



UNIVERSITY OF
CAMBRIDGE



CAMBRIDGE IGCSE Chemistry

Extended Curriculum



Study Notes



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Cambridge IGCSE

Chemistry study notes

Index:

Topic no.	Topic name	Pages
1	States of Matter	2
2	Experimental Techniques	11
3.1	Atomic Structure	23
3.2	Bonding	30
4	Formula, equations and calculations	42
5	Electrolysis	60
6	Chemical energetics	73
7.1	Rates of chemical reaction	78
7.2	Redox reactions	85
7.3	Reversible reactions & equilibrium	91
8.1	Acids, bases & salts	98
8.2	Chemical tests	113
9	The Periodic Table	118
10	Metals	125
11	Air & water	137
12	Organic Chemistry	144
	Definitions in chemistry	169
	Lab tools in chemistry	173
	Colors in chemistry	174
	Copy of the periodic table	175

Topic 1: States of Matter

- Matter is anything that has **mass** & occupies a space 'volume'.
- Substances exist in one of 3 states of matter at room temperature.

Solid or Liquid or Gas

	Solid	Liquid	Gas
			
Mass	All have definite mass		
Volume	Fixed volume	Fixed volume	No fixed volume
Shape	Fixed shape	No fixed shape 'Takes the shape of the bottom of the container'	No fixed shape 'Takes the shape of the container'

Kinetic particle Theory:

- It's a theory that states that matter is made of tiny particles called atoms or molecules.
- Particles are attracted to each other by forces which might be weak or strong.
- Particles are always moving.
- Particles **move faster** when substances are **heated**.
- **Lighter particles move faster** than heavy particles.

Topic 5: Electrolysis

Electrolysis: It is the breakdown of an ionic compound, molten or in aqueous solution, by the passage of electricity.

Components of the electrolytic cell:

1) **Battery:** Power Supply (Source of electrons)

2) **Copper Wire**

3) **Electrodes:** Connection between the battery & the Electrolyte.

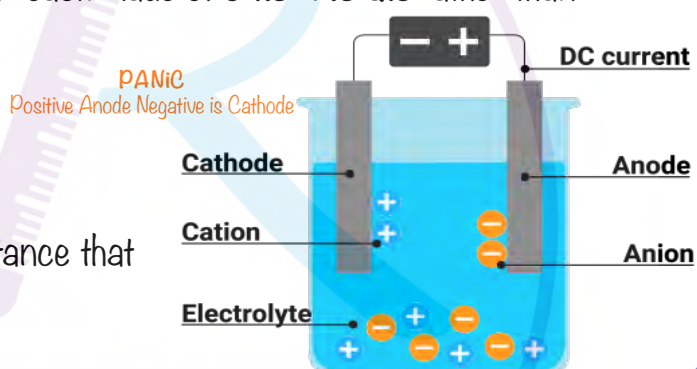
Electrodes can be **inert/ unreactive:** made of **Carbon “Graphite” or Platinum Metal.**

Or they can be **Active Electrodes** that react: made of **other metals** rather than platinum.

• **Anode:** The Positive Electrode

• **Cathode:** The negative Electrode

4) **Electrolyte:** Molten/Aqueous substance that undergoes electrolysis.



How it Works?

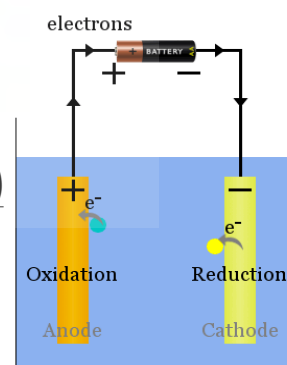
1) Electrons flow **from negative terminal of the battery to Cathode.**

2) In the Electrolyte, + & - Ions flow to the oppositely charged electrode.

★ **Positive Ions (Cations)** are attracted to **Negative electrode (Cathode)** where they **gain electrons (reduced)** and are discharged into atoms.

★ **Negative Ions (Anions)** are attracted to **Positive electrode (Anode)** where they **lose electrons (oxidized)** and are discharged into molecules.

3). **Electrons flow from the Anode to the Cathode** through the external circuit.



Electrons carry the current through **the wire & the electrodes,**
Positive & Negative Ions carry the current through **the electrolyte.**

Electrolysis Using Inert electrodes

Electrolysis of Molten ionic compounds

Example 1: Molten Lead (II) Bromide

- Lead Bromide is **heated till it melts** giving **Lead (Pb^{2+}) ions & Bromide (Br^-) ions**.
- Pb^{2+} ions** are attracted to the **cathode** where they gain electrons & become **reduced** into Pb atoms.
- Br^- ions** are attracted to the **anode** where they lose electrons & become **oxidized** into Br_2 molecules.



- Product at Cathode: Lead

- Half ionic equation:

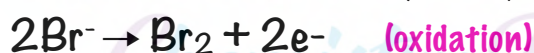


- Product at Anode: Bromine

- Half ionic equation:



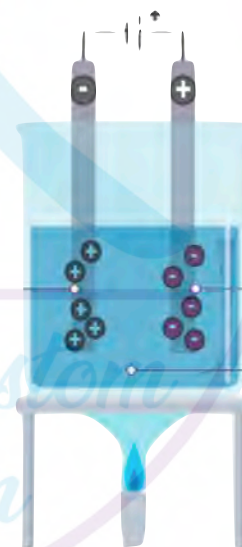
(Bromine is a diatomic molecule so we have to multiply the equation x 2)



Positive lead ions
attracted to the
negative electrode

Negative bromide
ions attracted to the
positive electrode

Molten lead(II) bromide



Observations:

- Silvery Grey Solid deposit at the Cathode.
- Bubbles of Orange "Reddish brown" gas at the anode.

REDuction at CAThode

= RED CAT



ANode for OXidation

= AN OX



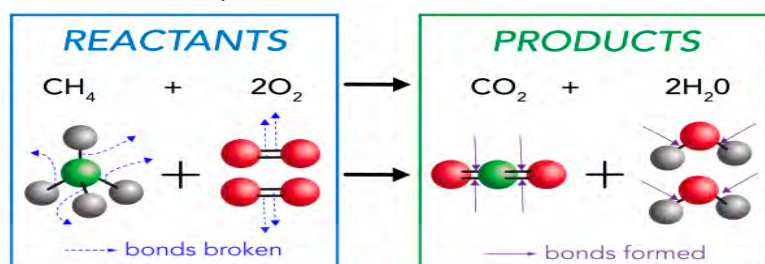
Topic 6: Chemical Energetics

- All chemical reactions & changes of states of matter involve energy changes.
- Energy is either taken in or released. It can be in the form of light, sound but most probably energy change is in the form of **heat**.
- Accordingly, we classified chemical reactions into: **Exothermic & Endothermic**
- We can determine if a reaction is Exothermic or Endothermic by:
 1. **Calculating the enthalpy change of the reaction:**
 $\Delta H = \text{energy needed in bond breaking} - \text{Energy released in bond making}$
 2. **Practically by measuring the temp. change taking place during the reaction.**
 $\text{Temperature Change} = \text{Final Temperature} - \text{Initial Temperature}$

Exothermic	Endothermic
Reactions that release thermal energy to the surrounding leading to an increase in the temperature of the surrounding.	Reactions that take in thermal energy from the surrounding leading to a decrease in the temperature of the surrounding.
Examples: Combustion (burning) of fuels - neutralization - reaction of alkali metals with water - Respiration	Examples: Thermal decomposition - Electrolysis - reaction of ammonium salt with water - Photosynthesis
Examples of Physical Changes: Condensation - freezing	Examples of Physical Changes: melting - evaporation - boiling
Energy Level diagrams:	
Energy of the reactants is greater than energy of the products	Energy of the products is greater than energy of the reactants

Energy changes in a chemical reaction:

- In a chemical reaction, bonds between reactants are first broken down, then new bonds are formed to make the products.

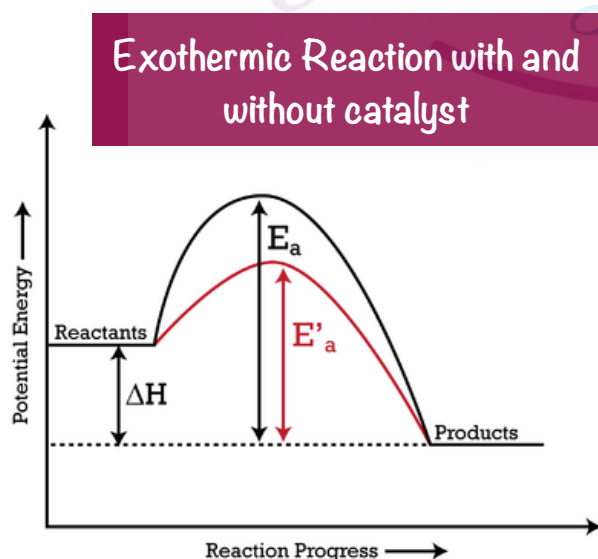
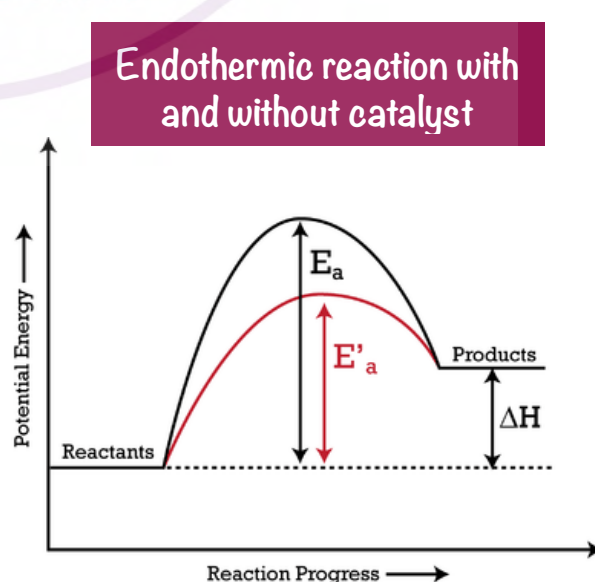


- Bond breaking needs energy, it's an endothermic process.
- Bond Making releases energy, it's an exothermic process

Enthalpy Change (ΔH) = Energy needed in bond breaking - Energy released in bond making

- **Endothermic reactions:** Energy needed for breaking bonds in reactants is greater than energy released in bond making in products.
- **Exothermic reactions:** Energy needed for breaking bonds in reactants is less than energy released in bond making in products.
- ΔH is **positive** for Endothermic reactions & **Negative** for Exothermic reactions.
- **Activation Energy (E_a):** The minimum energy needed by the colliding particles to react.
- Using **a catalyst** will lower the activation energy needed and speed up the reaction

Energy Profile diagrams



Topic 7.2: Redox reactions

Redox reactions: reactions that involve reduction & oxidation simultaneously.

Oxidation	Reduction
Gaining oxygen	Losing Oxygen
Losing Electrons (Increase in the oxidation number)	Gaining electrons (Decrease in the oxidation number)

Oxidizing agent (oxidant)	Reducing agent (Reductant)
It's a substance that oxidizes another substance and itself is reduced	It's a substance that reduces another substance and itself is oxidized
Examples: Acidified Potassium manganate KMnO_4 Acidified potassium dichromate $\text{K}_2\text{Cr}_2\text{O}_7$ Chlorine, Oxygen, Hydrogen peroxide	Examples: Hydrogen, Carbon, Carbon monoxide, Potassium iodide, Reactive Metals

Redox in terms of Oxygen transfer

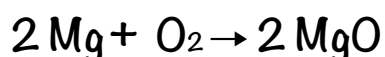
1) Reduction of Hematite (Iron oxide to Iron)



Fe_2O_3 lost oxygen so it's **reduced**, it's **the oxidizing agent**

CO gained oxygen so it's **oxidized**, it's **the reducing agent**

2) Burning "Combustion" of Magnesium

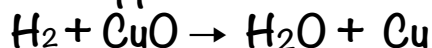


O_2 is **reduced**, it's **the oxidizing agent**

Mg is **oxidized**, it's **the reducing agent**



3) Passing Hydrogen over hot Copper (II) Oxide



CuO lost oxygen so it's **reduced**, it's **the oxidizing agent**

H_2 gained oxygen so it's **oxidized**, it's **the reducing agent**

Observations:

1. Black solid (CuO) turns reddish brown (Cu).
2. Colorless droplets of H_2O appear at the end of the tube.
3. A flame due to burning of excess unreacted H_2 .

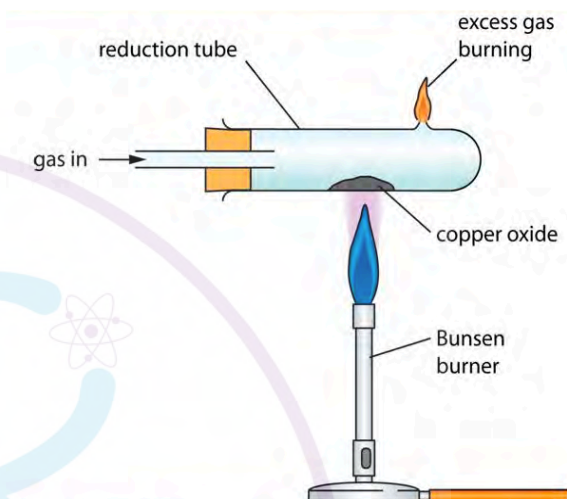
Explain why : it is important to relight Hydrogen at the end of the tube if the flame goes out i?

To prevent its escape to the lab. as Hydrogen is flammable .

Explain why it is important to continue passing Hydrogen into the tube after reaction finishes and burning the hydrogen at the end of the tube until the contents have cooled?

To prevent oxygen from entering the tube .

As it will react with the metal again/ oxidize the metal back into metal oxide.



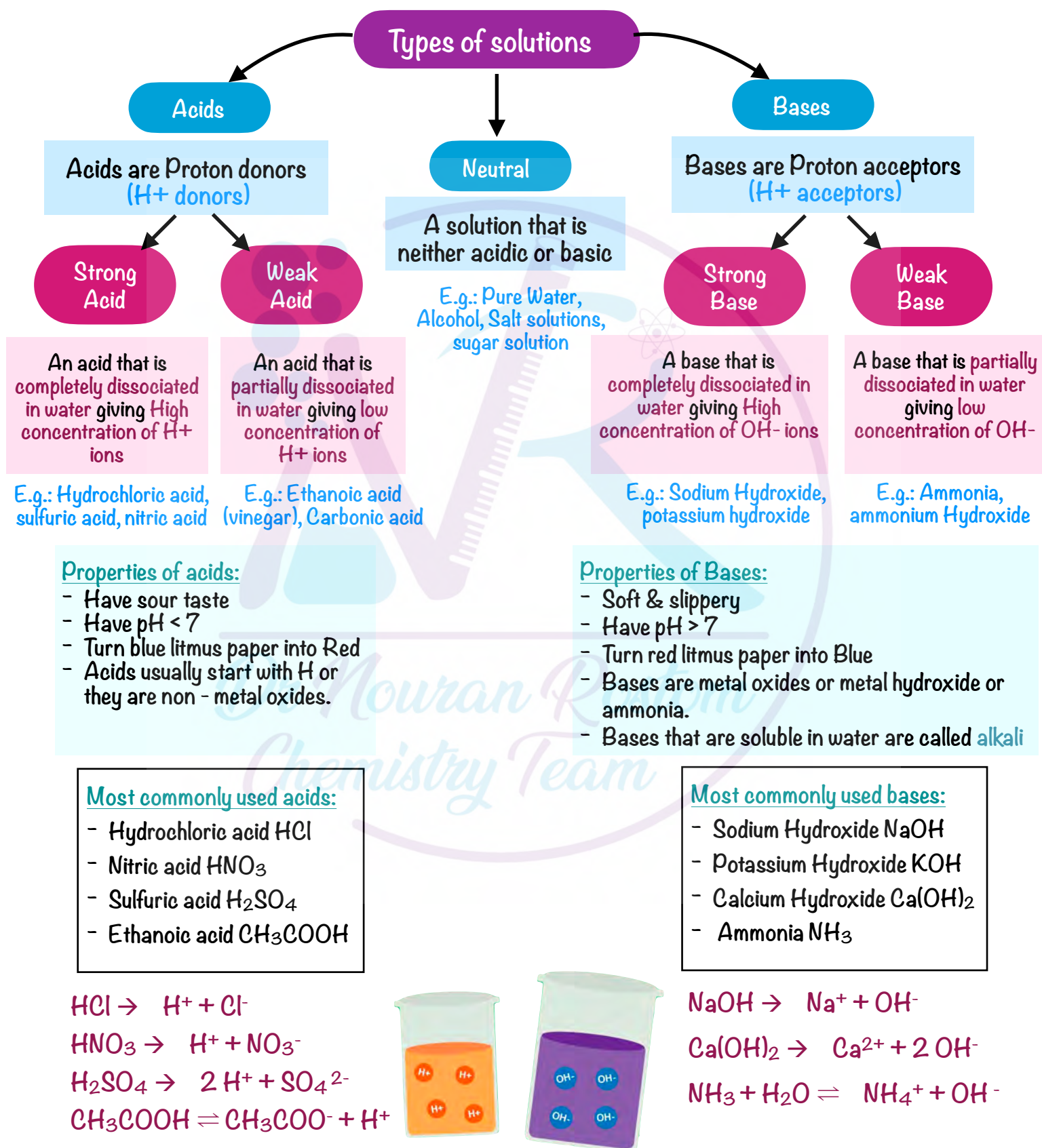
When a question asks which substance is oxidized or reduced or which substance is the oxidizing agent /reducing agent.

You always look at the reactants !

The answer is one of the reactants not the product .

IMPORTANT NOTICE !

Topic 8.1: Acids, Bases & Salts



Using the pH- scale



- Acids: have pH from (1 – 6)
 - ▶ A strong acid has pH of 1-3
 - ▶ A weak acid has pH of 4-6
- Neutral: has pH 7
- Bases: have pH from (8- 14)
 - ▶ A weak Base has pH of 8-10
 - ▶ A Strong Base has pH of 12-14

How can we measure the pH of a solution?

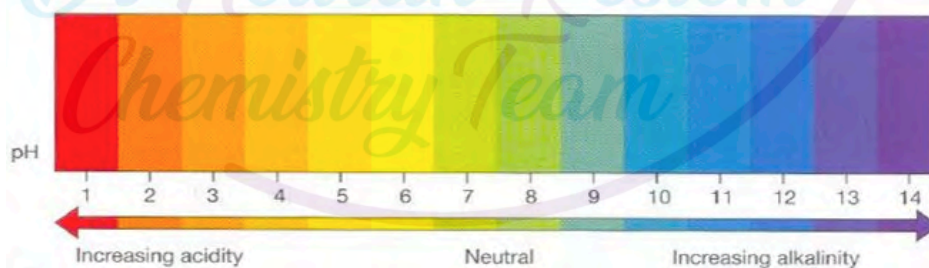
1- Using pH meter:

It's a digital instrument that measures the exact pH of the solution.



2. Using universal indicator:

It's a mixture of different plant dyes that gives a different color for every pH. We can determine the exact pH of the solution by comparing the color produced to the color chart.



- ▶ As pH decreases, concentration of H^+ ions increase & acidity increases & color of the indicator gets darker (Yellow → orange → red)
- ▶ Neutral: pH 7 (green color)
- ▶ As pH increases, concentration of H^+ ions decrease & alkalinity increases & color of the indicator gets darker (blue → dark blue → purple)

Topic 9: The Periodic Table

- All known elements are arranged in a table, called: **The periodic table of Elements.**
- Elements are arranged **in order of increasing their proton number.**
- Elements are classified according to their properties into: **Metals & Non-metals.**
- **Metals** can be found in **the left and the middle of the periodic table.**
- **Non- Metals** can be found in **the right of the periodic table.**
- The **Vertical** columns are called: **Groups** (8 groups)
- The **Horizontal** rows are called: **Periods** (7 periods)

Group No. = No. Of outer shell electrons (valence electrons).

Period No. = No. Of occupied electron shells.

Trends in the periodic table

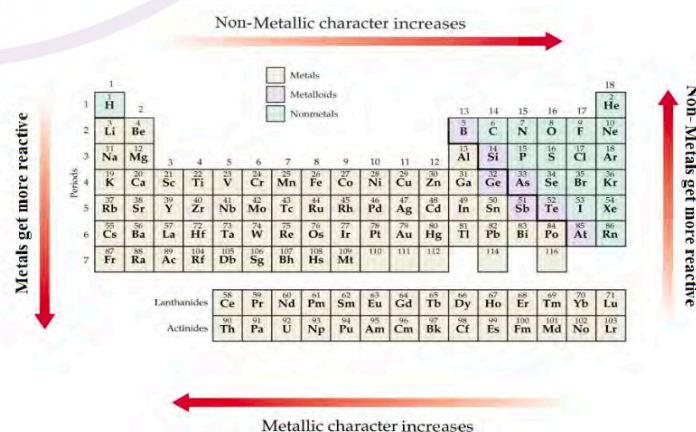
- A Trend is a gradual change in a property
- Elements in the same Group have similar chemical reactions as they have the same no. of electrons in their outermost shell (same valence electrons).
- **Elements down a group show a trend**
As We go down the groups:
 - ▶ **Metals become more reactive and Have lower melting points**
 - ▶ **Non- Metals become less reactive and Have higher melting points.**

- **Elements Across a period show a trend**

As we go to the right:

▶ **number of outer shell electrons increase, metallic character decreases & non- metallic character increases.**

▶ Bonding between the element in the group with another non metal changes **from ionic to covalent**



Group 1: Alkali Metals

- They are called **Group 1** elements **as they all have 1 electron in their outer shell.**
- They are called: **Alkali Metals** **as they react with water forming alkaline solution.**

Physical Properties:

- Good conductors of heat and Electricity
- Shiny

★ Special Physical Properties:

- Soft
- Low melting points
- Low Density

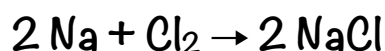
Trends in Physical Properties down the group:

- Melting point decreases
- Density increases
- Softness increases

GROUP 1	
PERIOD	
2	3 Li
3	11 Na
4	19 K
5	37 Rb
6	55 Cs
7	87 Fr

Chemical Properties:

- They are the **most reactive metals** **as they need to lose only 1 electron to become stable & have a full outer shell of electrons.**
- As we go **down the group**, they become **more reactive.**
- They form: **White compounds that dissolve in water** forming **colorless solutions.**
- They react with halogens forming salts



- They are stored under oil in lab **to prevent reaction with air & water.**



Topic 11: Air & Water

Test for purity of water "Physical test"

1) Measure boiling point.

Result: pure water boils at 100°C sharp.

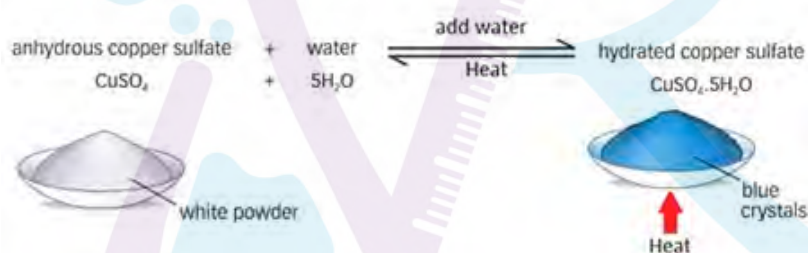
2) Measure freezing point.

Result: pure water freezes at 0°C sharp.

Test for presence of water "Chemical test"

1) Using Anhydrous Copper(II) Sulfate

Water changes color of Anhydrous Copper(II) Sulfate from White to Blue.



2) Using Anhydrous Cobalt(II) Chloride

Water changes color of Anhydrous Cobalt(II) Chloride from Blue to Pink.



Uses of water

Domestic:

Drinking, cooking, washing, showering, watering plants & flushing toilets.

Industrial:

1. Solvent.
2. Coolant for engines.
3. Raw material in production of Ethanol from Ethene.
4. Generate Electricity in hydroelectric power stations.

Distilled water is used in practical chemistry rather than tap water as it contains fewer chemical impurities.

Tap water contains dissolved substances that may:

- 1- interfere with the experiments giving unwanted side reactions.
- 2- interfere with the results of tests for ions analysis.



- Water from natural resources such as reservoirs, rivers, or the sea contain many dissolved substances. Some of them are **beneficial and others are potentially harmful**.

Substances in natural resources of water	Advantages for the water supply	Disadvantages for the water supply
Dissolved oxygen	Needed to support plants, fish & other aquatic life	-
Metallic compounds	Source of essential minerals	Some metal compounds are toxic such as lead & mercury
Plastics	-	Harm aquatic life
Sewage / microbes	-	Sewage contains harmful microbes that can cause diseases
Nitrates from fertilizers & Phosphates from fertilizers & detergents	-	Lead to deoxygenation of water & damage to aquatic life

Topic 12: Organic Chemistry

- Organic Chemistry is the chemistry of **Carbon** containing compounds.
- All Organic compounds contain **Carbon & Hydrogen** and may contain other atoms as **Oxygen or Nitrogen etc.**
- According to the type of atoms joined to Carbon and how they are bonded, organic compounds are classified into families called: Homologous series.
- The 4 Homologous series of Concern are:
 - Alkanes
 - Alkenes
 - Alcohols
 - Carboxylic Acids



Comparing Homologous series:

Organic compound	Homologous series	Comments
$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	Alkane	<ul style="list-style-type: none"> It's a Hydrocarbon Because it's made of C & H only It's an alkane because all C-C bonds are single bonds
$ \begin{array}{c} \text{H} \quad \quad \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{C}-\text{C}-\text{H} \\ \diagup \quad \diagdown \quad \\ \text{H} \quad \quad \text{H} \quad \text{H} \end{array} $	Alkene	<ul style="list-style-type: none"> It's a Hydrocarbon Because it's made of C & H only It's an alkene because it contains C=C bond
$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} $	Alcohol	<ul style="list-style-type: none"> It is not a Hydrocarbon Because it contains O not only C & H It's an Alcohol because it contains OH
$ \begin{array}{c} \text{H} \quad \quad \text{O} \\ \quad \quad // \\ \text{H}-\text{C}-\text{C} \\ \quad \quad \backslash \\ \text{H} \quad \quad \text{O}-\text{H} \end{array} $	Carboxylic acid	<ul style="list-style-type: none"> It is not a Hydrocarbon Because it contains O not only C & H It's a carboxylic acid because it contains COOH

- **Homologous Series;** It's a family of similar compounds with similar chemical properties due to the presence of the same functional group.
- **Functional Group:** It is an atom or a group of atoms that determine the chemical properties of a homologous series.

Homologous series	Functional group
Alkanes	$\text{C} - \text{C}$ (all c-c bonds are single)
Alkenes	$\text{C} = \text{C}$
Alcohol	OH
Carboxylic Acid	COOH

General Characteristics of a homologous series:

They have:

1. Same functional group.
2. Same general formula.
3. Similar Chemical Properties.
4. Each member differs than the next one by a CH_2 unit.
5. show a trend in their physical properties.

As the chain gets longer:

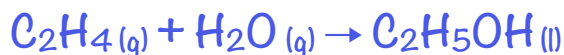
- ▶ Melting and Boiling Points increase.
- ▶ Density Increases.
- ▶ Viscosity increases (Compounds flow less easily).
- ▶ Compounds become less flammable.

Manufacture of Ethanol

Chemical Method

Biological Method

Catalytic addition of steam on Ethene



Conditions:

Temperature: 300 °C

Catalyst: phosphoric acid

Pressure: 60 atm / 6000 kPa

Fermentation of Aq. Glucose



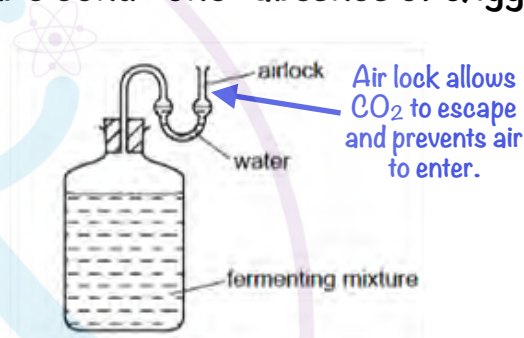
Conditions:

Temperature: 25 - 35 °C

Catalyst: yeast enzymes

Anaerobic conditions "absence of oxygen"

How to make Alcohol from Crude oil?



Catalytic addition of steam on Ethene	Fermentation of aq. Glucose
Advantages: <ul style="list-style-type: none"> - Fast "continuous process" - Makes pure Ethanol 	Advantages: <ul style="list-style-type: none"> - Glucose is renewable - Lower temperature and pressure so lower energy costs
Disadvantages: <ul style="list-style-type: none"> - Crude oil is non renewable - Higher temperature and pressure so higher energy costs 	Disadvantages: <ul style="list-style-type: none"> - Slow "Batch process" - Makes impure Ethanol

Q&A

Q.1 What's the purpose of yeast?

It contains enzymes that act as catalyst.

Q.2 Why the temperature shouldn't exceed 35 °C?

To avoid denaturing of yeast enzymes.

Q.3 Why Should Fermentation be carried out in absence of Oxygen?

1. To prevent oxidation of ethanol into Ethanoic acid (Vinegar).
2. To allow yeast to respire anaerobically & produce ethanol instead of CO_2 & H_2O .

Q.4 Why does the reaction mixture turn cloudy? As yeast multiplies

Q.5 Why does the fermentation rate increase initially?

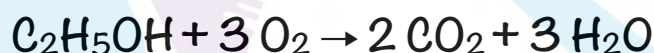
1. As yeast reproduces / multiply
2. As the reaction is Exothermic

Q.6 How is yeast removed from the fermentation mixture? By Filtration

Q.7 How to obtain pure Ethanol from the fermentation mixture? By Fractional Distillation

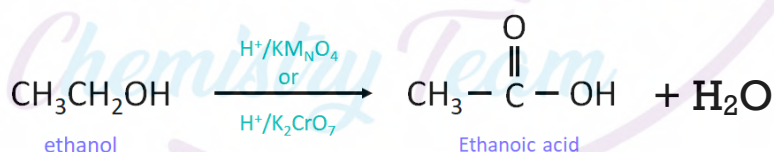
Reactions of Alcohols:

1. Combustion



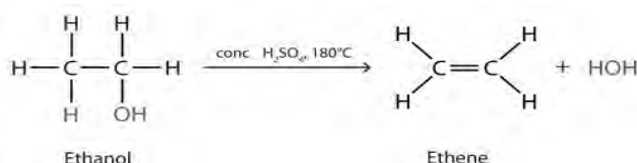
2. Oxidation

- Alcohols are oxidized into **Carboxylic acids** by **bacterial oxidation** or in presence of oxidizing agents such as: **acidified Potassium Manganate (VII)**



3. Dehydration

- Dehydration means removal of water
- Conditions needed: **Heat & catalyst**: conc. Sulfuric acid



This reaction is **reversible**

- Dehydration of alcohol $\rightarrow$ Alkene
- Hydration of alkene $\rightarrow$ Alcohol

4. Esterification

- It's a reaction between **alcohols and carboxylic acids** to make **esters**.
Discussed later in the topic

Colors in Chemistry

White

Compounds of Group I metals e.g. NaCl , KNO_3 , Na_2SO_4 , Li_2CO_3 etc.

Compounds of Magnesium, Zinc, Aluminum and Calcium

Silvery Grey:

All metals except Gold & Copper
Iodine Solid

Black:

Copper Oxide CuO
Manganese Oxide MnO_2
Carbon C
Astatine At_2

Orange:

Potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$)

Yellow:

Fluorine Gas F_2
Gold Au
Lead Iodide PbI_2
Silver Iodide AgI
Sulfur S

Green:

Chlorine Gas Cl_2
Copper Carbonate CuCO_3
Compounds of Iron II
Compounds of Chromium III

Blue

Hydrated copper (II)sulfate
Copper II salts
Anhydrous Cobalt Chloride CoCl_2

Reddish Brown:

Copper Cu
Bromine Br_2
Rust $\text{Fe}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$
Compounds of Iron III

Brown

Nitrogen dioxide NO_2
Iodine solution

Pink

Hydrated Cobalt chloride $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$

Purple

Potassium VII Manganate KMnO_4
Iodine gas



The Periodic Table of Elements

Cambridge IGCSE®

Group

atomic number

atomic symbol

name

relative atomic mass

alkali metals

alkaline earth metals

transition metals

other metals

non-metals

halogens

noble gases

lanthanoids

actinoids

unclassified

1Hhydrogen1

2Hehelium4

3Lilithium7

4Beberyllium9

5Bboron11

6Ccarbon12

7Nnitrogen14

8Ooxygen16

9Ffluorine19

10Neneon20

11Nasodium23

12Mgmagnesium24

13Alaluminium27

14Sisilicon28

15Pphosphorus31

16Ssulfur32

17Clchlorine35.5

18Arargon40

19Kpotassium39

20Cacalcium40

21Scscandium45

22Ttitanium48

23Vvanadium51

24Crichromium52

25Mnmanganese55

26Feiron56

27Cocobalt59

28Ninickel59

29Cucopper64

30Znzinc65

31Gagallium70

32Gegermanium73

33Asarsenic75

34Seselenium79

35Brbromine80

36Krkrypton84

37Rbrubidium85

38Srstromium88

39Yyttrium89

40Zrzirconium91

41Nbniohium93

42Momolybdenum96

43Tctechnetium

44Ruruthenium101

45Rhodium103

46Pdpalladium106

47Agilver108

48Cdcadmium112

49Inindium115

50Sntin119

51Sbsbimony122

52Tetellurium128

53Iiodine127

54Xexenon131

55Cscasium133

56Babarium137

57–71lanthanoids

72Hfhafnium178

73Tatantalum181

74Wtungsten184

75Rerhenium186

76Osomium190

77Irlridium192

78Ptplatinum195

79Augold197

80Hgmercury201

81Tlthallium204

82Pblead207

83Bibismuth209

84Polonium

85Astatine

86Rnradon

87Frfrancium

88Raradium

89–103actinoids

104Rfrutherfordium

105Dbdubnium

106Sgseaborgium

107Bhbohrium

108Hshassium

109Mtmelitnerium

110Dsdarmstadtium

111Rgroentgenium

112Cncopernicium

113Nhnihonium

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metals

non-metals

Recently discovered elements (113–118) only exist for fractions of a second, and only a few atoms of each have ever been made. Consequently, they are not yet classified as metals or non-metals.

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metals

non-metals

Recently discovered elements (113–118) only exist for fractions of a second, and only a few atoms of each have ever been made. Consequently, they are not yet classified as metals or non-metals.

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