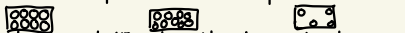
① Experimental Chem.

- Collection of gas: 1. Downward delivery: density gas > air
  2. Upward delivery: density gas < air
  3. Displacement of H_2O: gas insoluble
- Drying gas:
  1. Conc. H_2SO_4: gas don't react w H_2SO_4
  2. Quicklime: gas don't react w CaO
  → CaO absorb moisture & CO_2 from air, heated before use
  3. Fused $CaCl_2$: gas don't react w $CaCl_2$
  → $CaCl_2$ readily absorb moisture from air, heated before use
- Chromatography, retention factor: $R_f = \frac{\text{distance of substance}}{\text{distance of solvent}}$
- Pure substance: fixed m.p & b.p
- Impure substance: range of m.p & b.p

② Kinetic Particle Theory

- KPT: all matter is made of particles in continuous & random motion
- Diffusion: particles move from region of higher conc. to region of lower conc.

	Solid	Liquid	Gas
Arrangement	closely packed in orderly arrangement	more closely packed than solid but less closely packed than gas in disorderly arrangement	far apart in disorderly arrangement
Mvt	vibrate in fixed position	slide over each other	freely & randomly in all directions
Force of attraction	very strong	strong	very weak (negligible)



- As temp. ↑, thermal energy converted to KE, causing particles to vibrate more vigorously → when substance not changing state
- As temp. ↑, thermal energy converted to PE, causing particles to move further apart from each other to overcome attractive forces → when substance changing state

③ Atomic Structure

- Filled valence (outer) shell: stable & unreactive atom
- → ion: atom ± e^-
- → ± electrons to gains no. of valence e^-: similar chem. properties
  Cation: +ve ion
  Anion: -ve ion
- Isotope: same element, diff. nucleon no, same chem. properties, diff phys properties
- Relative mass of C^{-12}: 12
- Chem. Bonding
- Noble gas: inert, stable, do not form compounds → filled valence shells
- Ionic bond: strong electrostatic force of attraction between ions formed by transfer of valence e^- → metal & non-metal
  → Ionic compound: crystal lattice structure
- Covalent bond: electrostatic force of attraction between +ve nucleus & shared e^-
  → 2 non-metal
  → Covalent molecule: 1. Simple covalent molecule: countable no. of atoms in fixed ratio
  2. Giant molecule: uncountable no. of atoms
- Metallic bond: electrostatic force of attraction between +ve ions & sea of delocalised e^-
  → Solid metals: giant metallic lattice structure
  → held tgt by +ve ions in sea of delocalised e^-
  → only metallic bonding: evenly distributed free moving e^-

⑤ Structure & Properties of Materials

- Compounds: fixed properties, diff properties from the elements (chem combi)
- Mixtures: variable properties, same properties from its elements (phys combi)
- Ionic lattice: 1. high b.p. & m.p.: large energy to overcome electrostatic force of attraction
  2. soluble in H_2O, insoluble in org solvent
  electrical insulator when solid: no free moving ions or e^-
  3. electrical conductor when aq: free moving ions
  4. hard & brittle: when force applied, repulsive forces > electrostatic force of attraction

- Covalent molecules: 1. low m.p. & b.p.: little energy needed to overcome weak intermolecular forces

  2. insoluble in H_2O, soluble in org solvent
  3. electrical insulator in all states
  → some can dissociate in H_2O & conduct electricity
  → can form lattice at low temp.
- Giant covalent molecule: 1. always solid: strong covalent bond

  2. rigid
  3. very high b.p. & m.p.: very large energy to break covalent bond
  4. insoluble in H_2O & org solvent
  5. electrical insulator
  → graphite: 1 free e^-/C atom, conduct electricity
- Allotrope: different structure of same element
  → diff bonding & structure: diff properties
- Diamond: hard: only strong covalent bonds
- Graphite: soft & slippery: layers of C can slide over each other easily
- Macromolecules: grp of covalent structure
  → Polymer: chain of larger molecules
  1. vary in hardness & flexibility
  2. solid
  3. range of size: no fixed b.p. & m.p.: soften over range of temp.
  → insoluble in H_2O & org solvents
  → electrical insulatory in all states

Metals

- Alloy: mixture of metal & other elements
  → strong: diff size atoms, disrupt orderly layers of atoms
- Pure metals: soft
  → orderly arranged layers of atom, easily slide over each other

④ Chem. Eqn

- →Ammonium: NH_4^+
- →Hydroxide: OH^-
- →Nitrate: NO_3^-
- →Sulfate: SO_4^{2-}
- →Sulfite: SO_3^{2-}
- →Carbonate: CO_3^{2-}
- →Phosphate: PO_4^{3-}
- →Hydrochloric acid: HCl
- →Ammonia: NH_3
- →Methane: CH_4
- 2 elements: -ide
- Hydroxides contain OH^-
- No. of O atoms: -ate > -ite or -ide

⑦ Mole Concept

- % mass: $\frac{\text{no. of atoms of element} \times A_r \text{ or } M_r}{M_r \text{ of cpd}} \times 100\%$
- Avogadro's constant: no. of particles in 1 mol = 6.02×10^{23}
- no. of moles = $\frac{\text{mass}}{A_r \text{ or } M_r}$
- Vol. of 1 mol of gas = $24\ dm^3$
  → $1\ dm^3 = 1000\ cm^3$
  → no. of moles = $\frac{\text{vol.}}{24\ dm^3}$
- Avogadro's law: gas vol. ∝ no. of moles (if tp only involve gas vol.)
- Conc. (mol/dm^3) = $\frac{\text{no. of moles}}{\text{vol.}}$
- Conc. (g/dm^3) = $\frac{\text{mass}}{\text{vol.}}$
  → g/dm^3 = $\frac{\text{mass}}{\text{vol.}} \times \frac{1}{M_r}$ mol/dm^3
- Empirical formula: (e.g.)

Element	C	H	O
mass	40.0	6.70	53.3
A_r	12	1	16
no. of mole	40.0÷12 = 3.33	6.70÷1 = 6.70	53.3÷16 = 3.33
mole ratio	3.33÷3.33 = 1	6.70÷3.33 = 2.1	3.33÷3.33 = 1
Empirical formula	CH_2O		

- Molecular formula: n x empirical formula
  → n = $\frac{M_r \text{ of compound}}{M_r \text{ from empirical formula}}$
- limiting reactant: reactant completely used up in a chem. reaction
- excess reactant: reactant added in excess for chem. reaction
- Yield: amt of product from reaction
- % yield = $\frac{\text{actual yield}}{\text{theoretical max. yield}} \times 100\%$
  → ↑ % yield, ↑ efficiency
- % purity = $\frac{\text{mass of pure substance}}{\text{total mass}} \times 100\%$

⑧ Acids & Bases

- Acid: produce H^+ in H_2O
  → dp not conduct electricity in absence of H_2O
  → dissociates into ions in H_2O (ionisation)
  → conduct electricity due to free moving ions
- Hydrochloric acid: HCl: $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$
- Sulfuric acid: H_2SO_4: $H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$
- Nitric acid: HNO_3: $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$
- Ethanoic acid: CH_3COOH: $CH_3COOH(aq) \rightarrow H^+(aq) + CH_3OO^-(aq)$
- Acids do not dissociate in org solvents
- Properties of acid: 1. turn blue litmus red
  2. < pH7
  3. universal indicator: green to yellow, orange to red
  4. sour
  5. electrical conductor when aq
- Acid + metal → salt + H_2
  → only reactive metal
  → test for H_2: lighted splint in mouth of test tube → H_2 will extinguish lighted splint with 'pop' sound. Effervescence formed
- Acid + base → salt + H_2O (neutralisation)
  → Base: metal oxide & hydroxide, insoluble in H_2O
  → Ionic eqn: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
- Acid + carbonate → salt + H_2O + CO_2
  → Effervescence, CO_2 produced forms white ppt with limewater. CaO_2 dissolve & form colourless soln
  → test for CO_2: bubble gas into limewater → CO_2 will form white ppt with limewater

Alkali

- Alkali: base soluble in H_2O
  → produce OH^- in aq soln
- Properties of alkali: 1. turn red litmus blue
  2. > pH7
  3. turn universal indicator from green to blue or violet
  4. bitter & soapy
- Alkali + acid → salt + H_2O (neutralisation)
  → Ionic eqn: $OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$
- Alkali: + NH_4^+ salt + salt + H_2O + NH_3
  → sensor on heating
  → test for NH_3: heat red litmus paper → NH_3 will turn moist red litmus paper blue
  → NH_3 is colourless & pungent
- pH < 7: $H^+ > OH^-$: acidic
- pH = 7: $H^+ = OH^-$: neutral
- pH > 7: $H^+ < OH^-$: alkaline
- Liming: treating soil with excess acid

Indicators

- Very alkaline (pH 13-14): violet
- Weakly alkaline (pH 8-10): blue, indigo
- Neutral (pH 7): green
- Weakly acidic (pH 3-6): yellow, orange
- Very acidic (pH 0-1): red

Common indicators	Methyl orange	Screened methyl orange	Phenolphthalein
neutral	orange	grey	colourless
acidic	red	purple	colourless
alkaline	yellow	green	pink

Oxides

- Basic oxide: metal oxide, soluble in H_2O, react with acid to form salt + H_2O
  → solid at rtp
  → dissolve in H_2O to form alkalis
  → 1 O atom
- Acidic oxide: non-metal oxide, react with alkali to form salt + H_2O
  → multiple O atoms
- Amphoteric oxide: metal oxide, react with acid & alkali to form salt + H_2O
  → ZAP: Zinc oxide (Zn)
  Aluminium oxide (Al)
  Lead (II) oxide (Pb)
- Neutral oxide: non-metal oxide, doesn't react with acid & alkali
  → 1 O atom

⑨ Salts

- Salt: ionic compound, consist of cation & anion
  → Solubility: All Na, K, NH_4^+ salts & NO_3^-: soluble in H_2O
  All Cl^- except $AgCl$ & $PbCl_2$: soluble in H_2O
  All SO_4^{2-} except $BaSO_4$ & $PbSO_4$: soluble in H_2O
  → $CaSO_4$: sparingly soluble in H_2O
  All CO_3^{2-} except Na_2CO_3, K_2CO_3 & $(NH_4)_2CO_3$: soluble in H_2O
- Reaction of acid with insoluble substances: 1. acid + metal → salt + H_2
  2. acid + insoluble base → salt + H_2O
  3. acid + insoluble CO_3^{2-} → salt + H_2O + CO_2
  → metal, base & CO_3^{2-} must be in excess & insoluble in H_2O
- Titrations: 1. acid + alkali → salt + H_2O
  2. acid + soluble CO_3^{2-} → salt + H_2O + CO_2
  → both reactant are soluble
- Precipitation: mix 2 aq to form insoluble solid: AB (aq) + XY (aq) → insoluble AY + XB (aq)
  → AB contain A^+, XY contain Y^-

⑩ Ammonia

- NH_3 made by Haber process
  → N_2 from fractional distillation of liquid air
  → H_2 from cracking of crude oil fractions
- Haber process: $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (reversible)
  → As rxn pt.: N_2 is excessive & → does not take place
  → high temp & pressure required for → between N_2 & H_2
  → Fe added as catalyst
  → ↑ pressure, ↑ yield of NH_3 & faster reaction
  → ↓ temp, ↑ yield of NH_3: reduce decomposition of NH_3
- $CuSO_4 \cdot 5H_2O(s) \rightleftharpoons CuSO_4(s) + 5H_2O(l)$
  → blue $CuSO_4$ turns white

⑪ Qualitative Analysis

- Cation tests:

cation	NaOH (aq)	NH_3 (aq)
Al^{3+}	- white ppt: $Al(OH)_3$ - ppt dissolve in excess → colourless soln	- white ppt, $Al(OH)_3$ - ppt insoluble in excess
Zn^{2+}	- white ppt, $Zn(OH)_2$ - ppt dissolve in excess → colourless soln	- white ppt, $Zn(OH)_2$ - ppt dissolve in excess → colourless soln
Ca^{2+}	- white ppt, $Ca(OH)_2$ - ppt insoluble in excess	- no ppt - no change in excess
NH_4^+	- no ppt - no change in excess	—
Cu^{2+}	- light blue ppt, $Cu(OH)_2$ - ppt insoluble in excess	- light blue ppt, $Cu(OH)_2$ - ppt dissolve in excess → dark blue soln
Fe^{2+}	- green ppt, $Fe(OH)_2$ - ppt insoluble in excess → turn brown on standing	- green ppt, $Fe(OH)_2$ - ppt insoluble in excess → turn brown on standing
Fe^{3+}	- red-brown ppt, $Fe(OH)_3$ - ppt insoluble in excess	- red-brown ppt, $Fe(OH)_3$ - ppt insoluble in excess

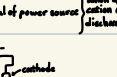
- Anion test:

Anion	Test	Observation
CO_3^{2-}	- Add dilute acid & bubble gas in limewater	- Effervescence - white ppt, $CaCO_3$ - CO_2 produced
Cl^-	- Add dilute HNO_3 & aq $AgNO_3$	- white ppt, $AgCl$
I^-		- yellow ppt, AgI
SO_4^{2-}	- Add dilute HNO_3 & aq $Ba(NO_3)_2$	- white ppt, $BaSO_4$
NO_3^-	- Add aq NaOH & piece of Al, warm mixture & test gas with damp red litmus	- Effervescence - litmus turn blue - NH_3 produced

- Gas test:

Gas	Colour & odour	test	observation
H_2	Colourless, Odourless	lighted splint at mouth of test tube	lighted splint extinguished with 'pop' sound
O_2		glowing splint into test tube	glowing splint relumes
CO_2		bubble gas through limewater	white ppt → dissolve upon further bubbling
Cl_2	yellow-green, pungent	damp blue litmus at mouth of test tube	litmus turn red & is bleached
SO_2	Colourless, pungent	Filter paper soak with acidified $KMnO_4$ at mouth of test tube	purple $KMnO_4$ turn colourless
NH_3		damp red litmus at mouth of test tube	litmus turn blue

11 Redox
- Oxidation: gain O / lose H / lose e^-
- Reduction: lose O / gain H / gain e^-
- Redox: O directly gained or lost
- Oxidation state: charge of an atom or element if it exist as ion in a compound
  → + o.s. oxidation, - o.s. reduction
  → atom in free element o.s. charge = o.s. = 0
  → special non-metal: Pf o.s. = -1
    H usually o.s. = +1, hydride: H o.s. = -1
    O usually o.s. = -2, peroxide: O_2 o.s. = -1
  → if a compound has no net charge, its o.s. = 0
- Oxidising agent: reduced itself to cause oxidation
- Reducing agent: oxidised itself to cause reduction
- KI test for oxidising agent: add a few drops of colourless KI to unknown soln
  → mixture turn yellow-brown when I^- oxidised to I_2 by oxidising agent
- Acidified $KMnO_4$ test for reducing agent: add a few of dark purple aq $KMnO_4$ to unknown soln
  → soln decolourises & MnO_4^{2-} reduced to Mn^{2+}

12 Electrolysis
- Electrolysis: pass electric current through compound to separate components
  → occur in electrolytic cell
- Electrolytic cell: device that convert electrical energy into chem. energy
  → Electrolyte: (electrical conductor in aq state (ionic compound)
    → contain mobile ions
  → Electrode: contain delocalised e^- to conduct electricity
    → Anode (+ve electrode connected to +ve terminal of power source → attract anion: anion lose e^- & oxidised
    → Cathode: -ve electrode connected to -ve terminal of power source → attract cation: cation gain e^- & reduced
  (anion & cation are discharged)
- The more reactive a metal/the more stable its ion
  → Electrochemical series: SO_4^{2-}, NO_3^-, Cl^-, Br^-, I^-, OH^-
  

  $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$
- Electrolysis of dilute NaCl:
  1. ions from NaCl: $Na^+(aq)$ & $Cl^-(aq)$
     ions from H_2O: $OH^-(aq)$ & $H^+(aq)$
  2. Cl^- & OH^- attract to anode & OH^- selectively discharged
     → OH^- lower than Cl^- in electrochemical series
  3. Na^+ & H^+ attract to cathode & H^+ selectively discharged
     → H less reactive than Na
  4. $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$
  → neutral as H^+ & OH^- discharged & H_2O level drop
- Electrolysis of conc. NaCl:
  1. ions from NaCl: $Na^+(aq)$ & $Cl^-(aq)$
     ions from H_2O: $OH^-(aq)$ & $H^+(aq)$
  2. Cl^- & OH^- attract to anode & Cl^- discharged as $Cl_2(g)$
  3. Na^+ & H^+ attract to cathode & H^+ selectively discharged
     → H less reactive than Na
  4. $2H^+(aq) + 2Cl^-(aq) \rightarrow H_2(g) + Cl_2(g)$
     → Na^+ & OH^- form alkaline NaOH (discharge H^+)
  → electrolyte turns pale when Universal Indicator added
- Electrolysis of conc. HCl:
  1. ions from HCl: $H^+(aq)$ & $Cl^-(aq)$
     ions from H_2O: $H^+(aq)$ & $OH^-(aq)$
  2. Cl^- & OH^- attract to anode & Cl^- discharged as $Cl_2(g)$
  3. H^+ attract to cathode & discharged
  4. $2H^+(aq) + 2Cl^-(aq) \rightarrow H_2(g) + Cl_2(g)$
  → conc. of HCl & H_2 soln less acidic (discharge H^+)

- Electrolysis used to purify metals & electroplating
  → Purification: 1. impure metal made anode
    → impurities fall to bottom as anode slime
    2. pure metal used as cathode
  → Electroplating: coat a layer of metal onto an object
    1. metal coated: object to form ions & ↓ mass
    2. cathode: object coated with metal
  (electrolyte contains respective metal ion)

Simple cell & Fuel cell
- Simple cell: device that converts chem. energy into electrical energy
  → Anode: oxidised more reactive metal
    → gives electrons that enter electrodes & release e^- into circuit
  → Cathode: less reactive metal
    → receive electrons to gain e^- & be reduced
  → the further apart the two metals in reactivity series are, ↑ voltage.
- H-fuel cell: H as fuel, O_2 from air as oxidiser
  → Cathode: $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
  → Anode: $H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$
  ($2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$)

13 Periodic Table
- Elements arranged in ↑ proton no. in periodic table
  → Alkali metals: most reactive metals (1)
  → Halogens: most reactive non-metals (7)
  → Noble gases: most unreactive (0)
  → Lanthanides: metals with very similar properties (3)
  → Actinides: all radioactive & mostly man-made (3)
- Across period: 1 → 8 metallic properties, ↑ non-metallic properties
  2 oxides basic to amphoteric to acidic
- Down grp: 1. proton no. & atomic rad. ↑
  2. ↑ metallic properties, ↓ non-metallic properties

Grp	1	2	13	15	16	17
charge	+1	+2	+3	-3	-2	-1

- Column: group
  → same grp, same no. of valence e^-
  → same chem. properties
- Row: period
  → same period, same no. of e^- shells
- LHS chain case: metals
  RHS chain case: non-metals
  Class to sharpen: metalloids
  → metalloids have both metal & non-metal properties

Alkali Metals
- Alkali metals: grp 1 elements
  → react with H_2O to form alkaline soln
  → $1e^-$ valence e^-
  → most reactive metals
- Phys. properties:
  1. shiny & silvery
  2. soft
  3. low mp & bp
  4. low density
  5. conduct electricity due to free moving e^-
- Chem. properties:
  1. react with H_2O to form H_2 + alkaline metal OH
  2. react with halogen to form ionic compounds
- Down the grp:
  1. ↓ mp & bp
  2. ↑ density (except K)
     → Li, Na, & K float on H_2O
  3. ↑ reactivity

Halogens
- Halogen: grp 17 elements
  → poisonous
  → 7 valence e^-
  → most reactive non-metals
  → diatomic
- Phys. properties:
  1. low mp & bp
  2. do not conduct electricity
  3. coloured

F_2	pale yellow (g)
Cl_2	greenish-yellow (g)
Br_2	reddish-brown (l)
I_2	purplish-black (s)
At	black (s)

- Chem. properties:
  1. react with metals to form covalent compounds
  2. react with metals to form ionic compounds
  3. more reactive displace less reactive halide soln
- Down the grp:
  1. ↑ mp & bp
  2. colour deepens
  3. e^- gain to (-1) to (s)
  4. ↓ reactivity

Noble Gas
- Noble gases: grp 18 elements
  → monatomic
  → inert
  → full octet valence shell

Transition elements
- Transition metals: grps 3–12 metals
  → high mp & density
  → O_2 bind to Hb due to Fe in Hb having o.s. +2 & +3
- Form ions with different o.s.:
  1. Cr: o.s. +3 & +6
  2. Mn: o.s. +2, +4 & +7
  3. Fe: o.s. +2 & +3
  4. Cu: o.s. +1 & +2
- Form coloured compounds:
  Cr: $CrCl_3$: green
  K_2CrO_4: orange
  Fe: $FeSO_4$: pale green
  $Fe_2(SO_4)_3$: yellow
  Mn: MnO_2: brown-black
  $KMnO_4$: purple
  Cu: Cu_2O: red
  CuO: black
  (good catalysts)

14 Reactivity Series
- Cold H_2O:

Element	Reaction	Eqn
K	Explosive	$2K + 2H_2O \rightarrow 2KOH + H_2$
Na	Violent	$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$
Ca	Readily	$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$
Mg	Very slowly	$Mg_{(s)} + 2H_2O_{(l)} \rightarrow Mg(OH)_{2(aq)} + H_{2(g)}$

- Steam:

Element	Reaction	Eqn
Mg	Violent	$Mg_{(s)} + H_2O_{(g)} \rightarrow MgO_{(s)} + H_{2(g)}$
Zn	Readily	$Zn_{(s)} + H_2O_{(g)} \rightarrow ZnO_{(s)} + H_{2(g)}$
Fe	Slow	$3Fe_{(s)} + 4H_2O_{(g)} \rightleftharpoons Fe_3O_{4(s)} + 4H_{2(g)}$

- Pb, Cu, Ag & Au: no reaction
- HCl:

Element	Reaction	Eqn
K	Explosive	$2K + 2HCl \rightarrow 2KCl + H_2$
Na		$2Na_{(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_{2(g)}$
Ca	Violent	$Ca_{(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_{2(g)}$
Mg	Rapid	$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(s)} + H_{2(g)}$
Zn	Moderately fast	$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$
Fe	Slow	$Fe_{(s)} + 2HCl_{(aq)} \rightarrow FeCl_{2(aq)} + H_{2(g)}$

- Pb & H: slow
- Cu, Ag, & Au: no reaction

Extraction
- K, Na, Ca, Mg, Al, C, Zn, Fe, Pb, H, Cu, Ag, Au
  → Electrolysis
  → Reduction by C: $X(s) + C(s) \rightarrow Y(s) + CO_{2(g)}$ (ore → metal)
  → or
  → Reduction by H (for oxide): $YO(s) + H_2(g) \rightarrow Y(s) + H_2O(g)$

- Most reactive metal displace less reactive metal from salt soln

Rust
- Rust: special case of corrosion
- $4Fe(s) + 3O_2(g) + 2xH_2O(l) \rightarrow 2Fe_2O_3 \cdot xH_2O(s)$
  → oxidation reaction
  → speed up by acid & salt
  → prevent by protective coating
    → Galvanising: dipped into molten Zn
    → Attach more reactive metal

15 Chemical Energetics
- Endothermic: heat energy absorbed
- Chem. reaction:
  1. Thermal decomposition: substance heated & decompose to form another substance + CO_2
  2. Photosynthesis
- Phys. reaction:
  1. Dissolution of ionic compound in H_2O
- Exothermic: heat energy released
- Chem. reaction:
  1. Combustion: substance burn in excess O_2 to form CO_2 + H_2O
  2. Neutralisation
  3. Respiration
- Phys. reaction:
  1. Dissolution of acid & alkali in H_2O

Energy Change
- Bond breaking: Endothermic
- Bond making: Exothermic
- Bond energy: amt of energy to break 1 mol of chem. bond
  → amt of energy released when 1 mol chem. bond formed
  → multiple bonds stronger than single bond
- Activation energy, E_a: min. energy that colliding particles need to react
- Enthalpy change, ΔH: diff. in energy of reactant & product
  → ΔH = total energy of products − total energy of reactants
  → Endothermic change: $\Delta H > 0$
  → Exothermic change: $\Delta H < 0$

- Overall enthalpy change:
  ΔH = total energy absorbed during bond breaking − total energy released during bond breaking
  → Endothermic: energy absorbed > energy released
  → Exothermic: energy absorbed < energy released

17 Rate of Reactions
- Collision theory: chem. reaction only take place when particles collide effectively
  → collide at proper orientation
  → ↑ freq, ↑ ROR
- ↑ ROR:
  1. temp: ↑ temp, ↑ KE move faster, collide more freq
  2. conc: ↑ conc, ↑ particles per unit vol.
  3. pressure (g): ↑ pressure, particles close together & ↑ particles per unit vol.
  4. particle size: ↓ particle size, ↑ TSA & ratio of contact ↑
  (Catalyst: ↑ ROR by ↓ E_a.)

18 Fuel & Crude Oil
- Fossil fuels: crude oil, natural gas & coal
  → hydrocarbons: contain only H & C
  → non-renewable
- Natural gas: mainly CH_4
  → on top of crude oil
  → colourless & pungent
- Crude oil: mixture of hydrocarbons
  → separate into fractions by fractional distillation
  → top of fraction: 1. smaller & few C
    2. low b.p.
    3. less viscous & flammable
  → bottom of fraction: 1. larger with more C
    2. high b.p.
- Biofuels: renewable energy sources

19 Hydrocarbon
- Homologous series: same general formula, similar chem. properties (same functional grp), same gradual change of phy. properties

Prefix	no. of C
meth-	1
eth-	2
prop-	3
but-	4
pent-	5
hex-	6
hept-	7
oct-	8
non-	9
dec-	10

Suffix	Homologous series
-ane	Alkane
-ene	Alkene
-anol	Alcohol
-anoic acid	Carboxylic acid

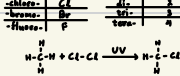
Alkane
- Alkane: saturated hydrocarbon
  → saturated: only C-C single bonds, strong & hard to break
  → unreactive
  → C_nH_{2n+2}
  → n is no. of C

Alkane	no. of C	chem formula	molecular formula	Structure
methane	1	CH_4	CH_4	H-C-H
ethane	2	C_2H_6	C_2H_6	H H / H-C-C-H / H H
propane	3	C_3H_8	C_3H_8	H H H / H-C-C-C-H / H H H
butane	4	C_4H_{10}	C_4H_{10}	H H H H / H-C-C-C-C-H / H H H H

- As size & mass ↑: m.p. & b.p. ↑
  2. density ↑
  3. viscosity ↑
  4. Flammability ↓
- Insoluble in H_2O, soluble in org solvents
- Combustion: Alkanes burn in excess O_2 to produce CO_2 & H_2O
  → blue flame, no/few smoke
  → incomplete combustion: soot, CO & H_2O formed
  → yellow smoking flame
- Substitution: Alkanes react w/ halogen in UV light

Prefix	Halogen
-chloro-	Cl
-bromo-	Br
-fluoro-	F

Prefix	no. of halogen
di-	2
tri-	3
tetra-	4



Alkene
- Alkenes: unsaturated hydrocarbons
  → unsaturated: C=C double bonds or C≡C triple bonds
  → reactive
  → C_nH_{2n}, 1C : 2H ratio

Alkene	no. of C	chem formula	molecular formula	Structure
ethene	2	C_2H_4	C_2H_4	H H / H-C=C-H
propene	3	C_3H_6	C_3H_6	H H H / H-C=C-C-H / H H
butene	4	C_4H_8	C_4H_8	H H H H / H-C=C-C-C-H / H H H

- As size & mass ↑: m.p. & b.p. ↑
  2. density ↑
  3. viscosity ↑
  4. Flammability ↓
- Insoluble in H_2O, soluble in org solvents
- Alkenes are more likely to undergo incomplete combustion & burn with a sootier flames than alkanes
  → ↑ % by mass of C in alkenes > alkanes
- Addition reactions:
  1. Hydrogenation: alkenes react with H_2 to form alkanes
     → Requires 150°C & catalyst (e.g. Ni)
     e.g. Hydrogenation of ethene: $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$
  2. Bromination: alkenes react with Br_2 to form dibromoalkanes
     → when alkene undergoes bromination, it decolourises
     → when alkene reacts with bromine, no reaction
     e.g. Bromination of ethene: $C_2H_4(g) + Br_2(l) \rightarrow C_2H_4Br_2(l)$
  3. Hydration: alkenes react with steam to produce alcohols
     → requires 300°C & pressure of 60 atm & catalyst (e.g. H_3PO_4)
     e.g. Hydration of ethene: $C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(aq)$
- Polymerisation: smaller molecules join to form longer molecules
  → requires high temp & pressure & catalyst
- Cracking: longer alkanes break down into smaller hydrocarbons
  → cracking long-chain alkanes can form mixture of short-chain alkenes & H_2
     e.g. $C_4H_{10} \rightarrow C_2H_4 + H_2$
  → cracking long-chain alkanes can form mixture of short-chain alkenes & alkanes
     e.g. $C_4H_{10} \rightarrow C_2H_4 + CH_4$
  → catalytic cracking can be used to speed up cracking process
  → requires high temp & pressure & catalyst (e.g. Al_2O_3 & SiO_2)

Isomers
- Isomer: compounds with same molecular formula but different structural formula
  → occurs when the length of the main C chain differs
  → straight-chain isomers have C atoms that are joined up in a row
  → branched-chain isomers contains branches or side chains
- Butene & methylpropene are isomers
  → butene is a straight-chain alkene
  → methylpropene is a branched-chain alkene
  → contains an alkyl grp branch, $-CH_3$, formed by removing H from an alkane
    → branched-chain alkenes can also have longer branches (e.g. ethyl grp, $-C_2H_5$)
- They have different physical properties (e.g. m.p & b.p.)
  → butene b.p.: −0.5°C
  → methylpropene b.p.: −11.7°C

Butene (C_4H_8)	Methylpropene (C_4H_8)
H H H H / H-C-C-C=C-H / H H H	H H H / H-C-C-C-H / H H / H-C=H / H

- Different placement of C=C functional grp gives rise to isomerism

But-1-ene	But-2-ene
H H H H / H-C=C-C-C-H / H H H	H H H H / H-C-C=C-C-H / H H H

- Branched-chain isomer can be drawn by shifting alkyl grp placement in straight-chain isomers

Saturation of Hydrocarbons
- Saturated: only C-C bonds
  → generally unreactive
  → test with Br_2 (aq): Br_2 (aq) remains brown
- Unsaturated: contain C=C or C≡C bonds
  → more reactive because atoms can be added across C=C or C≡C bonds
  → test with Br_2 (aq): Br_2 (aq) decolourises
- Polyunsaturated fats: contain hydrocarbon chains with 2 or more C=C bonds in each chain
  → ↑ level of saturation, ↑ m.p.
  → C=C in oil causes a bend in the structure & the chain do not stack well & cannot come close together
  → the chains stack well with one another
- Oil undergoes hydrogenation to form margarine

12 Alcohols & Carboxylic Acids & Esters
- Alcohol: organic compounds that contain hydroxyl grp (-OH)
  → $C_nH_{2n+1}OH$

Alkane	no. of C	chem formula	molecular formula	structure
methanol	1	CH_3OH	CH_4O	
ethanol	2	C_2H_5OH	C_2H_6O	
propanol	3	C_3H_7OH	C_3H_8O	
butanol	4	C_4H_9OH	$C_4H_{10}O$	

- As size & mass ↑: I. solubility in H_2O ↓
  i.e. m.p. & b.p. ?
- Carboxylic acid obtained from oxidising alcohol with hydroxyl grp bonded to terminal C
  → terminal C: at end of C chain
- Alcohols undergo oxidation when heated with oxidising agent (e.g. $KMnO_4$)
  e.g. Oxidation of ethanol: $C_2H_5OH(aq) + 2[O] \rightarrow CH_3COOH(aq) + H_2O(l)$
  [O]: oxidising agent
- Ethanol is produced by catalytic addition of steam to ethene
  → carried out at 300°C & 60 atm & catalyst H_3PO_4
  → $C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(l)$
- Low conc. of ethanol formed during fermentation of glucose
  → occurs when enzyme yeast acts on carbohydrates in absence of oxygen
  → temp. cannot be too high: yeast denatures
  → $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$
  → slower but more sustainable than catalytic addition

Carboxylic Acids
- Carboxylic acid: organic compounds that contain carboxyl grp (-COOH)
  → $C_{n-1}H_{2n-1}COOH$

Alkane	no. of C	chem formula	molecular formula	structure
methanoic acid	1	$HCOOH$	CH_2O_2	
ethanoic acid	2	CH_3COOH	$C_2H_4O_2$	
propanoic acid	3	C_2H_5COOH	$C_3H_6O_2$	
butanoic acid	4	C_3H_7COOH	$C_4H_8O_2$	

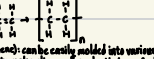
→ sour, reacts to form salts, turn blue litmus red
→ As size & mass ↑, b.p. ↑
→ completely miscible with H_2O
- Chem. reactions:
  1. Carboxylic acids are weak acids that partially ionise in H_2O to form carboxylate ion & H^+: $RCOOH(aq) \rightleftharpoons RCOO^-(aq) + H^+(aq)$
     → Alkyl grp (R): C_nH_{2n+1}
  2. Carboxylic acids + metal → carboxylate salt + H_2
  3. Carboxylic acids + CO_3^{2-} → carboxylate salt + CO_2 + H_2O
  4. Carboxylic acids + base → carboxylate salt + H_2O
  5. Carboxylic acid + alcohol → ester
- Ethanoic acid formed by:
  1. Ethanol react with air O_2 in presence of one type of bacteria
  2. Ethanol oxidised by [O] (e.g. $KMnO_4$)

Esters
- Ester: carboxylic acid + alcohol, contains ester link (-COO)
  → contains C, H & O
  → $C_{m+1}H_{2m+1}COOHC_nH_{2n+1}$
  → n is no. of C in carboxylic acid, m is no. of C in alcohol

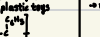
no. of C in each part	part from alcohol	part from carboxylic acid
1	methyl	methanoate
2	ethyl	ethanoate
3	propyl	propanoate
4	butyl	butanoate

- Fats are made up of esters
  → contain 3 functional grps: triesters
- Esterification/condensation reaction: carboxylic acid warmed with alcohol in presence of H_2SO_4 (catalyst) to form ester & H_2O

13 Polymers
- Polymer: large organic molecule built from monomers
  → oligomerisation: unsaturated monomers joined by covalent bonds
  → alkenes join at high temp. & pressure
  e.g. Polymerisation of ethene: $n(CH_2=CH_2) \rightarrow (-CH_2-CH_2-)_n$



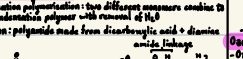
- Poly(ethene): can be easily molded into various shapes
  → used to make cling wrap, plastic bags & plastic toys
- Polystyrene: hard, light & brittle



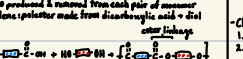
  → used to make disposable containers
- Polyvinyl chloride (PVC): used to make thin sheets, pipes, raincoats & flooring mats

- Polytetrafluoroethene: heat resistant & non-stick properties
  → used to coat frying pans

Condensation Polymerisation
- Condensation polymerisation: two different monomers combine to form condensation polymer with removal of H_2O
  → Nylon: polyamide made from dicarboxylic acid + diamine



  → H_2O produced & removed from each pair of monomer
  → Terylene: polyester made from dicarboxylic acid + diol



  → H_2O produced & removed from each pair of monomer

Plastics
- Plastics release CO when incinerated
  → PVC releases HCl on combustion
- Plastics can be recycled by phys. or chem. methods
  → Phys. methods:
    1. Mechanical recycling: plastic waste made into new products through melting & cooling
  → Chem. methods:
    1. Cracking: short-chain alkanes used as fuels, short-chain alkenes used as raw materials to produce new industrial products
    2. Depolymerisation: polymers converted back into monomers
       → Polyesters can be depolymerised by acid hydrolysis
       → Acid hydrolysis: polyester broken down in presence of acid catalyst back into dicarboxylic acids & diols

14 Air Quality
- Air: 78% N_2, 21% O_2, 0.04% CO_2, & 0.96% other gases
  → separate into component gases by liquefaction & fractional distillation

Gas	Colour	Smell	Characteristic	Effect
SO_2	Colourless	Pungent	non-flammable	- SO_2 causes breathing difficulties
NO	Colourless	Odourless	——	- React with O_2 to form acid rain → kills plants & aquatic life → corrodes limestone, marble & metals
NO_2	Reddish brown	Pungent	non-flammable	
CO	Colourless	Odourless	poisonous	- Combines reversibly with haemoglobin → prevents absorption & transport of O_2 in the body
CH_4	Colourless	Odourless	flammable	- Major greenhse. gas → larger warming effect on atmosphere than CO_2
Ozone	Pale blue	Pungent	——	- Cause eye & respiratory tract irritation → breathing difficulties - Cause chest pains & headaches when inhaled - Slows down photosynthesis in plants
Unburnt hydrocarbons	Colourless	Odourless (may be pungent due to fuel)	Vaporise at room temp.	- Cause eye & respiratory tract irritation - React with N-oxides in presence of sunlight to form photochemical smog → Photochemical smog appears as brown haze → formation of photochemical smog produces ozone, SO_2 & N-oxides

- The pH of H_2O decreases from 5.0-5.5 to 4.0 when more SO_2 & NO_x dissolve in rain to form acid rain
- Catalytic converters contains a casting of catalysts made up of Pt, Pd & Rh that speed up conversion of harmful substances into less harmful substances
  → catalysts arranged in honeycomb structure to ↑ SA for gases to interact
  → removes NO, NO_2 & CO by redox.
  → $2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$
  → $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$
  → $2NO_2(g) \rightarrow N_2(g) + 2O_2(g)$
  → $2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2(g)$
  → reduces pollution
- Flue gas desulfurisation removes significant portion of SO_2 from flue gas
  → wet scrubbing using $CaCO_3$ slurry
  → formed when $CaCO_3$ in form of limestone mined with H_2O
  1. slurry droplets sprayed at flue gas & $CaCO_3$ react with SO_2 to form $CaSO_3$ & CO_2
     → $CaCO_3(s) + SO_2(g) \rightarrow CaSO_3(s) + CO_2(g)$
  2. $CaSO_3$ oxidised by atm. O_2 to form $CaSO_4$
     → $2CaSO_3(s) + O_2(g) \rightarrow 2CaSO_4(s)$
  3. $CaSO_4$ hydrated to form gypsum
     → gypsum used to make drywalls, fertilisers, plaster for sculptures & casts to stabilise fractured bones
     → $CaSO_4(s) + 2H_2O(l) \rightarrow 2CaSO_4 \cdot 2H_2O(s)$
  → Excess S can be removed from fossil fuels by treating it with H_2 to produce H_2S, a low sulfur fuel

Ozone Layer
- Ozone layer in stratosphere can absorb UV
- Ozone formed when O_2 interact with UV from Sun
  → O atoms is an allotrope of O_2, O_3
  → O_3 break up to reform O_2 when they absorb UV: $2O_3(g) \rightleftharpoons 3O_2(g)$
  → pale blue & pungent
- Chlorofluorocarbons (CFC):
  1. UV breaks up CFC in stratosphere into Cl
  2. $Cl + O_3 \rightarrow ClO + O_2$
     → continues to break up O_3 in a chain reaction
  3. Holes in O_3 layer formed & UV can reach Earth surface