Chemical Analysis

chapter 11-3

- Quantitative Analysis is a type of chemical analysis used to identify cations and anions in solutions.

- Application of quantitative analysis in real-word contexts:
  1. ensure quality / safety of drinking water : identifying harmful ions (i.e lead (II)).

  2. in forensics investigations : identify ions in body fluids and parts such as hair, blood and bone.

TEST FOR CATIONS

substance that produce hydroxide ions, OH^- when dissolved in water.

soluble base, pH > 7

ammonia hydroxide
$NH_3(aq)$
$NH_4OH(aq)$

- A cation is an ion with a positive charge.
- Reagents used: Alkalis [aqueous sodium hydroxide ($NaOH(aq)$) and aqueous ammonia ($NH_4OH(aq)$)].
- observation: A precipitate is formed when cation react with the alkali. → solid (insoluble)
- Precipitate formed is an insoluble metal hydroxide → must be hydroxide (alkalis: OH^-)
- ionic equation: $M^{n+}(aq) + nOH^-(aq) \longrightarrow M(OH)_n(s)$

  must have s.s

  metal ion from unknown solution.

  From alkali

  precipitate

Experimental Procedure	1. Add a few drops of alkali, observe for precipitate formed. 2. If precipitate is formed, add excess alkali and shake reaction mixture.
observation	1. colour of precipitate formed. 2. whether precipitate is soluble or insoluble in an excess of the alkali. 3. If the precipitate is soluble in excess alkali, indicate colour of the solution formed. OR 4. If there is no precipitate formed when sodium hydroxide solution is added, warm the reaction mixture and test for ammonia gas using a damp red litmus paper. (Test for NH_4^+)
Describe chemical test	Add aqueous sodium hydroxide / aqueous ammonia to a sample of each solution.

QA

1. gas?
2. reagent added?
3. colour of ppt. formed?
4. solubility in excess?
   (if yes, colour of sol. formed?)

TEST & OBSERVATIONS FOR CATIONS

cation	Aqueous sodium hydroxide $NaOH_{(aq)}$	Aqueous ammonia $NH_4OH_{(aq)}$
Zn^{2+} zinc	- White precipitate is formed. - Precipitate is soluble in excess to give a colourless solution. solution colour	- White precipitate is formed. - Precipitate is soluble in excess to give a colourless solution.
Pb^{2+} lead (II)	- White precipitate is formed. - Precipitate is soluble in excess to give a colourless solution.	- White precipitate is formed. - Precipitate is insoluble in excess.
Ca^{2+} calcium	- White precipitate is formed. - Precipitate is insoluble in excess.	- No precipitate formed.
NH_4^+ ammonium	- No precipitate is formed. - Upon warming, gas produced turn damp red litmus paper blue. - Therefore, ammonia gas, NH_3, is produced.	→ Why? - particles move freely at a high speed. ↓ rxn faster
Cu^{2+} (copper (II))	- Light blue precipitate is formed. - Precipitate is insoluble in excess.	- Light blue precipitate is formed. - Precipitate is soluble in excess to give a dark blue solution.
Fe^{2+} iron (II)	- Green precipitate is formed. - Precipitate is insoluble in excess.	- Green precipitate is formed. - Precipitate is insoluble in excess.
Fe^{3+}	- Reddish-brown precipitate is formed. - Precipitate is insoluble in excess.	- Reddish-brown precipitate is formed. - Precipitate is insoluble in excess.

White ppt

	NaOH	NH_4OH
Zn^{4}	✓	✓
Pb^{2+}	✓	✗
Ca^{2+}	✗	–

Steps in answering questions on Quantitative Analysis (i.e in the form of flow charts)

① identify any gas produced
② identify reagent added
- test for cation / anion?
③ observations (e.g colour of precipitate / gas produced)
④ identify cation / anion in unknown
- work backwards from observation

Example 1:

Solutions A and B each contain a salt. Solution A is a nitrate solution while B is a chloride solution. The results on solution A and B are as shown below.

reagent added	observations with solution A	observations with solution B
aqueous sodium hydroxide	→ white precipitate formed → soluble in excess aqueous sodium hydroxide to form a colourless solution	→ blue precipitate formed → insoluble in excess aqueous sodium hydroxide
aqueous ammonia	→ white precipitate formed → soluble in excess aqueous ammonia to form a colourless solution.	→ blue precipitate formed → soluble in excess aqueous ammonia to form a dark blue solution.

a) Name and give the chemical formula of the cation present in solutions A and B.

→ cation : NOT copper ∵ qn is asking for cation

* note: zinc & silver are the only 2 transition metals with fixed charges.

A: Zn^{2+}, zinc B: Cu^{2+}, copper (II)

b) Write a chemical equation, including state symbols, for the reaction between solution A and aqueous sodium hydroxide.

→ precipitate (metal hydroxide)

$Zn(NO_3)_2\ (aq) + 2NaOH \longrightarrow Zn(OH)_2\ (s) + 2NaNO_3\ (aq)$

c) Write an ionic equation for the formation of the blue precipitate when aqueous ammonia was added to solution B.

blue ppt

$CuCl_2\ (aq) + 2NH_4OH\ (aq) \longrightarrow Cu(OH)_2\ (s) + 2NH_4Cl\ (aq)$

$Cu^{2+}\ (aq) + 2Cl^-\ (aq) + 2NH_4^+\ (aq) + 2OH^-\ (aq) \longrightarrow Cu(OH)_2\ (s) + 2NH_4^+\ (aq) + 2Cl^-\ (aq)$

Final ionic Eqn: $Cu^{2+}\ (aq) + 2OH^-\ (aq) \longrightarrow Cu(OH)_2\ (s)$

ionic eqn:
→ only involves ionic compounds in the aqueous state!

example 2:

Describe a chemical test to distinguish between aqueous zinc nitrate and aqueous lead (II) nitrate.

Add aqueous ammonia to a sample of each solution. If a white precipitate is formed, soluble in excess aqueous ammonia to form a colourless solution, it is aqueous zinc nitrate. If a white precipitate is formed, insoluble in excess aqueous ammonia, it is aqueous lead (II) nitrate.

note:
- need to write observations for BOTH substances stated in the question.

TEST FOR ANIONS

- An anion is an ion with a negative charge
- Anions include: CO_3^{2-}, Cl^-, NO_3^- and SO_4^{2-}
- When testing for Cl^- and SO_4^{2-} anions
  - ↳ add an equal volume of dilute nitric acid (HNO_3) to acidify solution first. (first reagent)
  - ↳ then add the second reagent required
  - ↳ do not need to add excess of the second reagent
  - ↳ sequence of the reagents added is important

note: Test for Cl^- and SO_4^{2-}, do not include dilute nitric acid in equation.

TEST AND OBSERVATIONS FOR ANIONS

anion	test	observation & inference
Cl^- chloride	- Add dilute nitric acid followed by aqueous silver nitrate. OR - Add acidified silver nitrate solution.	- White precipitate of silver chloride formed. - Ionic eqn: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
SO_4^{2-} sulfate	- Add dilute nitric acid followed by aqueous barium nitrate / aqueous barium chloride. OR - Add acidified barium nitrate / acidified barium chloride.	- White precipitate of barium sulfate formed. - Ionic eqn: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
NO_3^- nitrate	- Add aqueous sodium hydroxide followed by a piece of aluminium foil / powder. - Warm the mixture. - Test the gas produced with damp red litmus paper.	- The damp red litmus paper turns blue. - Ammonia gas is produced.
CO_3^{2-} carbonate	- Add any dilute acid (e.g. HCl) - Bubble the gas produced into limewater (i.e $CaOH_2$)	bubbles of gas - Effervescence / bubbles are observed. - A white ppt. (i.e $CaCO_3$) is formed in limewater. - carbon dioxide is produced.

Why don't use Lead(II)?
- lead (II) chloride & sulfate are both insoluble & forms

Why don't use Calcium?
- it is used for test for cations

Test for NH_4^+ vs Test for NO_3^-

- Add NaOH
- Warm

- Add NaOH
- Add Al foil — it is a lata
- Warm

spec

① H_2 → Hydrogen
② O_2 → oxygen
③ CO_2 → carbon Dioxide
④ Cl_2 → chlorine
⑤ SO_2 → sulfur Dioxide
⑥ NH_3 → Ammonia

; TEST FOR GASES ;

gas	nature of gas	colour & odour	test	observation
H_2	Neutral	- colourless - odourless	Place a lighted splint at the mouth of the test tube.	A 'pop' sound is heard.
O_2	Neutral	- colourless - odourless	Insert a glowing splint into the test tube.	Glowing splint relights.
CO_2	Acidic	- colourless - odourless	Bubble gas into limewater.	white precipitate formed in limewater.
Cl_2	Acidic	- Greenish - yellow - pungent	Place damp blue litmus paper at the mouth of the test tube.	Damp blue litmus paper turns red then bleached.
SO_2	Acidic	- colourless - pungent	Bubble gas into acidified potassium manganate(VII) sol.	solution turns from purple to colourless.
NH_3	Alkaline	- colourless - pungent	Place a damp red litmus paper at the mouth of the test tube.	Damp red litmus paper turns blue.

Note: Test for CO_2 using limewater
- observation : white precipitate formed in limewater.
- Chemical Eqn: $Ca(OH)_2(aq) + CO_2(g) \rightarrow \underbrace{CaCO_3}_{\text{white ppt.}}(s) + H_2O(l)$

why don't use Lead(II)?

- lead (II) chloride & sulfate are both insoluble & forms white ppt. } can't differentiate

why don't use calcium?

- it is used for test for cations

Test for NH_4^+	vs	Test for NO_3^-
- Add NaOH		- Add NaOH
- Warm		- Add Al foil — it is a catalysts ↓ speed up rxn.
		- warm

; TEST FOR GASES :

gas	nature of gas	colour & odour	test	observation
				A 'pop' sound is heard.

THE PERIODIC TABLE

Chapter 14

The Periodic Table of Elements

Key: proton (atomic) number / atomic symbol / name / relative atomic mass

1 H hydrogen 1

METALS

TRANSITION METALS

NON-METALS

Line dividing metals & non-metals.

Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group 0
							2 He helium 4
3 Li lithium 7	4 Be beryllium 9	5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon
87 Fr francium –	88 Ra radium –		114 Fl flerovium –		116 Lv livermorium –		

21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65						
39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112						
57 – 71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201						
89 – 103 actinoids	104 Rf Rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –						

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

*note: Zinc & silver are the only 2 transition metals with fixed charges.

Group

- vertical column of elements.
- Group no. is equal to the no. of valence e^- in an atom. (outermost)
- Elements in the same group has the same no. of valence electrons.
- [Elements in the same group have similar chemical properties.]
- Written in Roman numerals [I, II, III, IV…]

∴ same no. of valence e^-

Period

- Horizontal row of elements.
- Period no. is equal to the no. of electronic shells in an atom.
- Elements in the same period has the same no. of electronic shells.
- Written in Arabic numbers [1, 2, 3, 4, 5…]

Oxides
- metals
  - Basic
  - Amphoteric
- non-metals
  - Neutral
  - Acidic

- The elements in the Periodic Table are arranged in order of increasing proton number.
- Going down a group, the elements become [more (metallic)]
  - ↳ lose e^-
  - ↳ lose e^- more readily / easily.

Group I - Alkali Metals

Li
Na
K
Rb
Cs
Fr

- Form alkalis when Group I elements react with water. → SPAG ⇒ group I hydroxide
  - ↳ soluble base — metal oxide / metal / ammonium hydroxide

5 senses

Physical Properties of Group I metals

1. Low melting and boiling points
2. Low densities → * NOT phy prop. → it is a characteristic
3. Soft, can be cut easily
4. Have shiny and silver surface which tarnishes rapidly in air. → becomes dull.

Pattern (data)

Trends in the physical properties on going down Group I

1. Melting point and boiling point decreases.
2. Density increases. → $D = \frac{m}{V}$ → mass of the element ↑ down group I.

Ar / Relative Atomic Mass

dependent on valence e^- → involves chem rxn

Chemical Properties of Group I metals

- Group I metals are very reactive.
- They are stored in oil to prevent them from reacting with air and water.
- Each Group I metal has one valence electron. A Group I metal will lose the one valence electron to achieve a stable noble gas electronic configuration. Since all Group I metals have one valence electron, they will all have similar chemical properties.

① Group I metals react with cold water to form alkali and hydrogen gas.

Group I element	Observations & Equations
Lithium	Reacts quickly with water. Lithium floats on water. No flame is seen. $2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$
Sodium	Reacts very quickly. Sodium melts and darts around the water surface. A yellow flame is seen. $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
Potassium	Reacts very violently. Potassium melts. A lilac flame is seen. $2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

② Group I metals are powerful reducing agents since they give away their electrons readily.

E.g. $Na \rightarrow Na^+ + e^-$

- The reactivity of Group I metals increases down the group.

Trends in the chemical properties on going down Group I

- Going down Group I, the size of the atom increases, as the no. of electronic shells increase.
- Since the valence electron is further away from the nucleus in a bigger atom, it is easier for the atom to lose the valence electron.

∴ The reactivity of Group I metals increases on going down Group I.
i.e francium > rubidium > potassium > sodium > lithium.

Group VII - Halogens

Physical properties of Group VII Halogens

- Halogens are non-metals that exist as diatomic covalent molecules. (F_2, Cl_2, Br_2, I_2, At_2)

1. Low melting and boiling points.
2. They are coloured.

Halogen	Solid	Aqueous	Gas	R.t.p
Fluorine	-	-	Pale yellow	gas
Chlorine	-	Colourless / Pale yellow	Greenish-Yellow	gas
Bromine	-	Reddish-Brown	Reddish-Brown	liquid
Iodine	Purplish Black	Brown	Purple	solid
Astatine	Black	-	-	solid

→ explain: This is because they are covalent substances with weak intermolecular forces of attraction between the molecules which require a small amount of energy to be overcome.

3. They cannot conduct electricity.

Trends in physical properties on going down Group VII halogens

1. The melting and boiling points of halogens increase.
2. The colour of halogens become darker.

Chemical properties of Group VII halogens

① Halogens undergo displacement reactions with halide solutions.

↳ a reaction in which 1 element takes the place of another element in a compound.

- Criteria:
- a more reactive halogen (in element form & diatomic) displaces a less reactive halogen from its metal halide solution.

example	(elemental state) more reactive	(compound) less reactive	→ halide ion	
word eqn	chlorine + sodium bromide		→ sodium chloride + bromine	
colour	colourless	colourless	colourless	reddish-brown
chem eqn	$Cl_2(aq) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br_2(aq)$			
explaination	since chlorine is more reactive than bromine, chlorine displaced bromine from the sodium bromide solution.			
observation	the solution changed from colourless to reddish-brown.			

*note:
- for displacement rxns
→ always element vs element
→ need to say which sol. the element is displaced from

displacement

① Reactivity?
(which element is more reactive? which element is less reactive?)

② Displacement!
[more reactive = elemental state
less reactive = in the form of a compound]

③ observations?
- bubbles of gas / effervescence ?
- colour change in solution ?

④ products? (if qn ask)

- The reactivity of halogens decreases down the group.

Trends in the chemical properties on going down Group VII

- Going down Group VII, the size of the atom increases, as the no. of electronic shells increase.
- since the valence electron is further away from the nucleus in a bigger atom, it is difficult for the atom to gain one more electron.

∴ The reactivity of Group VII metals decreases on going down Group VII.
i.e fluorine > chlorine > bromine > iodine > astatine

② Halogens are powerful oxidising agents
- atoms of halogens readily gain electrons to form halide ions with a charge of -1.

$X_2 + 2e^- \longrightarrow 2X^-$ (where X_2 = halogen ; X^- = halide ion)

Group 0 - Noble Gases

- They are unreactive and do not react to form compounds.
- Elements in Group 0 or VIII are the least reactive elements in the Periodic Table.
- All the elements in this group have stable electronic structures.
- These elements are also known as inert gas as they are unreactive or rare gases as they comprise of less than 15% of air.
- Noble gases do not lose, gain or share electrons because they have fully-filled/ completely-filled valence shell.

Properties of Group 0 elements

The Noble Gases

1. are all colourless gases at room temperature.
2. have low melting and boiling points.
3. are insoluble in water.
4. are unreactive.
5. are monatomic elements.

Trends in the physical properties on going down Group 0

- The melting and boiling point increases down the group.

Uses of Inert Gases

① Helium

- To fill airships and weather balloons
- To inflat tyres of large aircraft

↳ Low density

↳ Non-flammable

② Neon

- To make lights and advertising signs.

↳ conductor of electricity at high voltage (glows red)

③ Argon

- To fill electric bulbs

↳ provides an inert atmosphere to protect the filament from oxidizing in the air.

④ Krypton & Xenon

- In lamps used in photographic flash units
- In stroboscopic lamps used in lighthouses.

↳ Gives out a lot of light when electricity passes through.

metals

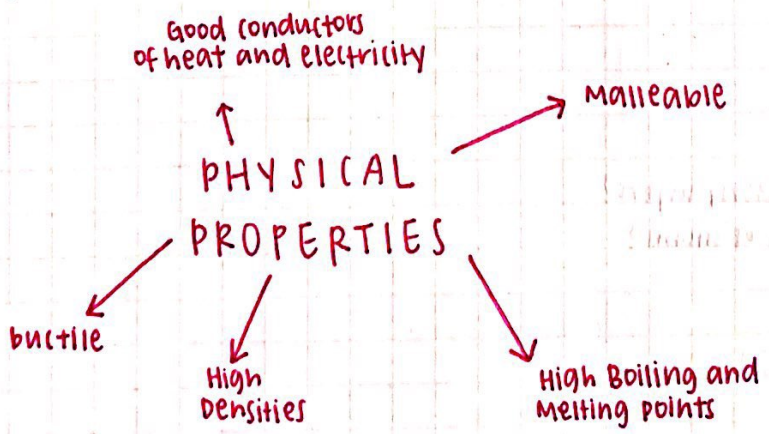
chapter 13

part one

[Physical properties]

Physical properties & structure of metals

- In a pure metal, atoms of same sizes are packed regularly in layers.
- These layers of atoms are able to slide over each other easily when a force is applied.
- Therefore, metals are malleable and ductile.
- Atoms of a metal are held together by strong metallic bonds. → metals & metals
- A large amount of heat energy is required to overcome these strong metallic bonds. → similar to ionic bonding
- Therefore metals usually have high melting and boiling points.
- Metals have giant metallic structures.
- The metal atoms are arranged in a regular and closely packed manner with little space in between them.
- Therefore metals usually have high densities. → $D = \frac{M}{V}$ → M → for solid, no space, ∴ high mass; V → always fixed
- When atoms of metals are tightly packed, the valence electrons are delocalised and can move about freely (mobile).
- These mobile electrons can carry electrical charges and heat.
- Therefore, metals are good conductors of heat and electricity.



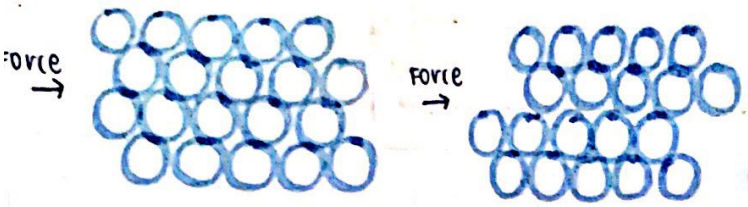
Alloys

- An alloy is a mixture of a metal with another element / elements. → can be separated using physical methods i.e seperation techniques but alloy is an exception.

↳ Example: Stainless steel, Brass, Bronze
- Stainless steel → mainly iron, a little carbon, nickel & chromium
- Brass → copper & zinc
- Bronze → copper & tin

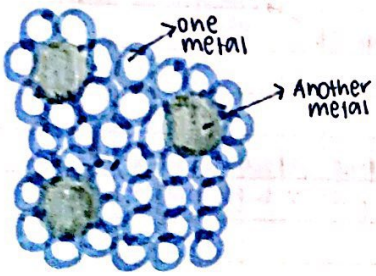
Why use alloys?

- Alloys are harder and stronger than metals.



① In metals, atoms of the same size are very
② closely packed in an orderly and layered manner.
When a force is applied, the layers of atoms
③ slide over each other easily.

VS



① In the alloy, the atoms are of different sizes.
② This disrupt the orderly layers of atoms and thus making it difficult for the atoms to slide over each other. ③

* Alloys VS Metals

① Size of atoms?
- same?
- different?

② Arrangement?
- very closely packed in orderly layers?
- disrupts orderly layers of atoms?

③ Movement?
(when force is applied)

- Alloys...
- improve the appearance of a metal.
- are more resistant to corrosion than pure metals.
- have lower melting points than metals.

- Brass Alloy (copper & zinc)
- used to make trophies, instruments and ornaments.

- Bronze Alloy (copper & tin)
- used to make coins.

part two

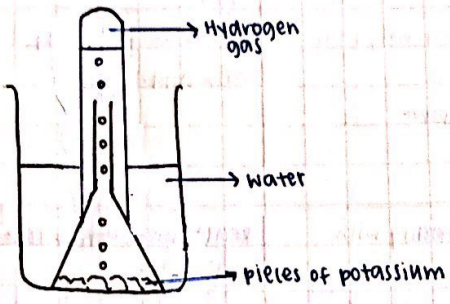
[chemical reactions]

Reaction of metals with cold water

metal(s) + water(l) → soluble metal hydroxide (aq) + hydrogen (g)

alkali (soluble base) — bases

example:
- potassium
- sodium
- calcium

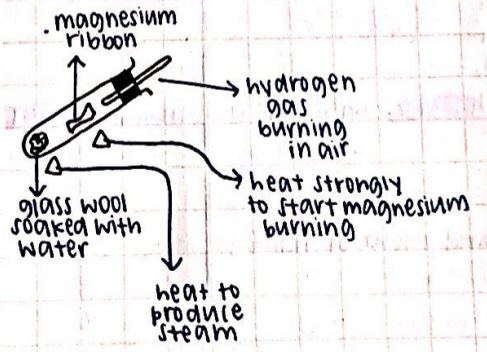


∴ $2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

Reaction of metals with Steam

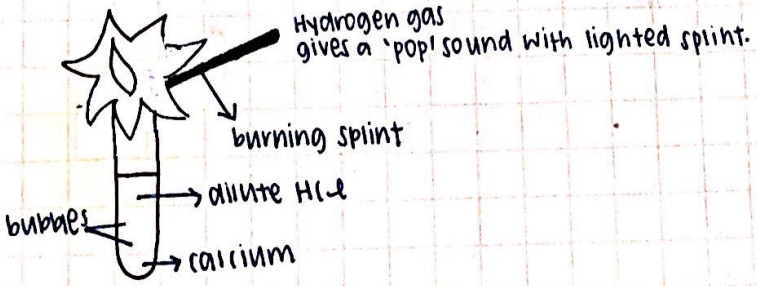
Metal(s) + steam (g) → insoluble metal oxide (s) + hydrogen (g)

example:
- magnesium
- zinc
- iron



∴ $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$

Reaction of metals with dilute HCl



∴ $Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$

Summary of reactions of metals

Metals	Reaction with cold water	Reaction with steam	Reaction with acid
Potassium	Reacts violently with cold water. Lilac flame.	Reacts violently with steam. Should not be carried out in sch lab.	Reacts explosively with acid. Should not be carried out in sch lab.
Sodium	Reacts very quickly with cold water. Yellow flame.		
Calcium	Reacts readily with cold water.		Reacts very quickly with acid.
Magnesium	Reacts slowly with cold water	Reacts violently with steam. White glow	Reacts very quickly with acid.
Zinc	No Reaction with cold water	Reacts readily with steam.	Reacts moderately fast with acid.
Iron		Reacts slowly with steam	Reacts slowly with acid
Lead		No reaction with steam.	No reaction with acid
Copper			
Silver			
Gold			

Reaction of metals with water & steam

- Products of rxn between metals with cold water and metals with steam are NOT the same.

Reaction with cold water:

observation: bubbles, nature of reaction and colour of flame if any.

forms: metal hydroxides & hydrogen gas.

Reaction with steam:

forms: metal oxides and hydrogen gas.

Reactivity series

K	Potassium	Please
Na	Sodium	Stop
Ca	Calcium	Calling
Mg	Magnesium	Me
C	Carbon	Crazy
Zn	Zinc	Zebra
Fe	Iron	I
Sn	Tin	Typically
Pb	Lead	Like
H	Hydrogen	Him
Cu	Copper	Calling
Hg	Mercury	Me
Ag	Silver	Striped
Au	Gold	Goat

Al: Aluminium

Reactivity decreases down the series.

* Recall
- K & Na both in Group I

reactivity increase down the group

K is below Na in Group I, ∴ K is more reactive than Na.

- The higher the position of the metal in the reactivity series, the more reactive the metal.
- The more reactive the metal, the more easily the metal atom loses electrons to form a positive ion / cation.
- Metals below Hydrogen are known as unreactive metals, as they do not undergo any reactions.

Displacement of metals

- A more reactive metal will displace a less reactive metal from its metal salt sol.

Checklist:

① Reactivity
- Which element is more reactive / less reactive?

② Displacement
- Which element displaces which? [Element vs Element].
- More reactive element must be present as an element, less reactive element must be present as a metal salt / metal halide solution for displacement to occur.
  ↓ compound

③ Observations (Practical)
- colour change of solution (if any) → student resource booklet
- colour of solid formed (if any)
- change in size of metal strip (if any)

④ Products formed (if stated in qn)

Reduction of metal oxides

Reduction:
- refers to the removal of oxygen from a metal oxide.

Reactivity:
- The more reactive a metal is, the harder it is to reduce its metal oxides.

∴ The more reactive a metal is, the harder it is to reduce the metal oxide to the metal by carbon.

Extraction of Metal by reduction of their oxides

(A) By reduction of a metal oxide using a more reactive carbon/coke

- the more reactive the metal, the harder it is to reduce the metal oxide using carbon / coke.
- metal oxides of a metal more reactive than carbon CANNOT be reduced by carbon.
- The oxides of metals from zinc to silver can be reduced with carbon.
- Explaination: carbon is more reactive than the metal in the metal oxide, so carbon will reduce the metal oxide to obtain the metal.
- General Word Eqn:

  carbon (s) + Metal oxide (s) → metal (s) + carbon dioxide (g)

Reduction of metal oxides with carbon

Metal Oxide	Reaction
Potassium oxide (K_2O) Sodium Oxide (Na_2O) Calcium oxide (CaO) Magnesium oxide (MgO)	oxides are not reduced by carbon ∵ more reactive than carbon
Zinc Oxide (ZnO) Iron (II) oxide (FeO) Lead (II) oxide (PbO) Copper (II) oxide (CuO)	Oxides are reduced by carbon ∵ metals are less reactive than carbon
Silver oxide (Ag_2O)	oxide is reduced by heating.

very not reactive

Element vs Element ∴ more reactive metal = harder compound.
↳ to reduce metal oxide back to metal.

*recall: The more reactive a metal, more easily to [lose electrons to achieve STABLE.]
↳ easily to form ionic cpd.

Part three
[Extraction of metals]

Extracting Metals

- only very unreactive metals occur in their elemental state in nature
- Most metals chemically react with other elements to form compounds found in ores

Ore

- A compound of the metal (usually the oxides, sulfides, chlorides / carbonates) mixed with large amounts of earth and rock.

Extracting metals from Ores.

2 main methods:

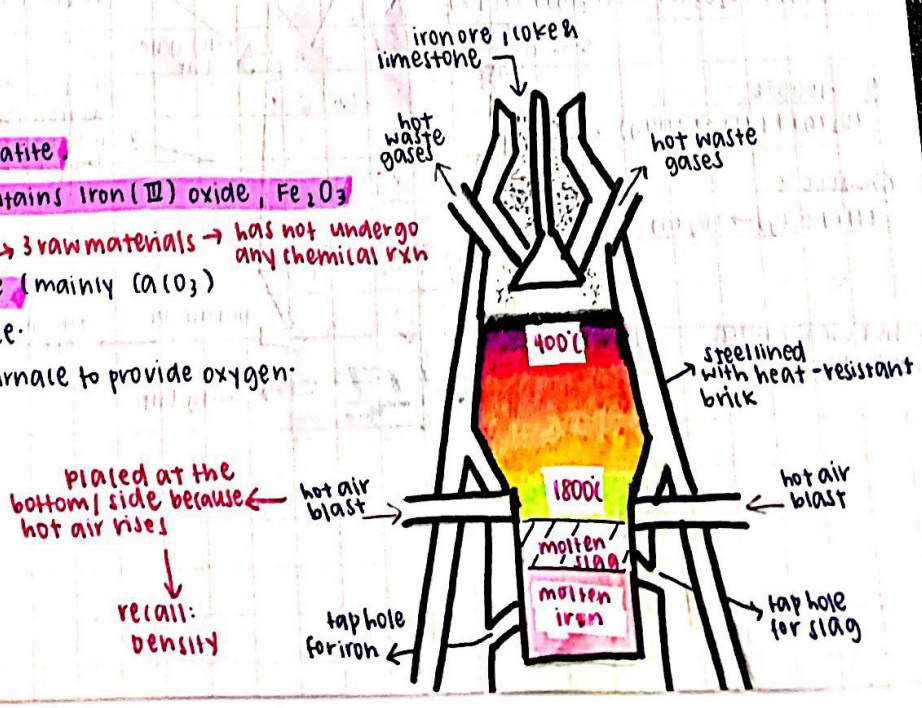
① Reducing the metal compound found in ore to the metal using carbon.
② Using electricity to decompose the molten metal compound (electrolysis) → very high temp. → used up a lot of energy

- Position of a metal in the reactivity series determines the method used for its extraction.
- The more reactive the metal is, the harder it is to extract the metal from its ore.

K	Potassium	extracted by electricity to decompose the molten metal compounds (electrolysis) → electricity breakdown
Na	Sodium	
Ca	Calcium	
Mg	Magnesium	
C	Carbon	extracted by reducing the metal oxides using carbon (reduction)
Zn	Zinc	
Fe	Iron	
Pb	Lead	
Cu	Copper	
Ag	Silver	
Au	Gold	found as pure metal

Extraction of Iron.

- Iron is extracted from the iron ore, haematite.
  ↳ contains Iron (III) oxide, Fe_2O_3
- Reaction takes place in a blast furnace. → 3 raw materials → has not undergo any chemical rxn
- Haematite, coke (mainly C) and limestone (mainly $CaCO_3$) are added at the top of the blast furnace.
- Hot air is blasted at the bottom of the furnace to provide oxygen.



Extraction of iron - reactions

1. Production of carbon dioxide
- Carbon of coke reacts with oxygen in the hot air blast to form carbon dioxide.

Equation: $C(s) + O_2(g) \rightarrow CO_2(g)$

2. Production of carbon monoxide — realt twice
- Carbon dioxide reacts with more coke to form carbon monoxide.

Equation: $CO_2(g) + C(s) \rightarrow 2CO(g)$

3. Formation of molten iron
- Carbon monoxide reacts with the iron(III) oxide to produce molten iron, which runs down to the bottom of the furnace / carbon monoxide reduce iron(III) oxide.

Equation: $\underbrace{Fe_2O_3}_{\text{From haematite} \rightarrow \text{iron ore}}(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$

4. Decomposition of Limestone
- Limestone is decomposed by heat to produce calcium oxide and carbon dioxide.

Equation: $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

↓ more stable because $CaCO_3$ breaks down

5. Removal of Acidic Impurities
- Impurities such as silicon dioxide (sand) realt with calcium oxide to form mainly calcium silicate (slag)

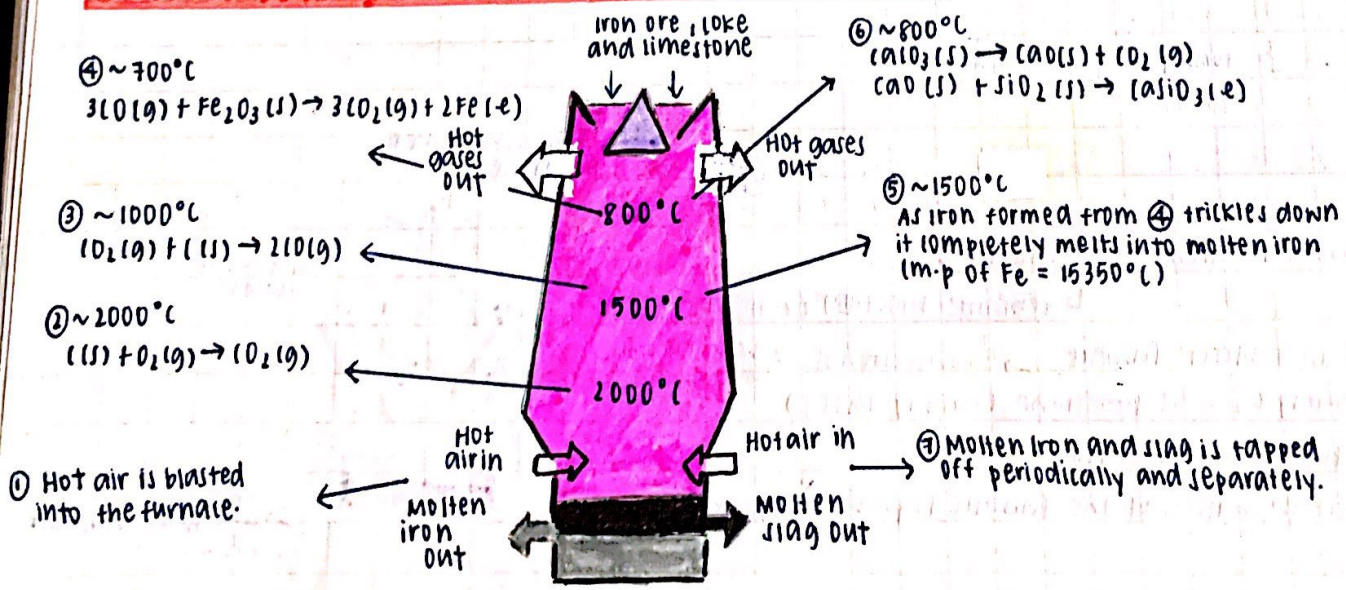
Equation: $SiO_2(s) + CaO(s) \rightarrow CaSiO_3(l)$

SiO_2 ↓ acidic oxide; CaO ↓ basic oxide; $CaSiO_3$ ↓ "salt"

6. Slag floats top of the molten iron (i.e slag is less dense)

7. Slag and molten iron are tapped off separately from the blast furnace.

Summary of extraction of iron



Rusting

- Corrosion of iron and steel is called rusting. → The rest of metal → only for iron
- Rusting takes place when iron is exposed to oxygen and water (both are needed at the same time)
- Rust is hydrated iron(III) oxide, $Fe_2O_3 \cdot H_2O$
- Dissolved salt can speed up rusting.

Different types of rust prevention

Type of Rust Prevention	Method	Where is it used?	Advantage / Disadvantage
(i) Having a protelective layer / Barrier around iron / steel. (coats the entire iron / steel object.	Painting	Cars, ships and bridges.	If paint is removed, rusting occurs.
	Greasing	Tools and machinery parts	Constantly needs to be replenished.
	Plastic coating	Kitchenware	If plastic layer is torn, rusting occurs.
	Tin-plating	Food cans	If the layer of tin is scratched, the iron beneath rust, as tin is less reactive than iron. It will also rust faster than normal.
	Galvanising (zinc-plating) ↓ more reactive than iron.	'zinc roof'	Iron / steel does not corrode even if zinc layer is scratched. This is because zinc is more reactive than iron / iron in steel. Thus, zinc corrodes in place of iron.
(ii) Using a sacrificial metal (metal used is MORE REACTIVE than iron)	Attach zinc / magnesium blocks	Hull of ships, underground pipes	As long as zinc / magnesium blocks is there, iron / steel will not rust. This is because zinc / magnesium is more reactive than iron. Thus zinc / magnesium corrode in place of iron.

Recycling Metals

- Metal ores are finite resources, therefore we need to conserve them to ensure sustainability / future generation has enough to use.

Reasons (why recycling of metals is preferred to extraction / Advantages of recycling)

- Metal ores (NOT metals) are finite resources, hence there is a need to conserve them for future use.
- Recycling is more energy-saving than extraction of metals
- Recycling is cheaper than extraction of metals (this is an advantage NOT an importance)
- Recycling reduces air pollution, as no air pollutants are produced in the recycling process.
- More land will be available for other uses such as agriculture / building infrastructure as less land is destroyed due to mining.
- Recycling reduces land pollution, as the waste metals which takes up space in landfills are recycled.

ATMOSPHERE and ENVIRONMENT

What is the composition of dry air?

- Nitrogen → 78%
- Oxygen → 21%
- Noble gases & carbon dioxide → 0.97% & 0.03%

Atmospheric pollutants	State primary source	Explain how pollutant is produced?	Effect on Health and/or Environment & Explain
Carbon Monoxide (CO)	The incomplete combustion of carbon-containing fuels in vehicles. Note: Cars use petrol as a fuel	During the incomplete combustion of carbon-containing fuels. Note: Incomplete combustion occurs when there is insufficient air (oxygen)	Effect on health • A poisonous gas which causes headaches / fatigue / respiratory difficulties or even death in severe cases. Why it is poisonous? • Carbon monoxide reacts with haemoglobin in the blood to form a stable compound which reduces the ability of blood to carry oxygen
engines		• At high temperatures, nitrogen reacts with oxygen in the air to form nitrogen monoxide / nitric oxide. • Nitrogen monoxide reacts with more oxygen to form nitrogen dioxide.	Effect on health • causes headaches, breathing difficulties. Effect on environment • causes acid rain which (i) corrodes with limestone building (ii) cause lakes to become acidic, kills fishes. (iii) cause soil to become acidic and plants cannot grow well.
...istion of ...uels	• combustion of fossil fuels in power stations / industries.	• Fossil fuels contain sulfur as impurity, hence when fossil fuels are burnt, sulfur reacts with oxygen to form SO_2. • $S(s) + O_2(g) \rightarrow SO_2(g)$	Effect on health • causes breathing difficulties, inflammation of the lungs (bronchitis) Effect on environment • same as oxides of nitrogen / nitrogen oxides.
unburned hydrocarbons (C_xH_y)	incomplete combustion of carbon-containing fuels in vehicles.	—	—

Recall:
BANA
nature of oxides

- Oxides
  - Metal
    - Basic – react with acid
    - Amphoteric – react with both acid & base: Z, A, Pb
  - Non-metal
    - Neutral: NO, CO, H_2O – do not react with acid / base
    - Acidic – react with bases

Nitrogen oxides (NO and NO_2)	• Lightning **Man-made** • internal combustion engines of vehicles. • incinerators } combustion of fossil fuels • Factories } combustion of fossil fuels • power stations

Oxidation & Reduction

— oxidation & reduction —

In terms of	Oxidation	Reduction
Oxygen Atoms	Gain	Lose
Hydrogen Atoms	Lose	Gain
Electrons	Lose	Gain
Oxidation state	Increase	Decrease

Oxidation
GoLeh
Substance Gain oxygen
Lose electrons & hydrogen
Reduction
LoGeh
Substance Lose oxygen
Gain electrons & hydrogen

— oxidising & reducing agents —

- An oxidising agent oxidises other substances, while it itself is reduced.
- A reducing agent reduces other substances, while it itself is oxidised.
  ↳ e.g: antioxidant

~ are reactants
~ exists together in a reaction.
~ A + B → C + D

i.e O.A + R.A → Redox rxn occurs
[R] [O]
O.A + O.A → No rxn
R.A + R.A → No rxn

— redox reactions —

- whereby both oxidation and reduction takes place at the same time.
- there is an electron transfer
- one substance is oxidised, another is reduced.
  i.e reactants has an oxidising agent and a reducing agent.

IMPORTANT

When identifying an oxidation / reduction / redox reaction, consider in the following sequence:

① Gain / Loss of oxygen / hydrogen
② Change in [oxidation state]

O.S ↓ → [R] reduction
O.S ↑ → [O] oxidation

reactions that are NOT redox reactions

① Neutralisation

e.g. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

② Precipitation

e.g. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

③ Decomposition of metal carbonates

e.g. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

in terms of oxygen

gain O, [O]

$Zn(s) + CuO(s) \rightarrow ZnO(s) + Cu(s)$

lose O, [R]

Zinc is oxidised to zinc oxide because it gain oxygen. Copper(II) oxide is reduced to copper because it lose oxygen. Copper (II) oxide is the oxidising agent, because it is reduced. Zinc is the reducing agent, because it is oxidised. Since oxidation and reduction takes place at the same time, this is a redox reaction.

in terms of hydrogen

gain H, [R]

$H_2S(g) + Cl_2(g) \rightarrow 2HCl(g) + S(s)$

lose H, [O]

GAIN

LOSS

Hydrogen sulfide is oxidised to sulfur because it lose hydrogen. Chlorine is reduced to Hydrogen Chloride because it gain hydrogen. Chlorine is the oxidising agent, because it is reduced. Hydrogen sulfide is the reducing agent, because it is oxidised. Since oxidation and reduction takes place at the same time, this is a redox reaction.

in terms of electron transfer

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

Zinc is oxidised to zinc chloride because it lose electrons. HCl is reduced to Hydrogen because it gains electrons. Hydrochloric acid is the oxidising agent, because it is reduced. Zinc is the reducing agent, because it is oxidised. Since oxidation and reduction takes place at the same time, this is a redox reaction.

steps to identify redox - [electron transfer]

① identify ionic compound and break down into ions.

② cancel ions that remain the same — i.e spectator ions (did not participate in the rxn)

Match the reactants to products.

— in terms of oxidation state —

what is O.S ?

- The oxidation state is the charge an atom of an element would have if it existed as an ion.
- Oxidation state is also known as oxidation number.
- The oxidation state of an element can be determined by using the following rules:

~ O.S: sign infront, no. behind
~ charge: no. infront, sign behind

NO	Rule	Example	O.S	charge
1.	For element in uncombined state, the O.S is zero.	C	0	0
		Na	0	0
		H_2	0	0
		O_2	0	0
2.	For simple ion, the O.S is equal to the charge of the ion.	H^+	+1	1+
		Na^+	+1	1+
		O^{2-}	-2	2-
		Cl^-	-1	1-
3.	The O.S of all the atoms present in the formula of a compound add up to zero.	NH_3	$(-3)+3(+1)=0$	
		H_2SO_4	$2(+1)+(+6)+4(-2)=0$	
4.	The O.S of all the atoms present in a polyatomic ion is equal to the charge of the ion.	NO_3^-	$(+5)+3(-2)=-1$	
		CO_3^{2-}	$(+4)+3(-2)=-2$	

— steps to calculate O.S —

1. Identify elements, O.S = 0.
2. Identify ionic cpds & break down into ions, O.S = charge of ion.
3. Cancel ions that remain the same. → did not participate in the rxn.
4. Match the reactants to products.

NOTE:

O.S of hydrogen (+1), oxygen (-2), Group I (+1), Group II (+2), Group III (+3) and Group VII (-1) elements in their compounds are fixed.

0 (elemental state)

O.S ↓ [R]

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

O.S ↑ [O]

Magnesium is oxidised to Magnesium sulfate because oxidation state of Magnesium increases from 0 to +2. Sulfuric acid is reduced to Hydrogen because oxidation state of Hydrogen in sulfuric acid decreases from +1 to 0. Sulfuric acid is the oxidising agent, because it is reduced. Magnesium is the reducing agent, because it is oxidised. Since oxidation and reduction takes place at the same time, this is a redox reaction.

- test to confirm the presence of an oxidising agent — [use a reducing agent]

Reagent used: Aqueous potassium iodide, KI
(colourless)

Observation & inference: If solution turns from colourless to brown, an oxidising agent is present.

- test to confirm the presence of an reducing agent — [use an oxidising agent]

Reagent used: Aqueous acidified potassium manganate (VII), $KMnO_4$
(purple)

Observation & inference: If solution turns from purple to colourless, a reducing agent is present.

- common agents -

Oxidising agent:
- Acidified potassium manganate (VII), $KMnO_4$
- Chlorine, Cl_2
- Oxygen, O_2
- Hydrogen Peroxide, H_2O_2

Reducing agent:
- Potassium iodide, KI
- Carbon Monoxide, CO
- Carbon, C
- Hydrogen, H_2
- Sulfur Dioxide, SO_2

Speed of reaction

ways to measure speed of a reaction

(a) Measure time taken for a reaction to be completed.

→ the time taken for the reaction to be completed.
(i.e no more bubbles / effervescence produced)

→ the shorter the time taken, the higher the speed of reaction.

→ the longer the time taken, the lower the speed of reaction.

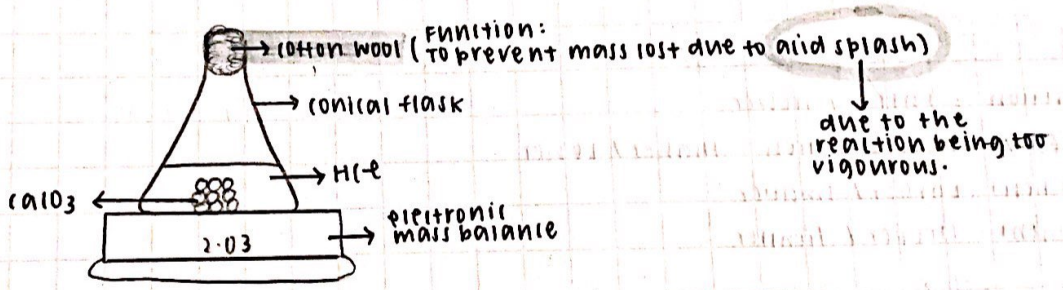
(b) Measure mass of reaction mixture / mass lost at fixed time intervals.
→ ∵ of the gas produced → escapes into surroundings

→ only applies for reactions that produce a gas.

→ mass of reaction mixture decreases with time as the gas produced escapes.

→ difference in mass of reaction mixture is equal to mass of gas produced.

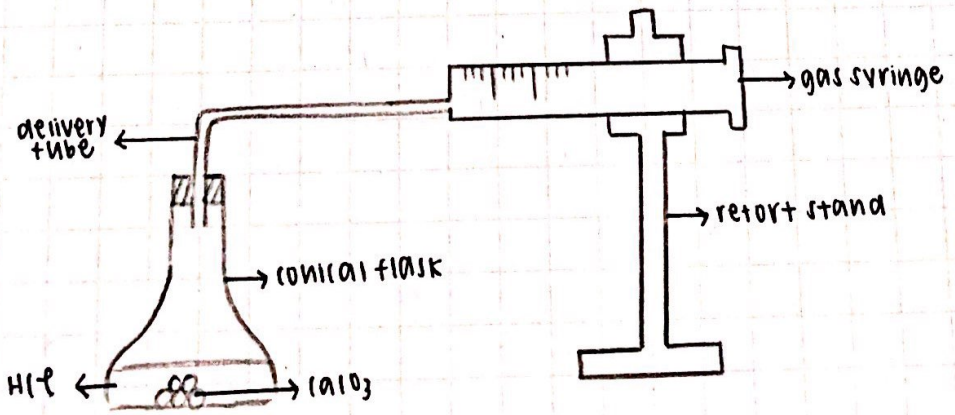
→ Diagram of experimental set-up:



(c) Measure volume of gas produced at fixed time intervals.

→ use a gas syringe to collect and measure volume of gas produced with time.

→ Diagram of experimental set-up:



interpretation of graphs

- if mass of reaction mixture / mass lost / volume of gas produced is plotted against time.
  ↳ The gradient of the graph indicates the speed of the reaction.
- The steeper the graph, the larger the gradient, the higher the speed of reaction.
- Speed of reaction at the start = initial speed of reaction.
- Most of the time, initial speed of reaction is the highest.
- As time proceeds, speed of reaction decreases.
- When the reaction is complete / has stopped, speed of reaction is zero.
  (i.e horizontal line)
  ↳ zero gradient
- The reaction is complete at the start of the horizontal line.
- To find the speed at any instant, draw a tangent at that point, find the gradient of tangent.
- To find how the speed of reaction changes with time, draw tangents along the graph.
- To find average speed, take total volume of gas produced / difference in mass of reaction mixture divide by total time for reaction to be completed.

in summary

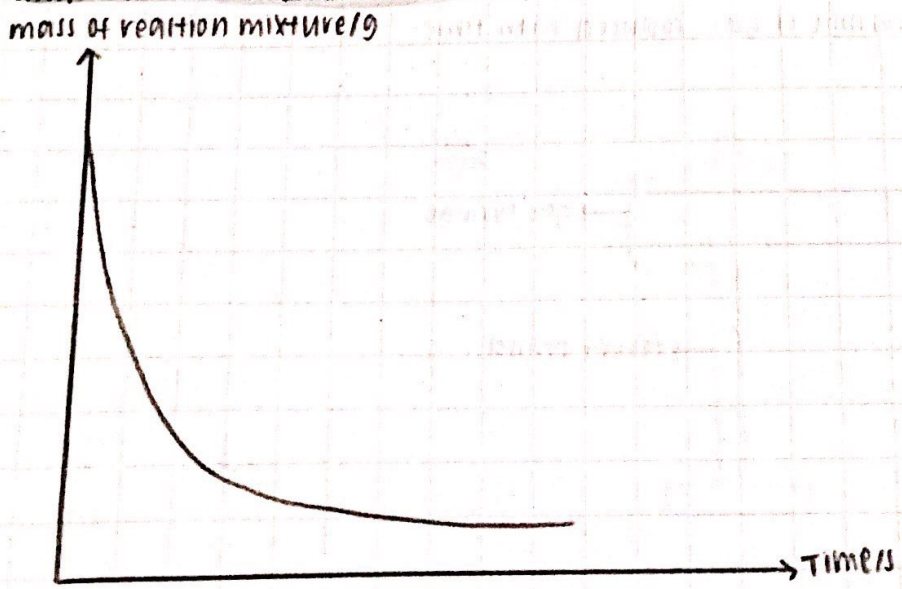
- Gradient of the graphs = speed of reaction
- The larger the gradient, the higher the speed.
- The smaller the gradient, the lower the speed.
- Reaction is complete / stops at the start of the horizontal line of the graph.

terms for SVR

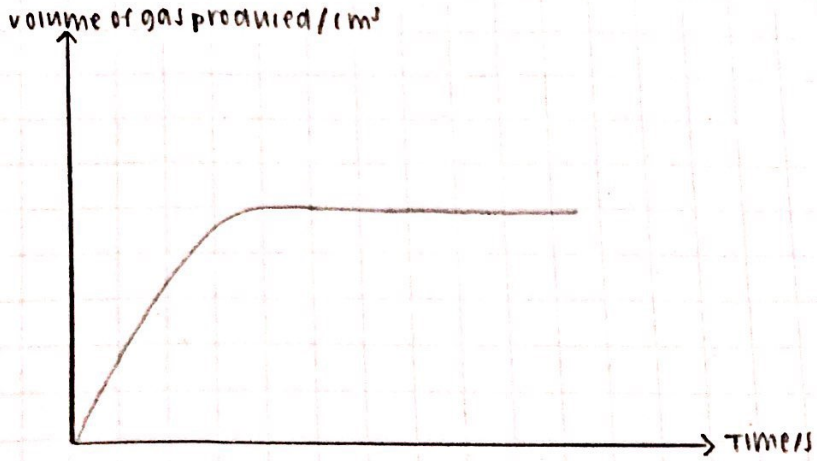
① Reaction : Faster / Slower
② Speed / Rate of Reaction : Higher / Lower
③ Gradient : Larger / Smaller
④ Tangent : Steeper / Gentler

sketching of graphs that show SVR

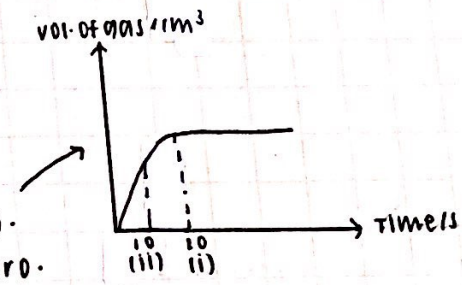
(a) Graph of mass of reaction mixture / g against time / s



(b) Graph of volume of gas produced / cm^3 against time/s

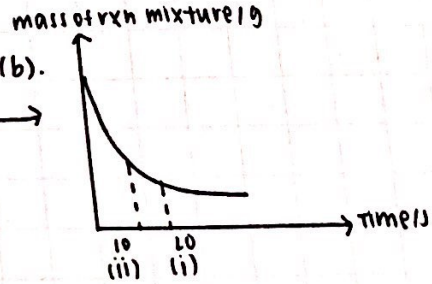


questions on graph



(a) Describe how speed change with time for graph (i) in (a) & (b).

- initial speed is the highest and decreases with time until zero.



(b) Describe how speed of reaction change with time for graph (ii) in (a) & (b).

- initial speed is the highest and decreases with time.

what are the conditions necessary for a reaction to take place?

The collision Theory

- Reactant particles collide and bounce off each other, no products form.

↳ no reaction occurs

- Reactant particles collide at high speeds and possess the sufficient energy (activation energy) for the reaction, products are formed.

↳ reaction occurs

- For a reaction to occur and products are formed, an effective collision must take place.
- Any factors that cause an increase in the rate of collision and effective collision, increases the speed of reaction.

when investigating how one factor affects the speed of a reaction:

- The experiment is repeated with the factor that is investigated changed.
- All the other experimental conditions are kept the same.
- Graphs for both the experiments are plotted on the same set of axes and the gradients are compared.

what factors that affects the speed of a reaction?

Affect:

1) Pressure of a gaseous reactant
2) Concentration of a solution (reactant)
3) Temperature of a solution (reactant)
4) Particle size / size of solid reactant

DO NOT Affect:

1) Volume of a solution (reactant)
2) Mass of solid (excess reactant)

important!

1. Why does the speed of a reaction decrease with time?

→ For reactions that involve a solution (usually acids) as a reactant, speed of reaction decreases with time because concentration of the solution decreases.

2. Explain why a reaction is completed after some time.

→ All the reactants / limiting reactant have been used up.

<u>Points to consider when sketching a new graph on the same set of axes</u>

1. Is there a limiting reactant?
   - moles of LR determine the m[illegible] of product formed.
   - the higher/lower the no. of moles of LR, the higher/lower the moles of products formed.
   - LR is completely used up in a reaction & it causes reaction to be complete / stop.
2. How does the initial speed change?
   - initial speed lower / higher OR decreases / increases
3. How does the mass of reaction mixture / mass lost / volume of gas produced (y-value) change?
   - y-value depends on moles of reactants / limiting reactant
4. How does the time taken for the reaction to be completed change?
   - takes a longer / shorter time
   - time taken depends on how initial speed and moles of product formed changes.

(A) Pressure of a gaseous reactant

- when pressure of a gaseous reactant increases/decreases, speed of the reaction increases/decreases.

explain:

- As the pressure of a gaseous reactant increases, there will be more reactant particles per unit volume.
- Reactant particles are closer together.
- This leads to a higher rate of collision and effective collision between reactant particles.
- Hence, speed of reaction increases.

(B) concentration of a solution (reactant)

- As the concentration of one reactant solution increases/decreases, speed of the reaction increases/decreases.
- Note: An increase/decrease in concentration of a solution, which is the limiting reactant, will increase/decrease the moles of product formed.

explain:

- As concentration of a solution increases, there will be more reactant particles per unit volume.
- Reactant particles are closer together.
- This leads to a higher rate of collision and effective collision between reactant particles.
- Hence, speed of reaction increases.

(C) temperature of a solution (reactant)

- When the temperature of a reactant solution (e.g acids) increases/decreases, speed of reaction increases/decreases.
- Note: Changes in temperature DO NOT affect moles of product formed.

explain:

- At a higher temperature, reactant particles possess more kinetic energy and move faster.
- This leads to a higher rate of collision and effective collision between reactant particles.
- Hence, speed of reaction increases.

(D) particle size of solid reactant

As the particle size of a reactant increases/decreases (total mass remains the same), speed of the reaction decreases/increases.

Particle size/size of solid decreases as follows: lumps > chips > granules > powder

explain:

- As the particle size of a solid reactant decreases, the exposed area increases.
- This leads to a higher rate of collision and effective collision between reactant particles.
- Hence, speed of reaction increases.

introduction to organic chemistry

chapter 18

Introduction

2/more atoms chemically combined

- All organic compounds contain carbon & hydrogen
- Hydrocarbons are organic compounds that contain only hydrogen & carbon
- Not all carbon-containing compounds are organic compounds; e.g. carbon dioxide, carbon monoxides & carbonates.

Petroleum & Natural Gas

liquid

- Petroleum & natural gas are used as sources of energy.
  - ~ Petroleum, also known as crude oil, is a mixture of several hydrocarbons (i.e alkanes)
  - ~ Natural gas consists of mainly methane & other short-chain alkanes.
    - ↳ CH_4

Separation of Petroleum by Fractional Distillation

liquids that can dissolve in/are soluble in water.

used to separate $\boxed{\text{miscible}}$ liquids with different b.p!

- Petroleum can be separated into different useful fractions by fractional distillation.
- Each fraction is a mixture of hydrocarbons / alkanes which boils over a certain temperature range.
- The less carbon atoms per hydrocarbon / alkane molecule (smaller molecules / lighter hydrocarbons), the lower the boiling point of the fraction.
- The more carbon atoms per hydrocarbon / alkane molecule (bigger molecules / heavier hydrocarbons), the higher the boiling point of the fraction.

recall: mixtures DO NOT have a fixed m.p / b.p
↳ they can boil/melt over a range of temp.

How is petroleum refined/separated into useful fractions in the oil refinery?

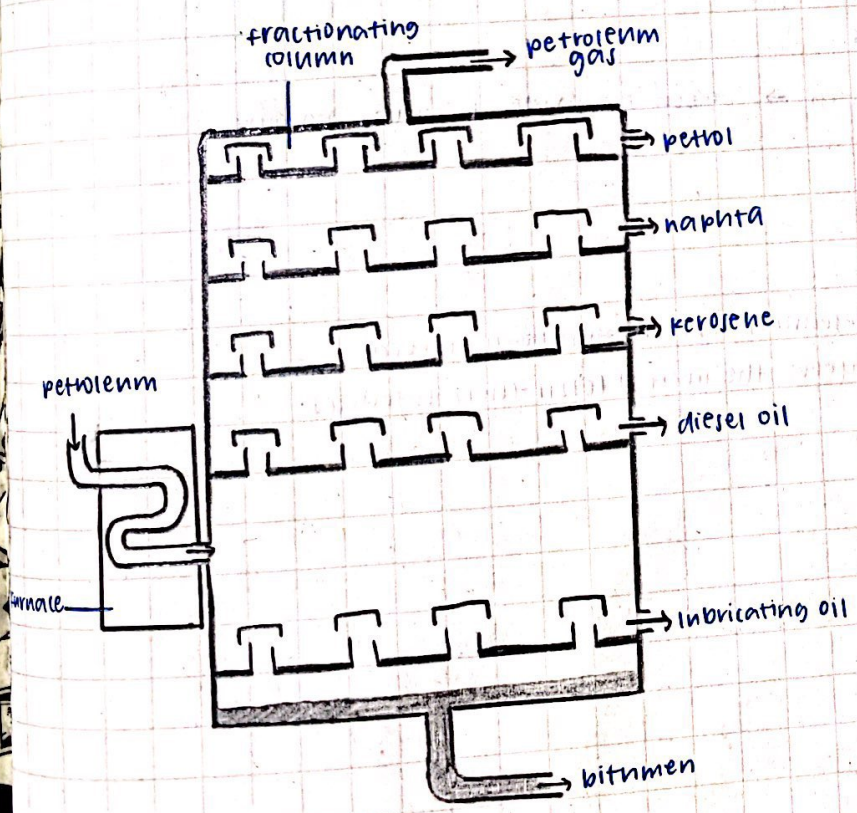
① Petroleum is separated using fractional distillation into useful fractions.
② Petroleum is heated in a furnace and all the hydrocarbons / alkanes boils and become a vapour.
③ The vapour rises up / enters the fractionating column.
④ The lower the boiling point of the fraction / hydrocarbons / alkanes, the higher up it condenses along the fractionating column.
∴ lower density

OR

The higher the boiling point of the fraction / hydrocarbons / alkanes, the lower down it condenses along the fractionating column.
∴ higher density

note:

- The different fractions / hydrocarbons / alkanes boil at the same time & are condensed & collected at the same time along the fractionating column.
  ↳ but at diff parts of the FC!
- The fractions / hydrocarbons / alkanes with lower boiling point do not boil & condense first.
  ↳ diff from laboratory FD!



Uses of Petroleum fractions

Fractions	Number of carbon atoms in one hydrocarbon molecule	Boiling point of fraction / °C	Uses
Petroleum gas	C_1 - C_4	Below 40	Fuel for cooking & heating
Petrol	C_5 - C_{10}	35 - 70	Fuel for cars.
Naphtha	C_8 - C_{12}	70 - 170	Chemical feedstock (raw material) for petrochemical industry (make plastics, detergents, drugs etc)
Kerosene (paraffin)	C_{10} - C_{14}	170 - 250	Fuel for aircraft ; fuel for heating & cooking using oil stoves.
Diesel	C_{15} - C_{25}	250 - 340	Fuel for buses, taxis & lorries
Lubricating oil	C_{19} - C_{35}	350 - 500	Lubricants for machines : for making waxes & polishes.
Bitumen	More than 70	Over 500	Paving road surfaces.

Fuels

- Main sources of fuels are fossil fuels such as coal, petroleum & natural gas.
- Fuels are substances that release heat energy when burnt / undergo combustion.
- Fuels are needed for activities such as generating electricity & powering a vehicle.
- Most fuels are hydrocarbons.

enough / excess O_2

Complete combustion of hydrocarbons

Hydrocarbon + oxygen → carbon dioxide + water vapour

Incomplete combustion of hydrocarbons

insufficient O_2

Hydrocarbon + oxygen → carbon monoxide + water vapour

Alternative Fuels

- Petroleum / fossil fuels are non-renewable resources, hence it must be conserved.
- Alternative fuels are needed in order to conserve the limited fossil fuels resources.
- Examples of alternative fuels :
  1. Palm oil
  2. Ethanol from sugar cane
  3. Biogas (mostly methane)

Alkanes

Chapter 19

WHAT ARE HYDROCARBONS?

- covalent compounds
- made up of molecules
- molecules contain carbon & hydrogen atoms only.

HOMOLOGOUS SERIES

- is a group of organic compounds with :

(a) the same general formula
(b) the same functional group (i.e a characteristic group of atoms found in every member of a homologous series)
(c) successive members differ by $-CH_2-$ group (i.e relative molecular mass differ by 14)
(d) a gradual change in their physical properties
(e) similar chemical properties

ALKANES

- are hydrocarbons as their molecules contain only carbon & hydrogen atoms.
- contain only carbon-carbon single covalent bonds, C-C
- General formula : $C_n H_{2n+2}$ ☆ $n \geq 1$
- known as saturated hydrocarbons
- spelling end with -ane
- has NO functional group

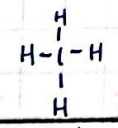
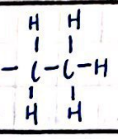
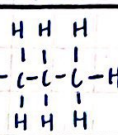
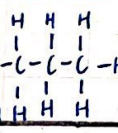
DEFINITIONS

(i) Molecular Formula
↳ shows the total no. of each type of atom in a molecule

(ii) Full Structural Formula
↳ shows how the atoms are arranged in a molecule & all the covalent bonds between the atoms.

(iii) Structural Formula
↳ shows how the atoms are arranged in a molecule.

ALKANE HOMOLOGOUS SERIES

No. of carbon atoms in 1 molecule	Molecular Formula	Mr	Physical state at R.T.P	Prefix	Chemical Name	Full Structural Formula	Structural Formula
1	CH_4	16	gas	Meth	Methane		CH_4
2	C_2H_6	30	gas	Eth	Ethane		CH_3CH_3
3	C_3H_8	44	gas	Prop	Propane		$CH_3CH_2CH_3$
4	C_4H_{10}	58	gas	But	Butane		$CH_3CH_2CH_2CH_3$

PHYSICAL PROPERTIES

(A) MELTING & BOILING POINT

- melting & boiling point increases as the size of the molecule increases
  - ↳ i.e size of molecule increases as no. of carbon atoms per molecule increases.
- explaination:
  - ↳ when there are more carbon atoms per molecule, size of molecule increases, the weak intermolecular FOA between molecules becomes more extensive.
  - ↳ more energy is required to overcome the FOA.
  - ↳ therefore, the higher the boiling point.

(B) VISCOSITY

- viscosity increases / more viscous as the size of the molecule increases
  - ↳ i.e more difficult to flow.
- explaination:
  - ↳ when size of molecule increases, the weak van der Waals' / intermolecular FOA becomes more extensive.

(C) FLAMMABILITY

- definition: how easily a substance undergoes complete combustion
- flammability decreases / less flammable as the size of the molecule increases.
- explaination:
  - ↳ when size of molecule increases, the no. of carbon atoms increases
  - ↳ larger no. of moles of oxygen is required for complete combustion
  - ↳ hence, produce a smokier flame due to incomplete combustion occuring.

Complete combustion: (methane)

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

☆ $\boxed{\text{no. of moles of } O_2 = \text{no. of carbon atoms}}$

checklist:

1. Reactants?
2. Type of rxn? [substitution? addition?]
3. Conditions? [Pressure? Temp? catalyst?]
4. Products?

CHEMICAL REACTIONS

(A) COMPLETE COMBUSTION

- burn/react in excess air/oxygen to produce a lot of heat energy
  - ↳ i.e used as a source of fuels
- products are: carbon dioxide and water vapour
- general equation: Alkane(g) + oxygen(g) → carbon dioxide(g) + water vapour(g).

(B) INCOMPLETE COMBUSTION

- burn/react in limited/insufficient amount of air/oxygen
- products are: carbon monoxide and water vapour
- general equation: Alkane(g) + oxygen(g) → carbon monoxide(g) + water vapour(g)

(C) SUBSTITUTION RXN WITH CHLORINE

- alkane reacts with gaseous chlorine, Cl
- products are:
  - ↳ gaseous chloroalkane
  - ↳ gaseous hydrogen chloride
- produce a mixture of substituted products of chloroalkanes
- condition: needs UV light
- 2 reactants react to form 2 products
- involves substituting 1/more of the hydrogen atoms in the alkane with chlorine atom/s.
- in any 1 rxn, only 1 hydrogen atom is substituted with 1 chlorine atom.
- general equation: Alkane(g) + chlorine(g) → chloroalkane(g) + Hydrogen chloride(g)

example: Methane gas with chlorine gas, Cl_2.

$$CH_4(g) + Cl_2(g) \rightarrow \underset{\text{monochloromethane}}{CH_3Cl(g)} + \underset{\text{by-product}}{HCl(g)}$$

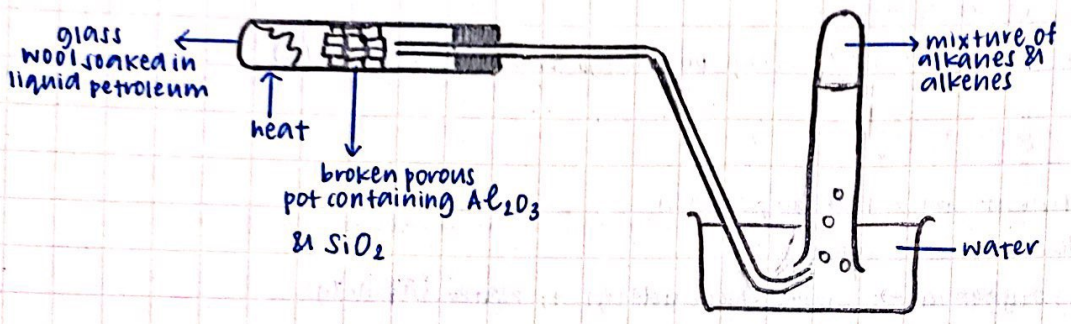
$$CH_3Cl(g) + Cl_2(g) \rightarrow \underset{\text{dichloromethane}}{CH_2Cl_2(g)} + HCl(g)$$

$$CH_2Cl_2(g) + Cl_2(g) \rightarrow \underset{\text{trichloromethane}}{CHCl_3(g)} + HCl(g)$$

$$CHCl_3(g) + Cl_2(g) \rightarrow \underset{\text{tetrachloromethane}}{CCl_4(g)} + HCl(g)$$

(D) CRACKING

- involves breaking down long-chain (large) alkanes
- Products: mixture of short-chain (small) molecules such as alkane and/or alkene and/or hydrogen gas
- Conditions required:
  - ↳ high temp.
  - ↳ catalyst is Aluminium Oxide and/or Silicon Dioxide
- general equation: Long Chain Alkanes → Short chain Alkane + Short chain Alkene + Hydrogen Gas
- cracking is essential to produce fractions containing smaller molecules which are more useful such as petrol to meet their high demand.
- Diagram:



- importance:

(1) A source of short-chain alkanes ($C_2 - C_3$)
- ↳ raw materials for important industrial processes
- ↳ example: produce ethene & propene which are used to make plastics & ethanol
- ↳ $C_{18}H_{38} \rightarrow C_6H_{14} + 6C_2H_4$

(2) A source of Hydrogen Gas
- ↳ $C_{18}H_{38} \rightarrow C_8H_{16} + C_{10}H_{20} + H_2$

(3) A source of petrol
- ↳ heavier fractions (a ↑ l.) from the fractional distillation of crude oil are less useful, such as lubricating oil & diesel, which are cracked to produce petrol to meet the high demand.

alkenes

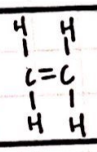
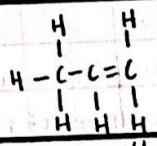
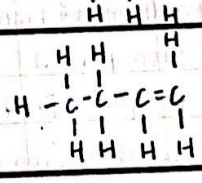
alkene homologous series

- are covalent compounds consisting of molecules
- are hydrocarbons as their molecules contain only carbon & hydrogen atoms
- each molecule consists of only 1 carbon-carbon double bond, C=C
- functional group: C=C
- general formula: C_nH_{2n} ★ $n \geq 2$
- are unsaturated hydrocarbons / compounds because they consist of at least 1 C=C.
- alkenes are an example of an unsaturated hydrocarbons / compounds
- spelling end with -ene.

physical properties

- The alkene homologous series has the same physical properties as alkanes.

alkene homologous series (carbon)

No. of carbon atoms in 1 molecule	Chemical Name	Molecular formula	Mr	Physical state at R.T.P	Full structural formula
2	Ethene	C_2H_4	28	gas	
3	Propene	C_3H_6	42	gas	
4	Butene	C_4H_8	56	gas	

chemical reactions

(A) complete combustion
(B) incomplete combustion
} same as alkanes

(C) Addition Reactions

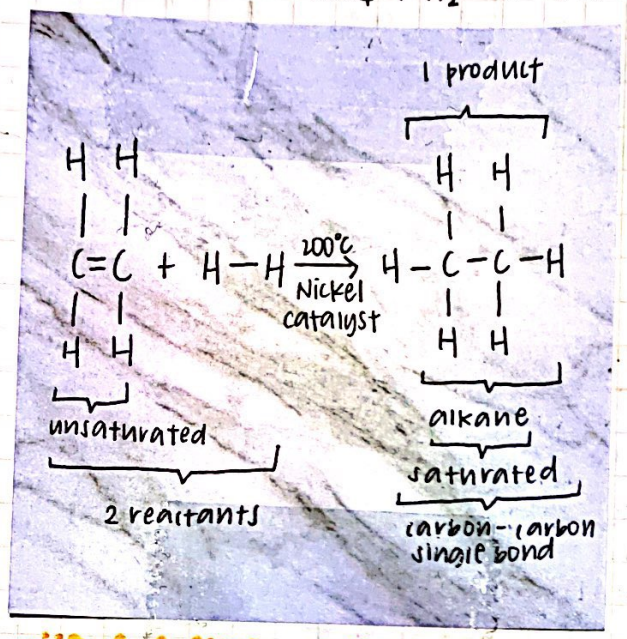
- unsaturated compounds are reactive because the carbon-carbon double bond is rich in electrons.
- hydrogen and bromine react with unsaturated compounds
- a carbon-carbon double bond is converted to a carbon-carbon single bond
- an unsaturated compound becomes a saturated compound
- 2 reactants form 1 product

(ii) Addition Reaction with Hydrogen

- type of reaction : addition of hydrogen
- name of reaction : hydrogenation
- alkenes react with hydrogen gas
- product is alkanes
- conditions required :
  - → temperature of 200°C
  - → catalyst is nickel
- general equation : Alkene (g) + Hydrogen (g) → Alkane (g)

example : Addition of hydrogen to ethene to form ethane :

$$C_2H_4 + H_2 \rightarrow C_2H_6$$



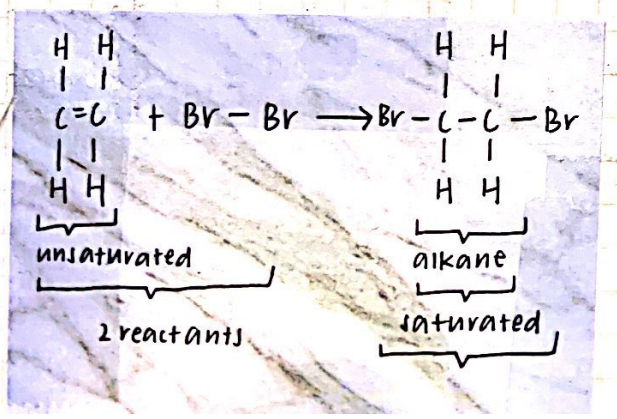
(iii) Addition Reaction with Bromine

[chemical test for presence of unsaturated compounds]

- type of reaction : addition of bromine
- name of reaction : bromination
- chemical test for the presence of unsaturated compounds (e.g. alkenes)
- alkenes react with aqueous bromine / bromine water
- product is bromoalkane
- conditions required : at room temp.
- general equation : Alkene (g) + Bromine (aq) → Dibromoalkane (g)

example : Addition of bromine to ethene

$$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$$



test for unsaturated hydrocarbons

- chemical reagent : aqueous bromine / bromine water
- condition required: room temp.

observation	→ solution turns from reddish-brown to colourless OR → reddish-brown solution is decolourised	→ solution remains reddish-brown
conclusion	compound is unsaturated (e.g. Alkene)	compound is saturated (e.g. Alkane)

- if compound is in liquid state, add aqueous bromine / bromine water to it and shake
- if compound is in gaseous state, bubble compound through aqueous bromine/ bromine water.

difference between saturated & unsaturated hydrocarbons

	saturated	unsaturated
structure	consists of only carbon-carbon single bond.	consists of at least one carbon-carbon double bond.
chemical Reactions	undergo substitution reactions	undergo addition reactions.
Reaction with aq bromine/ bromine water	Aq bromine remains reddish-brown	Aq bromine turns from reddish-brown to colourless.

(D) Addition Polymerization

- involves many, short-chain, unsaturated molecules joining / reacting together to form one long chain molecule as the ONLY product.
- short-chain molecule: monomer
- long-chain molecule: polymer
- monomers must have carbon-carbon double bond (unsaturated)
- conditions required:

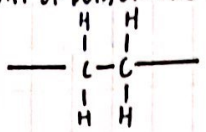
→ high temp.
→ high pressure.
→ catalyst

- examples : Polyethene, polyvinyl chloride (PVC) and polystyrene

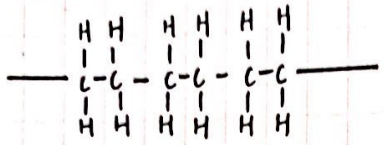
example: Polyethene

monomer: Ethene

repeat unit of polyethene:



part of the structure of polyethene (at least 3 repeat units):



general formula of polyethene:

$$-(C_2H_4)_n-$$

chemical equation for formation of polyethene:

$$nC_2H_4 \longrightarrow -(C_2H_4)_n-$$

uses:

make plastic bag & clingwrap

advantages (plastic)

- light, durable, corrosion-resistant

disadvantages (plastic)

- flammable
- non-biodegrable, cannot be decomposed by bacteria in the soil
- pollution problems
  - → land pollution (take up space in the landfills)
  - → air pollution (produce poisonous gases ⇒ carbon monoxide)

industrial application (Addition of hydrogen)

- manufacture margarine
- raw materials: vegetable oil (unsaturated) & $H_2(g)$
- conditions required:
  - → 200°C
  - → catalyst is nickel
- polyunsaturated fats are found in the food, it means that each fat molecule contains > 1 carbon-carbon double bond.
- vegetable oil & margarine are polyunsaturated foods, however margarine has less carbon-carbon double bonds than vegetable oil.

Alcohols and Carboxylic Acids

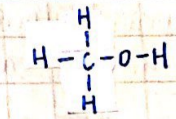
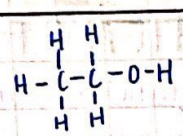
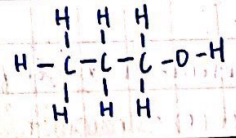
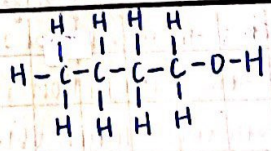
Chapter 20

ALCOHOL HOMOLOGOUS SERIES

- are covalent compounds containing carbon, hydrogen and oxygen atoms.
- consists of only carbon-carbon single bond, therefore they are saturated compounds.
- functional group: $-O-H$
- spelling end with -ol
- general formula : $C_nH_{2n+1}OH$

  ★ $n \geq 1$

($C_nH_{2n+1}OH$)

No. of carbon atoms in 1 molecule	Molecular formula	Mr	Physical state at R.T.P	Prefix	Chemical Name	Full Structural Formula
1	CH_3OH	32	liquid	Meth	Methanol	
2	C_2H_5OH	46	liquid	Eth	Ethanol	
3	C_3H_7OH	60	liquid	Prop	Propanol	
4	C_4H_9OH	74	liquid	But	Butanol	

CHEMICAL RXNS [ALCOHOL]

(A) COMPLETE COMBUSTION

- burns in excess air / oxygen to produce a lot of heat energy
  i.e used as source of fuels
- products are : carbon dioxide & water vapour
- general equation : Alcohol (l) + oxygen (g) → carbon Dioxide (g) + water vapour (g)

(B) INCOMPLETE COMBUSTION

- burns in limited / insufficient amount of air / oxygen
- products are : carbon monoxide and water vapour
- general equation: Alcohol (l) + Oxygen (g) → carbon Monoxide (g) + Water vapour (g)

(C) OXIDATION

- alcohols are oxidised to form carboxylic acids

(i) oxidised by oxygen in the air

- conditions required:
  - → presence of air (atmospheric O_2)
  - → at room temp. by bacteria in the air
- general equation : Alcohol (l) + Oxygen (g) → carboxylic Acid (l) + water (l)

(ii) oxidised by adding a chemical reagent (oxidising agent) [chemical test for presence of alcohol]

- conditions required:
  - → an oxidising agent [acidified potassium manganate (VII)]
  - → warm / heat / boil the mixture of alcohol and oxidising agent
- (a) observation: solution turns from purple to colourless (+ test) [∴ alcohol]
- (b) observation : solution remains purple (- test) [∴ not an alcohol]
- general equation : Alcohol (l) + oxidising agent → carboxylic Acid (l) + water (l)

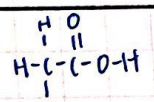
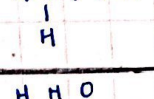
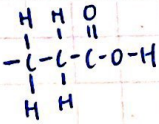
FORMATION OF ETHANOL

- by fermentation of glucose / sugar / starch
- experimental conditions:
  - → 37°C
  - → in the absence of oxygen / air
  - → add yeast (s) as catalyst
- product : dilute ethanol solution and carbon dioxide
- dilute ethanol solution is separated from the yeast by filtration
- dilute ethanol solution obtained has to be purified using fractional distillation
  - ↳ ↑ temp, enzymes denatured, no longer act as catalyst, so R ↓
- word equation: Glucose solution (aq) → Dilute Ethanol (aq) + carbon Dioxide (g)
- chemical equation: $C_6H_{12}O_6$ (aq) → $2C_2H_5OH$ (aq) + CO_2 (g)

CARBOXYLIC ACID HOMOLOGOUS SERIES

- organic acids
- covalent compounds containing carbon, Hydrogen and Oxygen atoms
- consists of ONLY carbon-carbon single covalent bond, therefore they are saturated cpds.
- functional group: $-COOH$
- spelling end with -oic
- general formula: $C_{n-1}H_{2n-1}COOH$

$(C_{n-1}H_{2n-1}COOH)$

No. of carbon atoms in 1 molecule	Molecular Formula	Mr	Physical state at R.T.P	Prefix	Chemical Name	Full structural formula
1	$HCOOH$	46	liquid	Meth	Methanoic acid	
2	CH_3COOH	60	liquid	Eth	Ethanoic acid	
3	C_2H_5COOH	74	liquid	Prop	Propanoic acid	

☆ undergo reactions of acids!