8.3 Notes for use in qualitative analysis

Tests for anions

anion	test	test result
carbonate (CO_3^{2-})	add dilute acid	effervescence, carbon dioxide produced
chloride (Cl^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
iodide (I^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	yellow ppt.
nitrate (NO_3^-) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulfate (SO_4^{2-}) [in solution]	acidify, then add aqueous barium nitrate	white ppt.

Tests for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
aluminium (Al^{3+})	white ppt., soluble in excess giving a colourless solution	white ppt., insoluble in excess
ammonium (NH_4^+)	ammonia produced on warming	–
calcium (Ca^{2+})	white ppt., insoluble in excess	no ppt. or very slight white ppt.
copper (Cu^{2+})	light blue ppt., insoluble in excess	light blue ppt., soluble in excess, giving a dark blue solution
iron(II) (Fe^{2+})	green ppt., insoluble in excess	green ppt., insoluble in excess
iron(III) (Fe^{3+})	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
zinc (Zn^{2+})	white ppt., soluble in excess, giving a colourless solution	white ppt., soluble in excess, giving a colourless solution

Tests for gases

gas	test and test result
ammonia (NH_3)	turns damp red litmus paper blue
carbon dioxide (CO_2)	turns limewater milky
chlorine (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	'pops' with a lighted splint
oxygen (O_2)	relights a glowing splint

Notes for use in qualitative analysis

Tests for anions

anion	test	test result
carbonate, CO_3^{2-}	add dilute acid, then test for carbon dioxide gas	effervescence, carbon dioxide produced
chloride, Cl^- [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
bromide, Br^- [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	cream ppt.
iodide, I^- [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	yellow ppt.
nitrate, NO_3^- [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulfate, SO_4^{2-} [in solution]	acidify with dilute nitric acid, then add aqueous barium nitrate	white ppt.
sulfite, SO_3^{2-}	add a small volume of acidified aqueous potassium manganate(VII)	the acidified aqueous potassium manganate(VII) changes colour from purple to colourless

Tests for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
aluminium, Al^{3+}	white ppt., soluble in excess, giving a colourless solution	white ppt., insoluble in excess
ammonium, NH_4^+	ammonia produced on warming	–
calcium, Ca^{2+}	white ppt., insoluble in excess	no ppt. or very slight white ppt.
chromium(III), Cr^{3+}	green ppt., soluble in excess	green ppt., insoluble in excess
copper(II), Cu^{2+}	light blue ppt., insoluble in excess	light blue ppt., soluble in excess, giving a dark blue solution
iron(II), Fe^{2+}	green ppt., insoluble in excess, ppt. turns brown near surface on standing	green ppt., insoluble in excess, ppt. turns brown near surface on standing
iron(III), Fe^{3+}	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
zinc, Zn^{2+}	white ppt., soluble in excess, giving a colourless solution	white ppt., soluble in excess, giving a colourless solution

Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	turns limewater milky
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns acidified aqueous potassium manganate(VII) from purple to colourless

Flame tests for metal ions

metal ion	flame colour
lithium, Li^+	red
sodium, Na^+	yellow
potassium, K^+	lilac
calcium, Ca^{2+}	orange-red
barium, Ba^{2+}	light green
copper(II), Cu^{2+}	blue-green

Common Polyatomic Ions

Name	Formula	Charge
ammonium	NH_4^+	+1
hydroxide	OH^-	-1
acet**ate**	$C_2H_3O_2^-$	-1
nitr**ate**	NO_3^-	-1
nitr**ite**	NO_2^-	-1
bicarbon**ate**	HCO_3^-	-1
carbon**ate**	CO_3^{2-}	-2
sulf**ate**	SO_4^{2-}	-2
sulf**ite**	SO_3^{2-}	-2
phosph**ate**	PO_4^{3-}	-3

Simple compounds:

carbon dioxide CO_2	nitric acid HNO_3	calcium carbonate $CaCO_3$
oxygen gas O_2	sodium hydroxide $NaOH$	calcium chloride $CaCl_2$
ammonia NH_3	sodium chloride $NaCl$	copper (II) oxide CuO
methane CH_4	sodium carbonate Na_2CO_3	copper (II) sulfate $CuSO_4$
sulfur dioxide SO_2	magnesium oxide MgO	copper (II) carbonate $CuCO_3$
hydrochloric acid HCl	calcium oxide CaO	aluminium oxide Al_2O_3
sulfuric acid H_2SO_4	calcium hydroxide $Ca(OH)_2$	iron (III) oxide Fe_2O_3
lead (II) nitrate $Pb(NO_3)_2$	silver nitrate $AgNO_3$	

Relative atomic mass: The average mass of naturally occuring atoms of the element where the C-12 atom has a mass of exactly 12 units (Ar)

Relative molecular mass: The sum of the relative atomic masses (Mr) relative formula mass will be used for ionic compound

Moles triangles:

examples for each:

what mass of sodium hydroxide is needed to neutralise 10kg of sulfuric acid?

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

1) Find the Ar for sodium, oxygen, hydrogen and sulfur: H=1 S=32 O=16 Na=23

2) Find the Mr for sodium hydroxide and sulfuric acid: NaOH = 23+16+1 = 40

H_2SO_4 = (1X2)+23+(16X4) = 98

3) Convert 10kg to g = 10000

4) Find the moles: mass ÷ Mr → 10000 ÷ 98 = 102.04 (moles of sulfuric acid)

5) molar ratio of H_2SO_4 and $2NaOH$ → 1:2 so 102.04 X 2 = 204.08

6) mass → moles X Mr the Mr of sodium hydroxide is 40 204.08 X 40 = 8163.3g

examples for each:

25.0 cm^3 of 0.200 mol/dm^3 sodium hydroxide solution reacted with 28.7 cm^3 sulfuric acid. calculate the concentration of the sulfuric acid in mol/dm^3

1) we can find the moles of sodium hydroxide. convert cm^3 to dm^3: 25÷1000 = 0.025 dm^3

2) formula is: concentration X volume = moles so 0.025 X 0.200 = $\frac{1}{200}$

3) molar ratio of $2NaOH$ and H_2SO_4 → 2:1 so $\frac{1}{200} \div 2 = \frac{1}{400}$

4) convert 28.7cm^3 to dm^3 → 0.0287 and the formula for concentration is: moles÷ volume so $\frac{1}{400} \div 0.0287 = 0.087$ mol/dm^3

examples for each:

A solution containing 1.7g of hydrogen peroxide decomposes to produce water and oxygen gas. calculate the volume of oxygen produced at RTP:

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

1) Find the Ar for hydrogen, oxygen H=1 O=16

2) Find the Mr for hydrogen peroxide and oxygen $2H_2O_2 = (1 \times 2) + (16 \times 2) = 34$ $O_2 = (16 \times 2) = 32$

3) Do mass÷ Mr to find the moles. 1.7÷34 = 0.05

4) The molar ratio of $2H_2O_2$ and O_2 is 2:1 so we do 0.05÷2 = 0.025

5) The formula for volume is: molar gas volume (24 dm^3) X moles so 0.025 X 24 = 0.6 dm^3

The mole and chemical formulae:

The mole - the chemical counting unit:

- mol → the symbol or shortened form of mole/moles
- used to measure amounts of elements and compounds

The number per mole: 6.02×10^{23} Avogrado constant

One mole of a substance:

- has a mass equal to its relative formula mass in grams
- contains 6.02×10^{23} atoms

Molar ratio: between the number of moles of reactants consumed and the number of moles of products generated in a chemical reaction

Molecular formula and empirical formula:

Molecular formula (regular formula): tells us how many atoms of each element are in a compound

Ethene. C_4H_8 $\frac{4 \text{ carbons}}{8 \text{ hydrogens}}$

Empirical formula: tells us the simplest or most reduced ratio of atoms in a compound

$$\frac{4 \text{ carbons} \div 4}{8 \text{ hydrogens} \div 4} = \frac{1 \text{ carbon}}{2 \text{ hydrogens}} = CH_2$$

Many different compounds can all have the same empirical formula

Example: CH_2: Empirical formula MR: 14 molecular MR. 42 $\frac{42}{14} = 3$ C_3H_6

Relative isotopic abundance:

copper-63: 75% copper-65: 25%

$$\frac{(63 \times 75) + (65 \times 25)}{100} = 63.50$$

Metals:

- ↳ form positive ions when they react
- ↳ very strong metallic bonding
- ↳ malleable
- ↳ conductor of heat / electricity
- ↳ High melting / boiling points (transition metal)
- ↳ lustrous
- ↳ sonorous

Non-metals:

- ↳ don't form ions / form negative ions
- ↳ lower densities
- ↳ Brittle
- ↳ Dull
- ↳ low melting and boiling points

- metals tend to become more reactive towards the bottom of the table:
  - Elements far down the table has lots of shells
    - ↳ outermost shell is really far from the nucleus
  - In any atom, the positive nucleus holds the negative electrons in place so if the electrons are really far away, the nucleus can't hold on to them so strongly so the atom will lose them more easily and form a positive ion

Chemical properties of metals:

- ↳ metal + dilute acid → salt + hydrogen gas
- ↳ metal + water → metal hydroxide + hydrogen gas
- ↳ metal + steam → metal oxide + hydrogen gas
- ↳ metal + oxygen → metal oxide

Only form metal salt if metal is higher than hydrogen in the reactivity series

Uses of metals: Physical properties

↳ Alvminivm:

- manufacture of aircraft → low density
- manufacture of overhead electricity cables → low density, good electrical conductivity
- Food containers → resistance to corrosion

↳ copper:

- Electrical wiring → good electrical conductivity and ductility

Alloys.

↳ we can change the properties of a metal to make it harder or more resistant to corrosion → mixing it with another metal or non-metal

↳ An Alloy is not just a mixture of metal crystals, the atoms of the second metal form part of the crystal lattice

Atoms in pure metal → arranged in regular layers:

- force applied → layers slide over each other
  - malleable and ductile

Metal alloyed with second metal → different sized metal atoms make the arrangement of the lattice irregular

- disrupt the crystal lattice → stops the layers from sliding

Smart alloys are able to remember their shapes

Uses of alloys:

Alloy	Properties	Uses
Brass (Cu + Zn)	Strong, still malleable	instruments, ornaments
Bronze (Cu + Sn)	very hard	statues, bells
Stainless steel (Fe + Cr + Ni)	does not rust like iron	car parts, cutlery, surgical instruments

Reactivity series:

How to remember the Reactivity Series?

Please	Potassium	Most reactive
Stop	Sodium	
Calling	Calcium	
Me	Magnesium	
A	Aluminium	
Careless	(Carbon)	
Zebra	Zinc	
Instead	Iron	
Try	Tin	
Learning	Lead	
How	(Hydrogen)	
Copper	Copper	
Saves	Silver	
Gold	Gold	Least reactive

potassium + cold water → potassium hydroxide + hydrogen

sodium + cold water → sodium hydroxide + hydrogen

calcium + cold water → calcium hydroxide + hydrogen

These reactions give out a metal hydroxide because its high in the reactivity series and is more reactive than hydrogen

magnesium + steam → magnesium oxide + hydrogen

copper does not react with hydrogen because it is below hydrogen in the reactivity series

magnesium + dilute hydrochloric acid → magnesium chloride + hydrogen

↳ bubbles formed

copper does not react with dilute hydrochloric acid because it can't replace hydrogen

The more reactive a metal is, the greater its tendency to lose electrons and form positive ions

Aluminium: does not react well with oxygen in the air

↳ it had already reacted → aluminium oxide formed

a thin, tightly bonded layer

that protects the aluminium from further corrosion

Corrosion of Metals:

Rusting of iron: chemical reaction between iron, water and oxygen to form the compound hydrated iron (III) oxide (rust)

↳ oxygen and water must be present for rust to occur

↳ During rusting, iron is oxidised

iron + water + oxygen → hydrated iron (III) oxide

Barrier methods:

↳ Rust can be prevented by coating iron with barriers that prevent the iron from coming into contact with water and oxygen

- if the coatings are washed away or scratched, the iron is once again exposed to water and oxygen and will rust

Common barrier methods:

- Grease
- Oil
- paint
- plastic

Galvanizing: the process of applying a protective zinc coating to iron, to prevent corrosion

↳ hot dip galvanizing → cleaning steel and immersing it in molten zinc to obtain a coating: temp 450°C

example:

- zinc – more reactive than iron
- zinc corrodes in preference to iron

Sacrificial protection:

↳ Corrosion protection method in which a more electrochemically active metal is electrically attached to a less active metal

- highly active metal donates electrons to replace those which may have been lost during oxidation of the protected metal
- reverts the protected metal back to its original form, prevents it from corroding

A more reactive metal is used as a sacrificial anode by attaching it to steel pipes or pump bodies:

- iron → cathode which does not corrode
- anode → corrodes to provide the desired sacrificial protection
  - ↳ replaced periodically as its consumed otherwise the protected metal starts corroding

Sacrificial protection is used for corrosion protection in:

- underground tanks
- water heaters
- Above-ground tanks
- Hulls of ships
- pipelines

Advantages:

- low cost
- provides protection without power requirement
- simple installation

Disadvantages:

- periodic replacement of the anode
- increased noise level

Extraction of metals:

↳ Most metals are produced by chemical reactions from compounds found in rocks

- if a metal can be extracted for profit from compounds in a rock → ore

Reduction: loss of oxygen / gain of electrons

↳ Most ores contain metal oxides → to extract the metal from a metal oxide → oxygen is removed

- when all metals are extracted, metal ions in the compound gain electrons to form metal atoms → involve reduction

Example of ores:

- haematite (Fe_2O_3)
- bauxite (Al_2O_3)
- galena (PbS) ← not important

haematite

galena

bauxite

method used to extract a metal from its ore depends on the stability of its compound → depends on the reactivity of the metal:

- very reactive metals (aluminium) form stable oxides and other compounds
  - ↳ Electrolysis is commonly used to extract
  - ↳ requires a lot of electric current to reduce them → extract the metal
- less reactive metals (iron) form less stable oxides and other compounds
  - ↳ Reduction with carbon is often used to extract
  - ↳ requires less energy to reduce them → extract the metal

metals more reactive than carbon → electrolysis

metals less reactive than carbon → reduction by carbon

unreactive metals → chemical reactions

↳ metals more reactive than carbon cannot be reduced by carbon

Reactivity series of metals	Method of extracting metals from their ores
Potassium, Sodium, Calcium, Magnesium, Aluminium	Extract through electrolysis
(Carbon)	
Zinc, Iron, Tin, Lead	Extract by burning with carbon
Copper, Mercury	Extract by burning directly in air
Silver, Gold	No extraction needed!

Onlinetuition.com.my

Extraction of Iron from haematite:

The oxygen must be removed from the Iron (III) oxide, Fe_2O_3 to leave the iron behind

Raw materials for the reaction:

↳ haematite:

- contains: Fe_2O_3
- Function. compound that the iron is extracted from

↳ Coke:

- contains: C
- Function: fuel, reacts to form carbon monoxide

↳ limestone:

- contains: $CaCO_3$
- Function: helps to remove acidic impurities from the iron by reacting with them to form molten slag

↳ Air:

- contains: O_2
- Function: allow the coke to burn and produce heat

Carbon → more reactive than Fe so it can displace Fe from Fe_2O_3

Step 1: hot air (oxygen) reacts with the coke to produce CO_2 and energy to heat up the furnace: 550°C – 850°C

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$$

Step 2: more coke is added to the furnace → reduces the CO_2 to CO (a good reducing agent):

$$CO_{2(g)} + C_{(s)} \rightarrow 2CO_{(g)}$$

Step 3: Fe_2O_3 is reduced: iron (III) oxide + carbon → iron + carbon dioxide

$$2Fe_2O_{3(s)} + 3C_{(s)} \rightarrow 4Fe_{(l)} + 3CO_{2(g)}$$

iron (III) oxide = reduced carbon = oxidised

In the blast furnance → so hot → CO can be used instead of C to reduce the Fe_2O_3

iron (II) oxide + carbon monoxide → iron + carbon dioxide

$$Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(l)} + 3CO_{2(g)}$$

Reactants are added constantly so that the reaction does not stop

Removing impurities:

↳ $CaCO_3$ thermally decomposes to form CaO: calcium carbonate → calcium oxide + carbon dioxide

$$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$$

– CaO reacts with silica impurities in the haematite → produce slag (calcium silicate) → separated from the iron and used to make road surfaces + cement:

$$CaO_{(s)} + SiO_{2(s)} \rightarrow CaSiO_{3(l)}$$

↳ neutralisation reaction:

CaO (metal oxide) = basic

SiO_2 (non-metal oxide) = acidic

Reversible reactions:

↳ some chemical reactions are reversible

Equilibrium:

- rate of forward reaction is equal to the rate of the backward reaction
- concentration of the reactants and products does not change

⇌ This double arrow shows that the reaction is reversible

- Top arrow forwards reaction
- bottom arrow backwards reaction

↳ both reactions can happen at different rates

Example: $NH_4Cl \rightleftharpoons NH_3 + HCl$

beginning of reaction: contains lots of NH_4Cl but no NH_3 or HCl so the forward reaction will be very fast

reactants turn into products → forward reaction slows down and backward reactions will be at the same speed → concentration of reactants and products won't change anymore → reaction is at equilibrium

At equilibrium: both reactions are still happening but they effectively cancel each other out so there is no overall change in concentration

concentration constant ≠ they're the same

position of equilibrium changes: more products than reactants → equilibrium lies to the right

more reactants and fewer products → equilibrium lies to the left

position can change depending on the conditions

heat encourages forward reaction

cooling encourages backward reaction

Closed system: The reactant or product can not escape the reaction mixture

The rate of forward reaction is equal to the rate of the reverse reaction

The concentrations of reactants or products are no longer changing

position of the equilibrium → tells us how far the reaction goes in favour of reactants or products.

- concentration of product greater than concentration of reactant in a reaction mixture at equilibrium → position of equilibrium is to the right
- concentration of reactant greater than concentration of product → position of equilibrium to the left

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

Shifting the equilibrium:

If you change the conditions of a reversible reaction → The position of equilibrium will shift to try and counteract the change:

- catalyst does not affect the position of the equilibrium

changing the concentration:

↳ concentration of reactant increased → equilibrium moves to the right (product side)

- Adding more unbalances the equilibrium
- equilibrium moves to the right → form more products until the equilibrium is restored

Changing the pressure:

↳ only affects reactions where there is a gas in the chemical reaction with different numbers of moles of gas.

- increasing the pressure → equilibrium moves to the side with less molecules
- decreasing the pressure → equilibrium moves to the side with more molecules

increasing →

$$\overset{4}{N_2} + 3H_2 \rightleftharpoons \overset{2}{2NH_3}$$

← decreasing

↳ This happens because increasing the pressure squashes the molecules closer together

- reaction mixture overcomes this by moving the equilibrium to the right to reduce overall number of molecules

increase in pressure will increase the temperature as well

molecules are more sparse

decreasing pressure

increasing pressure

more molecules squashed

(a) low pressure
reverse reaction favoured

backwards reaction so more H_2, N_2

(b) high pressure
forward reaction favoured

forward reaction so more NH_3

Changing the temperature:

↳ if a reaction is exothermic in the forward reaction, it must be endothermic in the backward reaction:

- decreasing the temperature → equilibrium will shift to the exothermic side → release heat energy and counteract the change
- increasing the temperature → equilibrium will shift to the endothermic side → absorbing more thermal heat

higher yield ← increasing temp

$$N_2 + 3H_2 \underset{\text{endo}}{\overset{\text{exo}}{\rightleftharpoons}} 2NH_3$$

decreasing temp → higher yield

Heating hydrated salts:

heat crystals of blue copper (II) sulfate → decompose to form a white powder

$$CuSO_4 \cdot 5H_2O\,(s) \xrightarrow{\text{heat}} CuSO_4\,(s) + 5H_2O\,(l)$$

hydrated copper (II) sulfate (blue) → anhydrous copper (II) sulfate (white)

- when heated, the water of crystallisation is lost → left with white anhydrous copper (II) sulfate
- reaction is reversible when water is added back to the white copper (II) sulfate
  ↳ turns blue again

$$CuSO_4 \cdot 5H_2O\,(s) \rightleftharpoons CuSO_4\,(s) + 5H_2O\,(l)$$

Another reversible reaction to test for water:

$$CoCl_2 \cdot 6H_2O\,(s) \rightleftharpoons CoCl_2\,(s) + 6H_2O\,(l)$$

hydrated cobalt (II) chloride → anhydrous cobalt (II) chloride

red/pink → blue

Making ammonia:

NH_3 → fertilisers, nitric acid, nylon, explosives

Haber process: nitrogen combines with hydrogen at high pressure and temperature

Sources of hydrogen and nitrogen:

↳ heating steam and methane in the presence of a nickel catalyst → hydrogen

$$CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$$

methane steam carbon monoxide hydrogen

↳ nitrogen is extracted from the air → oxygen removed by reaction with hydrogen

1. gas stream containing nitrogen and hydrogen enters
2. they are mixed and compressed

3. compressed gas enters a converter with trays of iron catalyst:
   temp: 450°C
   pressure: 200 atmospheres
   $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
4. mixture → cooling chamber ammonia condenses then is removed
5. unreacted nitrogen and hydrogen are returned to the converter

Reaction conditions explained:

↳ reversible reaction

↳ yield: percentage of ammonia produced in the equilibrium mixture:

- yield increases with pressure as there are fewer molecules at the product

side so the equilibrium shifts to the right

↳ high pressure is expensive, fuel is expensive, a strong vessel is expensive so pressure is at maximum 200 atmospheres

↳ forward reaction is exothermic → increase in temperature favours the endothermic side

- yield of ammonia decrease with increasing temperature
- too low temperature will cause the rate of reaction to become too slow
- compromised temperature of 450°c → good yield with fast enough rate of reaction

Sulfuric acid: industrial chemical → dibasic acid

uses:

- paint / dyes
- cleaning metals
- soaps and detergents
- plastics
- phosphate fertilisers
- other fertilisers
- Fibres

SO_2 uses:

- preserving food

Acidic properties:

↳ reacts with metals above hydrogen in the reactivity series to form a salt and hydrogen gas

↳ reacts with bases (metal oxides / hydroxides) to form a salt and water

↳ reacts with carbonates to form a salt, water and carbon dioxide gas

manufactured by → contact process

Raw materials: sulfur, air, water

Figure 9.1 The manufacture of sulphuric acid, H_2SO_4 through the Contact Process

① spray of molten sulfur → burned in a furnace in a current of dry air containing oxygen → sulfur dioxide gas:

$$S(l) + O_2(g) \rightarrow SO_2(g)$$

can also be made by roasting sulfide ores

② sulfur dioxide → reacted with excess air in the converter containing vanadium (V) oxide

Temp: 450°c

pressure: 2 atmospheres

product: sulfur trioxide: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ exothermic reaction

③ sulfur trioxide → absorbed into 98% solution of sulfuric acid to form a thick liquid called oleum $H_2S_2O_7$

④ oleum mixed with a little water to make concentrated 98% sulfuric acid:

$$H_2S_2O_7 + H_2O(l) \rightarrow 2H_2SO_4(l)$$

Reaction conditions explained:

↳ yield of sulfur trioxide increases with an increase in pressure

- pressure of only 2 atmospheres used
- yield of sulfur trioxide very high even at atmospheric pressure

↳ exothermic reaction → yield decreases with increasing temperature

same reason as Haber process

Fertilisers:

↳ plants need nitrogen → make protein

- take up nitrate ions: NO_3^- and ammonium ions: NH_4^+ ions from the soil

↳ phosphorus and potassium also essential for plant growth

↳ Adding fertilisers replace the essential elements in the soils that were depleted

NPK fertilisers: fertilisers containing nitrogen, phosphorus and potassium

- are made up of compounds of the elements
- typically include potassium nitrate: KNO_3 and ammonium phosphate $(NH_4)_3PO_4$

making fertilisers:

→ fertilisers that contain ammonium salts, nitrates and phosphates are made by neutralising aqueous ammonia with acids:

$$NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$$

ammonia nitric acid ammonium nitrate

$$3NH_3(aq) + H_3PO_4(aq) \rightarrow (NH_4)_3PO_4(aq)$$

ammonia phosphoric acid ammonium phosphate

ammonia made by the Haber process

sulfuric acid made by the contact process

potassium comes from salts → potassium chloride

practical: making ammonium sulfate fertiliser

1. titrate ammonia with sulfuric acid using methyl orange indicator
2. methyl orange → pink record the burette reading

3. repeat titration without indicator
4. pour the solution into an evaporating basin → evaporate some water → leave to crystallise

crop plant → do not grow well in acidic conditions

↳ farmers add lime (CaO) to the soil to neutralise the acidity

- lime + soil → calcium hydroxide (alkaline)
- too much lime released ammonia from ammonium salts
- may escape as gas and lost from the soil

$$2NH_4Cl(aq) + Ca(OH)_2(aq) \rightarrow 2NH_3(g) + CaCl_2(aq) + 2H_2O(l)$$

ammonium chloride, calcium hydroxide, ammonia, calcium chloride, water

Organic chemistry:

↳ Chemistry of carbon structures, reactions that carbon-containing compounds do, properties + reactivity

The study of molecules that have carbon atoms

carbon can form 4 strong bonds, catenates (bonds to itself), form lots of different compounds

This is a lewis structure, it illustrates what atoms are connected and they show all of the bonds and lone pairs of electrons in a molecule

Organic molecules can make carbon chains

Homologous series: A group of organic molecules with similar chemical properties

- Family of similar compounds with similar chemical properties due to the presence of the same

functional group:

↳ an atom or group of atoms that gives a compound particular chemical properties

Characteristics of a homologous series:

Alcohols: $C_nH_{2n+1}OH$ ↳ functional group

- have the same functional group
- same general formula
- similar chemical properties
- display a trend in physical properties

Alkane: C_nH_{2n+2}

Alkene: C_nH_{2n}

Hydrocarbon: Any compound thats formed from carbon and hydrogen only

Formula of organic compounds:

Displayed formula → shows all of the atoms and bonds in a molecule:

ethane ethene ethanol ethanoic acid

Carbon → 4 bonds

oxygen → 2 bonds

hydrogen → 1 bond

molecular formula: the formula showing the number and types of different atoms in one molecule

C_2H_6 C_2H_4 C_2H_6O $C_2H_4O_2$

The prefix tells us how many carbon atoms there are in the chain

Monkey Eat peanut Butter

meth-	1	methane CH_4
eth-	2	ethane C_2H_6
prop-	3	propane C_3H_8
but-	4	butane C_4H_{10}
pent-	5	pentane C_5H_{12}
hex-	6	hexane C_6H_{14}
hep-	7	heptane C_7H_{16}

oct-	8	octane C_8H_{18}
non-	9	nonane C_9H_{20}
dec-	10	decane $C_{10}H_{22}$

Structural formulae and isomerism:

Structural formulae: An unambiguous (clearly defined) description of the way the atoms in a molecule are arranged:

↳ shows us each carbon atom in the molecule

↳ hydrogen atoms and functional groups which are bonded to each carbon atom in the molecule

— = displayed formula

— = structural formula

$CH_3CH_2CH_2CH_3$

$CH_3CH=CHCH_3$

$CH_3CH_2CH_2OH$

Structural isomers: compounds with the same molecular formula but with a different structural formula

- carbon chain in alkanes and other organic compounds can be branched

2-methylpropane

butane

not butane! carbon atoms are arranged differently

- similar chemical properties but different physical properties
- branched-chain isomers have lower boiling and melting point:
  - when branching, the surface area of the molecule decrease → forces of attraction decreased → melting/boiling point decreases

All members of the alkene homologous series with 4 or more carbon atoms in a chain: forms isomers where the position of the double bond changes

position isomer

but-1-ene

but-2-ene

How to draw isomers:

Example: write all the possible isomers of C_3H_7Br and name them:

1) draw the 3 carbon atoms C-C-C

2) placing the bromine: C-C-C (Br) and C-C-C (Br) are the same → 1-bromopropane

3) This is different: C-C-C (Br) → 2-bromopropane

There are only 2 possibilities for this one

2nd example: write all the possible isomers of C_5H_{12} and name them:

1) draw the 5 carbon atoms C-C-C-C-C

2) complete with hydrogen →

pentane

3) don't put carbon at the edge as it will be the same

instead, do: C-C-C (C) - C 2-methylbutane

This is also possible: C-C (C) - C (C) 2,2-dimethyl propane

Alkanes:

Saturated hydrocarbons → have only single covalent C-C and C-H bonds in their structures, no more atoms can be added to their molecules

general formula: C_nH_{2n+2}

methane

ethane

propane

physical properties:

↳ colourless gases, liquids or solids

↳ first 4 members → gases at room temperature and pressure RTP

↳ 5-17 carbon atoms → liquids

↳ more than 17 → solids

↳ carbon chain gets longer → boiling point increase

Chemical properties:

↳ generally unreactive compounds except for combustion and substitution by chlorine

Substitution reaction:

- one atom / group of atoms → replaced by another atom or groups of atoms

↳ don't react with acids or alkalis

↳ burn with a clean blue flame if there is excess oxygen or air present: complete combustion

→ forms carbon dioxide and water:

$$C_3H_8\,(g) + 5O_2\,(g) \rightarrow 3CO_2\,(g) + 4H_2O\,(l)$$

propane oxygen carbon dioxide water

Not enough oxygen → incomplete combustion → forms carbon monoxide gas + black soot

photochemical reaction:

↳ Alkanes don't react with chlorine in the dark

↳ Alkane + chlorine in bright sunlight → green color of chlorine disappears

↳ UV light in sunlight provides the activation energy for the reaction (catalyst)

↳ chlorine atom replaces a hydrogen atom in the alkane

$$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$$

methane chlorine chloromethane hydrogen chloride

Test:

↳ acidic gas (hydrogen chloride) is produced → turns damp blue litmus paper red

Excess chlorine → substitute more hydrogen atoms

$$CH_3Cl + Cl_2 \rightarrow CH_2Cl_2 + HCl$$

$$CH_2Cl_2 + Cl_2 \rightarrow CHCl_3 + HCl$$

if enough chlorine is present, all 4 hydrogen atoms can be replaced by chlorine atoms

Cracking alkanes:

some fraction we get from the distillation of petroleum are more useful than others

cracking: breaking down larger hydrocarbons into smaller, more useful alkenes and alkanes

↳ thermal decomposition of alkanes

↳ catalyst is often used

$$C_{10}H_{22} \xrightarrow[\text{catalyst}]{\text{heat}} C_5H_{12} + C_2H_4 + C_3H_6$$

decane pentane ethene propene

hydrogen can also be produced:

$$C_2H_6 \rightarrow C_2H_4 + H_2$$

ethane ethene hydrogen

practical:

1) heat catalyst + paraffin
2) paraffin vapour passes over the alvminium oxide
3) collect the gases from the test tube
4) check if the gas contains alkenes → bromine water test

Alkenes:

unsaturated hydrocarbons → they have one or more C=C double bonds or C≡C triple bonds, more atoms can be added to their molecules

– first 3 alkenes: colourless gases

General formula: C_nH_{2n}

ethene

propene

Alkenes contain a C=C

when drawing, remember carbon can't have more than 4 bonds:

= wrong!

test for unsaturated compounds:

↳ aqueous bromine → orange

- decolorise when mixed with excess hydrocarbon
  → unsaturated (alkene)
- remain the same → saturated (alkane)
  ↳ disappears after a while

chemical properties:

↳ complete combustion produces CO_2 and H_2O

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$$

ethene oxygen carbon dioxide water

↳ steam reacts with alkenes to form alcohols:

- hydration reaction: high temperature (300°c) and high pressure
  ↳ steam is passed over a catalyst of concentrated phosphoric acid H_3PO_4

$$C_2H_4 + H_2O \xrightarrow{H_3PO_4} C_2H_5OH$$

ethene steam ethanol

This is essentially an addition reaction as only one product formed

Addition reaction: two or more reactants add together to form only one product

hydration is one example

Another: reaction of alkenes with bromine liquid.

$$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$$

ethene bromine 1,2-dibromoethane

one of the bonds in C=C breaks → allow the bromine to be added

bromine does not react with saturated compounds → no double bond to break and add on to

Another: hydrogen reacts with alkenes to form alkanes: hydrogenation reaction / reduction reaction

↳ 60°c in the presence of a nickel catalyst:

$$C_2H_4 + H_2 \xrightarrow{\text{nickel } 60^\circ c} C_2H_6$$

ethene hydrogen ethane

Fuels:

Fossil fuel coal, petroleum (crude oil), natural gas (CH_4) → contain hydrocarbons

petroleum: A mixture of many types of hydrocarbons with different carbon chain lengths

Fractional distillation: used to separate the hydrocarbon molecules in petroleum into groups that have similar boiling points (fractions)

Fraction: contains hydrocarbons with a certain range of carbon atoms → many of them are used as fuels

Understanding boilings:

Example: melting point = 70°c Boiling point = 361°c

melting point: temperature when the substance can turn from solid to liquid

boiling point: temperature when the substance can turn from liquid to gas

Chain length properties:

↳ Short chain length → low boiling point as chain length increases, the higher the boiling point

↳ the longer the chain length, the higher the viscosity (thickness).

· Viscosity can be bad as it can block up the pipes

↳ Shorter the chain, the higher the flammability

Fractional distillation:

Apparatus: boiler, fractionating column

Steps:

1) crude oil is heated in the boiler until all hydrocarbons evaporate
2) crude oil is pumped into a column → gets cooler towards the top
3) trays go up the column to catch any vapours that condense to a liquid so they don't fall

back down

4) longest chain lengths have higher boiling points, so condenses near the bottom

5) shorter chain lengths have lower boiling points so need to be cooled more to condense, therefore they condense nearer the top

6) fractions are drawn off and stored separately

Organics 2:

Alcohols:

chemical property

Homologous series: -OH functional group

names end with -ol

general formula → $C_nH_{2n+1}OH$

methanol	ethanol	propanol	butanol
CH_3OH	C_2H_5OH	C_3H_7OH	C_4H_9OH

properties of alcohol:

↳ flammable:

- can undergo complete combustion in air:

Alcohol + oxygen → carbon dioxide + water

↳ soluble: can dissolve in water to form a solution with a neutral pH

↳ can be oxidised to form a carboxylic acid:

uses of alcohol:

↳ good fuel as they can undergo combustion → release lots of energy

↳ solvent in industries → often used instead of water as they can dissolve things water can't

Solute
Solvent
Solution

Color	colorless
Odor	they have faint odor (alcoholic odor) **except** glycerol which is odorless.
Solubility	completely miscible with water.
Flammability	flammable with blue, non smoky flame.
State	liquid except glycerol which is viscous liquid.
Acid-base properties	neutral

Ethanol:

molecular formula: C_2H_6O

structural formula: CH_3CH_2OH

Display formula:

↳ colorless liquid that boils at 78°C

↳ mixes with water

↳ burns with a clean blue flame in excess air → carbon dioxide + water:

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

Can be manufactured from:

↳ ethene: steam + ethene + high pressure and temperature + phosphoric acid catalyst (H_3PO_4)

↳ glucose: fermentation

uses:

↳ perfumes, other cosmetics

↳ making chemicals → make esters → food flavourings

Oxidising ethanol:

↳ can be oxidised to ethanoic acid

1) oxidation in the air: only in the presence of oxygen

Acetobacter: group of bacteria present in the air and on surfaces

↳ ethanol exposed in the air → enzymes from bacteria speed up the conversion of ethanol to ethanoic acid

$$C_2H_5OH + 2O \longrightarrow CH_3COOH + H_2O$$

ethanol oxygen ethanoic acid water

This reaction makes vinegar

2) oxidation using acidified potassium manganate (VII):

potassium permanganate

↳ good oxidising agent

- heat ethanol with potassium manganate (VII) and sulfuric acid

catalyst!

- flask with condenser in upright position → refluxing

↳ prevents volatile alcohol from escaping

Fermentation:

Chemical reactions are catalysed by enzymes:

↳ work best at 25°c - 35°c

living organism

↳ Bacteria + yeast → produce enzymes → catalyse fermentation reactions in organic materials

Fermentation: the breakdown of organic material with effervescene (bubbles) and the release of thermal energy

Fermentation of glucose (sugars):

1) add moist yeast to flask of warm glucose solution → rate is fast → high temp, more yeast present

2) shake the solution → yeast suspended in solution cloudy look

3) leave flask alone → keep warm for 30 minutes

4) pour the gas from the flask into a boiling tube containing limewater → turns milky due to the presence of CO_2

rate decrease → ethanol kills yeast, glucose is used up

Conditions:

- anaerobic respiration
  temperature of 25-35°C
- neutral pH

$$C_6H_{12}O_6 \xrightarrow{\text{yeast}} 2C_2H_5OH + 2CO_2$$

glucose — ethanol — carbon dioxide

ethanol is separated from the reaction mixture by fractional distillation

Advantages of fermentation compared to ethene + steam:

↳ simple method

↳ low temperature required → relatively low energy input

↳ uses renewable resources

Disadvantages of fermentation compared to ethene + steam:

↳ uses a batch process → start again from the beginning

↳ slow rate of reaction

↳ Ethanol needs further purification by distillation

1 atm = 100 kPa

Alkene + steam:

↳ hydration reaction. high temperature (300°C) and high pressure (60 atm (6000 kPa))

- addition reaction

↳ steam is passed over a catalyst of concentrated phosphoric acid H_3PO_4:

$$C_2H_4 + H_2O \xrightarrow{H_3PO_4} C_2H_5OH$$

ethene — steam — ethanol

Advantages of ethene + steam compared to fermentation:

↳ A continuous process → ethanol + ethene + steam removed and replaced constantly

↳ fast rate of reaction

↳ produces ethanol of high purity

Disadvantages of ethene + steam compared to fermentation:

↳ ethene is made from a non-renewable resource

↳ more complex method

↳ needs high temperature and pressure → high energy input

Carboxylic acids

- COOH functional group

↳ names end in 'Anoic acid'

general formula: $C_nH_{2n+1}COOH$

methanoic acid	ethanoic acid	propanoic acid	butanoic acid
$HCOOH$	CH_3COOH	C_2H_5COOH	C_3H_7COOH

↳ all acids → react like any other acid

- weak acids → don't fully ionise (dissociate)
- molecules don't all release their hydrogen ions

ionised version:

$C_2H_5COOH \rightleftharpoons C_2H_5COO^- + H^+$

↳ negative ions that they form have names that end in 'Anoate'

propanoic acid → propanoate + hydrogen

Chemical properties of carboxylic acids:

1) carboxylic acid + metal carbonate → salt + water + carbon dioxide:

ethanoic acid + sodium carbonate → sodium ethanoate + water + carbon dioxide

$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$

This comes first

2) carboxylic acid + metal → salt + hydrogen:

ethanoic acid + magnesium → magnesium ethanoate + hydrogen

$2CH_3COOH + Mg \rightarrow (CH_3COO)_2Mg + H_2$

3) carboxylic acid + alkali → salt + water:

ethanoic acid + sodium hydroxide → sodium ethanoate + water

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

How to make carboxylic acid:

Alcohol is oxidised: alcohol + oxidising agent (oxygen) → carboxylic acid

potassium manganate (VII)

Esters:

- ↳ -COO- functional group somewhere in the middle of the molecules
- ↳ tend to have pleasant smells → 'sweet or fruity'
- ↳ volatile → evaporate easily
- ↳ commonly found in perfumes and food flavourings

How to make an ester:

carboxylic acids + alcohol

thyl — alcohol

anoate — carboxylic acid

1) making ethyl ethanoate →

$CH_3COOC_2H_5$

2)

ethanoic acid	ethanol	ethyl ethanoate	water
CH_3COOH	C_2H_5OH	$CH_3COOC_2H_5$	H_2O

↪ Acid catalyst: concentrated sulfuric acid H_2SO_4

3)

ethanoic acid	ethanol	ethyl ethanoate	water
CH_3COOH	C_2H_5OH	$CH_3COOC_2H_5$	H_2O

↪ carboxylic acid loses OH
↪ Alcohol loses H
} forms H_2O

↪ -COO- in the middle, called ester group / ester link → links together carboxylic acid and alcohol

↪ when naming: 'yl' is for the alcohol, 'anoate' is for the carboxylic acid

methanol + propanoic acid → methyl propanoate

NAME OF ALCOHOL	NAME OF CARBOXYLIC ACID	NAME OF ESTER
ETHANOL	PROPANOIC ACID	ETHYL PROPANOATE
BUTANOL	METHANOIC ACID	BUTYL METHANOATE
PENTANOL	ETHANOIC ACID	PENTYL ETHANOATE

USES OF ESTERS

esters have characteristic **sweet smells** and are used as **food flavourings**.

they are also widely used as **solvents**

and as **plasticisers**

polymers: large molecules made from many small molecules called monomers

polymerisation: process of joining hundreds or thousands of monomers together to form polymers

identifying polymers:

↳ small section that repeats:

polypropene

repeating monomer

n ← how many repeating units in the polymer

↳ used curved brackets → bonds coming through the brackets

Melting + boiling points:

↳ covalent bonds → strong → high temperature to break

↳ intermolecular forces → weaker than covalent or ionic bonds

- long polymers → large surface area → lots of intermolecular forces
  ↳ require high energy

↳ lower melting + boiling points than giant covalent

↳ higher melting + boiling points than simple molecular substances

polymers are generally solid at room temperature

plastics + disposal:

↳ type of polymer → can be moulded

uses: bottles, buckets, ropes, drain pipes, clothing

- many are non-biodegradable → not broken down by microorganisms

↳ long chain of hydrocarbon → resistant to hydrolysis: break down of compounds by water, acids or alkalis

- build up → block drains → flooding
  → kill wildlife → trapping / entangling → blocking digestive system
  → floating on the surface of the water → block sunlight + oxygen

solution:

↳ land fill sites. use up land that could be used for agriculture + housing

↳ Burn them: release thermal energy → provide electricity / heating

- some plastics produce poisonous gases when they burn: PVC produces acidic hydrogen chloride
- some nitrogen containing plastics produce toxic hydrogen cyanide
- some produce dioxins

↳ recycling: melted + moulded

↳ Biodegradable: can be broken down by bacteria in the soil

polymer PET: make plastic bottles

↳ melt + remould + mix with other plastics → carpets

↳ hydrolysing PET polymers to its monomers → higher grade plastics

- monomers re-polymerised → make food containers

Addition polymers:

↳ To name: put the name of the monomer inside brackets and put 'poly' in front:

poly (propene), poly (chloroethene)

An alkene: carbon - carbon double bond → unsaturated

↳ double bond can break into a single bond → allow the carbons to form new bonds with something else

Can be drawn in 2 ways: propene and poly (propene)

1)

Change double bond to single bond

2)

Equation for the addition polymerisation of butene:

polymer to monomer → hydrolysis

Condensation polymers:

Conditions: pressure + catalyst

↳ made up of lots of individual monomers

- monomers react together to form the polymer + another product (water / hydrogen chloride)

↳ involves 2 different monomers with different functional groups

Types of monomers:

1) Dicarboxylic acid monomer

contains 2 dicarboxylic groups

2) Diol monomer

contains 2 alcohol groups

3) Diamine monomer

contains 2 amine groups

coloured rectangles = the rest of the molecule

polyesters: Terylene

PET

types of monomer: Dicarboxylic acid + Diol

ester linkage is formed

Dimer → two monomers combined

Show repeating units:

Remove

continuation bond

so they can bond to other units

↳ forms another water molecule

Summary: Dicarboxylic acid monomer + Diol monomer → condensation polymer + water

(polyester due to ester link)

Example:

ethanedioic acid ethanediol

polyamide:

Nylon

types of monomer: Dicarboxylic acid + Diamine

amine. $-NH_2$ functional group

amide linkage is formed

Amino acids and proteins: The monomers which react together to make proteins

↳ have the amine ($-NH_2$) and carboxylic acid ($-COOH$) groups in common

joined together by central carbon

'R' changes depending on which amino acid it is

↳ Amino acids can join together through condensation reactions

produce water

Amide link

Example:

There is no regular repeat units → amino acid residue is irregular

proteins are natural polyamides

Structure of protein:

Amide link

Amine + carboxylic acid

Environmental chemistry:

composition of clean air:

oxygen → 21% of clean air
needed for:
- combustion
- rusting
- respiration

Nitrogen → 78% of clean air
↳ unreactive gas
- slows down burning + rusting

1% → argon and other gases: 0.04% of air is carbon dioxide
water vapour → 1% - 4% of the atmosphere
air around us also contains pollutants, sulfur dioxide and nitrogen oxides

Air pollutants and their effects:

pollutants: dust particles and smoke that are harmful
Fossil fuels:
↳ contain hydrocarbons → burns in excess air to produce CO_2 + H_2O
burn completely → complete combustion
hydrocarbon + oxygen → carbon dioxide + water
↳ increased concentration of carbon dioxide in atmosphere → global warming → climate change

Carbon monoxide CO:

↳ not enough oxygen to burn a carbon-containing fuel completely, CO and H_2O are formed
→ soot as well: incomplete combustion
↳ toxic gas:
- combines with haemoglobin in red blood cells
- prevents oxygen from binding → stop respiration

↳ colorless with no smell

particles: tiny particles of solids present in the air

↳ can get into the lungs → into the blood

↳ increase respiratory problems → cause cancer

methane CH_4:

↳ formed by the decomposition of vegetation

↳ waste gases when animals digest their food

↳ increase global warming

oxides of nitrogen, sulfur dioxide SO_2.

↳ acid rain

↳ nitrogen oxides from car exhausts → photochemical smog:

- smog → smoky fog that cause irritation and increased respiratory problems

↳ nitrogen oxides → react with oxygen in the atmosphere → with sunlight → form ozone, O_3

↳ ozone → reacts with unburned hydrocarbons from the vehicle exhausts → photochemical smog

↳ nitrogen oxides → harm lungs and cause breathing difficulties → make asthma worse

CO_2 in the atmosphere:

ways that carbon dioxide get into the atmosphere:

↳ complete combustion of carbon-containing fuels

↳ respiration:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

glucose oxygen carbon dioxide water

↳ reaction between acids and carbonates: acid rain reacts with carbonate rocks

$$CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$$

calcium carbonate nitric acid calcium nitrate water carbon dioxide

↳ thermal decomposition of carbonates:

$$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$$

calcium carbonate calcium oxide carbon dioxide

carbon dioxide removal from the atmosphere: opposite of respiration

photosynthesis: carbon dioxide + water → glucose + oxygen

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

carbon dioxide water glucose oxygen light is needed

chlorophyll, the green pigment in plants acts as a catalyst for this reaction

Greenhouse gases:

gas that absorbs thermal energy, stops thermal energy escaping into space

main greenhouse gases:

↳ carbon dioxide CO_2: from burning fossil fuels in power stations
— emissions from vehicle engines

↳ methane CH_4: from cattles during digestion
— decomposition of vegetation

↳ Nitrous oxide N_2O: from vehicle, air craft engines

↳ Sulfur dioxide SO_2: from fossil fuels, roasting sulfide ores

lowering the amount of greenhouse gases:

↳ decrease the use of fossil fuels

↳ develop more efficient fuels

↳ plant more trees to absorb CO_2

↳ reduction of livestock farming

The greenhouse effect and global warming:

1) ultraviolet rays from the sun get through the Earth's atmosphere

2) rays hit the Earth's surface
↳ absorbs the rays & heats up

3) Thermal energy is transferred from the Earth's surface as infared rays
↳ can be absorbed by greenhouse gases

4) some of the thermal energy is re-radiated back to the Earth and some escapes into space

global warming: more thermal energy is re-radiated back to Earth and less is lost to space

Reducing environmental pollution:

Reducing sulfur dioxide emissions.

passing it through a spray of calcium oxide/ carbonate/ hydroxide in water

Flue gas desulfurisation:

$$CaO(s) + SO_2(g) \rightarrow CaSO_3(s)$$

calcium oxide sulfur dioxide calcium sulfite

calcium sulfite → reacted with air + water to form calcium sulfate
- ↳ plasterboard
- ↳ making sulfuric acid

- using low-sulfur fuels

Reducing oxides of nitrogen:

↳ formed in car engines

Catalytic converters: fitted to a car exhaust

exhaust gases from the car engine → passed through a 'honeycomb' in a catalytic converter
- ↳ surface covered with a thin layer of catalyst made of platinum/ rhodium/ palladium
- ↳ gases react on the surface of the catalyst

conversion of nitrogen oxides to nitrogen:

$$2NO(g) \rightarrow N_2(g) + O_2(g)$$
$$2NO_2(g) \rightarrow N_2(g) + 2O_2(g)$$

conversion of carbon monoxide to carbon dioxide:

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$

Overall reactions:

$$2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$$
$$2NO_2(g) + 4CO(g) \rightarrow N_2(g) + 4CO_2(g)$$

Clean water:

Dissolved oxygen:

↳ rapidly moving water such as fast-flowing rivers and mountain streams contains more oxygen than lakes and ponds

↳ amount of O_2 in water depends on temperature → warm water dissolves less than cold

water purification

Filtration:

- water passes through metal screens which collect large objects
- water passes through a filter made of sand and gravel/crushed coal → removes any small insoluble particles

Sedimentation: particles of solids (soil particles) fall to the bottom as they're denser than water

Carbon: used to remove bad tastes and bad odours

Chlorine: Kill bacteria (Chlorination)

Water pollution:

pollutants:

- metal compounds
- sewage and harmful microbes
- nitrates and phosphates
- plastics

Ground water → dissolve compounds and remove them from the soil → leaching
- poison aquatic animals
- get into drinking water

untreated sewage containing harmful microbes

fertilisers → eutrophication

plastic in the ocean:

harm aquatic life:
- plastic nets can trap and strangle organisms
- harm digestive system
- plastic trapped in gills → oxygen supply decreases
- chemicals can be poisonous
- tiny particles can get into the blood stream

States of matter:

Solids, liquids + gases:

solid: particles are in fixed arrangements → particles vibrate around in fixed positions

- little kinetic energy
- strong forces between them

liquid: more widely spaced apart → not touching as much

- intermediate forces between them
- vibrate more
- don't have fixed positions

gas: particles are further apart

- large amounts of kinetic energy
- not in fixed positions
- weak forces between the particles

Conversions between the states of matter

solid → liquid = melting

liquid → solid = freezing

liquid → gas = evaporation

gas → liquid = condensation

particles have different kinetic energy

↳ particles with the most amount of kinetic energy → evaporate first → remaining particles have lower kinetic energy

heat gas → particles gain energy → move faster → hit the walls more often → increase in pressure

closed container → condensation + evaporation occur simultaneously

compress gas → pressure increase → particles in smaller space hit walls more often

Heating + cooling graphs

They summarise:

↳ How the temperature of a substance changes when energy is transferred to or away from it

↳ where changes of state occur

Heating: energy is transferred to the substance → Kinetic energy of the molecules increases

cooling: energy is transferred away from the substance (dissipate to the surrounding) → Kinetic energy of the molecules decreases

Heating:

- energy transferred to a solid → temperature increase + particles gain Kinetic energy → vibrate faster
- temperature reaches melting point
  ↳ energy transferred is now used to overcome the intermolecular forces of attraction holding the particles in their solid structure:
    - temperature stops increasing
    - Melting → continues until all the particles have reached the liquid state
- More energy added → temperature of the liquid increases → particles gain more Kinetic energy → move faster
- temperature reaches boiling point
  ↳ energy transferred is now used to overcome the intermolecular forces of attraction holding the particles in their liquid structure:
    - temperature stops increasing
    - evaporation → continue until all the particles have reached the gaseous state

Cooling:

- process → repeated backwards
  - ↳ energy is transferred away:
    - gas → turns back into liquid → condensation
    - liquid → turns back into solid → freezing
- energy transferred away from a gas → temperature decreases → particles lose kinetic energy + move slower
- temperature of the substance → reaches its boiling point
  - ↳ energy transferred away from the substance → taken from the energy used to overcome the intermolecular forces of attraction
    - temperature stops decreasing
    - particles succumb to those intermolecular forces of attraction → held together in their liquid structure → condensing → continue until all the particles have reached the liquid state
- energy transferred away from a liquid → temperature decreases → particles lose kinetic energy + move slower
- temperature of the substance → reaches its melting point
  - ↳ energy transferred away from the substance → taken from the energy used to overcome the

intermolecular forces of attraction

- temperature stops decreasing
- particles succumb to those intermolecular forces of attraction → held together in their solid structure → freezing → continue until all the particles have reached the solid state

Ionic equations:

equation that shows which atoms/ions in a reaction are being reduced + oxidised

$$LiCl + Na \rightarrow NaCl + Li$$

Step 1: write the formula of all ions/atoms

$$Li^+ + Cl^- + Na \rightarrow Na^+ + Cl^- + Li$$

atom so no charge

Step 2: delete the formulae of any spectator ions

Spectator ion = an ion that is not oxidised or reduced during a reaction

↳ charge will not have changed

$$Li^+ + \cancel{Cl^-} + Na \rightarrow Na^+ + \cancel{Cl^-} + Li$$

$$Li^+ + Na \rightarrow Na^+ + Li$$

$$HCl \rightarrow H^+ + Cl^-$$ strong

$$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$$ weak

$CuSO_4 \cdot H_2O$ hydrated copper (II) sulfate

$CuSO_4$ anhydrous copper (II) sulfate

Effect of temperature on a fixed volume of gas:

- Higher temperature → higher kinetic energy → increased pressure
- Lower temperature → less kinetic energy → lower pressure

Diffusion: The random movement of particles from an area of high concentration to an area of low concentration

- passive process → doesn't require energy

examining diffusion using ammonia and hydrochloric acid:

concentrations are high either end of the tube

↳ ammonium chloride is formed → white ring

↳ location of white ring tells us how quickly diffusion is happening

- ring forms much closer to the HCl → ammonia diffused further + faster
- ammonia has a smaller Mr

Atom, mixture, compound

Atom: smallest particle of a substance that can exist

Element: contains only one type of atom - can't be split by any chemical means

Compound: two or more elements chemically combined

Mixture: contains two or more elements or compounds not chemically combined

Atomic structure + the periodic table

molecule: two or more atoms bonded together

nucleus: contains protons + neutrons

Shells → contains electrons

- first shell → maximum of 2
- After → maximum of 8

	mass	charges
proton	1	+1
neutron	1	0
electron	1/2000	-1

atom → uncharged → must have equal numbers of protons + electrons

Atomic number = number of protons

mass number = proton number + neutron number

Neutron number = mass number − Atomic number

Nucleon number = total number of protons + neutrons in the nucleus

Group number = number of the electrons in the outershell

period number = number of shells of electrons

elements in the same group have the same chemical properties because they have the same number of outer shell electrons

Group 0 - noble gases

unreactive → full outer shell of electrons

Isotopes:

atoms of an element with the same number of protons but different number of neutrons

- different mass number
- have the same properties → same number of electrons in outershell
- radioactive / non-radioactive

uses of radioactive isotopes:

- carbon dating using carbon-14
- treating cancer (radiotherapy) with cobalt-60

Ionic bonding:

ion: charged particle formed by atoms either losing or gaining electrons

lose electron → lose negative charge → positive

gain electron → gain negative charge → negative

Ionic bond: metal + non-metal

positive ions — negative ions

- electrostatic attraction between oppositely charged ions

Giant ionic structures: high melting + boiling points

→ strong electrostatic forces

→ require a lot of energy to break

↳ don't conduct electricity when solid

→ ions aren't free to move

↳ conduct when molten

→ ions are free to move to carry the current

↳ Brittle → layers of ions slide → same charge end up next to each other → like charges repel

→ structure breaks apart

Ionic diagram: Sodium chloride NaCl

magnesium fluoride:

Aluminium oxide:

Covalent bonding:

2 non-metals

shared pair of electrons

Water H_2O

Methane CH_4

higher with higher Mr

↳ low melting + boiling point → weak intermolecular forces

↳ soft + relatively flexible

↳ do not conduct electricity → no charged particle capable of transporting electrons

Allotrope: different forms of the same element

Macromolecules:

Diamond:

- giant tetrahedral structure
- each C atom → bonded to 4 others
- many strong covalent bonds

  require a lot of energy to break → high melting point
- doesn't conduct electricity → no free electrons

Graphite:

- each C atom → bonded to 3 others
- many strong covalent bonds

  require a lot of energy to break → high melting point (lower than diamond)
- lubricator. C atoms arranged in weak layers

↳ weak intermolecular forces → little energy to break

- delocalised electron → conduct electricity

Silicon (IV) oxide: sand + quartz

- bonded to 4 oxygen
- oxygen bonded to 2 silicon

hard

very high boiling point

- insoluble in water
- doesn't conduct electricity

This is similar to diamond

Metallic bonding:

electrostatic attraction between positive metal ions and the sea of delocalised electrons

- conduct heat → delocalised electrons → pass on thermal energy easily
- conduct electricity → sea of delocalised electrons → carry the current
- malleable
- ductile

} layers of ions → slide over each other

Moles:

relative atomic mass: The ratio of the average mass of an element when compared with 1 atom of carbon 12

Empirical formulae: simplest ratio of atoms of each element present in a compound CH_2

Molecular formulae: actual number of atoms of each element present in a compound C_3H_6

Empirical vs Molecular Formula

Empirical	Molecular
Simplest whole number ratio of elements	Actual whole number ratio Multiple of Empirical
CO_2	CO_2
H_2O	H_2O
NO_2	N_2O_4
P_2O_5	P_4O_{10}
C_5H_{11}	$C_{10}H_{22}$
C_2H_6O	$C_6H_{18}O_3$

sciencenotes.org

1) A compound containing 40% carbon, 6.73% hydrogen and 53.27% oxygen by mass, determine the empirical formulae

	C	H	O
mass	40	6.73	53.27
Mr	12	1	16
n	3.33	6.73	3.33
÷ smallest	1	2.02	1
	1 :	2 :	1

CH_2O

2) 35.75g of $Na_2CO_3 \times H_2O$ are heated strongly. 13.25g remain after heating. Calculate x

	Na_2CO_3	H_2O
mass	13.25	22.5
Mr	106	18
n	0.125	1.25
÷ smallest	1	10
	1 :	10

x=10

3) 3.3g HCl reacted with Na_2CO_3. Calculate the mass + volume of CO_2 collected

$$2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2$$

	2HCl	CO_2
mass	3.3g	X
Mr	36.5	44
n	0.0904...	0.0904÷2 = 0.045205

mass of CO_2: 44×0.045...
=1.98904 = 2.00g

1 mol of gas: 24 dm^3
0.045×24 = 1.08 dm^3

4) 3.2g of copper reacted with 0.4 mol of nitric acid. Which regeant is in excess?

$$Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2H_2O + 2NO_2$$

	Cu	$4HNO_3$
mass	3.2	X
Mr	63.5	
n	0.05	0.05x4 = 0.2

we have 0.4 mol of nitric acid but we only need 0.2 mol

nitric acid is in excess

5) In a reaction, 11.2g of copper sulfate was obtained when theoretically 12.5g should have been obtained. Calculate the percentage yield

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

$$\frac{11.2}{12.5} \times 100$$

$$= 89.6\%$$

6) A student reacted 2.4g of copper oxide with sulfuric acid. She made 1.8g of copper sulfate. Calculate the % yield.

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$

	CuO	$CuSO_4$
mass	2.4	X
Mr	79.5	159.5
n	0.0302	0.0302

$$\frac{1.8}{4.8169} \times 100 = 37\%$$

$$X = 159.5 \times 0.0302$$

$$= 4.8169g \rightarrow \text{theoretical yield}$$

Titration calculations:

1) 25 cm^3 of 2.0 mol/dm^3 HCl reacted with 30 cm^3 of NaOH. Calculate the concentration of NaOH

$$NaOH + HCl \rightarrow NaCl + H_2O$$

	NaOH	HCl
n	0.05	2×0.025 = 0.05
c	x	2
v	$\frac{30}{1000}$	$\frac{25}{1000}$

$x = 0.05 \div 0.030 = 1.67$

$= 1.67$ mol/dm^3

The Avogrado constant: 6.02×10^{23}

number of atoms of molecules $\xleftarrow{\times 6.02 \times 10^{23}}$ moles $\xrightarrow{\times Mr}$ mass (g)

number of atoms of molecules $\xrightarrow{\div 6.02 \times 10^{23}}$ moles $\xleftarrow{\div Mr}$ mass (g)

1) calculate the amount in mol of H_2O in a sample of 2.30×10^{23} molecules

$$n(H_2O) = \frac{2.30 \times 10^{23}}{6.02 \times 10^{23}} = 0.382 \text{ mol}$$

2) calculate the number of oxygen atoms contained in 3 mols of glucose, $C_6H_{12}O_6$

no. of molecules $= 3 \times 6.02 \times 10^{23} = 1.806 \times 10^{24}$

$1.806 \times 10^{24} \times 6 = 1.08 \times 10^{25}$

6 of oxygen

Redox.

oxidation state → allow us to identify what has been oxidised + what has been reduced

oxidation state rules.

1) elements not combined with other elements have an oxidation state of 0:

O_2, P_4

2) The oxidation number of an uncombined ion is the same as its charge:

Na^+, Ca^{2+}

3) The sum of all the oxidation numbers in a molecule is 0:

H_2O, CO_2, HCl

In a complicated ion, the sum of oxidation numbers is equal to the charge of the ion

SO_4^{2-}, NO_3^-

4) Hydrogen = 1 (exception: hydrogen combined as a metal hydride, oxidation number = -1

5) Fluorine = -1

6) oxygen = -2

exceptions: · in peroxides = -1 H_2O_2

· combined with fluorine = +1

7) Cl = -1

exceptions: · combined with fluorine = positive

· combined with oxygen = positive

8) For groups 1, 2, 3 the oxidation number is the same as the group numbers:

Na^+ = +1

Examples:

① $4Na_{(s)} + O_{2(g)} \rightarrow 2Na_2O_{(s)}$

rule 1: oxidation state 0

rule 8: oxidation state 1

rule 6: oxidation state -2

sodium went from 0 to +1 → lost electrons → oxidised

it is a reducing agent → caused oxygen to be reduced

② $CuO_{(s)} + H_{2(g)} \rightarrow Cu_{(s)} + H_2O_{(l)}$

rule 3: +2

rule 1: 0

rule 6: -2

rule 1: 0

rule 3: +1

+1 not +2 because there are 2 hydrogens

Copper went from +2 to 0 → gained electrons → acts as an oxidising agent

hydrogen went from 0 to +1 → lost electrons → acts as an reducing agent

Redox reactions:

oxidation: gain of oxygen → $4Al + 3O_2 \rightarrow 2Al_2O_3$ loss of electrons

reduction: loss of oxygen → $2Al_2O_3 \rightarrow 4Al + 3O_2$ gain of electrons

redox reactions → involving simultaneous oxidation and reduction

↳ one substance loses an electron, another substance gains it

individual half equation: show gain and loss of electrons

$Cu \rightarrow Cu^{2+} + 2e^-$ loses 2

$Fe^{2+} + 2e^- \rightarrow Fe$ gains 2

check that the overall charge on each side balances

oxidising agent: A substance that oxidises another substance and is itself reduced
↳ gains / accept an electron from a reducing agent → halogens, oxygen
reducing agent: A substance that reduces another substance and is itself oxidised
↳ donates an electron to an electron recipient → metals

Electrolysis:

↳ the decomposition (break down) of an ionic compound when molten or in an aqueous solution by the passage of an electric current

What makes a good conductor of electricity?
↳ low resistance to the passage of electricity
↳ metals due to delocalized mobile electrons
↳ aluminium. low density, resistant to corrosion

copper → very good conductor of electricity

Electrolysis Cell Diagram

- voltage provided by a direct current power supply

- electrolyte: molten / aqueous ionic compound that conducts electricity and decomposes during electrolysis

Electrodes properties:
↳ good electrical conductors
↳ inert: do not react
↳ graphite / platinum
↳ cheaper than platinum

Electrodes: rods that carry the electric current to and from the electrolyte

ions have to be able to move around so its either molten or aqueous

The products of electrolysis:

In a circuit, when the lamp lights it shows that an electric current is flowing because the ions in the molten electrolyte are able to move to the electrodes

Electrolysis of dilute sulfuric acid H_2SO_4 (aq)

- bubbles of gases at both electrodes
- oxygen → anode
- hydrogen → cathode

There is a pattern:

when the electrode decomposes .

↳ metal is found at the cathode → negative electrode attract positive charge

↳ non-metal forms at the anode → positive electrode attract negative charge

Electrolysis of aqueous solutions:

Reactivity series:

- potassium
- sodium
- lithium
- calcium
- magnesium
- carbon
- zinc
- iron
- hydrogen
- copper

If any ions above hydrogen is present, hydrogen would be discharged because it is less reactive

If its copper, it would be the one discharged because it is less reactive than hydrogen

cathode

The ion of the least reactive element will be discharged

Anode

If a halide is present, it will be the one that gets discharged

Experiment:

concentrated solution of NaCl (aq)

In concentrated solutions of ionic compounds in water → greater variety of ions than in molten ionic compounds

↳ aqueous compounds have H_2O so there is H^+ and OH^- ions

possible products:

- concentrated NaCl (aq): anode → chlorine
- moderately concentrated NaCl (aq): anode → chlorine and oxygen
- very dilute NaCl (aq): anode → mainly oxygen with a little chlorine

done in a fume cupboard because chlorine is poisonous

Explaining electrolysis:

- electrons move from the negative pole of the battery to the cathode and towards the positive pole from the anode
- electrons lost from cathode, gained at the anode

In molten/aqueous ionic compounds → ions are free to move around within the liquid

Electricity current applied → cations move towards the cathode

→ anions move towards the anode

ions reach the electrode → gain or lose electrons

loss of electrons: oxidation gaining electrons: reduction

Metal ions → gain electrons

non-metals → lose electrons

important half equations:

$2H^+ (aq) + 2e^- \rightarrow H_2 (g)$

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

purifying copper:

done to make copper more pure so they aren't too brittle and conduct electricity well

- impure strip of copper → anode
- Thin pure strip of copper → cathode
- electrolyte → solution of copper (II) ions usually copper (II) sulfate solution

1) At the impure copper anode, copper atoms are oxidised → go into solution as electrolyte:

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

2) At the pure copper cathode, copper ions are reduced and becomes copper atoms → deposited on the strip of pure copper:

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

3) cathode → thicker as it gains more copper

4) overtime the cathode of pure copper is removed and replaced

5) anode → lose mass → impurities fall to the bottom (anode sludge)

6) valuable materials such as gold and platinum can be extracted from the anode sludge

pure copper is transferred from the anode to the cathode

Effect of changing the electrodes:

Electrolysis with inert electrodes:

Anode → can't lose electrons, hydroxide ions discharged, oxygen gas bubbles off:

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

Cathode → copper ions discharged, copper metal deposited:

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

electrolyte → loses blue colour → blue copper ions are turning to copper atoms at the cathode but are not being replaced in the solution at the anode

Electrolysis with copper electrodes:

Anode → loses electrons, copper ions go into solution, anode gets smaller:

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

cathode → copper ions discharged, copper metal deposited:

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

electrolyte → remains the same deep blue colour → copper ions are removed from the solution at the cathode, they are replaced by the copper ions formed at the anode

Electroplating:

used to put a thin layer of one metal on top of another metal using electrolysis

object to be electroplated → cathode

↳ object can be anything made of metal

↳ must be clean so the cover does not flake off

plating metal → anode

electrolyte → solution of an ionic compound of the plating metal

Electroplating with silver:

1) At the anode, silver atoms lose electrons (oxidised) and become silver ions which go into solution: $Ag(s) \rightarrow Ag^+(aq) + e^-$

2) silver ions move to cathode, gain electrons (reduced) to become silver atoms:

$Ag^+(aq) + e^- \rightarrow Ag(s)$

3) Forms a thin layer of silver on the surface of the object

Uses of electroplating.

1) protection of metal from corrosion

2) improving their appearance

Tin → protects the metal underneath from air and water so it doesn't rust

Chromium → shiny surface for jewellry, cutlery, electronics

Extracting aluminium:

Aluminium is found in the mineral ore → bauxite → 50-60% Al_2O_3 (Sometimes called alumina)

1) purify the ore → crushed and mixed with sodium hydroxide → Al_2O_3 dissolves

$$Al_2O_3(s) + 2NaOH(aq) \rightarrow 2NaAlO_2(aq) + H_2O(l)$$

2) impurities → insoluble and are filtered off

3) Sodium aluminate undergoes further treatment → heated to make pure aluminium oxide

1) electrolysis carried out in shallow cells

2) Aluminium oxide is dissolved in large amounts of molten cryolite

3) melting point of the electrolyte is much lower compared with pure aluminium oxide

↳ improves the electrical conductivity

4) carried out using carbon (graphite) electrodes

overall equation: $2Al_2O_3 \rightarrow 4Al + 3O_2$

Cathode → carbon lining of the steel cell

↳ Aluminium ions gain electrons → reduced to aluminium metal

molten aluminium falls to the bottom → removed over time by siphon tube

$Al^{3+} + 3e^- \rightarrow Al$

Anode → several, raised/lowered, high current → decompose and keep electrolyte molten

↳ oxide ions lose electrons → oxidised to oxygen → react with hot carbon anodes → form CO_2 gas carbon burns over time (wears off) → need to be replaced from time to time

$2O^{2-} \rightarrow O_2 + 4e^-$

Fuel cells:

Cathode → hydrogen loses electrons and forms hydrogen ions in the electrolyte

$2H_2(g) \rightarrow 4H^+(aq) + 4e^-$

Anode → oxygen gains electrons and reacts with hydrogen ions from the acid electrolyte

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

The hydrogen ions removed at the positive electrode are replaced by those produced at the negative electrode → concentration of the electrolyte remains constant

overall reaction: $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

Advantages:

- water is the only product
- transfer more energy per gram of fuel than gasoline
- higher efficiency than gasoline
- silent when engine is running
- not as big as gasoline engines

Disadvantages:

- more expensive
- hydrogen is expensive to produce
- hydrogen is highly flammable
- very few hydrogen filling points at garages

Ea

Energetics

exothermic: heat energy is released — Bond making

↳ more energy is needed to make the bonds in the products than is needed to break the bonds in the reactants

endothermic: heat energy is taken in — Bond breaking

↳ more energy is needed to break the bonds in the reactants than is needed to make the bonds in the products

Activation energy: the minimum amount of energy required for a reaction to occur

Catalysts → provide an alternative reaction pathway with lower activation energy

↳ not used up by the reaction

* During a chemical reaction reactant is being converted to product

Diagrams:

Energy is taken in from surroundings

endothermic:

$+\Delta H$

exothermic:

$-\Delta H$

Energy is lost to surroundings

Bond breaking + bond forming:

Bond breaking: endothermic process

↳ energy needs to be taken in from the surroundings to break the chemical bonds

Bond making: exothermic process

↳ energy is transferred to the surroundings as the new bond is formed

Exothermic:

- more energy is released than is absorbed
- more energy is released when new bonds are formed than energy required to break the bonds in the reactants

change in energy → negative products have less energy than the reactants

$-\Delta H$ $H_{(reactant)} - H_{(product)}$

Endothermic:

- more energy is absorbed to break bonds than is released to form new bonds
- change in energy → positive products have more energy than the reactants

$+\Delta H$

H → symbol for enthalpy

endo = bond breaking

mixing dissolving burning gas

physical + chemical change:

differences:

- physical change don't make new substances
- chemical change take in/give out energy
- chemical change → harder to reverse

signs of a chemical reaction:

irreversible

- color change
- precipitate formed
- bubbles of gas produced

Rates of reaction:

1) increasing temperature:

- increase rate of reactions
  - ↳ particles have more kinetic energy to overcome the activation energy
  - ↳ collisions occur more frequently + harder
  - ↳ increased successful collisions

2) increased concentration:

- increase rate of reactions
  - ↳ more particles in the same volume
  - ↳ increased frequency of collisions

changing pressure of gas

frequency of collisions ↑

3) larger surface area:

- increase rate of reactions
  - ↳ increased frequency of collisions

none of these lower the activation energy, only a catalyst is capable of doing that

Acids + bases:

Acids: donate H^+, proton donor

pH ≤ 6

- turn litmus indicator red
- universal indicator:
  - turn red in a strong acid
  - orange → medium acid
  - yellow → weak acid
- methyl orange → pink / red

Metal + acid → salt + hydrogen

metal oxide / hydroxide + acid → salt + water

Metal carbonates + acid → salt + water + carbon dioxide

ammonia + acid → ammonium salt

Bases: H^+ acceptors, proton acceptors

OH^- pH ≥ 8

- turn litmus indicator blue
- universal indicator → blue / purple
- methyl orange → yellow

Base + acid → salt + water

COLOURS OF pH INDICATORS

Thymolphthalein

Alkali + Base

↓

soluble base

All alkalis are bases

Not all bases are alkalis

Indicator	Colour in acid	Colour in alkaline	Colour in neutral
Litmus solution	Red	Blue	Purple
Litmus paper: red	Stays red	Turns blue	No change
Litmus paper: blue	Turns red	Stays blue	No change
Methyl orange	Red	Yellow	Orange
Phenolphthalein	Colourless	Pink	Colourless

pH 7 is neutral

above that is basic

below that is acidic

Copyright © Save My Exams. All Rights Reserved

Strong + weak acid:

Strong: contains lots of H^+ ions → readily dissociate / ionise

HCl (strong acid) → easily give out H^+

weak: H^+ ions → don't readily dissociate

stay combined with other ions

CH_3COOH → weak

Acids in solution can carry current due to H^+ ions

strong → contains more H^+ ions → can carry more currents

Strong + weak bases:

Strong: readily dissociate, carry much larger current

weak: not readily dissociate

Base + ammonium salt → salt + ammonia + water

Oxides:

Acidic oxides:

- non-metals react with oxygen to make acidic oxides (carbon dioxide)
- CO_2 dissolves in water → carbonic acid

Basic oxides:

- metals react with oxygen to make basic oxides
- can neutralise acid

(copper (II) oxide)

Amphoteric oxides:

- can be both acidic + basic
- will react with both acids + bases

Aluminium oxide $(Al)_2O_3$ zinc oxide (ZnO)

Neutral oxides:

- neither acidic or basic
- will not react with either acid or base

(carbon monoxide)

Salts:

A salt is formed when the hydrogen of an acid is replaced by a metal or ammonium

- only metals above hydrogen in the reactivity series will react with acids → copper, silver, gold will not react
- elements at the top of the reactivity series → potassium, sodium + lithium → react extremely explosively

Solubility rules:

Soluble:

1) All nitrates are soluble
2) All sodium, potassium + ammonium compounds are soluble
3) All group 1 elements are soluble
4) All sulfates are soluble

   EXCEPT:

   - lead (II) sulfate
   - Barium sulfate
   - calcium sulfate

5) All chlorides are soluble

   EXCEPT:

   - lead (II) chloride
   - silver chloride

insoluble:

1) All carbonates are insoluble

   EXCEPT:

   - sodium carbonate
   - potassium carbonate
   - ammonium carbonate
   - lithium carbonate

2) All hydroxides are insoluble

   EXCEPT:

   - sodium hydroxide
   - potassium hydroxide
   - ammonium hydroxide

Methods of preparing salts.

1) Soluble salt: Crystallisation

↳ Metal oxide/hydroxide/carbonate

↳ acid

- react with acid
  (can also use metal + acid)
- Filter excess
- Evaporate some water (evaporating basin)
- cool → allow for crystals to form
- dry → allow the crystals to dry in a warm place or on filter paper

2) ammonium, sodium + potassium salt: titration

- can't use crystallisation: they are extremely soluble → would react to both acid + water → continuosly dissolve away → nothing to evaporate
- set up burette with an acid, alkali in conical flask
- use an indicator in conical flask (methyl orange / thymolphthalien)
- close burette when indicator starts to change color
- repeat without an indicator
- Evaporate some water (evaporating basin) → concentrates the solution
- cool → allow for crystals to form
- dry → allow the crystals to dry in a warm place or on filter paper

3) insoluble salt: react 2 soluble salts → precipitation

- react → mix 2 soluble salts together
- Filter any excess solid
- wash the solid
- dry in a warm place or on filter paper

Silver nitrate + sodium chloride:

silver nitrate solution → Ag^+ + NO_3^- are attracted weakly

sodium chloride → Na^+ + Cl^- are attracted weakly

mix 2 solutions → 4 ions mix together

Ag^+ + Cl^- attract strongly → forming AgCl

Na^+ + NO_3^- attract weakly + remain in solution

hydrated substance: A substance that is chemically combined with water

Anhydrous substance: A substance containing no water

water of crystallisation: The water molecules present in hydrated crystals

The decomposition of nitrates:

G1 metal: $KNO_3 \longrightarrow KNO_2 + O_2$

Non G1 metal: $Ca(NO_3)_2 \longrightarrow CaO + NO_2 + O_2$

only Ag: $AgNO_3 \longrightarrow Ag + NO_2 + O_2$

only Ag

THERMAL DECOMPOSITION

G1 *

NO_3^- nitrate

NO_2^- nitrite

periodic table:

metals - left

non-metals - right

Transition metals - middle

valency = no. of outershell electrons

Group 1 elements: alkali metals

more reactive when you descend

- atoms are larger → have more shells of electrons
- outer shell electron → further from nucleus + more easily lost

↳ extremely reactive → stored in oil

- react with H_2O + O_2

↳ soft - can be cut with a knife

↳ oxidise when cut

↳ low melting + boiling point

↳ low density → float on water

↳ react with O_2 to form oxides

↳ react with cold H_2O to form hydroxides

↳ can partake in ionic bonding

Observation in water:

- fizz → releases H_2
- float
- dissolve
- universal indicator turns blue

lilac

Metal + water → metal hydroxide + hydrogen

Burn in air

Alkaline solution

down the group

- increasing softness
- density increase
- melting point decrease
- rate of reaction with H_2O increase

Group 2 elements: Alkali earth metals

more reactive when you descend

- atoms are larger → have more shells of electrons
- outer shell electron → further from nucleus + more easily lost

overall harder than the alkali metals

4	Be
	beryllium
9	
12	Mg
	magnesium
24	
20	Ca
	calcium
40	
38	Sr
	strontium
88	
56	Ba
	barium
137	
88	Ra
	radium
–	

Group 2 elements react to form 2+ ions

· All metals except for magnesium is stored in oil

reactions: $2Mg + O_2 \rightarrow 2MgO$ combustion of Mg: bright white flash

$Mg + H_2O \rightarrow MgO + H_2$ Mg only reacts with steam, not cold water

reactions: $2Ca + O_2 \rightarrow 2CaO$ combustion of calcium: red flame

$Ca + H_2O \rightarrow Ca(OH_2)$ limewater

cold water

Reaction of calcium with water is more vigorous than magnesium

↳ calcium with cold water sinks, effervescence produced

Group 2 metals below calcium reacts the same way calcium does with an increased reactivity

Beryllium is the only group 2 metal that doesn't react with water

down the group

- increasing softness
- density increase
- melting point decrease
- rate of reaction with H_2O increase

Group 7 elements: Halogens

States at room temperature:

- F_2 + Cl_2 = gases
  - ↳ yellow gas
  - ↳ green gas
- Br → red/brown liquid
- Iodine → grey solid to purple gas during sublimation

↳ react with hydrogen to form hydrogen halides:

hydrogen + bromine → hydrogen bromide

↳ acidic + soluble in water

more reactive halogen will displace less reactive halogens

top = most reactive

↳ bottom → outershell electrons are further from the nucleus

→ harder to gain extra electron

	Chlorine (Cl_2)	Bromine (Br_2)	Iodine (I_2)
Potassium chloride (KCl)	X	No reaction	No reaction
Potassium bromide (KBr)	Chlorine displaces the bromide ions. Yellow–orange colour of bromine is seen	X	No reaction
Potassium iodide (KI)	Chlorine displaces the iodide ions. Brown colour of iodine is seen	Bromine displaces the iodide ions:. Brown colour of iodine is seen	X

Displacement equations:

$Cl_2 + 2KBr \rightarrow 2KCl + Br_2$

$Br_2 + 2KI \rightarrow 2KBr + I_2$

ionic:

$Cl_2 + 2K^+ + 2Br^- \rightarrow 2K^+ + 2Cl^- + Br_2$

$Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$

properties:

- low boiling point
- low melting point
- poor conductors of electricity + heat

Diatomic non-metals

Trend in color – gets deeper down group

Trend in density – increases down group

Reactivity decreases down the group

Transition metals:

physical properties:

- good conductors of heat + electricity
- malleable + ductile
- high melting points
- hard + tough
- high densities

differences from group 1:

- high melting point
- hard
- high density

Chemical properties:

- less reactive than alkali metals
- form colored compounds
  often act as catalysts
- have variable oxidation states

Noble gases: group 8/0

- unreactive
- monoatomic
- gases
- have full outer electron shells

uses:

- providing inert atmosphere
- Argon in lamps
- Helium in balloons

Water:

physical test: check boiling point → boils at 100°c

chemical test:

1) anhydrous copper (II) sulfate → white to blue
2) anhydrous cobalt (II) chloride → blue to pink

paper 6 notes:

Apparatus

Advantage of measuring cylinder: fast measurement

Disadvantage of measuring cylinder: not accurate

Advantage of pipette: very accurate

Disadvantage of pipette: slow

Burettes: measure many volumes

pipette: fixed volume

Separation techniques:

Filtration: insoluble solid from liquid

Distillation: solvent from solution

Fractional distillation: separate mixture of miscible liquids according to their boiling points

Crystallisation: soluble solid from solutions

Chromatography: separation + identification of sugars, dyes, pigments and amino acids

Chromatography:

cover beaker with lid in case of a volatile solvent

spot hasn't moved = substance is insoluble in the solvent

change the solvent

level of solvent always below the baseline

base line drawn with pencil

ink will dissolve in the solvent

if 2 spots have the same RF value they are the same substance

Fractional distillation:

upper → water out

lower → water in

Oil bath because 1 or more liquid has a higher B.P than H_2O

Sources of error:

1) use a polystyrene cup instead of a beaker
2) use a pipett/burette instead of measuring cylinder to measure the volume
3) repeat + take the average

Safety precautions:

- Gloves
- lab coat
- fume cupboard
- goggles
- electric heater instead of direct flame in heating alcohols

Appearances:

- All metals are grey
- copper is brown
- copper oxide is black
- copper salts are blue except copper carbonate is green
- mineral acids + alkalis → colorless solutions
- Hydrocarbons burn with a smoky flame
- Nitrogen dioxide is a brown gas

Writing an experiment:

↳ write all steps including all the tools used
↳ write all the variables that should be kept constant
↳ principle that you will use to measure the result
↳ general conclusion
↳ calculations → write the formula
↳ equation if any