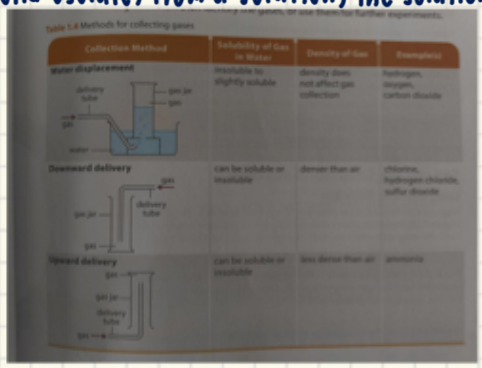
1. Experimental chemistry

experimental design:
- mass (kg)
  → beam balance, electronic balance
- time (s)
  → stopwatch
- temperature (°C)
  → thermometer
- volume (cm^3)
  → measuring cylinder
  → burette (2d.p.) → nearest $0.05\ cm^3$
  → pipette (1d.p.) → $20.0\ cm^3$, $25.0\ cm^3$
  → gas syringe

methods of purification and analysis:
- filtration } solid - liquid
- evaporation
- crystallisation
- fractional distillation } liquid - liquid
- simple distillation
- paper chromatography
- pure substances
  → fixed m.p. & b.p.
- impure substances
  → m.p. & b.p. over a range of temperatures

crystallisation:
- when a sugar solution is strongly heated, the sugar burns and breaks down into a black solid. Therefore, sugar cannot be separated from its solution by evaporation. Some solutes (dissolved solids) may decompose or break down into simpler substances when heated.
- used to obtain a pure solid from its saturated solution

evaporation to dryness:
- substance with a lower boiling point will turn into a gas first, leaving the other substance behind. In the case of seawater, the solvent has a lower boiling point than the solute. The difference in boiling points can be used to separate the dissolved solute from the solvent.
- To obtain the dissolved solid (solute) from a solution, the solution can be heated in an evaporating dish until all the liquid (solvent) evaporates. The solid will be left behind.
- used to separate a dissolved solid from its solvent by heating the mixture until all the solvent has vaporised.



2. Kinetic Particle Theory

	solid	liquid	gas
arrangement	- very closely packed - orderly arrangement	- quite closely packed - disorderly / irregular arrangement	- very far apart - disorderly / irregular arrangement
movement	- vibrate about fixed positions	- slide over one another	- move randomly in all directions at high speeds
forces of attraction	- very strong	- strong	- weak (negligible)

3. Atomic Structure

	proton	neutron	electron
relative mass	1	1	1/1840
relative charge	+1	0	-1
location	nucleus	nucleus	electron shell

arrangement of electrons:
1st shell: 2 electrons
2nd shell: 8 electrons
3rd shell: 8 electrons

proton number = number of protons in an atom
mass number = total number of protons & neutrons in an atom

element: substance that cannot be broken down into simpler substances
compound: 2 or more elements chemically combined
mixture: 2 or more substances physically combined → element / substance
isotope: atoms of the same element with the same number of protons but different number of neutrons
atom: smallest particles of an element that have the chemical properties of that element
molecule: 2 or more atoms that are chemically combined

4. Chemical bonding

Ionic compound (metal + non-metal)
→ high m.p. / b.p.
→ conducts electricity in molten and aqueous states only! → NOT solid
→ soluble in water
→ insoluble in organic solvents

Covalent compound (non-metal + non-metal)
→ low m.p. & b.p.
→ cannot conduct electricity in ALL states
→ insoluble in water
→ soluble in organic solvents

	ionic	covalent
particles	- oppositely-charged particles	- molecules
FOA	- strong electrostatic FOA	- weak intermolecular FOA
structure	- giant ionic lattice structure	- simple molecular structure

charged particles that conduct electricity:
- ions
- electrons → sub-atomic particle

5. Structure and properties of materials

properties of metals and alloys:
- malleable and ductile [all metals, some alloys]
- good conductors of electricity
- good conductors of heat
- high density
- high m.p. & b.p.
- insoluble

e.g. metals: Cu, Fe, Zn
alloys: brass, bronze, stainless steel

6. Chemical formulae and equations

polyatomic ions

OH^-	hydroxide	NH_3	ammonia
NO_3^-	nitrate	$Cu(SO_4)_2$	copper sulfate
SO_4^{2-}	sulfate	$NaOH$	sodium hydroxide
CO_3^{2-}	carbonate	CH_3COOH	ethanoic acid
PO_4^{3-}	phosphate		
NH_4^+	ammonium		

7. Mole concept

Ar: average mass of an atom of an element compared to $^1/_{12}$ of an carbon-12 atom

Mr: average mass of a molecule of a substance compared to $^1/_{12}$ of an carbon-12 atom

Formulas:

mass = mol x Mr

vol. = mol x 24 (dm^3)

$\frac{mass}{vol.}$ = conc. (g/dm^3)

$\frac{mol}{vol.}$ = conc. (mol/dm^3)

particles: 6×10^{23}

Steps to construct ionic eqns.:
1. ensure that the eqn. has state symbols
   → (aq) / (g) / (l) / (s)
2. solid, liquid and gaseous species should be left as they are
3. cancel the ions that appear on both sides

8. Acids and bases

acid: a substance that produces H^+ ions when dissociated in water

alkali: a soluble base that produces OH^- ions when dissociated in water

base: a metal oxide / metal hydroxide that reacts with acid to form salt and water only

Strong acids vs weak acid: [same for alkali]

strong acid: dissociates completely in water to produce $H^+(aq)$ ions

weak acid: dissociates partially in water to produce $H^+(aq)$ ions

properties of acid:
- sour taste
- pH < 7
- turns moist / damp blue litmus paper red
- conducts electricity
- corrosive when concentrated

3 strong acids:
- HCl - hydrochloric acid
- HNO_3 - nitric acid
- H_2SO_4 - sulfuric acid

weak acid:
- ethanoic acid

properties of alkali:
- bitter taste
- pH > 7
- turns moist / damp red litmus paper blue
- conducts electricity
- corrosive when concentrated

reactions:
- acid + metal → salt + hydrogen (H_2)
- acid + base → salt + water
- acid + carbonate → salt + water + carbon dioxide
- alkali + ammonium salt → salt + water + ammonia gas ($NH_3(g)$)

Oxides

basic (oxides of most metals)
- Na_2O, MgO, Fe_2O_3
- can react with acids

amphoteric
- ZnO, Al_2O_3, PbO (ZAP)
- can react with acids & alkali

acidic (oxides of most non-metals)
- CO_2, SO_3, NO_2
- can react with alkalis

neutral
- NO, CO, H_2O
- does not react with anything

common uses:

H_2SO_4 (sulfuric acid): to manufacture agricultural fertilisers, to produce dyes and paints

alkali:
- neutralise acids
- dissolved grease (soaps, flour, etc.)
- control pH in soils

9. Qualitative Analysis

cation test:

ion	$NaOH_{(aq)}$	$NH_{4(aq)}$
Ca^{2+}, calcium	- white ppt. - insoluble in excess	- no observable change
Al^{3+}, aluminium	- white ppt. - soluble in excess	- white ppt. - insoluble in excess
Zn^{2+}, zinc	- white ppt. - soluble in excess	- white ppt. - soluble in excess
Cu^{2+}, copper	- light blue ppt. - insoluble in excess	- dark blue ppt. - soluble in excess, giving a dark blue solution
Fe^{2+}, iron(II)	- green ppt. - insoluble in excess	- green ppt. - insoluble in excess
Fe^{3+}, iron(III)	- red-brown ppt. - insoluble in excess	- red-brown ppt. - insoluble in excess
NH_4^+, ammonium	- ammonia produced on warming	

anion test:

ion	test	result
CO_3^{2-}, carbonate	- add dilute acid	- effervescene observed - gas evolved gives white ppt. in limewater - carbon dioxide is present
NO_3^-, nitrate	- add $NaOH_{(aq)}$, then aluminium foil and warm gently	- gas evolved turns moist/damp red litmus paper blue - ammonia is produced
SO_4^{2-}, sulfate	- acidify with dilute nitric acid, then add aqueous barium nitrate	- white ppt.
Cl^-, chloride	- acidify with dilute nitric acid, then add aqueous silver nitrate	- white ppt.

gases test:

gas	colour & odour	test & results
H_2, hydrogen	- colourless - odourless	- gas evolved 'pops' a lighted splint
O_2, oxygen	- colourless - odourless	- gas evolved relights a glowing splint
CO_2, carbon dioxide	- colourless - odourless	- gas evolved gives white ppt. in limewater
NH_3, ammonia	- colourless - pungent	- gas evolved turns damp red litmus paper blue
Cl_2, chlorine	- greenish-yellow - pungent	- gas evolved bleaches damp litmus paper
SO_2, sulfur dioxide	- colourless - pungent	- gas evolved turns aqueous acidified potassium manganate(VII) from purple to colourless

10. Oxidation and reduction

oxidation +-+-
SHOE
reduction -+-+

Oxidation states:
$Br_2 = 0$
$Br^- = -1$
$Mg^{2+} = +2$
$Na^+ = +1$
$Mg = 0$

Oxidising agent:
- oxidise another substance
- increase the oxidation state of an element in another substance
- gain electrons from other substances
  → causes oxidation, while being reduced

Reducing agent:
- reduce another substance
- decrease the oxidation state of an element in another substance
- lose electrons to other substances
  → causes reduction, while being oxidised

11. The Periodic Table
- Elements are arranged in order of increasing proton number
  Period: same number of electron shells
  Group: same number of valence electrons

Group I elements : Alkali Metals
- m.p./b.p. decreases down the group
- reactivity increases down the group
- reacts easily in air
- soft and can be cut
- good electrical conductor

metal + water → metal hydroxide + hydrogen

Group 17 elements : Halogens
- m.p./b.p. increases down the group
- reactivity decreases down the group
- exist as diatomic covalent molecules
- colour intensity becomes darker down the group

metal + steam → metal oxide + hydrogen (H_2)

displacement:
- more reactive halogen displaced a less reactive halogen from its aqueous solution
  e.g. $Cl_2 + 2KI \rightarrow I_2 + 2KCl$ (Cl more reactive than I)
  e.g. $Cl_2 + 2KF \rightarrow$ no reaction (Cl less reactive than F)

element	colour	state
fluorine	pale yellow	gas
chlorine	yellow-green	gas
bromine	reddish-brown	liquid
iodine	purplish-grey	solid
astatine	shiny black	solid

Group 18 elements: Noble gases
- stable electronic configuration
- colourless gas at r.t.p.
- low m.p. & b.p.
- insoluble in water

12. The reactivity series

reactivity increases ↑

K	Potassium	reacts with cold water ✓
Na	Sodium	reacts with steam ✓
Ca	Calcium	reacts with acid ✓
Mg	Magnesium	
Al	Aluminium	cold water ✗
C	Carbon	steam ✓
Zn	Zinc	acid ✓
Fe	Iron	
Pb	Lead	acid ✓
H	Hydrogen	cold water ✗
Cu	Copper	steam ✗
Ag	Silver	acid ✗

Conditions for rusting:
- presence of both oxygen (in air) and water are necessary for rusting to occur

rust preventation:
- painting
- oiling / greasing
- coating with plastic

13. Chemical Energetics

Endothermic:
- absorb the heat from the surroundings
- temp. of surroundings ↓

endothermic reactions and processes:
- thermal decomposition
  e.g. heating of calcium carbonate forms carbon dioxide and calcium oxide)
- photosynthesis
- boiling
- melting
- sublimation
- dissolution of some ionic compounds
  e.g. NaCl, NH_4Cl, $Ba(NO_3)_2$ in water

Exothermic:
- release heat to the surroundings
- temp. of surroundings ↑

exothermic reaction and processes:
- combustion
- neutralisation
- respiration
- freezing
- condensation
- dissolution of acid and alkali in water.

14. Rate of reactions

can be measured by:
- the volume of gas produced over time
- the change in the mass of a reactant / product over time

determined by:
- effective collisions

factors affecting ROR:
→ collisions
→ pressure [gases only]
→ temperature
→ particle size
→ particle size ↓, surface area for collisions ↑

15. Fuels and crude oils

- Fuels undergo combustion, which is an exothermic reaction

Fuels → can be → renewable → e.g. biofuels → comes from plants / animals
- e.g. bioethanol
  - made from sugarcane
  - more environmentally stable

non-renewable → e.g. fuels and crude oils → contains hydrocarbons → example
- crude oil → seperated by fractional distillation
- natural gas → made up of mainly methane

Natural gas:
- methane 93.1%
- ethane 3.4%
- nitrogen 2.3%
- propane 1.2%

16. Hydrocarbons

homologous series : a family of similar organic molecules with a general formula

functional group: a group of atoms responsible for the characteristics and reactions of a particular compound

hydrocarbon: a compound that contain carbon-carbon double bonds

Organic compound in the same homologous series:
- same general formula
- similar chemical properties
- gradual change in their physical properties when going down the series

prefixes	no. of carbon atoms
meth-	1
eth-	2
prop-	3
but-	4

suffix	homologous series
-ane	alkane
-ene	alkene
-ol	alcohol
-oic acid	carboxylic acid

properties of a homologous series:
- same functional group and general formula
- similar chemical properties
- b.p. increases down the group

Alkanes are a homologous series of hydrocarbon that contain only hydrogen and carbon atoms.

general formula: C_nH_{2n+2}

- Alkanes are called saturated hydrocarbons because they contain only carbon - carbon single bonds
- Alkanes are generally unreactive

2 kinds of chemical reactions:

1. combustion (excess oxygen)
   → produces CO_2 + H_2O
2. substitution
   → alkanes can react with halogens in the presence of UV light

→ unsaturated

Alkenes are a homologous series of hydrocarbons that contain carbon - carbon double bonds.
↳ C=C

general formula: C_nH_{2n}

- Alkenes are more reactive than alkanes (C=C bond)
  alkene + oxygen → carbon dioxide + water

- Incomplete combustion:
  CO_2 and soot (carbon) are produced

Addition reactions (alkene):

1. Hydrogenation (hydrogen)
   alkene + hydrogen → alkanes
   conditions:
   - catalyst: nickel (Ni)
   - temp.: 200°C

2. Hydration (steam)
   alkene + steam → alcohols
   conditions:
   - catalyst: phosphoric acid (H_3PO_4)
   - temp.: 300°C
   - atmosphere: 60-70 atm (high pressure)

   * alcohols made from this reaction is for industrial uses

why is margarine solid and vegetable oil liquid?
- margarine has a higher Mr (more H atoms after hydrogenation)
→ stronger intermolecular FOA
→ more energy required to overcome the FOA
→ higher m.p. and b.p.

3. Bromination (bromine)
   - bromine solution (aq) / bromine water is reddish-brown in colour
   - when bromine (aq) is added to the alkenes, the reddish-brown aqueous bromine will be decolourised
   - no conditions required
     ethene + bromine → dibromethane

4. Addition polymerisation (alkenes):
   - many alkene molecules can join together to make one big molecule, a polymer, if a presence of catalyst is there

Cracking
→ alkanes to alkenes
conditions:
- temp.: ~600°C
- catalyst: Al_2O_3 / SiO_2

} not necessary to memorise

17. Alcohols and carboxylic acids

- Alcohols are a homologous series which have the hydroxyl (-OH) group

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

physical properties:
- b.p. increases steadily as Mr increases
- more energy required to overcome the stronger intermolecular FOA
- solubility ↓, Mr ↑

chemical properties:
- combustion
- oxidation

→ can be oxidised into carboxylic acids

* important: ethanol

molecular formula: C_2H_5OH
structural formula: CH_3CH_2OH

Fermentation:
conditions:
- low temp.: 37°C (best temp.)
- no air / oxygen
  ↳ if exposed to air / oxygen, it will turn sour after a few days
- gas given off during fermentation is CO_2

$$\text{glucose / sugar} \xrightarrow[37^\circ C]{\text{yeast}} \text{ethanol} + CO_2$$

- carboxylic acids are a homologous series which have the carboxyl (-COOH) functional group

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

properties of ethanoic acid:
- smell of vinegar
- soluble in water
- weak acid, pH~3
- same properties as acid
  → can react with metal, base, carbonate

salt name: ..... - ethanoate

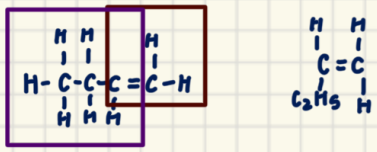
$$\text{ethanol} \xrightarrow{\text{oxidised}} \text{ethanoic acid}$$

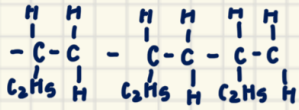
18. Polymers

- Macromolecules are very large covalent molecules
- They may contain up to thousands of atoms

Examples:
- silk
- plastics

e.g.

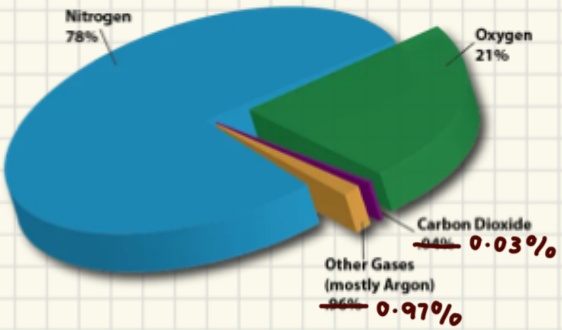




Addition polymerisation (alkenes):
conditions:
- molecule with carbon – carbon double bonds
- high pressure
- high temp.

Disadvantages of using particles
- non-biodegradable
  → cannot be broken down

19. Maintaining Air Quality



Common atmospheric pollutants:

air pollutant	sources	harmful effects
SO_2, Sulfur dioxide	- combustion of fossil fuels - volcanic eruptions	- breathing difficulties in humans and animals - SO_2 and NO/NO_2 reacts with oxygen in the air to form acidic compounds which dissolve in rain water, forming solutions of strong acids, acid rain
NO/NO_2, nitrogen oxides	- vehicle combustion engineering - lightning	
CO, carbon monoxide	- incomplete combustion of carbon-based fuels	- CO combines with haemoglobin in our red blood cells - can result in the loss of consciousness and even death
CH_4, methane	- anaerobic (absence of oxygen) bacterial decay of organic substances - waste gases from cattle	- methane, a major greenhouse gas, leads to global warming
C_xH_y, unburnt hydrocarbons	- vehicle combustion engines	- causes eye and respiratory tract irritation
O_3, ozone	- lightning - from reactions between oxygen molecules and sunlight in the upper atmosphere	- causes eye and respiratory tract irritation, leading to breathing difficulties

global warming:
- gases that trap radiation are called greenhouse gases
  → CO_2, CH_4 and N_2O allows visible radiation from the sun to reach the Earth's surface but trap some of the IR radiation which is emitted by Earth.
- global warming is the increase in the Earth's average temperature due to the build-up of greenhouse gases in the atmosphere

acid rain:
- caused by sulfur dioxide and nitrogen dioxide
- pH: ~ 4

effects:
- metal bridges and limestone buildings will get damaged
  ↳ contains carbonate
- kills fish and aquatic life in the lake

minimising the effects of acid rain:
- liming:
  add $CaCO_3$ to soils and water bodies to remove excess acids

carbon cycle: ↗ balance
- to maintain the level of carbon dioxide in the atmosphere, 0.03%
- add carbon dioxide to atmosphere:
  1. respiration
  2. combustion of fuels
  3. decay and bacterial composition
- remove carbon dioxide from the atmosphere:
  1. photosynthesis
  2. ocean uptake