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TOPIC 11.5: CARBOXYLIC ACIDS

THE ABOUT

CHAPTER ANALYSIS

MASTERY

- Key component of Organic Chemistry
- Important build up to ‘Macromolecules’

EXAM

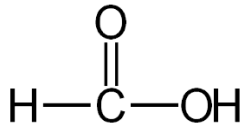
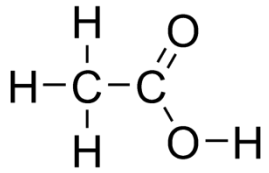
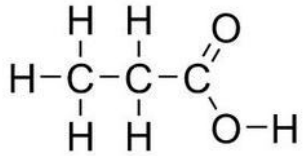
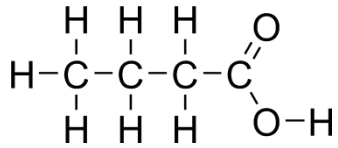
- Know how to draw your –COOH functional group
- Understand how esterification works and the conditions needed

WEIGHTAGE

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

KEY CONCEPT

CARBOXYLIC ACIDS
HOMOLOGOUS SERIES
FUNCTIONAL GROUP
GENERAL FORMULA

Name	Carbon atoms	Molecular Formula	Full Structural Formula	Condensed structural formula
Methanoic acid	1	HCOOH		HCOOH
Ethanoic acid	2	CH_3COOH		CH_3COOH
Propanoic acid	3	C_2H_5COOH		CH_3CH_2COOH
Butanoic acid	4	C_3H_7COOH		$CH_3\,CH_2CH_2COOH$

CARBOXYLIC ACIDS

Carboxylic acids have a general formula: **$C_nH_{2n+1}COOH$.**

Functional group

Carboxylic acids contain the **-COOH functional group** (carboxyl group).

Isomerism

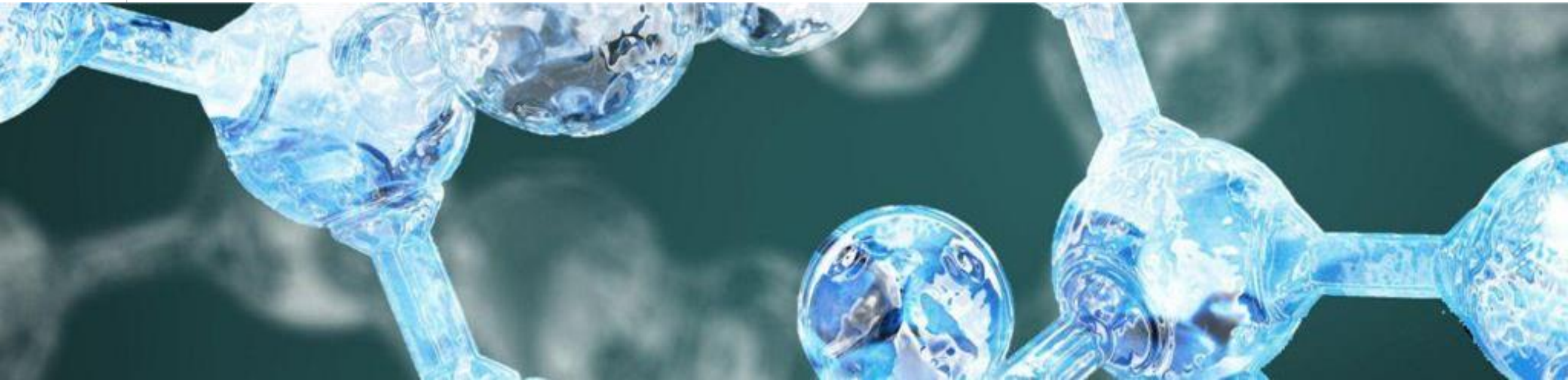
Carboxylic acid molecules that contain **at least four carbon atoms will display isomerism.**

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

CARBOXYLIC ACIDS
PHYSICAL PROPERTIES
PRODUCTION OF ETHANOIC ACID
ESTERIFICATION



PHYSICAL PROPERTIES

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

MAKING ETHANOIC ACID

PRODUCTION OF ETHANOIC ACID

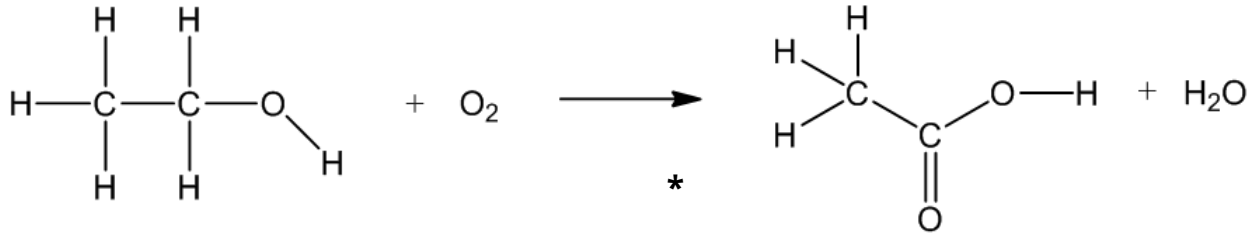
1) **Oxidation of alcohol**

PRODUCTION OF CARBOXYLIC ACID

1) **Oxidation of alcohol**

Ethanol C_2H_5OH can be converted to ethanoic acid C_2H_5COOH using oxidising agents.

C_2H_5OH (aq) + O_2 (g) → CH_3COOH (aq) + H_2O (l)



WEAK ACID

Carboxylic acids are **weak acids** as they only **partially dissociate in water** to release a low concentration of H^+ ions.

$$\mathbf{CH_3COOH\ (aq) \rightleftharpoons CH_3COO^-\ (aq) + H^+\ (aq)}$$

NAME OF SALT FORMED

Carboxylic acids are weak acids and will be able to react with reactive metals, bases and carbonates.

The name of the salt formed would be based on the carboxylic acid that is used and ends with '-ate'.

Reaction	**Products formed**
Potassium hydroxide + propanoic acid (base + acid)	Potassium propanoate + water (salt + water)
Calcium Carbonate + pentanoic acid (carbonate + acid)	Calcium pentanoate + carbon dioxide gas (salt + CO_2)
Magnesium + ethanoic acid (metal + acid)	Magnesium ethanoate + hydrogen gas (salt + hydrogen gas)

CHEMICAL REACTIONS

CHEMICAL REACTIONS OF CARBOXYLIC ACIDS

1) Esterification

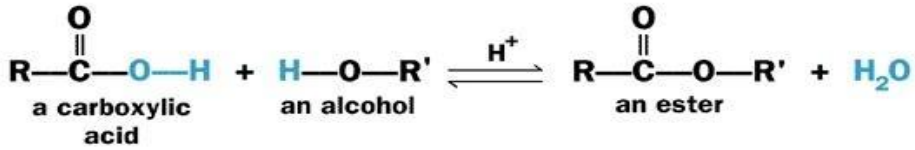
Real-life applications for esters

- Used as artificial fruity flavourings to soft drinks and ice creams.
- Used as solvents for organic compounds
- Used as as solvents for glues and perfumes

CARBOXYLIC ACID & ALCOHOL REACTION (ESTERIFICATION)

Carboxylic acids and alcohols can react to form esters.

carboxylic acid + alcohol ⇌ ester + water
(sulfuric acid & warming)



(Where R and R' are general hydrocarbon groups)

The first half of the ester's name comes from the **alcohol**.

The second half of the ester's name comes from the **carboxylic acid** and ends with **'-oate'**.

Organic compounds used to form the ester		
Alcohol	**Acid**	**Name of ester**
Ethanol	**Propano**ic acid	**Eth**yl **propan**oate
Propanol	**Butano**ic acid	**Prop**yl **butan**oate

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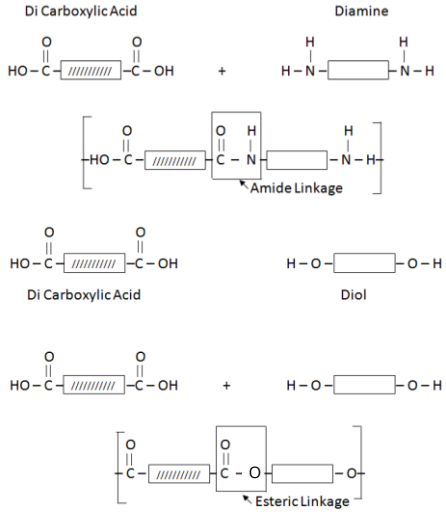
POLYMER

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)

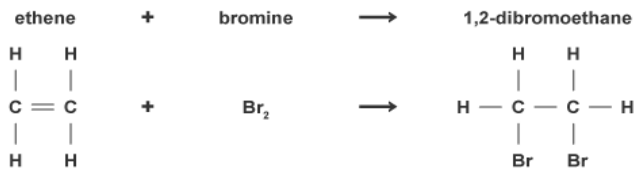
Esterification
(warm, sulfuric acid)

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)

37. What will propanol, C_3H_7OH, form on complete oxidation? (N2018/P1/Q35)

A CH_3CO_2H
B $C_2H_5CO_2H$
C $C_3H_7CO_2H$
D $C_4H_9CO_2H$

( )

Answer:

37. **B**
When propanol is completely oxidised, propanoic acid is formed.
$CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$

Try it yourself! (TYS Question)

41. An alcohol and a carboxylic acid are reacted together to form an ester.

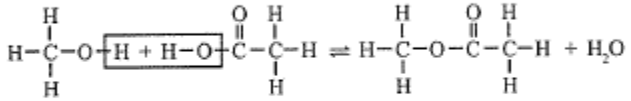
Which statement is correct? (N2018/P1/Q39)

A The ester molecule has fewer oxygen atoms than the carboxylic acid molecule.
B The ester molecule has the same number of oxygen atoms as the alcohol molecule.
C The ester molecule has more oxygen atoms than the alcohol molecule.
D The ester molecule has more oxygen atoms than the carboxylic acid molecule.

( )

Answer:

41. **C**
Example:



The number of oxygen atoms in the ester is more than that in the alcohol but same as that in the carboxylic acid.

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