Then the system will no longer be at equilibrium
 - A reaction will happen that counteracts the change
- Effect of change in concentration
 - If the concentration of one of the reactants or products is increased
 - A reaction will happen that decreases the concentration (the reaction is favoured)
 - e.g. $A + B \rightleftharpoons C + D$
 - If the concentration of A increase, the rate of the forward reaction will increase
 - The forward reaction has been favoured
 - The equilibrium has moved to the right hand side
 - There will be more C + D in the mixture, equilibrium yield of products increase
- Effect of change in pressure
 - If the pressure of the reactants or products is increased
 - A reaction will happen that decreases the pressure by decreasing the number of gas

particles / number of moles of gas in the mixture

- * Only if gases are present
- * No change in equilibrium when there are no gases / same number of particles of both sides
- Temperature
 - If the temperature of one of the reactant or products is increased
 - A reaction will happen that decreases the temperature
 - The endothermic reaction is favoured
- Catalysts
 - Both forward and backward reaction speed up equally
 - The position of equilibrium and the equilibrium yield does not change
 - Equilibrium is achieved faster

7.1 Carbon compounds as fuels and feedstock

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7.1.1 Crude oil, hydrocarbons and alkanes

- Crude oil
 - A finite resource found underground in rocks
 - Made from the remains of ancient biomass
 - Ancient biomass = plants and animals that died a very long time ago
 - Mostly made from dead plankton that was covered by sediments
 - Subjective to high temperature and high pressure for millions of years
 - A mixture of lots of different compounds
 - Most of the compounds are hydrocarbons
 - Most of the hydrocarbons in crude oil are alkanes
- Alkanes
 - A homologous series of saturated hydrocarbons (no functional group)
 - General formula = C_nH_{2n+2}
 - Four smallest alkanes

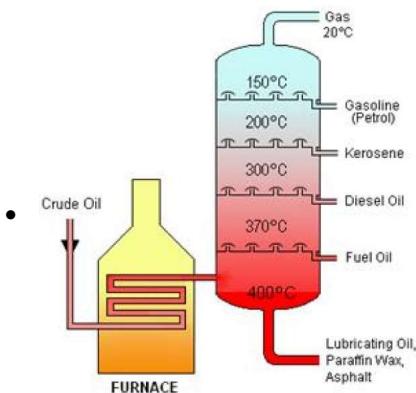
	Molecular formula	Displayed formula
Methane	CH_4	$\begin{array}{c} H \\ \\ H-C-H \\ \\ H \end{array}$
Ethane	C_2H_6	$\begin{array}{cc} H & H \\ & \\ H-C-C-H \\ & \\ H & H \end{array}$
Propane	C_3H_8	$\begin{array}{ccc} H & H & H \\ & & \\ H-C-C-C-H \\ & & \\ H & H & H \end{array}$
Butane	C_4H_{10}	$\begin{array}{cccc} H & H & H & H \\ & & & \\ H-C-C-C-C-H \\ & & & \\ H & H & H & H \end{array}$

- Hydrocarbon
 - Compounds or molecules made from carbon and hydrogen only
- Homologous series
 - Family of similar molecules with similar properties and similar chemical reactions
 - Same general formula
 - Same functional group
 - Differ from one another by CH_2
- Saturated / unsaturated
 - Saturated = all carbon to carbon bonds are single
 - Unsaturated = contains at least one carbon to carbon double bond ($C=C$)

7.1.2 Fractional distillation and petrochemicals

- Fractional distillation process
 - Uses the property that different hydrocarbons have different boiling points
 - Each fraction has a different temperature at which it condenses back into liquid
 - The crude oil is heated up at about $350^{\circ}C$
 - Heat until almost all hydrocarbons have turned into gases

- Vapour from the oil enter at the bottom of the fractionating column
- Vapour rise through the fractionating column
- The column is hot at the bottom and gets cooler towards the top
- The vapour cools down as it rises
- When some of a fraction cool to their boiling point they condense
- The condensed fraction separates from the vapour and flows out through a pipe
- Some of the hydrocarbons remain as vapour → rise out from the top of the fractionating column
- Higher boiling point = collected closer to the bottom
 - Bottom = bitumen, top = gas
- Hydrocarbons in crude oil is separated into fractions
 - A fraction = a mixture of hydrocarbons with a similar number of carbon atoms



- Uses of different fractions
 - Mostly used as fuels
 - Many of the fuels that we depend on for our modern lifestyle are produced from crude oil
 - e.g. petrol, diesel oil, kerosene, heavy fuel oil, liquefied petroleum gases
 - Petrol, diesel, liquefied petroleum gases = car fuel
 - Some fraction are used as feedstock to produce other chemicals for the petrochemical industry
 - e.g. Naphtha
 - Many useful materials on which modern life depends on are produced by the petrochemical industry from crude oil
 - Crude oil can make solvents, lubricants, polymers and detergents
 - The vast array of natural and synthetic carbon compounds occur due to the ability of carbon atoms to form families of similar compounds

7.1.3 Properties of hydrocarbons

- Properties and molecule size link

	Small hydrocarbons	Big hydrocarbons	Explanation
Boiling points	Low	High	<ul style="list-style-type: none"> • As hydrocarbons get bigger there are strong intermolecular forces • More heat energy is needed to overcome the strong intermolecular forces
Flammability	Catch fire easily	Hard to ignite	<ul style="list-style-type: none"> • Gases are easiest to set light to • Gas = smallest hydrocarbons → small hydrocarbon = very flammable
Viscosity	More runny	More viscous	<ul style="list-style-type: none"> • Viscosity depends on how easily the molecules can move around • Smaller molecules = weaker intermolecular forces = move around more easily
*Cleanliness	Clean	Smoky	<ul style="list-style-type: none"> • Less complete combustion for longer chains

- Combustion of hydrocarbon fuels
 - Hydrocarbon fuels release lots of energy when they burn (oxidation reaction)
 - Complete combustion of alkane equation
 - $\text{Alkane}_{(\text{g})} + \text{Oxygen}_{(\text{g})} \rightarrow \text{Carbon dioxide}_{(\text{g})} + \text{Water}_{(\text{l})}$
 - Carbon and hydrogen atoms in alkane are oxidised (gain oxygen)
 - $$\text{C}_x\text{H}_y + (\text{x} + \frac{y}{4})\text{O}_2 \rightarrow \text{xCO}_2 + \frac{y}{2}\text{H}_2\text{O}$$
- Incomplete combustion of alkane
 - Alkane + Oxygen \rightarrow Carbon monoxide + Water
 - Alkane + Oxygen \rightarrow Carbon + Water

7.1.4 Cracking and alkenes

- Cracking
 - Breaks down large hydrocarbons into smaller, more useful hydrocarbons
 - A mixture of alkanes and alkenes are produced
- Reasons for cracking
 - Crude oil usually contains lots of the very large hydrocarbon molecules
 - These large molecules are not very useful and there is a lot of them left unused
 - Not wasting them by cracking them into smaller, more useful hydrocarbons which have a high demand
 - Break down longer hydrocarbons into small alkanes and alkenes
 - Alkenes can be used to produce polymers and used as the starting material for the production of other chemicals
 - Not used as fuels because other uses are a lot more valuable
 - Alkane = used as fuel
- Types of cracking
 - Steam cracking = heating with steam
 - Catalytic cracking = heating with a catalyst
- Testing for alkene
 - Alkenes are more reactive than alkanes so they react with bromine water while alkanes don't
 - Alkenes decolourise bromine water but alkanes don't

7.2 Reactions of alkenes and alcohols

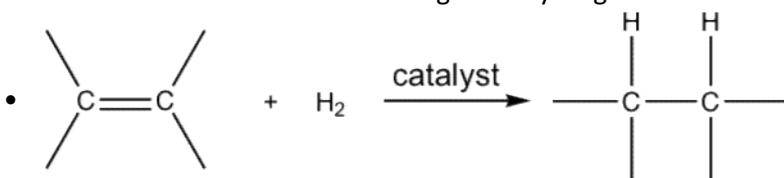
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7.2.1 Structure and formulae of alkenes

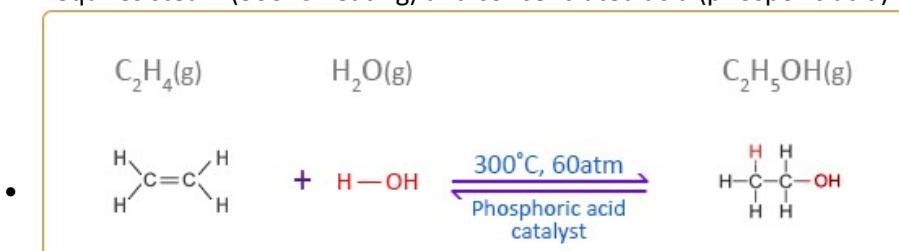
- Alkenes
 - Unsaturated hydrocarbon molecules that contain at least one carbon to carbon double bond
 - Unsaturated because they contain two fewer hydrogens than the alkane with the same number of carbon atoms
 - More reactive than alkanes
 - General formula = C_nH_{2n}

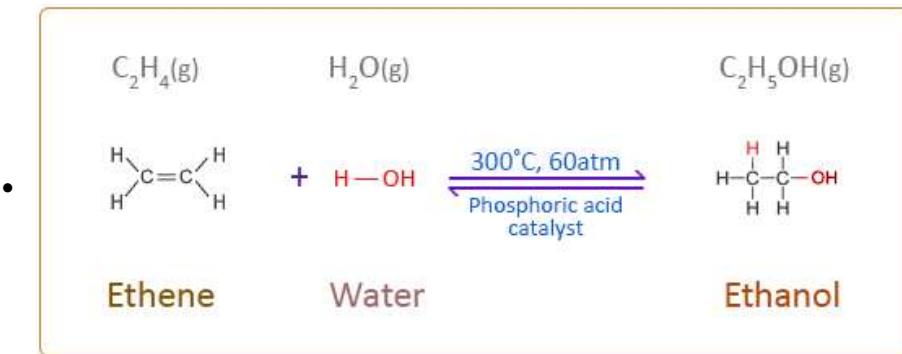
7.2.2 Reactions of alkenes

- Functional group
 - The part of the molecule that takes part in chemical reactions
 - It is the generality of reactions of functional groups that determine the reactions of organic compounds
 - Alkene functional group: $C=C$
 - When reacting with hydrogen / water / halogens the atoms are added to the $C=C$ bond so it is turned into a single bond
- First four in the homologous series
 - Ethene
 - Propene
 - Butene
 - Pentene
- Reaction with oxygen
 - Combustion reaction
 - Complete combustion
 - $Alkene_{(g)} + oxygen_{(g)} \rightarrow carbon\ dioxide_{(g)} + water_{(l)}$
 - Incomplete combustion
 - Alkane + Oxygen \rightarrow Carbon monoxide + Water
 - Alkenes tend to burn with smoky flames because they tend to undergo incomplete combustion
 - Carbon or carbon monoxide formed in incomplete combustion instead of CO_2
- Addition reaction
 - Two or more molecules combining to form just one product
- Reaction with hydrogen
 - React with hydrogen to form alkanes
 - Alkene + Hydrogen \rightarrow Alkane
 - Need nickel catalyst + $150^\circ C$ heat
 - Addition reaction
 - Reduction reaction as the alkene gained hydrogen

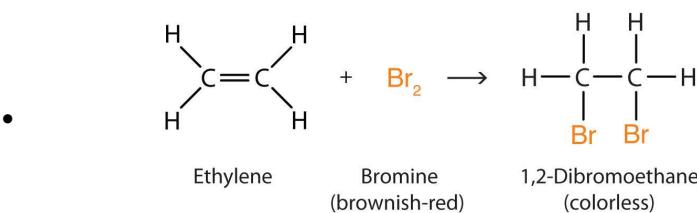


- Reaction with water
 - Alkene + water \rightarrow alcohol
 - Requires steam ($300^\circ C$ heating) and concentrated acid (phosphoric acid) is used as a catalyst





- Reaction with halogens
 - e.g. ethene + bromine \rightarrow dibromoethane
 - RTP (room temperature and pressure)
 - No catalyst needed



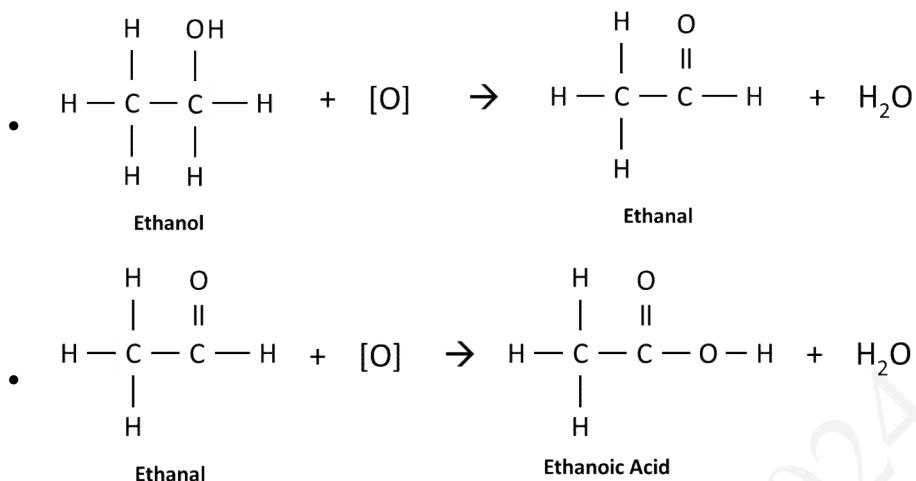
7.2.3 Alcohols

- Functional group of alcohols
 - OH
- First four in the homologous series

Methanol	CH_4O	CH_3OH
Ethanol	C_2H_6O	CH_3CH_2OH
Propanol	C_3H_8O	$CH_3CH_2CH_2OH$
Butanol	$C_4H_{10}O$	$CH_3CH_2CH_2CH_2OH$

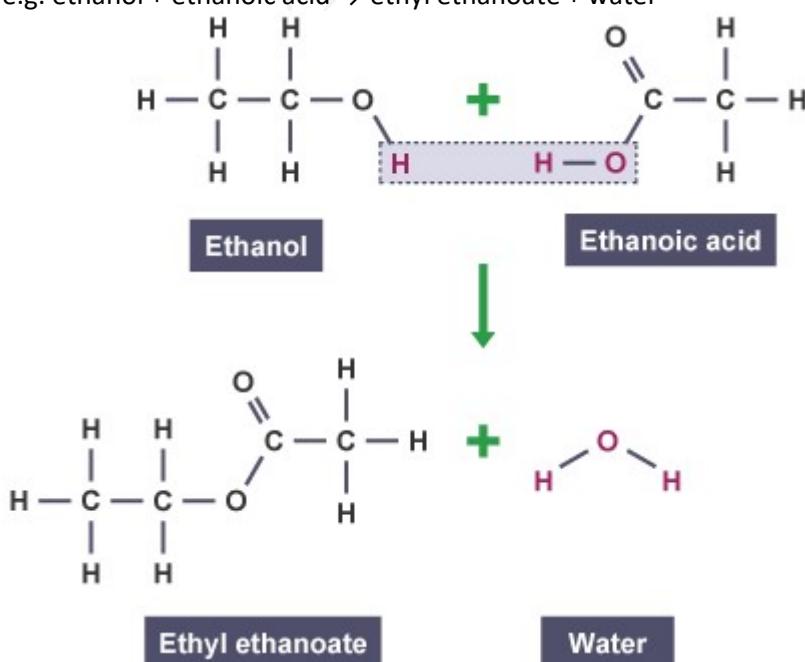
- General formula
 - $C_nH_{2n+2}O$
- Uses of alcohol
 - Methanol is used as a chemical feedstock
 - Ethanol in alcoholic drinks
 - Fuel
 - Alcohol release lots of energy when burning and is very flammable
 - Solvent (alcohols are very good solvents)
- Ethanol
 - Aqueous solution of ethanol are produced when sugar solutions are fermented using yeast
 - Yeasts carrying out anaerobic respiration to release energy from sugar and convert it into ethanol and CO_2
 - Fermentation conditions
 - Sugars dissolved in water, and mixed with yeast
 - Anaerobic: an air lock to allow carbon dioxide out, while stopping air getting in
 - Warm temperature, $25-35^\circ C$
- Reactions with sodium
 - Ethanol + sodium \rightarrow sodium ethoxide + hydrogen
 - Gentle fizzing because hydrogen gas is produced
 - Sodium will float on the surface as it is less dense than ethanol
 - Salt produced is sodium ethoxide which gives a pH of 14
- Reactions with air
 - $Alcohol(l) + oxygen(g) \rightarrow carbon\ dioxide(g) + water(l)$
 - Alcohol catch fire and burn readily because they are very flammable
 - Burn with a blue flame

- Reactions with water
 - Dissolve in water to form neutral solutions
- Reactions with an oxidising agent
 - Oxidised by a chemical oxidising agent to form carboxylic acids
 - Oxidising agent = acidified dichromate, H_2SO_4 / $\text{K}_2\text{Cr}_2\text{O}_7$
 - Changes colour from orange to green as the reaction happens
 - Water molecule given off
 - $\text{CH}_3\text{CH}_2\text{OH} + 2[\text{O}] \rightarrow \text{CH}_3\text{COOH} + \text{H}_2\text{O}$



4.7.2.4 Carboxylic acids

- Carboxylic acid
 - $-\text{COOH}$ functional group
 - Dissolve in water to form acidic solutions with pH 3-4
 - Weak acids because most of the acid molecules do not release their H^+ ions when dissolved in water / does not fully dissociate into H^+ ions
 - First four members = methanoic acid, ethanoic acid, propanoic acid, butanoic acid
- Making esters
 - Alcohol reacts with carboxylic acids to form esters
 - Catalyst = concentrated sulfuric acid
 - Esters = organic compounds which all contain the functional group $-\text{COO}-$
 - Esters have pleasant fruity smells and can be used as solvents
 - e.g. ethanol + ethanoic acid \rightarrow ethyl ethanoate + water



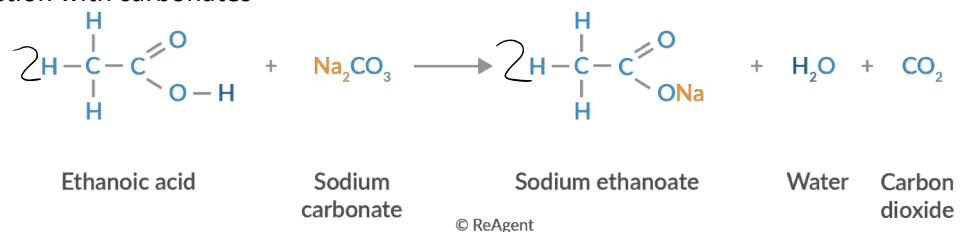
★ (Ethyl ethanoate name need to be remembered)

- Reaction with carbonates



★ (Ethyl ethanoate name need to be remembered)

- Reaction with carbonates

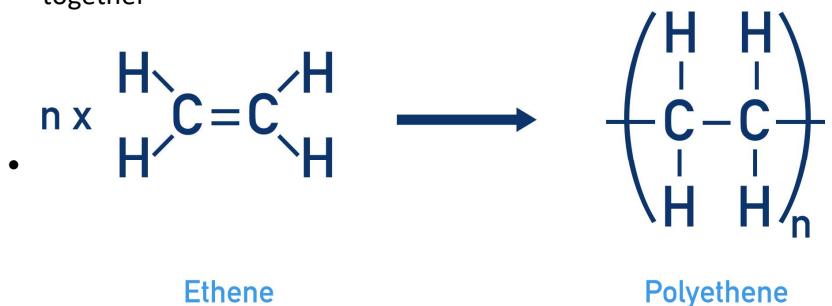


7.3 Synthetic and naturally occurring polymers

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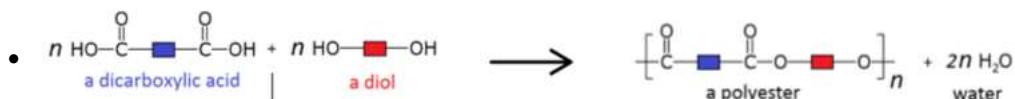
7.3.1 Addition polymerisation

- Addition polymerisation
 - Monomers (always alkenes) join together to form very large molecules
 - No other substance is formed
 - Double bond of the alkene is changed into a single bond and the alkene molecules link together



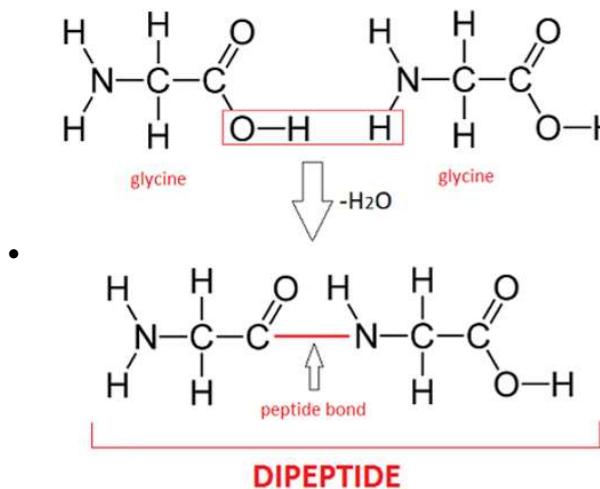
7.3.2 Condensation polymerisation

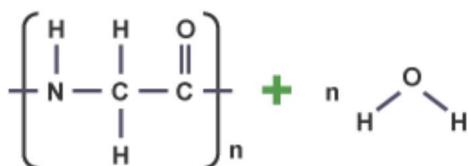
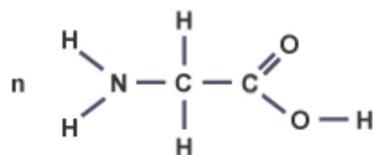
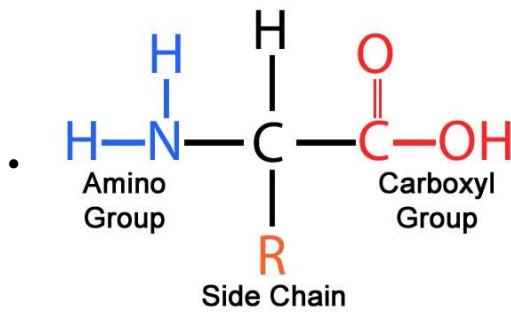
- Condensation polymers
 - Involves monomers with two functional groups
 - Small molecules (usually water) is given off when they join together → condensation reactions
- Polyesters formation
 - An alcohol and a carboxylic acid
 - Alcohol must be a diol
 - Carboxylic acid must be a dicarboxylic acid
 - Polymerise to join together and form a polyester with water molecules released



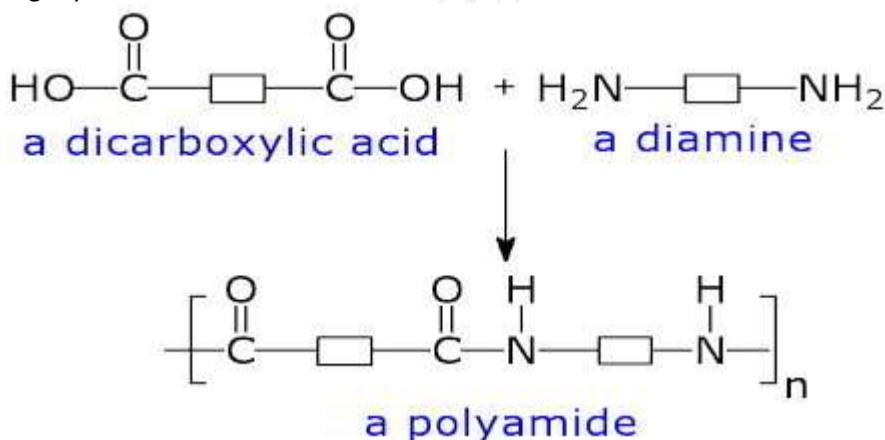
7.3.3 Amino acids

- Polyamides formation (amino acids)
 - Amino acids have two functional groups: a carboxylic acid and an amine
 - Link together to form proteins
 - -OH lost from carboxylic acid and -H lost from amine to join together → a water molecule is released so it is a condensation reaction
 - Polypeptides produced from condensation reaction
 - Join between two amino acids = an amide bond
 - * Different amino acids can be combined in the same chain to produce proteins





- Synthetic polyamides formation**
 - Formed when a carboxylic acid and an amide group link together
 - Dicarboxylic acid + diamine
 - Link together in a condensation polymerisation
 - e.g. nylon and Kevlar



7.3.4 DNA (deoxyribonucleic acid) and other naturally occurring polymers

- DNA**
 - Deoxyribonucleic acid
 - Very large molecule essential for life
 - Encodes all genetic instructions for the development and functioning of living organisms and viruses
 - Two polymer chains made from 4 different monomers called nucleotides
 - In the form of a double helix
 - Each monomer has a sugar phosphate backbone and a base attached to it
- Examples of naturally occurring polymers important for life**
 - DNA = nucleotides joining together
 - Proteins = amino acids joining together
 - Starch = glucose joining together

- Cellulose = glucose joining together

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8.1 Purity, formulations and chromatography

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8.1.1 Pure substances

- Pure substance in everyday language
 - One that has nothing added to it
 - Unadulterated and in its natural state
- Pure substance definition
 - A single element or compound, not mixed with any other substances
- Melting and boiling point of pure substances
 - Pure substances melt or boil at a specific temperature
 - Melting and boiling point data can be used to distinguish pure substances from mixtures
- Effect of impurity on melting and boiling points
 - Melting point decrease
 - They disrupt the forces between the molecules, making them easier to break
 - Less energy needed to break the intermolecular forces
 - Boiling point increase
 - The forces between the molecules of water and the molecules of the impurity must also be broken
 - More energy needed to break the intermolecular forces
 - Melting and boiling point happens over a temperature range rather than a specific temperature
 - More impurities = bigger change

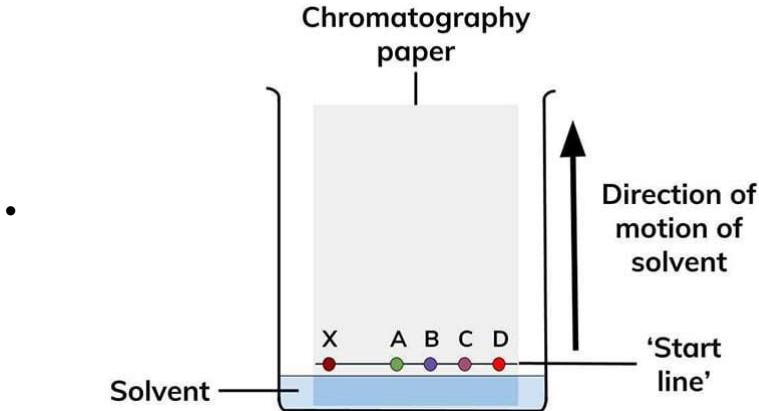
8.1.2 Formulations

- Formulation
 - A mixture that has been designed to be a useful product
 - There is a complex mixture of many chemicals and each chemical in the mixture has a specific purpose
 - Made by mixing the chemical components in carefully measured quantities which ensures that the final product has the required properties
- Examples
 - Fuels
 - Cleaning agents
 - Paints
 - Medicines
 - Alloys
 - Fertilisers
 - Foods

4.8.1.3 Chromatography

- Chromatography purpose
 - Used to separate mixtures into its components (the separated substances)
 - Can help to identify the compounds in a mixture
- Paper chromatography process
 - Often used to separate the colours in ink or food colouring
 - Paper = stationary phase
 - Draw pencil start line on paper
 - Place a spot of the mixture being separated on the start line
 - The paper is placed in a beaker containing a liquid that will separate the different substances in the ink
 - Liquid in the beaker = mobile phase, usually water
 - The bottom of the paper is in the solvent but the spot of mixture + start line is above the liquid
 - Use a lid to cover the beaker

- Wait for solvent to travel up the paper and separate the components in the mixture
- The final level that the liquid rises to = solvent front, marked on the paper in pencil
- Dry the chromatography paper
- Spots on the paper can be identified by their R_f values (retention factor)
 - $R_f = \frac{\text{Distance moved by substance}}{\text{Distance moved by solvent}}$
 - The same substance will always have the same R_f value, but two different substances can also have the same R_f value
- Different solvent (different mobile phase) = different R_f value + different number of components detected
- * Pure compounds will produce a single spot in all solvents



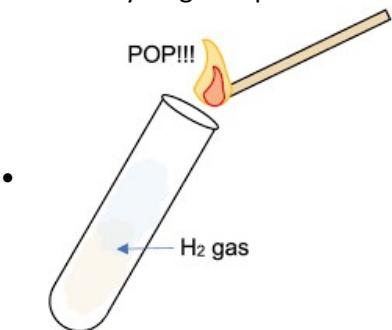
- Why chromatography works
 - The colours in the ink stick to the paper and dissolve in the solvent
 - Each colour has a different affinity for the stationary and mobile phase
 - If a colour likes to stick to the paper more than it likes to dissolve in the water it will mostly stick to the paper and won't travel very far up the paper
 - If a colour likes dissolving in the water more → mostly move with the water and travel a long way up the paper
 - Separation depends on the distribution of substances between the mobile and stationary phases
 - Different solvent (different mobile phase) = different R_f value + different number of components detected

8.2 Identification of common gases

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8.2.1 Test for hydrogen

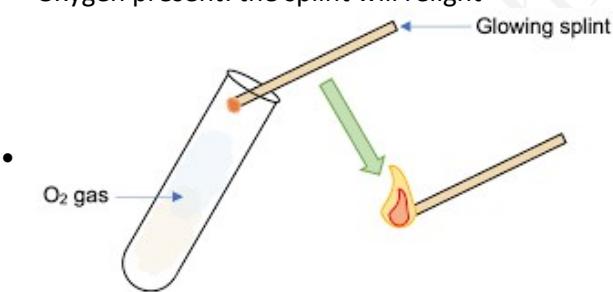
- Hydrogen test
 - Hold a lit splint in the gas
 - Hydrogen present: the gas will explode with a squeaky pop sound or burn depending on how much hydrogen is present



- Precautions
 - If in a test tube hold the lit splint just outside the top of the tube so hydrogen can mix with oxygen to make the test work ($2\text{H}_{2(g)} + \text{O}_{2(g)} \rightarrow 2\text{H}_2\text{O}_{(l)}$)
 - Tube should face upwards as hydrogen is lighter than air so it is easier to escape and mix with air

8.2.2 Test for oxygen

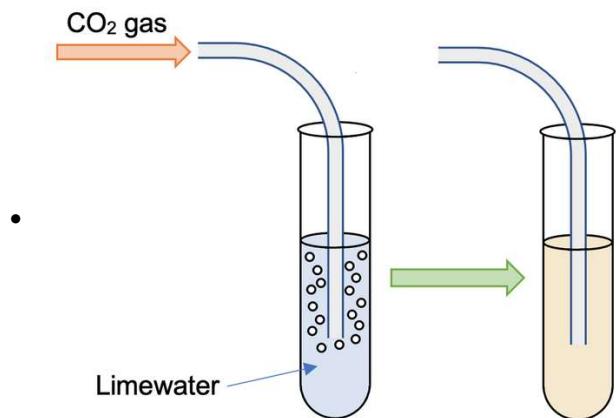
- Oxygen test
 - Hold a glowing splint in the gas
 - Oxygen present: the splint will relight



- Precautions
 - Best to put the splint slightly inside the test tube
 - Splint may just glow more brightly rather than relighting if only little oxygen is present

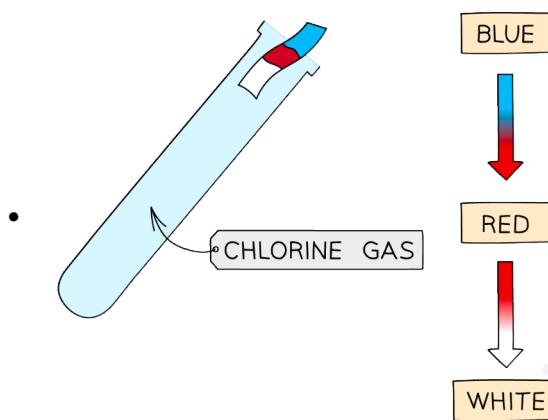
8.2.3 Test for carbon dioxide

- Carbon dioxide test
 - Bubble the gas through limewater (aqueous solution of calcium hydroxide)
 - CO₂ present: the limewater turns milky / cloudy



8.2.4 Test for chlorine

- Chlorine test
 - Place damp, blue litmus paper in the gas
 - Chlorine present: the litmus paper is bleached and turns white



8.3 Identification of ions

2024年2月6日 17:10

8.3.1 Flame tests

- Process
 - Used to identify the positive metal cation
 - Dip a nichrome wire loop into concentrated hydrochloric acid
 - Then dip the wire into the solid
 - Hold the solid, on the wire, in the hottest part of a hot, blue Bunsen flame
 - Observe the colour of the flame
 - Colour seen is caused by the positive metal ions (not metal atom)
 - If a mixture of positive ions is present some colours may be hidden
- Colour

Ion	Colour
Lithium ion / Li^+	Crimson
Sodium ion / Na^+	Yellow
Potassium ion / K^+	Lilac
Calcium ions / Ca^{2+}	Orange-red
Copper ions / Cu^{2+}	Green
Magnesium ions / Mg^{2+}	No colour
Transition metal	Sparkling

- Problem
 - Can be difficult to distinguish the colour of a flame test, especially if there is only a low concentration of the metal compound
 - Sometimes a sample contains a mixture of metal ions which can mask the colour of the flame

8.3.2 Sodium hydroxide solution

- Process
 - Identify positive metal cations in an ionic compound
 - Must be carried out in a solution
 - Solid: mixing a little bit of the solid with about 2 cm^3 of distilled water in a test tube
 - Put about 2 cm^3 of the test solution in a test tube
 - Add a few drops of sodium hydroxide solution
 - Observe the colour of the precipitate
 - There is precipitate: add excess NaOH solution and observe whether or not the precipitate re-dissolves
- Result

Precipitation	Solubility in excess NaOH	Metal
No precipitation	/	Na^+ , K^+ , Li^+ , NH_4^+
Blue precipitation	Insoluble	Cu^{2+}
Green precipitation	Insoluble	Fe^{2+}
Brown precipitation	Insoluble	Fe^{3+}
White	Soluble	Al^{3+}
White	Insoluble	Ca^{2+} , Mg^{2+} Flame test needed to determine the metal ion (Ca^{2+} = orange-red, Mg^{2+} = no colour)

8.3.3 Carbonate test

- Process
 - Can be done on either solid or solution
 - Put a small amount of the substances to be tested in a test tube
 - Add some dilute acid
 - If it fizzes there is a carbonate (CO_3^{2-})
 - CO_2 gas is given off
 - Can be further tested by bubbling it through limewater and see if it goes cloudy

8.3.4 Halide test

- Process
 - Must be carried out on a solution
 - Put about 2 cm^3 of the solution in a test tube
 - Add a few drops of nitric acid
 - If it fizzes and more acid until fizzing stops to use up any carbonate ion leftover
 - Add a few drops of silver nitrate solution
 - If there is a precipitate there are halide ions present
 - White = Cl^- / chloride ions
 - Cream = Br^- / bromide ions
 - Yellow = I^- / iodide ions

8.3.5 Sulfate test

- Process
 - Must be carried out on a solution
 - Put about 2 cm^3 of the solution in a test tube
 - Add a few drops of hydrochloric acid
 - If it fizzes and more acid until fizzing stops to use up any carbonate ion leftover
 - Add a few drops of barium chloride solution
 - If there is a white precipitate there are sulfate ions present
- Doing anion tests together
 - Carbonate \rightarrow sulfate \rightarrow halide

8.3.6 Instrumental methods

- Types of instrumental methods
 - Mass spectrometry
 - Gas chromatography
 - High performance liquid chromatography (HPLC)
 - Nuclear magnetic resonance (NMR) spectroscopy
 - Atomic absorption (AA) spectroscopy
 - Atomic emission spectroscopy
- Instrumental method advantages
 - Accurate
 - Sensitive so very small samples needed
 - Rapid
- Instrumental method disadvantages
 - Expensive to set up
 - Expensive to maintain
 - Require access to technology (harder to carry out)

8.3.7 Flame emission spectroscopy

- Process
 - Analyse metal ions in solutions
 - The sample is placed in a flame
 - Heat from the flame causes the metal ions in the sample to give out light
 - The light is passed through a spectroscope that can detect the wavelength of the individual light given out to analyse it
 - The spectroscope produces a line spectrum

- The lines on the spectrum can be used to identify the metal ions in the solution as every different metal ion produces a different pattern of wavelengths and so have a unique line spectrum
- The intensity of the lines can be used to measure the concentration of the metal ions in the solution (more intense = higher concentration)
- Advantage
 - If a sample contains multiple different metal ions the spectrum will show the lines for all ions
- Uses
 - Identify metal ions in a solution
 - Detect and solve crimes (especially forgery and murder by poisoning)
 - Used on spacecraft sent to other planets to analyse their atmosphere and surface materials, operated remotely using computerised robots

9.1 The composition and evolution of the Earth's atmosphere

2024年2月6日 17:25

9.1.1 Current atmosphere

- Proportion of gases
 - Two main gases: nitrogen approx. 80%, oxygen approx. 20%
 - Small proportion of other gases, e.g. carbon dioxide, water vapour, noble gases
 - Current composition has been the same for 200 million years

9.1.2-4 Concentration changes

- Early atmosphere
 - Very limited evidence due to the time scale of 4.6 billion years
 - During the first billion years of the Earth's existence there was intense volcanic activity that released the gases that formed the early atmosphere
 - The early atmosphere mainly consisted of carbon dioxide and water vapour
 - Little or no oxygen
 - Small amounts of nitrogen due to volcanic activity
 - May also have been small amounts of methane and ammonia
 - The water vapour condensed to form the oceans as the Earth cooled
 - Thought to be similar to the atmospheres on Venus and Mars today
- Carbon dioxide
 - Dissolved in water and converted to carbonate when oceans formed
 - Produce soluble (calcium) hydrogen carbonate and insoluble (calcium) carbonate
 - Carbonates were precipitated from the water and produce the sediments that form sedimentary rocks
 - Algae and plants decreased the amount of carbon dioxide in the atmosphere by photosynthesis
 - Further carbon dioxide was locked away in the bodies of dead plants and animals when fossil fuels were formed
 - CO₂ amount in the atmosphere falls
- Nitrogen
 - Appeared in the atmosphere due to volcanic activity
 - Only small amounts initially but over time the amount of nitrogen in the atmosphere gradually increases
 - There may have also been small amounts of methane and ammonia
- Oxygen
 - Living organisms started to appear once liquid water was present: first plant and later animals
 - Algae and plants used the carbon dioxide in the atmosphere for photosynthesis
 - Photosynthesis produced oxygen as a waste product
 - $6\text{CO}_{2(\text{g})} + 6\text{H}_{2\text{O}(\text{l})} \xrightarrow{\text{light}} \text{C}_6\text{H}_{12}\text{O}_{6(\text{s})} + 6\text{O}_{2(\text{g})}$
 - First produced oxygen about 2.7 billion years ago and oxygen started to appear in the atmosphere soon after this
 - Over the next billion years plants evolved and oxygen levels increased
 - Eventually the percentage of oxygen increased to a level that enable animals to evolve
- Formation of coal
 - Before the dinosaurs many giant plants died in swamps
 - Over millions of years the plants were buried under water and dirt
 - Heat and pressure turned the dead plants into coal
- Oil and natural gas formation
 - Tiny sea plants and animals died and were buried in the ocean floor
 - Over time they were covered by layers of silt and sand
 - Over millions of years the remains were buried deeper and deeper
 - The enormous heat and pressure turned them into oil and gas
 - Today, we drill down through layers of sand, silt, and rock to reach the rock formation that contain oil and gas deposit

9.2 Greenhouse gases

2024年2月27日

19:09

9.2.1 Greenhouse gases

- Greenhouse effect
 - Greenhouse gases in the atmosphere maintain temperature on Earth high enough to support life
 - Natural + essential for life
 - The energy that reaches the Earth from the Sun is short wavelength solar radiation (visible light)
 - Greenhouse gases allow them to pass through the atmosphere
 - The short wavelength solar radiation is absorbed by the Earth and warms the surface
 - The energy is then re-emitted from the surface of the Earth as long wavelength infra-red radiation
 - Some of this long wavelength infra-red radiation is reflected back to the surface by greenhouse gases in air → extra warming
- Types of greenhouse gases
 - Carbon dioxide
 - Methane
 - Water vapour

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

- Global warming
 - Human activities cause CO₂ and methane level to increase in the atmosphere
 - Causes an additional warming effect
 - Activities that increase CO₂ level
 - Burning fossil fuels
 - Cutting down (and burning) rainforests
 - Activities that increase methane level
 - Growing rice paddies
 - Keeping animals such as cows for meat and milk
- Scientists' belief
 - Human activity is causing the temperature of the Earth's to increase at the surface → global climate change
 - Based on peer-reviewed evidence
- Simplified models
 - Sometimes used as climate change is complex and difficult to model
 - Problems:
 - Simple models are inaccurate
 - Predictions are difficult to produce
 - Different predictions are possible
 - Different people have different opinions about the different predictions (uncertainty)
 - Resulted in speculation and opinions in the media
 - Based on only some of the evidence or biased data / evidence

9.2.3 Global climate change

- Generally accepted ideas
 - Human activity has caused increases in atmospheric levels of greenhouse gases e.g. CO₂ / methane
 - The average global temperature is increasing which is a major cause of climate change
- Possible effects of global climate change
 - Higher average temperatures
 - Changes on rainfall patterns: more frequent / severe storms, more droughts
 - Ice caps melting, sea levels rising and flooding of low lying land

- Habitats changing

9.2.4 The carbon footprint and its reduction

- Carbon footprints
 - The total amount of carbon dioxide and other greenhouse gases emitted over the full life cycle of a product, service or event
- Ways of reducing carbon footprint
 - Reducing the emissions of CO₂ and methane
 - Insulate the walls and roof so less fuel is burned for heating
 - Turn down the temperature of the thermostat
 - Fit a more energy efficient boiler
 - Install solar panels for electricity
 - Draught-proof the external doors and windows
 - Fit double (or triple) glazing
 - LED lighting

9.3 Common atmospheric pollutants and their sources

2024年2月27日

19:09

9.3.1 Atmospheric pollution from fuels

- Combustion of fuels
 - Major source of atmospheric pollutants
 - e.g. Carbon monoxide, sulfur dioxide, oxides of nitrogen
- Carbon monoxide and soot
 - Burning coal
 - Carbon is oxidised when coal is burned
 - Complete combustion: carbon + oxygen \rightarrow carbon dioxide
 - Incomplete combustion: carbon + oxygen \rightarrow carbon monoxide / carbon (soot)
 - Hydrocarbon fuels
 - Carbon and hydrogen oxidised
 - Hydrogen + oxygen \rightarrow water (not a pollutant)
 - Complete combustion: carbon + oxygen \rightarrow carbon dioxide
 - Incomplete combustion: carbon + oxygen \rightarrow carbon monoxide / carbon (soot)
- Sulfur dioxide
 - Produced in most fuels due to sulfur impurities in fuel
 - Sulfur + oxygen \rightarrow sulfur dioxide
- Oxides of nitrogen
 - Produced when petrol and diesel are burned in car engines
 - High temperature and pressure in car engine so nitrogen and oxygen from the air react
 - Nitrogen + oxygen \rightarrow oxides of nitrogen
 - $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$
 - $\text{N}_2(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$
- Pollutant released for different fuels

Fuel	Pollutants
Coal	<ul style="list-style-type: none">• Carbon dioxide• Carbon monoxide• Carbon particles / soot• Sulfur dioxide
Petrol	<ul style="list-style-type: none">• Carbon dioxide• Carbon monoxide• Carbon particles / soot• Sulfur dioxide• Oxides of nitrogen• Unburned hydrocarbons
Diesel	<ul style="list-style-type: none">• Carbon dioxide• Carbon monoxide• Carbon particles / soot• Sulfur dioxide• Oxides of nitrogen• Unburned hydrocarbons
Natural gas	<ul style="list-style-type: none">• Carbon dioxide• Carbon monoxide• Carbon particles / soot• Sulfur dioxide• Unburned hydrocarbons

9.3.2 Properties and effects of atmospheric pollutants

- Carbon dioxide

- Greenhouse gas → global warming
- Carbon monoxide
 - Toxic
 - Colourless and odourless so not easily detected
- Sulfur dioxide / oxides of nitrogen
 - Respiratory problem in humans
 - Acid rain
- Carbon particles / soot (particulates)
 - Global dimming
 - Health problems

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10.1 Using the Earth's resources and obtaining potable water

2024年3月8日 9:20

10.1.1 Using the Earth's resources and sustainable development

- What is Earth's resources used to provide
 - Warmth
 - Shelter
 - Food
 - Transport
- What natural resources + agriculture provide
 - Food (farming)
 - Timber (forestry)
 - Clothing (growing cotton, farming sheep for wool)
 - Fuels
- Finite resources
 - Once they have been used up they will not be replaced in the foreseeable future
 - From the Earth, oceans and atmosphere
 - Processed to provide energy and materials
- Renewable resources
 - Are constantly being replenished or replaced
- Use of chemistry
 - Important for improving agriculture and industrial processes to provide new products
 - Important in 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

- Drinking water criteria
 - Should have low levels of dissolved salts and microbes
- Potable water
 - Water that is safe to drink
 - Not pure water as it contains dissolved substances
- Method to produce potable water
 - Depend on available water supplies and the local conditions
 - Rain water provides water with low levels of dissolved substances in the UK
 - Water collected in ground water, lakes and rivers
 - An appropriate source of fresh water is chosen
 - Undissolved solid particles removed by adding a coagulant + filtering water
 - Sterilising water to kill harmful microbes by adding chlorine / ozone / UV light
 - In other countries desalination of salty / sea water may be used
 - Distillation / reverse osmosis using membranes
 - Require large amounts of energy

10.1.3 Waste water treatment

- Sewage treatment plant parts
 - Screening and grit removal
 - Sedimentation to produce sewage sludge and effluent
 - Anaerobic digestion of sewage sludge
 - Aerobic treatment of effluent

10.1.4 Alternative methods of extracting water

- Uses of copper ores
 - Water pipes (can be replaced by plastic)

- Electrical wiring (can't replace)
- Coins (can be replaced by paper / plastic money)
- Problem of using copper
 - Copper becomes more scarce and expensive
 - Low-grade ores (containing less copper) become worth mining
- Mine advantages disadvantages

Benefits of a mine	Environmental problems
<ul style="list-style-type: none"> • Job opportunities • Boosts the local economy • 	<ul style="list-style-type: none"> • Destruction of habitats • Noise • Extra traffic on the roads • Dust • Light at night • Unsightly

- New ways of extracting copper ores
 - Phytomining
 - Plants grown in soil with low-grade ore
 - Plants absorb metal ions through their roots and concentrate these ions in their cells
 - Plants harvested and burned
 - Ash left behind contains metal compounds
 - Metal can be extracted from ash
 - Bioleaching
 - Certain bacteria can break down low-grade ores to produce an acidic solution containing metal compounds
 - Solution = leachate
- Evaluation

	Advantages	Disadvantages
Phytomining	<ul style="list-style-type: none"> • Reduce the need to obtain new ore by mining • Conserves limited supplies of high-grade ores • Reduces the amount of rock waste that must be disposed of after traditional mining • Reduces damage to environment <ul style="list-style-type: none"> • Mining creates noise, dust and traffic • Destroy natural habitats 	<ul style="list-style-type: none"> • Slow
Bioleaching	<ul style="list-style-type: none"> • Do not need high temperatures so less energy is needed 	<ul style="list-style-type: none"> • Produces toxic substances, including sulfuric acid, which damage the environment

- Processing metal compounds
 - Displacement
 - Iron is more reactive than copper → it can displace copper from the leachate
 - Iron is cheaper than copper so scrap iron can be used to obtain copper from the leachate
 - Dissolve copper compound and electrolyse the solution

10.2 Life cycle assessments and recycling

2024年3月8日 9:20

10.2.1 Life cycle assessment

- Life Cycle Assessments (LCAs)
 - Carried out to assess the environmental impact of products
 - Main stages accessed
 - extracting and processing raw materials
 - manufacturing and packaging
 - use and operation during its lifetime
 - disposal at the end of its useful life, including transport and distribution at each stage.
 - What is accessed at each stage
 - Use of raw materials (including water)
 - Use of energy
 - Release of waste substances into the environment
- Extracting and processing raw materials
 - Plastic from crude oil
 - Extracted from the ground + transported to oil refineries
 - Hydrocarbons separated and cracked
 - Polymer can then be produced
 - Takes large amount of energy, burning fossil fuel causes climate change
 - Extracting metal
 - Ore dug out of the mine and transported for processing
 - Metal extracted from the ore and this can produce large amounts of toxic waste products
 - Using up limited resources, such as ores and crude oil
 - Damaging habitats due to mining
- Manufacturing and packaging
 - Require energy
 - Using up land for factories
 - Production of polluting waste (emitted into rivers or the atmosphere)
- Use and operation during lifetime
 - The transport of both the final products and the raw materials used to make them requires energy
 - The amount of pollutants released into the atmosphere varies according to the type of transport used and the length of the journeys that have to be made
 - The impact of a product on the environment during its use depends on the type of product
 - e.g. a wooden chair has very little impact unless it needs cleaning or repair, a car will have a significant impact.
- Disposal
 - Toxic chemicals in waste products might be released
 - Using up land for landfill sites
 - Release of waste gases during incineration
 - Use of energy and production of waste substances if the product is recycled
 - Reduction in impact if the product is reused
 - Energy needed to transport the waste products
- Plastic vs. paper bag

	Plastic bag	Tree
Raw materials	<ul style="list-style-type: none">• Crude oil - finite• Oil extracted underground - may harm habitats	<ul style="list-style-type: none">• Wood - renewable• Cutting down trees - damage habitats
Manufacturing and packaging	<ul style="list-style-type: none">• Hydrocarbon from fractional distillation• Cracked to make alkenes	<ul style="list-style-type: none">• Wood processed• Lots of energy used

	<ul style="list-style-type: none"> • Lots of energy used, burning fossil fuel cause global warming • Lots of waste product 	<ul style="list-style-type: none"> • Lots of waste • Huge amount of water required for making paper
Using the product	<ul style="list-style-type: none"> • Strong - can be reused multiple times 	<ul style="list-style-type: none"> • Not very strong - single use
Disposal + transport	<ul style="list-style-type: none"> • Transported to recycling or landfills • Non-biodegradable <ul style="list-style-type: none"> • Take up space in landfill • Get into the wild and harm animals 	<ul style="list-style-type: none"> • Transported to recycling or landfills • Heavier, need more energy to transport • Biodegradable

- Problems
 - The use of water and waste product produced can be measured but we cannot be certain how damaging they are to the environment
 - Estimates or value judgments needed - inaccuracy
 - Can be biased to support claims by advertisers

10.2.2 Ways of reducing the use of resources

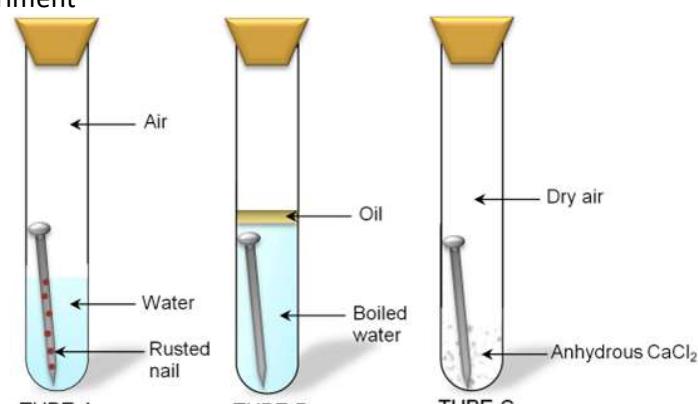
- What to consider when evaluating whether it is viable to recycle materials
 - Balancing the use of the raw materials, such as finite resources like crude oil or metal ores, with the need to conserve their supply
 - Availability of the material to be recycled
 - Economical and practical issues with collecting the material
 - Removal of impurities
 - Energy use for transport and processing
 - Environmental impact of the processes
 - Level of demand for the recycled material
- Problems of extracting new materials
 - Quarries and mines
 - Produce large amounts of dust and damage natural habitats
 - Harmful chemicals may be released into the environment
 - Lots of energy (from finite sources e.g. fossil fuels) needed to turn metal ores into useful products
 - Metal ores are running out
 - Waste produced
 - Recycling / reusing is needed to reduce our need for raw materials + produce less waste
- Disadvantages of recycling
 - The collection and transport of used items needs organisation, workers, vehicles and fuel
 - It can be difficult to sort different metals from one another
 - The sorted metal may need to be transported to where it can be turned into ingots
- Reusing glass bottles
 - Glass bottles can be crushed and melted to make different glass products
- Recycling metals
 - Collecting used items and transporting the used items to a recycling centre
 - Breaking up the items and sorting the different metals
 - Melting the metal and removing impurities from the molten metal
 - Solidifying the metal in ingots (slabs of metal)
 - The ingots can then be recast/reformed into new metal items
- Disposing polymers
 - Polymers are unreactive which makes difficult to be disposed of
 - Most polymers are not biodegradable (biodegradable = can be broken down or decomposed by microorganisms)
 - Landfill sites
 - Cause a litter problem if disposed of carelessly
 - Last for many years in landfill sites, waste space in landfill sites
 - Difficult to find suitable location landfill sites
 - Incineration
 - Involves combustion at very high temperatures

- Incineration releases a lot of energy which can be used to heat homes or to generate electricity
- Waste gases are produced
 - Carbon dioxide: a greenhouse gas which contributes to global warming
 - Toxic gases: need removing before they leave the chimney
- Waste valuable resources: crude oil needed for making polymers, a finite resource
- Recycling PET plastics
 - Reduces the problem of disposal
 - First separate items at a recycling centre
 - Open-loop recycling
 - The flaked PET is not totally pure, so the quality of the recycled material is less than the original polymer
 - Once the recycled material has been used it cannot be recycled again
 - It is likely to end up in landfill sites
 - Closed-loop recycling
 - The quality of the recycled material is as high as the original material, so it may be recycled again
 - This reduces the use of raw material (crude oil) and landfill even more than open-loop recycling

10.3 Using materials

2024年3月8日 9:20

10.3.1 Corrosion and its prevention

- Corrosion
 - The destruction of materials by chemical reactions with substances in the environment
 - Heat can speed up corrosion reactions
 - Only the surface corrodes
- Rusting
 - Corrosion of iron
 - Both air(oxygen) and water are necessary for iron to rust
 - Iron + oxygen + water → hydrated iron (III) oxide
 - Redox
 - $\text{Fe} \rightarrow \text{Fe}^{3+} + 3\text{e}^-$
 - $\text{O}_2 + 4\text{e}^- \rightarrow 2\text{O}^{2-}$
- Experiment
 - 
 - A: rusts as there is both water and oxygen
 - B: layer of oil stops new oxygen from the air dissolving into water
 - C: CaCl_2 remove any water vapour from the air
- Barrier methods
 - Painting the metal
 - Applying a layer of grease or oil
 - Electroplating the metal: using electrolysis to cover the iron in a thin layer of another metal
 - Protect the metal by creating a barrier between the metal and the corrosive substances in the environment
 - Prevent the metal from contacting with air and water
 - If the barrier is broken or damaged the metal will corrode
- Sacrificial methods
 - The metal to be protected is attached to a more reactive metal
 - The more reactive metal corrodes instead of the iron or steel (sacrificed)
- Galvanising
 - Coating the object in a layer of zinc
 - Zinc react with any oxygen as it is more reactive
- Naturally corrosion resistant
 - Aluminium has an oxide coating that protects the metal from further corrosion
 - The oxide layer on the surface of the metal sticks strongly to the metal underneath
 - Zinc and chromium also have protective oxides
 - When iron rusts, rust does not stick to the iron metal underneath → does not protect the metal underneath

10.3.2 Alloys as useful materials

- Alloy
 - A mixture of different metals

- Generally harder than pure metals because the different sized atoms in the mixture
 - Distort the layers and
 - Prevent the layers of metal atoms from sliding past one another
- Alloy examples
 - Steel
 - Alloys of iron
 - Other metals + specific amounts of carbon
 - High carbon steel: strong but brittle
 - Low carbon steel: softer but more easily shaped
 - Stainless steel: contains chromium and nickel, hard and resistant to corrosion
 - Bronze = copper + tin
 - Brass = copper + zinc
 - Aluminium alloys are low density
- Gold alloys
 - Gold used in jewellery is normally an alloy with silver, copper and zinc to make it harder + get different colours of gold
 - Proportion of gold in the alloy is measured in carats
 - Pure gold = 24 carat, 18 carat = 75% gold

10.3.3 Ceramics, polymers and composites

- Soda-lime glass
 - Made by heating a mixture of sand, sodium carbonate and limestone
 - Used to make bottles, jars and other glass items that can be recycled
- Borosilicate glass (Pyrex glass)
 - Made from sand and boron trioxide
 - Melts at a higher temperature than soda-lime glass
- Clay ceramics
 - Including pottery and bricks
 - Made by shaping wet clay and then heating it in a furnace
- Main forms of poly(ethene)
 - LDPE - low-density poly(ethene)
 - Conditions: Moderate temperatures, high pressure, catalyst
 - Properties: more stretchy, weaker, lower melting point because the chains pack less closely than HDPEs
 - Uses: Carrier bags
 - HDPE - high-density poly(ethene)
 - Conditions: Low temperature/pressure, catalyst
 - Properties
 - Stronger and has a higher melting point because the polymer chains can pack more closely together
 - Higher density because more atom / molecule per unit volume
 - Uses: Drainpipes
- Types of polymers
 - Thermosoftening polymers
 - Made from lots of polymer chains held together by weak intermolecular forces
 - Melt and turn into a liquid when heated
 - Thermosetting polymers
 - Made from lots of polymer chains held together by cross links (strong covalent bonds)
 - Do not melt, go black (char) and burn when heated
- LDPE HDPE comparison

Comparison LDPE versus HDPE		
	LDPE	HDPE
Advantages	<ul style="list-style-type: none"> • High elasticity/flexibility • Softer material • Lightweight = more energy efficient • Clear plastic 	<ul style="list-style-type: none"> • Rigid and firm • More puncture-resistant • Resistant to weather conditions/higher UV-resistant • Thicker material
Disadvantages	<ul style="list-style-type: none"> • Can be flimsy and thin • Less strength than HDPE • No UV properties 	<ul style="list-style-type: none"> • Less flexible material • Thicker material requires more energy to produce • Plastic film is not clear
Applications	“Lighter” jobs that require more elasticity but limited strength	“Heavier” jobs that require extra strength, but less flexibility

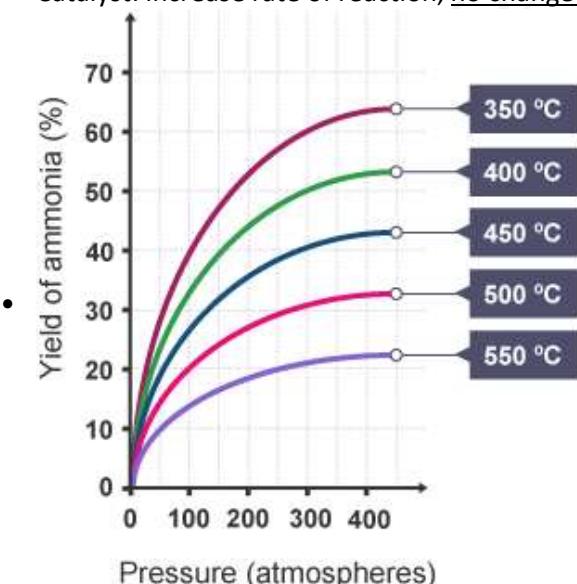
- Composites
 - Most composites are a mixture of two materials:
 - A matrix (a binder)
 - Fragments or fibres (the reinforcement)
 - The matrix surrounds the fibres or fragments and binds them together
 - Without the fibres or fragments, the binder or matrix would be much weaker
 - Without the matrix or binder, the fragments would not stay together or would form a solid that was too inflexible

10.4 The Haber process and the use of NPK fertilisers

2024年3月8日 9:20

10.4.1 The Haber process

- Haber process
 - Used to make ammonia
 - $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
 - Reversible reaction so some of the ammonia produced breaks down into nitrogen and hydrogen
 - Condition: iron catalyst, high temperature 450 °C, high pressure 200 atmospheres
 - Raw material = hydrogen + nitrogen
 - Nitrogen extracted from air
 - Hydrogen from reacting methane and steam / natural gas
 - Ammonia removed by cooling ammonia and turning it into liquid, remaining hydrogen and nitrogen recycled
- Use of ammonia
 - Produce nitrogen-based fertilisers
- Conditions to increase the yield
 - Le Chatelier's principle: if a system is at equilibrium and a there is a change in conditions then the system responds to counteract the change
 - Cooling: forward reaction is exothermic, so lower temperature favours the forward reaction and shift the equilibrium to the RHS
 - Higher temperature = higher rate but lower yield, cool temperature increase yield but makes reaction slower → 450 °C as a compromise temperature
 - High pressure: forward reaction reduces pressure and is favoured → push equilibrium to the RHS
 - Higher pressure = more energy needed, more expensive and dangerous so a compromise pressure of 200 atmospheres is used
 - Catalyst: increase rate of reaction, no change on position of equilibrium



10.4.2 Production and uses of NPK fertilisers

- NPK fertilisers
 - Contain compounds of nitrogen, phosphate and potassium
 - A formulation of various salts containing the elements in the percentages needed by plants
 - Improve agricultural productivity, help plants to grow larger and more rapidly
- Compounds
 - Nitrogen
 - Mainly ammonium nitrate (NH_4NO_3)

- Produced using ammonia from the Haber process
- Ammonia used to produce nitric acid
- React nitric acid with more ammonia (neutralisation)
- Potassium
 - Mainly potassium chloride or potassium sulfate mined from the ground
 - Used directly without further processing
- Phosphorus
 - Phosphate rock mined from the ground
 - Treated with acids to produce soluble salts
 - Treating phosphate rock with nitric acid → phosphoric acid
 - Phosphoric acid contains phosphorus but it cannot be added directly to plants so it is neutralised with ammonia
 - Phosphate rock treated with sulfuric acid → make a mixture of calcium phosphate and calcium sulfate (known as single superphosphate)
 - Phosphate rock treated with phosphoric acid → triple superphosphate
 - Mixtures found in NPK fertilisers
- Production in lab
 - Dilute solutions of ammonia and nitric acid → safe to work with
 - Produce crystals using a water bath and a Bunsen burner → lots of heat energy needed
 - Only produce a small amount of ammonium nitrate in one go - batch process
- Production in industry
 - Ammonia used as a gas
 - Concentrated nitric acid used
 - Much more dangerous as the reaction is very exothermic
 - Heat produced has to be safely removed and used in later stages
 - Some of the energy for evaporation is provided by the exothermic reaction
 - Can be produced in a continuous process - can produce very large amounts easily