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TOPIC 11.4: ALCOHOLS

THE ABOUT

CHAPTER ANALYSIS

MASTERY

- Important topic
- Take note of alcohol's chemical reactions

EXAM

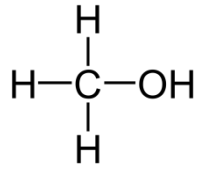
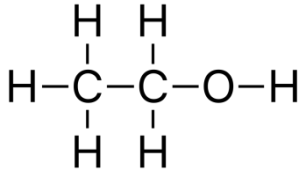
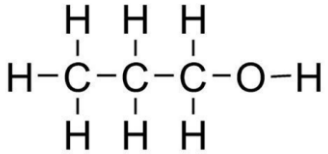
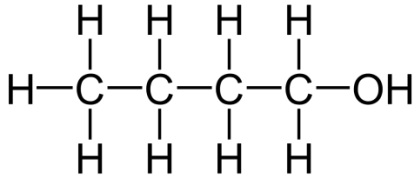
- Alcohols are **commonly tested**
- Understand how **fermentation** works and the conditions needed

WEIGHTAGE

- **Heavy** overall weightage
- Entire Organic Chemistry portion accounts for **15-20%** of each year's Chemistry paper

KEY CONCEPT

ALCOHOLS
HOMOLOGOUS SERIES
FUNCTIONAL GROUP
GENERAL FORMULA

Name	Carbon atoms	Molecular Formula	Full Structural Formula	Condensed structural formula
Methanol	1	CH_3OH		CH_3-OH
Ethanol	2	C_2H_5OH		CH_3CH_2-OH
Propanol	3	C_3H_7OH		$CH_3CH_2CH_2$-OH
Butanol	4	C_4H_9OH		CH_3 $CH_2CH_2CH_2$-OH

Alcohols

Alcohols have the **general formula $C_nH_{2n+1}OH$** and can be identified by the **hydroxyl -OH functional group**.

Functional group

Alcohols have the **hydroxyl -OH functional group.**

Isomers

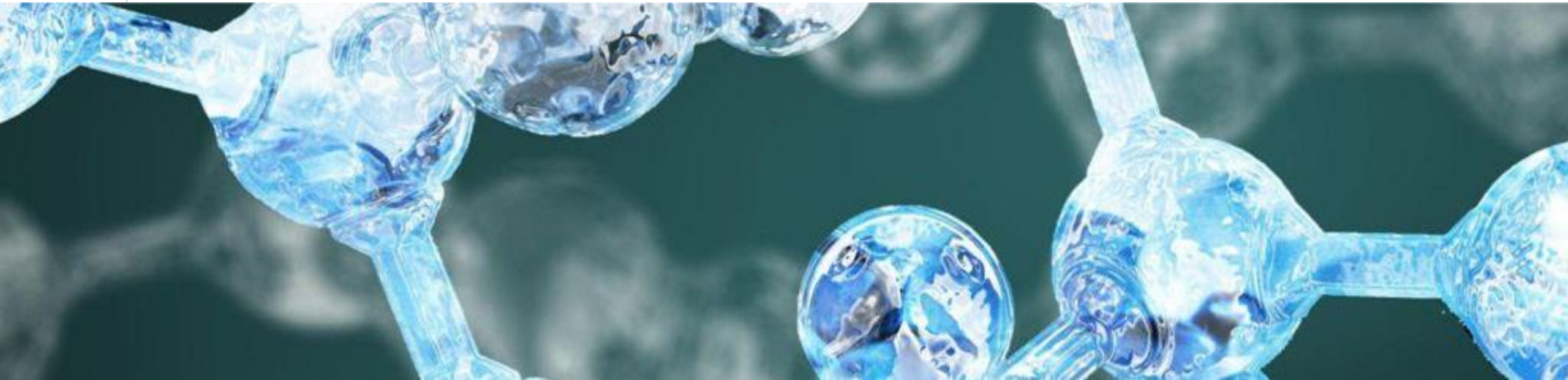
Isomerism can occur in alcohols that contain **at least three carbon atoms**.

Isomers have the same molecular formula and similar chemical properties.

However, isomers have **different physical** properties such as **different melting and boiling points** and **densities.**

KEY CONCEPT

ALCOHOLS
PHYSICAL PROPERTIES
PRODUCTION OF ALCOHOL
CHEMICAL REACTIONS



PHYSICAL PROPERTIES

Physical property	Reasoning
Melting and boiling points	**As the number of carbon atoms in the alcohols increases**, the **melting and boiling points of alcohols increases as well.** As the **number of carbon atoms in an alcohol increases**, **the size of the molecules are bigger and have stronger intermolecular forces of attraction between each other.** As such, more heat energy is needed to overcome the intermolecular forces of attraction between the alcohol molecules. Hence, larger alcohol containing more carbon atoms will have higher melting and boiling points.
Volatility	**As the number of carbon atoms in the alcohol increases**, the **volatility of alcohol decreases.** (similar to m.p. & b.p.) **With a higher relative molecular mass, there would be stronger intermolecular forces of attraction between the alcohol molecules.** As such, more energy is needed to overcome the intermolecular forces of attraction between the alcohol molecules. Hence, larger alcohol molecules are less likely to evaporate in room temperature.
Density	**As the number of carbon atoms in the alcohols increases**, the **density of alcohols increases**.
Viscosity	**As the number of carbon atoms in the alcohols increases**, the **viscosity of alcohols decreases**. **(more difficult to flow)** Alcohols with longer hydrocarbon chains flow less easily as they tend to get stuck together.
Flammability	**As the number of carbon atoms in the alcohols increases**, the **flammability of alcohols decreases. (more difficult to burn)**
Solubility	Alcohols are **soluble in water**, but as the number of carbon atoms increases, solubility in water decreases.

MAKING ALCOHOL

PRODUCTION OF ALCOHOLS

1) **Fermentation**

1) **Manufacture of ethanol from ethene**

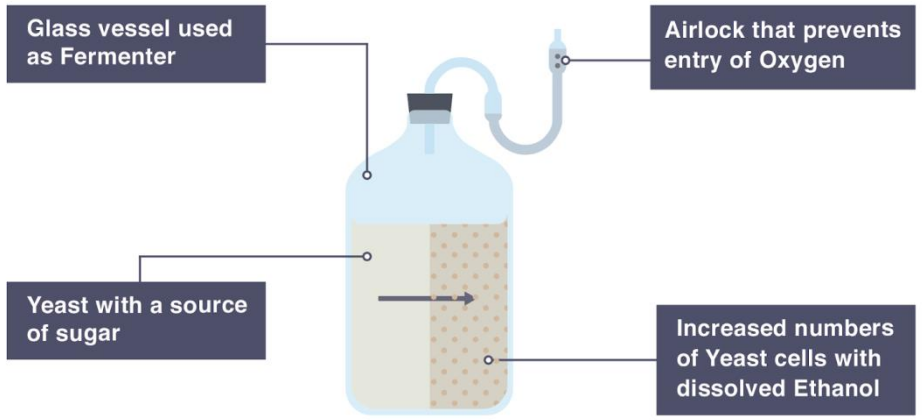
PRODUCTION OF ALCOHOL

1) Fermentation
Fermentation is a chemical reaction where glucose/sugar are broken down by micro-organisms into smaller molecules such as alcohol and carbon dioxide.

For instance, yeast contains enzymes that are used as catalyst for the breakdown **of glucose $C_6H_{12}O_6$ into ethanol C_2H_5OH and carbon dioxide.**

glucose → ethanol + carbon dioxide
(in the presence of yeast)

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$



MAKING ALCOHOL

PRODUCTION OF ALCOHOLS

1) **Fermentation**

1) **Manufacture of ethanol from ethene**

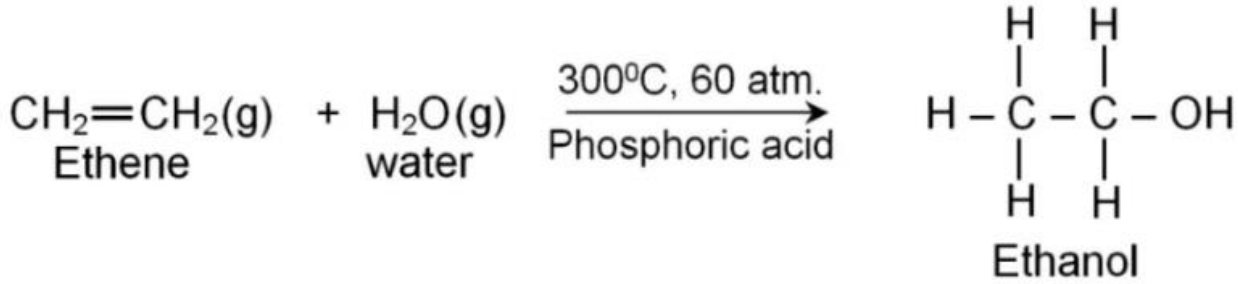
PRODUCTION OF ALCOHOL

2) Manufacture of ethanol from ethene (Hydration)

To produce alcohol, alkene and steam are reacted together at a temperature of **300°C** and at **60 atm**.

Phosphoric(V) acid is used as a catalyst for the reaction.

The following equation below shows the reaction between ethene and steam.



Uses of ethanol

Ethanol is used in **alcoholic drinks** such as beer and wine.

Ethanol is used as a organic **solvent for many organic compounds**.

Ethanol has high volatility and it is an **ideal solvent for perfume and deodorants**.

As it can undergo complete combustion to form carbon dioxide and water, ethanol is used as a **clean fuel**.

CHEMICAL REACTIONS

CHEMICAL REACTIONS OF ALCOHOLS

1) **Combustion**
1) **Oxidation**
1) **Esterification**

1) Combustion

In the presence of excess oxygen, an alcohol would undergo **complete combustion**, producing carbon dioxide and water.

If there is insufficient oxygen present for complete combustion, the alkene undergoes **incomplete combustion** to produce water and carbon monoxide instead.

Soot (carbon) could also be produced as a by-product during incomplete combustion.

2) Oxidation

Alcohols will be oxidised to form carboxylic acids in the presence of a strong oxidising agent.

Oxidising agents:
$KMnO_4$ (purple to colourless)
$K_2Cr_2O_7$ (orange to green)

For example, ethanol can be oxidised to ethanoic acid:

CHEMICAL REACTIONS

CHEMICAL REACTIONS OF ALCOHOLS

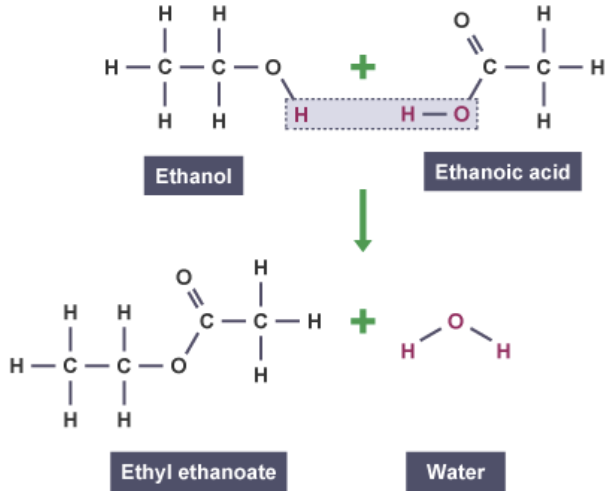
1) **Combustion**

1) **Oxidation**

1) **Esterification**

3) Esterification

In the presence of a catalyst, **alcohols will react with carboxylic acids** to form **esters**.



Conditions: Concentrated H_2SO_4, heating under reflux

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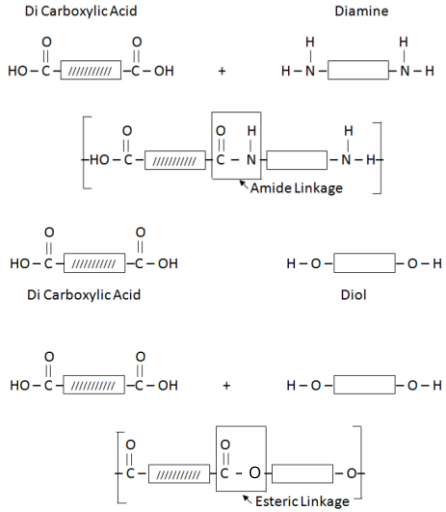
POLYMER

Condensation Polymerisation
(elimination of water)



LONG CHAIN ALKANE

H_2 gas
(For Haber process)

Catalytic Cracking
(Al_2O_3 & SiO_2, 600 °C)

Addition Polymerisation
(High temp & pressure)

SUGAR

$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$

Fermentation
(37°C, yeast & no O_2)

Oxidation
(acidified aqueous potassium manganate(VII) / exposed to air)

Hydration
(300 °C & 60 atm, Phosphoric(V) acid)

ALKANE
C - C

Hydrogenation
(200 °C & nickel)

# ALKENE
C = C

ALCOHOL
-OH

CARBOXYLIC ACID
-COOH

Substitution
(UV light)

Bromination
(Test for C=C bonds)

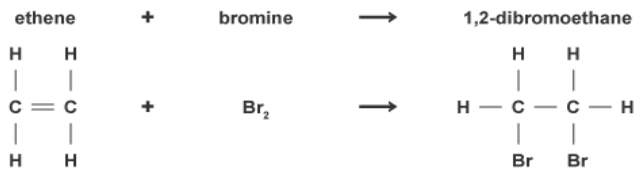
Esterification
(warm, sulfuric acid)

Prefix

Meth- 1
Eth- 2
Prop- 3
But- 4
Pent- 5
Hex- 6
Hep- 7
Oct- 8
Non- 9
Dec- 10

$CH_4\,(g) + Br_2\,(g) \rightarrow CH_3Br\,(g) + HBr\,(g)$

$C_2H_4\,(g) + Br_2\,(aq) \rightarrow C_2H_4Br_2\,(aq)$



ESTER
-COO-

+ H_2O

ALL ORGANIC COMPOUNDS
Complete Combustion

$X + O_2\,(g) \rightarrow CO_2\,(g) + 2H_2O\,(l)$

Incomplete Combustion

$X + O_2\,(g) \rightarrow CO\,(g) + 2H_2O\,(l)$

Try it yourself! (TYS Question)

46. Which statements about ethanol are correct?
Ethanol can be used:

(N2019/P1/Q37)

1 as the source of energy in car engines
2 to dissolve the active ingredients in perfumes
3 to manufacture polyesters.

A 1 only
B 1 and 2
C 2 only
D 2 and 3

( )

Answer:

46. **B**
Ethanol can be used as a source of energy in cars and as a solvent. In the manufacture of polyesters, it is a diol that is used.

Try it yourself! (TYS Question)

48. Which alcohol and acid can be reacted together to make the ester $CH_3CH_2CH_2CO_2CH_3$?
(N2019/P1/Q39)

A C_4H_9OH and HCO_2H
B C_3H_7OH and CH_3CO_2H
C C_2H_5OH and $C_2H_5CO_2H$
D CH_3OH and $C_3H_7CO_2H$ ( )

Answer:

48. **D**
The ester is made from $CH_3CH_2CH_2COOH$ and CH_3OH.

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