CHAPTER 1

Apparutus :

- Pipette : fixed volumes, 10.0cm³ or 25.0cm³
- Volumetric flask : larger fixed volumes, 100cm³ or 250cm³
- Measuring cylinder : nearest **0.5cm³**
- Burette : nearest **0.05cm³**

Method for collecting gases :

COLLECTING METHOD	SOLUBILITY OF GAS IN WATER	DENSITY OF GAS	EXAMPLES
Water displacement	insoluble , slightly soluble	Density does not affect gas collection	Hydrogen Oxygen Carbon dioxide
Downward delivery	soluble/insoluble	Denser than air	Chlorine Hydrogen chloride Sulfur dioxide
Upward delivery	soluble/insoluble	Less dense than air	Ammonia

Method for drying gases :

DRYING AGENT	EXAMPLES	NOTES
Concentrated sulfuric acid	Most gases, chlorine & hydrogen chlorine	Not suitable for gases which react with sulfuric acid (e.g. ammonia)
Quicklime (calcium oxide)	Ammonia	Calcium oxides absorbs moisture & CO_2, freshly heated before use. Cannot be used to dry gases which with calcium dioxide (carbon dioxide)
Fused calcium chloride	Hydrogen. Nitrogen, CO_2	Calcium chloride readily absorbs moisture from the air, freshly heated before use. Cannot be used to dry gases which react with calcium chloride(ammonia)

Separate techniques :

Type of mixture		
SOLID–SOLID MIXTURE	**SOLID–LIQUID MIXTURE**	**LIQUID–LIQUID MIXTURE**
Magnetic attraction	Filtration	Separating Funnel
Sieving	Evaporation to dryness	Chromatography
Using suitable solvents	Crystallisation	Fractional distillation
Sublimation	Simple distillation	

CHAPTER 2

Affecting rate of diffusion :

Conditions	Rate of diffusion	Reason
Increase ↑ in temperature	Increase ↑	More ↑ thermal energy is converted to KE of the particles
Increase ↑ in particle mass	Decrease ↓	Higher ↑mass require more ↑ KE to move at same speed

CHAPTER 3

Subatomic particles :

SUB-ATOMIC PARTICLES	RELATIVE MASS	RELATIVE CHARGE	LOCATION IN THE ATOM
Proton	1	+1	Nucleus
Neutron	1	0	Nucleus
Electron	1/1840	-1	Electron shell

CHAPTER 4

Types of chemical bonding :

1. Ionic bonding [NM + M]

- ↑ Melting point, ↑boiling point
- Conduct electricity in MOLTEN & AQUEOUS
- Soluble ✓ in water, insoluble ✗ in organic solvents
- Hard but brittle

2. Covalent bonding [NM + NM]

- ↓ Melting point, ↓boiling point
- CANNOT conduct electricity at any state
- insoluble ✗ in water, soluble ✓in organic solvents

3. Metallic bonding [M + M]

- ↑ Melting point, ↑boiling point
- Good conductors of electricity & heat due to SEA OF DELOCALISED ELECTRONS
- insoluble ✗ in water & organic solvents

CHAPTER 5

*Giant **ionic** crystal lattices :*

- ↑ Melting point, ↑boiling point
- Conduct electricity in MOLTEN & AQUEOUS
- Solids at room temperature
- Usually soluble ✓ in water, insoluble ✗ in organic solvents

*Types of giant **covalent** structures/macromolecules :*

1. Diamond [tetrahedral — 1 C atom to 4 C atom]

- Extremely ↑ Melting point, ↑boiling point
- CANNOT conduct electricity
- Very hard
- insoluble ✗ in water & organic solvents

2. Graphite [1 C atom to 3 C atom]

- ↑ Melting point, ↑boiling point
- CAN conduct electricity
- Soft & slippery
- insoluble ✗ in water & organic solvents

3. Macromolecules

- ↓ Melting point, ↓boiling point
- CANNOT conduct electricity in any state
- insoluble ✗ in water, soluble ✓in organic solvents

*Giant **metallic** lattices :*

1. Elemental (regular lattice)

- ↑ Melting point, ↑boiling point
- CAN conduct electricity in all states
- Solids at room temperature
- insoluble ✗
- Malleable & ductile

2. Alloys (irregular lattices)

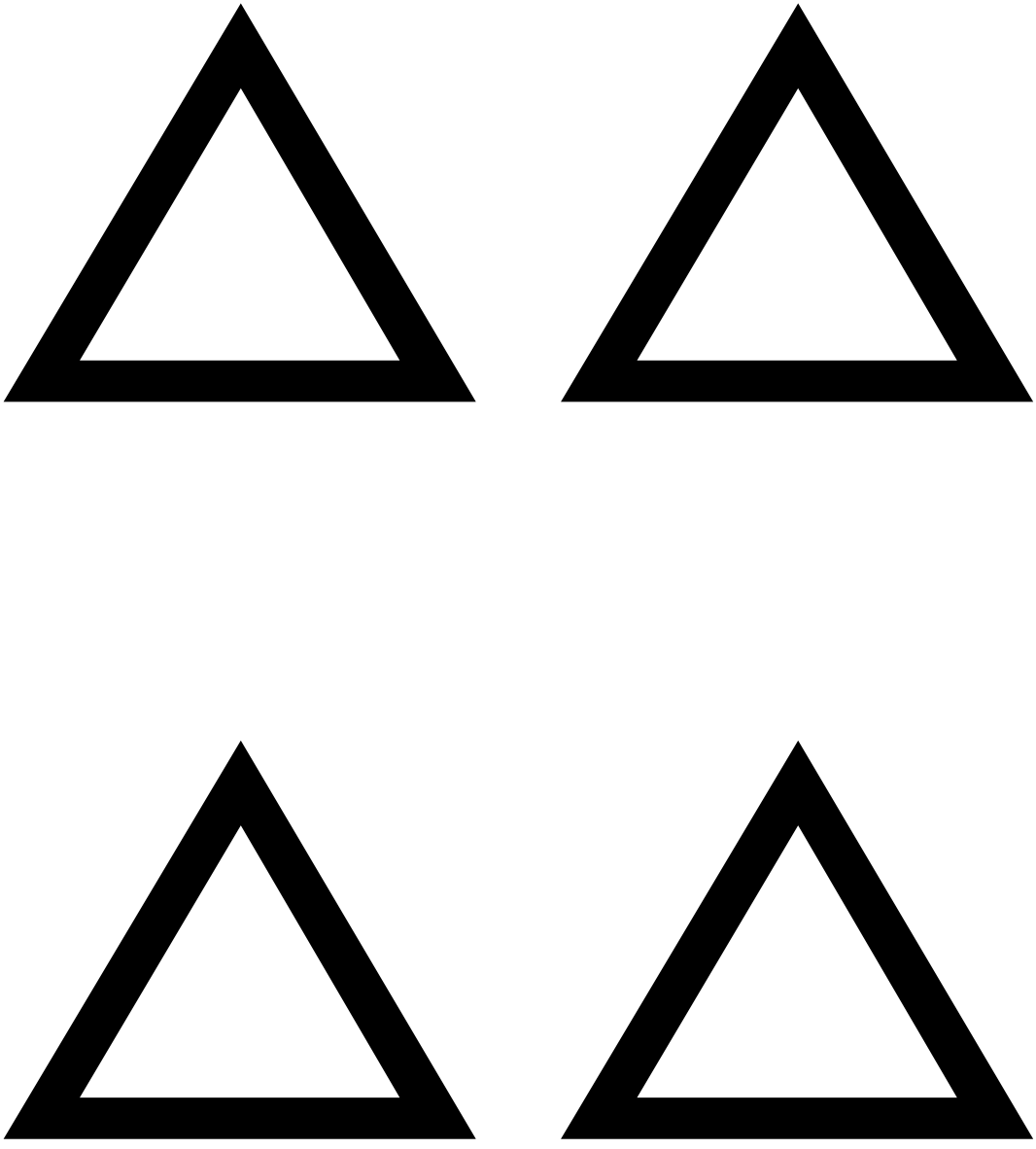
- ↑ Melting point, ↑boiling point
- CAN conduct electricity in all states
- Solids at room temperature
- insoluble ✗
- Harder and stronger than pure metals

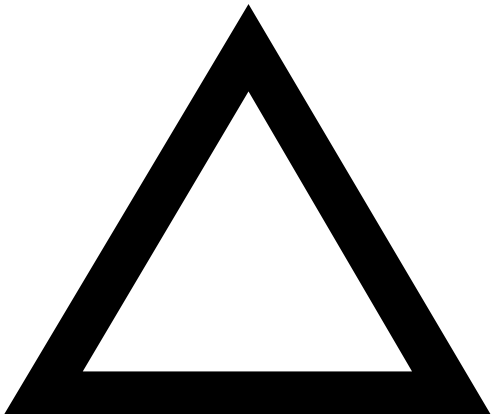
CHAPTER 6

Common polyatomic ions :

Name of polyatomic ion	Formula of ion
Ammonium	NH_4^+
Hydroxide	OH^-
Nitrate	NO_3^-
Sulfate	SO_4^{2-}
Carbonate	CO_3^{2-}
Phosphate	PO_4^{3-}

CHAPTER 7





Percentage yield :

% yield = $\frac{actual\ yield}{theoretical\ yield}$ x 100%

Percentage purity :

% purity = $\frac{mass\ of\ pure\ substance\ present\ in\ sample}{total\ mass\ of\ impure\ sample}$ x 100%

Empirical formula :

n = $\frac{M_r\ of\ compound}{M_r\ from\ empirical\ formula}$

CHAPTER 8

Reactions :

1. Acid + metal ⟶salt + hydrogen
2. base/alkali + acid ⟶salt + water
3. Acid + carbonate ⟶ salt + water + CO_2
4. Alkali + ammonium salt ⟶salt + water +ammonia

Types of acids/base/alkalis :

1. Acid

Stong acid = completely ionised

Weak acid = partially ionised

- Hydrochloric acid [HCl]
- Ethanoic acid [CH_3COOH]
- Nitric acid [HNO_3]
- Sulfuric acid [H_2SO_4]

2. Bases

- Sodium hydroxide [Na_2O]
- Zinc oxide [ZnO]
- Copper(II) oxide [CuO]
- Magnesium hydroxide [$Mg(OH)_2$]
- Aluminium hydroxide [$Al(OH)_3$]

3. Alkalis

- Sodium hydroxide [$NaOH$]
- Potassium hydroxide [KOH]
- Calcium hydroxide [$Ca(OH)_2$]
- Ammonia [NH_3]

Colour changes of some indicators :

INDICATOR	COLOUR IN ACIDIC SOLUTION	pH RANGE AT WHICH INDICATOR CHANGES COLOUR	COLOUR IN ALKALINE SOLUTION
Methyl orange	Red	3-5	Yellow
Screened methyl orange	Violet	3-5	Green
Litmus	Red	5-8	Blue
Thymolphthalein	Colourless	9-10.5	Blue

Oxides of metals :

1. Basic oxides (reacts with acids)

- **C**her ⇒ copper(II) oxide [CuO]
- **C**hong ⇒ calcium oxide [CaO]
- **M**afan ⇒ magnesium oxide [MgO]

2. Amphoteric oxides (reacts with acids & alkalis)

- **Z** ⇒ zinc oxide [ZnO]
- **A** ⇒ aluminium oxide [Al_2O_3]
- **P** ⇒ lead(II) oxide [PbO]

Oxides of non-metals :

3. Acidic oxides (reacts with alkalis)

- **C**riminals ⇒ carbon dioxide [CO_2]
- **S**tay ⇒ sulfur trioxide [SO_3]
  in
- **P**rison ⇒ phosphate(V) oxide [P_4O_{10}]

4. Basic oxides (do not react with acids & alkalis)

- **NO** ⇒ nitric oxide [NO]
- **HO** ⇒ water [H_2O]
- **CO** ⇒ carbon monoxide [CO]

CHAPTER 9

Solubility of salts :

Soluble salts	Insoluble salts
All **s**odium salts All **p**otassium salts All **a**mmonium salts All nitrates	
All chlorides	Silver chloride, AgCl lead(II) chloride, $PbCl_2$
All sulfates	Barium sulfate, $BaSO_4$ lead(II) sulfate, $PbSO_4$ Calcium sulfate, $CaSO_4$
Sodium carbonate, Na_2CO_3 Potassium carbonate, K_2CO_3 Ammonium carbonate, $(NH_4)_2CO_3$	All carbonates

Method for preparation of salts :

1. Adding in excess
   - Insoluble + soluble $\longrightarrow$soluble
2. Titration
   - soluble + soluble $\longrightarrow$soluble
3. Precipitation
   - soluble + soluble $\longrightarrow$insoluble

Steps to prepare Adding in excess :

1. Fill half a beaker with dilute sulfuric acid
2. With constant stirring, add zinc power until no more zinc will dissolve in the acid pr no effervescence is observed
3. Filter to remove the excess (unreacted) zinc powder
4. Collect the filtrate, this is zinc sulfate solution
5. Heat the filtrate until it saturated
6. Allow the saturated solution to cool so that the salt can crystallise
7. Filter to collect the crystals
8. Wash the crystals with a little cold distilled water to remove impurities
9. Dry the crystals between a few sheets of filter paper

Steps to prepare titration :

1. Fill a burette with dilute nitric acid, note the initial burette reading (V_1 cm^3)
2. Pipette 25.0cm^3 of aqueous sodium hydroxide into a conical flask
3. Add 1 or 2 drops of methyl orange indicator to the aqueous sodium hydroxide, solution turns yellow
4. While swirling the conical flask, add dilute nitric acid from the burette slowly until solution turns orange permanently
5. This is the endpoint. Record the final burette reading (V_2 cm^3)
6. Find the volume of dilute nitric acid required for complete neutralisation, which is (V_2 - V_1 cm^3)

Steps to prepare precipitation :

1. Pour about 50 cm^3 of aqueous barium nitrate into a small beaker
2. Add aqueous sodium sulfate (in excess)
3. Stir until no more precipitate forms
4. Filter to collect the precipitate
5. Wash the precipitate with distilled water to remove impurities
6. Allow the precipitate to dry between few sheets of filter paper

CHAPTER 10

Ammonia equation :

N_2 (g) + $3H_2$ (g) $\rightleftharpoons$ $2NH_3$ (g)

Forward reaction: N_2 (g) + $3H_2$ (g) $\longrightarrow$ $2NH_3$ (g)

Backward reaction: $2NH_3$ (g) $\longrightarrow$ N_2 (g) + $3H_2$ (g)

Optimal conditions for Haber Process :

- A pressure of 250 atm
- Temperature of 450°C
- Presence of finely-divided iron catalyst

Steps of Haber Process :

1. Nitrogen and hydrogen gas, 1 : 3 ratio by volume
2. Gas mixture compressed to 250 atm
3. Compressed gas flow over iron catalyst, heater to 450°C, 15% of mixture leaving chamber is ammonia
4. Mixture of ammonia, nitrogen, hydrogen obtained and cooled
5. Ammonia gas condensed into liquid, pumpedC into tanks & stored under pressure
6. Unreacted nitrogen and hydrogen are transferred back into converter to be recycled

CHAPTER 11

Cations :

ION	A FEW DROPS OF NaOH	IN EXCESS OF NaOH
Ca^{2+}	White precipitate of $Ca(OH)_2$ formed $Ca^{2+}(aq) + 2OH^-(aq) \longrightarrow Ca(OH)_2(s)$	White precipitate remained
Zn^{2+}	White precipitate of $Zn(OH)_2$ formed $Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$	White precipitate dissolved
Al^{3+}	White precipitate of $Al(OH)_3$ formed $Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$	White precipitate dissolved
Fe^{2+}	Green precipitate of $Fe(OH)_2$ formed $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$	Green precipitate remained, turned brown on standing
Fe^{3+}	Reddish brown precipitate of $Fe(OH)_3$ formed $Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$	Reddish brown precipitate remained
Cu^{2+}	Blue precipitate of $Cu(OH)_2$ formed $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$	Blue precipitate remained
NH_4^+	No precipitate formed, turned red litmus paper blue Ammonium gas (NH_3) released when heated	-

ION	A FEW DROPS OF NH_3	IN EXCESS OF NH_3
Ca^{2+}	No precipitation	-
Zn^{2+}	White precipitate of $Zn(OH)_2$ formed $Zn^{2+}(aq) + 2OH^-(aq) \longrightarrow Zn(OH)_2(s)$	White precipitate dissolved
Al^{3+}	White precipitate of $Al(OH)_3$ formed $Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$	White precipitate remained
Fe^{2+}	Green precipitate of $Fe(OH)_2$ formed $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$	Green precipitate remained, turned brown on standing
Fe^{3+}	Reddish brown precipitate of $Fe(OH)_3$ formed $Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$	Reddish brown precipitate remained
Cu^{2+}	Blue precipitate of $Cu(OH)_2$ formed $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$	Blue precipitate dissolved to give dark blue solution

Anions :

ION	REAGENT	OBSERVATION
NO_3^-	• Add aqueous NaOH followed by aluminium powder/foil • Warm carefully. Use damp red litmus paper to test for gas released	• Effervescence is observed due to the release of NH_3 gas • Damp red litmus paper turns blue. (NH_3 is a weak alkali)
CO_3^{2-}	Add any dilute acid. Use limewater to test for gas released	• Effervescence is observed due to the release of CO_2 gas • White precipitate is formed in limewater when CO_2 produced is bubbled into it
Cl^-	Add dilute nitric acid followed by aqueous silver nitrate solution	White precipitate of AgCl is formed $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$
I^-	Add dilute nitric acid followed by aqueous silver nitrate solution	Yellow precipitate of AgI is formed $Ag^+(aq) + I^-(aq) \longrightarrow AgI(s)$
SO_4^{2-}	Add dilute nitric acid followed by aqueous barium nitrate solution	White precipitate of BaSO is formed $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

Test for gas (odorless) :

GAS	TESTING REAGENT	OBSERVATION
CO_2	Limewater	White ppt formed & dissolves in excess CO_2
H_2	Lighted splint	The lighted splint extinguishes with a 'pop' sound
O_2	Glowing splint	Glowing splint rekindles

Test for gas (pungent) :

GAS	TESTING REAGENT	OBSERVATION
NH_3	Damp red litmus paper	Damp red litmus paper turns blue
Cl_2	Damp blue litmus paper	Damp blue litmus paper turns red first before it is bleached.
SO_2	Filter paper soaked with acidified potassium manganate(VII), $KMnO_4$	$KMnO_4$ changes from purple to colourless

CHAPTER 12

Redox reaction :

DEFINITION OF OXIDATION	DEFINITION OF REDUCTION
Gain on oxygen	Loss of oxygen
Loss of hydrogen	Gain of hydrogen
Loss of electron	Gain of electron
Increase in oxidation state	Decrease in oxidation state

Oxidation states :

RULE	SPECIES	EXAMPLES	OXIDATION STATE
1	Elements	Na, H_2, O_2, S_8, Cl_2	0
2	Group 1 metals in compounds	NaCl, KCl, LiBr	+1
3	Group 2 metals in compound	$MgCl_2$, $CaCO_3$	+2
4	Aluminium in compound	Al_2O_3, $AlCl_3$	+3
5	Group 17 non-metals in compound	$MgCl_2$, NaBr	-1
6	Hydrogen in compound (except in metal hydride)	H_2O, HCl	+1 (NaH : -1)
7	Oxygen in compound (except in H_2O_2)	H_2O, Na_2O	-2 (H_2O_2 : -1)

Test for reducing agents :

OXIDISING AGENT	CHEMICAL FORMULA	OBSERVATION IF REDUCING AGENT PRESENT
Acidified potassium manganate(VII)	$KMnO_4$	Purple to colourless (MnO_4 reduced to Mn^{2+})

Test for oxidising agents :

REDUCING AGENT	CHEMICAL FORMULA	OBSERVATION IF OXIDISING AGENT PRESENT
Aqueous potassium iodide	KI	Colourless to yellow-brown (Fe^{2+} oxidising to Fe^{3+})

CHAPTER 13

Electrolytic cell :

1. Electrodes

- Anode ⇒ positively charged, attracts anions, connected to positive terminal of power source
- Cathode ⇒ negatively charged, attracts cations, connected to negative terminal of power source
- Inert electrodes ⇒ do not take part in the electrolysis reaction

2. Electrolyte

- Conduct electricity in molten/aqueous state
- Contains mobile ions, act as mobile charge carriers, to conduct electricity

3. Power supply

- Causes electrons to flow from anode to cathode, electron pump
- Creates positive charge (anode) & negative charge (cathode)

4. At the anode

- **An Ox** ⇒ Anions lose electrons, become oxidised

5. At the cathode

- **Red Cat** ⇒ Cations gain electrons, become reduced

Electrolysis in molten binary ionic compounds :

- Molten binary ionic compounds ⇒ typically a salt containing 1 cation & 1 anion in liquid state

Examples of molten binary ionic compounds :

MOLTEN BINARY IONIC COMPOUND	IONS PRESENT
Sodium chloride (NaCl)	Na^{+} & Cl^{-}
Magnesium bromide ($MgBr_2$)	Mg^{2+} & Br^{-}
Aluminium oxide (Al_2O_3)	Al^{3+} & O^{2-}
Iron (III) nitride (FeN)	Fe^{3+} & N^{3-}

Examples of ionic compounds dissolved in water :

AQUEOUS SOLUTION	FROM DISSOLVED SUBSTANCE	FROM WATER
Sodium chloride (NaCl)	Na^+ & Cl^-	H^+ & OH^-
copper(II) sulfate ($CuSO_4$)	Cu^{2+} & SO_4^{2-}	H^+ & OH^-
Hydrochloric acid (HCl)	H^+ & Cl^-	H^+ & OH^-
Potassium hydroxide (KOH)	K^+ & OH^-	H^+ & OH^-

Selective discharge of cations (reactivity series) :

Pop	Potassium (K)	K^+
Song	Sodium (Na)	Na^+
Can	Calcium (Ca)	Ca^{2+}
Make	Magnesium (Mg)	Mg^{2+}
A	Aluminium (Al)	Al^{3+}
Crazy	Carbon (C)	C^{4+} / C^{4-}
Zebra	Zinc (Zn)	Zn^{2+}
In	Iron (Fe)	Fe^{2+}
The	Tin (Sn)	Sn^{2+} / Sn^{4+}
Lecture	Lead (Pb)	Pb^{2+}
Hall	Hydrogen (H)	H^+
Cold,	Copper (Cu)	Cu^{2+}
Many	Mercury (Hg)	Hg^{2+}
Sure	Silver (Ag)	Ag^+
Go	Gold (Au)	Au^+ / Au^{3+}
Pee	Platinum (Pt)	Pt^{2+} / Pt^{4+}

Selective discharge of anions :

Sulfate	SO_4^{2-}
Nitrate	NO_3^-
Chloride	Cl^-
Bromide	Br^-
Iodide	I^-
Hydroxide	OH^-

Determining the products of electrolysis of aqueous solutions (with example) :

Step 1	Identify the ions present in the electrolyte	
Step 2	Determine the anion discharged at the anode by referring to the electrochemical series. Write the half-equation involved	$4OH^-(aq) \longrightarrow O_2(g) + 2H_2O(l) + 4e^-$
Step 3	Determine the cation discharged at the cathode by referring to the reactivity series. Write the half-equation involved	$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$
Step 4	Write the overall equation for the reaction	$2Cu^{2+}(aq) + 4OH^-(aq) \longrightarrow 2Cu(s)\ O_2(g) + 2H_2O(l)$
Step 5	Identify the anion and cation left behind to determine the products of electrolyte	

Electrolysis using reactive electrodes using copper(II) sulfate solution :

1. <u>At the anode</u>

- SO_4^{2-} & OH^- ions are attracted to the anode.
- Copper is NOT an inert electrode, copper oxidised instead
- Copper anode dissolves to form Cu^{2+} ions and decrease ↓ in mass

2. <u>At the cathode</u>

- Cu^{2+}& H^+ ions are attracted to the cathode
- Since copper is below hydrogen in reactivity series, Cu^{2+} ions are selectively discharged over H^+ ions
- Red-brown copper is deposited onto the copper cathode and increase ↑ in mass

Metal purification using impure copper & pure copper :

1. <u>At the anode</u>

- Impure copper (anode)
- After electrolysis, the impure copper anode dissolved and decreases ↓ in mass
- Impurities present in the impure copper fall to the bottom to form anode slime

2. <u>At the cathode</u>

- Pure copper (cathode), deposited onto cathode

Electroplating using copper & metal spoon :

- Electroplating allows us to coat a thin layer of metal onto an object

1. <u>At the anode</u>

- Copper (anode)
- Dissolves to form Cu^{2+} ions, decrease ↓ in mass

2. <u>At the cathode</u>

- Metal spoon (cathode)
- Coated with layer of copper metal, increase ↑ in mass

Simple cell :

1. <u>At the anode</u>

- More ↑ reactive metal
- Selectively oxidised
- Releases electrons that flow through the external circuit
- Forming cations that enter electrolyte

3. <u>At the cathode</u>

- Less ↓ reactive metal
- Causes cations from the electrolyte to gain electrons
- Reduced

Differences between simple and electrolytic cells :

	SIMPLE CELL	**ELECTROLYTIC CELL**
SOURCE OF ELECTRICAL ENERGY	Electrical energy is produced through chemical reactions	Electrical energy is supplied by an external source (e.g. battery)
ELECTRON MOVEMENT	Electrons move spontaneously from the anode to cathode	Electron flow is driven by the battery, moving from the anode to cathode
POLARITY OF ELECTRODES	Anode : negative (-) Cathode : positive (+)	Anode : positive (+) Cathode : negative (-)

Hydrogen fuel cells :

- Fuel cell is similar to simple cell. It derives its power from a fuel that is continuously added at the anode and an oxidiser, or an oxidising agent, continuously added at the cathode

1. <u>Advantages of hydrogen as a fuel</u>

- Renewable fuel
- Electrolysis of water
- Cracking of hydrocarbons
- Produce only water as by-product

2. <u>Disadvantages of hydrogen as a fuel</u>

- Difficult to store and transport hydrogen safely
- Highly flammable gas

<u>CHAPTER 14</u>

Group 1 elements – alkali metals :

Mother	daughter	relationship
Melting point	**density**	**reactivity**
high	low	low
⇩	⇩	⇩
low	high	high

Reactions of some alkali metals with water :

ALKALI METAL	OBSERVATIONS & EQUATION FOR REACTION WITH WATER
Lithium	Reacts quickly, float on water
Sodium	Reacts violently, dart around water surface, might be explosive
Potassium	Reacts very violently, explosive

Order of reactivity :

Lithium < sodium < potassium < rubidium < caesium < francium

Group 17 elements – halogens :

Malaysia B **Melting & boiling point**: low ⇩ high

A **appearance**: low ⇩ high

R **reactivity**: high ⇩ low

Halogens appearance at r.t.p :

Chlorine ⇒ yellow-green gas

Bromine ⇒ red-brown liquid

Iodine ⇒ purple-black solid

Order of reactivity :

Fluorine > chlorine > bromine > iodine > astatine > tennessine

Displacement reaction :

- A displacement reaction ⇒ one element takes the place of another element in the compound
- A more reactive halogen will displace a less reactive halogen ⇒ stronger beats weaker

Halogen \ halide solution	**Potassium chloride (KCl)**	**Potassium bromide (KBr)**	**Potassium iodide (KI)**
Chlorine (Cl_2)	-	Chlorine displaces bromine from a bromide solution	Chlorine displaces iodine from an iodide solution
Bromine (Br_2)	No reaction	-	Bromine displaces iodine from an iodide solution
Iodine (I_2)	No reaction	No reaction	-

Group 18 elements – noble gases :

- Monoatomic non-metals
- Colourless gas at room temperature
- Low melting point & boiling point
- Insoluble in water
- Unreactive

Transition metals :

High mark points ↑ **Melting point**

high distinction ↑ **density**

	CHROMIUM	**IRON**	**MANGANESE**	**COPPER**
NAME OF COMPOUND	chromium(III) chloride	iron(II) sulfate	manganese(IV) oxide	copper(I) oxide
CHEMICAL FORMULA	$CrCl_3$	$FeSO_4$	MnO_2	Cu_2O
OXIDATION STATE	+3	+2	+4	+1
COLOUR	Green	Pale green	Brown-black	red
NAME OF COMPOUND	Potassium dichromate(VI)	iron(III) chloride	Potassium manganate(VII)	copper(II) oxide
CHEMICAL FORMULA	$K_2Cr_2O_7$	$FeCl_3$	$KMnO_4$	CuO
OXIDATION STATE	+6	+3	+7	+2
COLOUR	Orange	Yellow	Purple	Black

CHAPTER 15

Reactions :

1. Metal + water $\longrightarrow$metal hydroxide + hydrogen
2. Metal + steam $\longrightarrow$metal oxide + hydrogen
3. Metal + dilute hydrochloric acid $\longrightarrow$ metal chloride + hydrogen

Reactions of some metals with cold water & steam :

Metal	OBSERVATION FOR REACTION WITH COLD WATER	OBSERVATION FOR REACTION WITH STEAM
potassium	- Reacts very violently - Form potassium hydroxide & H_2 gas - Enough heat to cause H_2 gas to catch fire & explode	- Reacts explosively - Should not be carried out in school lab
sodium	- Reacts violently - Form sodium hydroxide & H_2 gas - H_2 gas may catch fire & explode	
calcium	- Reacts readily - Form calcium hydroxide & H_2 gas	
magnesium	- Reacts very slowly - Form magnesium hydroxide & H_2 gas - A test tube of H_2 gas is produced only after a few days	- Hot magnesium reacts violently - Form magnesium oxide (white solid) and H_2 gas - Bright white glow produced
zinc	No reaction occurs	- Hot zinc reacts readily Produce zinc oxide & H_2 gas - Hot zinc oxide is yellow - Cold zinc oxide is white
iron	No reaction occurs	- Red-hot iron reacts slowly - Form iron oxide - Must be constantly heated
lead copper silver	No reactions occurs	No reaction occurs

Reactions of some metals with dilute hydrochloric acid :

Metal	OBSERVATION FOR REACTION WITH DILUTE HCl
potassium	- React explosively - Should not be carried out in school lab - Gives out H_2 gas
sodium	- React explosively - Should not be carried out in school lab - Gives out H_2 gas
calcium	- Reacts violently - Gives out H_2 gas
magnesium	- Reacts rapidly - Gives out H_2 gas
zinc	- Reacts moderately - Gives out H_2 gas
iron	- Reacts slowly - Gives out H_2 gas
lead copper silver	No reaction occurs

Important rules :

1. metals above hydrogen in reactivity series react with HCl to produce H_2 gas
2. The lower ↓ the metal is in the reactivity series from carbon, the more ↑ readily the reduction of the metal oxide will occur
3. A more ↑ reactive metal has a greater ↑ tendency to form positive ions compared to a less reactive metal
4. A more reactive metal can reduce the oxide of a less reactive metal
5. The more ↑ reactive a metal is, the more ↑ difficult it is to decompose its carbonate by heat

Methods for extracting its ore :

1. Potassium to magnesium ⇒ electrolysis
2. Aluminium to platinum (everything below magnesium) ⇒ reduction by carbon

Conditions for rusting :

- Presence of oxygen (in air) & water for rusting to occur

Barrier methods :

TYPE OF RUST PREVENTION	METHOD	WHERE IT IS USED	ADVANTAGE / DISADVANTAGE
Using a protective layer	painting	Large objects like cars, ships, bridges	- Paint scratched off - Rusting under paint surface
	oiling / greasing	Tools & machine parts	- Protective film of oil gathers dust - Must be renewed
	plastic coating	Kitchenware like draining racks	- Plastic layer torn - Starts to rust
	tin-plating	Food cans	- Tin layer scratched - Starts to rust
	chrome-plating	Taps, kettles, bicycle handle bars	- Bright shiny finish - Rust protection
Using a sacrificial metal	galvanising (zinc-plating)	Water buckets, dustbins, “zinc” roofs, kitchen sinks	- Does not rust even if zinc is scratched - Zinc is more reactive than iron - Zinc corrodes instead of iron
	attaching zinc / magnesium metal blocks	Underground pipes, ships, columns of steel piers	- Zinc and magnesium corrode in place of iron - More reactive

CHAPTER 16

Energy changes :

1. Endothermic change

- Absorb thermal energy from surroundings
- Decrease in temperature in surroundings

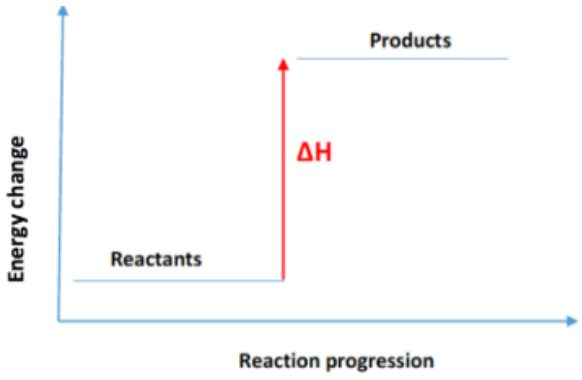
2. Exothermic change

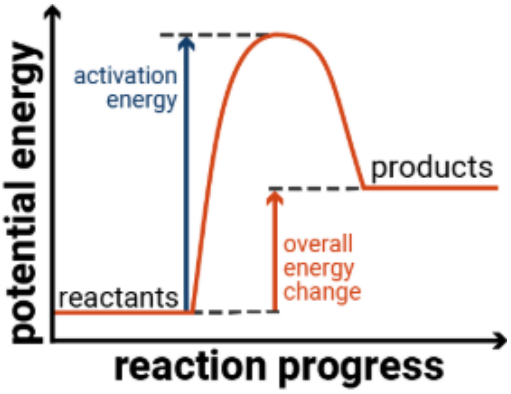
- release thermal energy to surroundings
- Increase in temperature in surroundings

Important definitions :

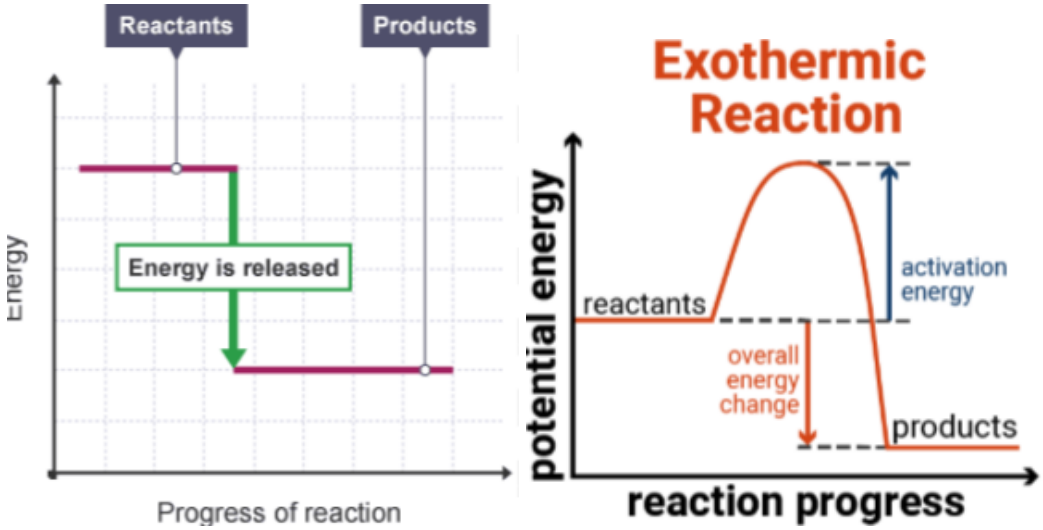
1. Bond energy ⇒ amount of energy absorbed to break 1 mole of chemical bond, also amount of energy released when 1 mole of that bond is formed
2. Activation energy, E_a ⇒ minimum amount of energy that colliding reactant particles must possess to react with each other
3. Enthalpy change, ΔH measures the difference in energy content of reactants and products,

- ΔH = bonds broken (reactants) - bonds formed (products)
- Endothermic, positive enthalpy change (ΔH > 0), BB > BM





- Exothermic, negative enthalpy change (ΔH < 0), BB < BM



CHAPTER 17

Collision theory :

- Reacting particles must collide with each other
- Collide with energy that is greater than or equal to E_a
- Old bonds broken, new bonds formed
- Collisions will result in the formation of products, effective collisions
- Minimum energy required to start the reaction is activation energy

Factors affecting ROR :

1. <u>concentration of reactants</u>

- ↑ concentration ⇒ ↑ no. of particles per unit volume ⇒ ↑ frequency of collisions ⇒ ↑ frequency of effective collisions ⇒ ↑ ROR

2. <u>pressure of reactants</u>

- ↑ pressure ⇒ particles are closer to each other ⇒ ↑ frequency of collisions ⇒ ↑ frequency of effective collisions ⇒ ↑ ROR

3. Particle size / surface area of reactants

- ↓ smaller particle ⇒ ↑ S.A of contact ⇒ ↑ frequency of collisions ⇒ ↑ frequency of effective collisions ⇒ ↑ ROR

4. Temperature at which the reaction occurs

- ↑ temperature ⇒ 1. Particles have more ↑ KE, move faster / 2. More ↑ particles have energy, equal / more than E_a ⇒ ↑ frequency of collisions ⇒ ↑ frequency of effective collisions ⇒ ↑ ROR

Collision theory :

1. Characteristics of catalysts

- Small amount is needed to speed up reaction
- Speeds up rate of reaction
- A catalyst is selective in its action – 1 catalyst cannot act on or speed up all types of reactions
- Different catalysts speed up different reactions
- Lowers activation energy
- Remains chemically unchanged
- Same amount of catalyst is present at the beginning & end of reaction
- Impurities can prevent it from working

2. Catalysts & activation energy

- Increase speed of reaction
- Alternate pathway for reaction to proceed
- Catalysed reaction has a lower activation energy than reaction without the catalyst
- More colliding particles will have energy greater than or equal to E_a
- Higher rate of formation of product particles
- Speed of reaction increased

USES	CATALYST
Haber process (manufacture ammonia)	Iron
Catalytic converter	Platinum, palladium, rhodium
Cracking of hydrocarbon	Aluminium oxide, silicon dioxide

3. Biological catalyst

- Enzymes, made of proteins
- Specific in their action – amylase, changes starch into sugar
- Sensitive to temperature
- Effective at 35°C to 40°C
- Denatured by heating
- Inactive when temperature is low
- Use in manufacturing of wine / alcoholic drink
- Use in biological washing powders

CHAPTER 18

Fossil fuels / natural gas :

- Natural gas – 95% methane
- Atmosphere – 78% nitrogen, 21% oxygen, 1% CO_2 / noble gases
- Fossil fuels decayed plants and animals from millions of years ago, known as hydrocarbons, exothermic reaction : combustion
- 3 types of natural gas :

1. Liquefied natural gas (g) – does not burn easily, safe for consumers, addictive THT (pungent smell) added to detect a gas leak
2. Petroleum (l)
3. Coal (s)

- Natural gas & crude oil considered non-renewable, limited amounts, high demand

Separation of crude oil by fractional distillation :

- Crude oil heated in a furnace to about 400°C\
- Hottest at the bottom
- Higher ↑ BP collected at lower ↓ levels of the fractionating column
- Lower ↓ BP collected at higher ↑ levels of the fractionating column

Fractionating column name & function(s) :

Pretty	Petroleum gas	Cooking & heating
Petty	Petrol	motorcars
Nanny	Naphtha	Feedstock
Kelly	kerosene	Aircraft engine, cooking using gas stove, heating
Did	Diesel	Diesel engines in buses, lorries, trains
Luv	Lubricating oil	Lubricating machine, making waxes, polishes
Birthday (party)	Bitumen	Road surfaces, roofing

Ways to conserve crude oil :

- Reducing the number of vehicles
- Driving smaller cars
- Taking public transport
- Alternative fuels
- Solar / nuclear energy
- Improve design of power stations
- Use crude oil more efficiently

Biofuels :

- Alternative renewable sources energy sources to crude oil & natural gas
- Bioethanol ⇒ fermentation of the sugar in sugarcane plants

CHAPTER 22

Air pollutants & harmful effects :

Air pollutant	Sources	Harmful effects
Sulfur dioxide (SO_2) - A colourless gas with a pungent odour	- Combustion of fossil fuels - Volcanic eruptions	- Breathing difficulties - React with oxygen to form acidic compounds, acid rain - Corrode limestone, marble, metals
Nitrogen dioxide (NO & NO_2) - NO is colourless & odourless - NO_2 is red-brown & has a pungent smell	- Vehicle combustion engines - lightning	- Breathing difficulties - React with oxygen to form acidic compounds, acid rain - Corrode limestone, marble, metals
Carbon monoxide (CO) - Colourless & odourless gas - Toxic	- Incomplete combustion of carbon-based fuels	- Carbon monoxide binds irreversibly with haemoglobin with red blood cells - Lower ability to transport oxygen - Loss of consciousness / death
Methane (CH_4) - Colourless & odourless gas - Highly flammable	- Anaerobic (absence of oxygen) - Bacterial decay - Waste gases from cattle	- Major greenhouse gas - Global warming

Unburnt hydrocarbons (C_xH_y) - Colourless gases naturally odourless - May be pungent due to fuel addictives	- Vehicle combustion engines	- Eye & respiratory tract irritation - React with nitrogen oxides in the presence of sunlight, smog - Produces ozone, sulfur dioxide, nitrogen dioxide
Ozone (O_3) - A pale blue gas - Pungent odour	- Lightning - Reactions between oxygen & sunlight in upper atmosphere - Unburnt hydrocarbons & nitrogen oxides in the presence of sunlight in lower atmosphere	- Eye & respiratory tract irritation - Chest pains, headaches - Slows down photosynthesis

Acid rain :

- Rain combines with excessive amounts of sulfur dioxide & nitrogen dioxide
- pH of around 4.0
- 10 to 30 times more acidic than pH 5.0 to 5.5
- Devastating effects on forests & water bodies
- Leaches nutrients like magnesium & calcium from the soil
- Hampers the health & growth of trees
- Lower pH of soil, killing them
- Experienced prolonged exposure to acid rain
- Much less biodiverse

Flue gas desulfurisation :

- Remove significant proportion of the sulfur dioxide
- Wet scrubbing
- Calcium sulfate can then be hydrated to form hydrated calcium sulfate, known as gypsum