East Spring Secondary
Chemistry
Chapter 20.1: Alcohols

Name: Husna (12) Class: 4A Date: 21.5.25

At the end of the lesson, you should be able to:

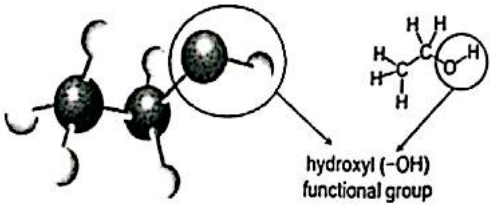
- describe the alcohols as an homologous series containing the –OH group
- draw the structures of branched and unbranched alcohols, C_1 to C_4, and name the unbranched alcohols, methanol to butanol
- describe the properties of alcohols in terms of combustion and oxidation to carboxylic acids
- describe the formation of ethanol by the catalysed addition of steam to ethene and by fermentation of glucose

Alcohol homologous series

- are **simple molecular (covalent)** compounds containing carbon, hydrogen and oxygen atoms
- consists of ONLY carbon-carbon single bonds (C-C), therefore they are covalent (saturated) compounds
- functional group: ~~OH~~ hydroxyl –O–H
- spelling end with **–ol**

General formula: ~~OH~~ $C_nH_{2n+1}OH$

where n = number of carbon atoms, positive integer



Physical properties of Alcohol

- The alcohol homologous series has the same physical properties as alkanes and alkenes

Additional physical property of Alcohol: Solubility in water

- **Soluble** in water (only methanol to propanol)
- Solubility decreases as the number of carbon atoms in the molecule increases as size of molecule increases ↑
- the trend in the physical properties of alcohol such as (i) melting and boiling points, (ii) viscosity ↑ and (iii) flammability ↓ is the same as that in alkane and alkene

Isomers

- **Unbranched (straight-chain)** and **branched-chain** alcohols
  OR
- **ALL** are straight-chain alcohols but the position of the –O–H group is different
- Methanol and ethanol do not have isomers

CH_3OH C_2H_5OH

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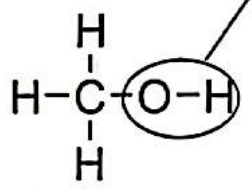
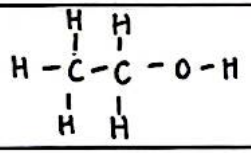
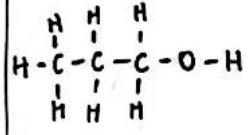
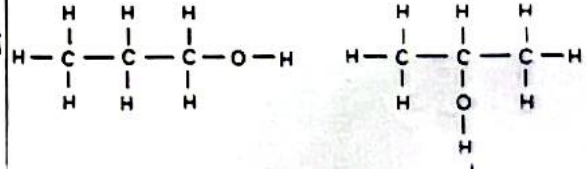
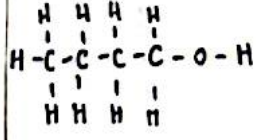
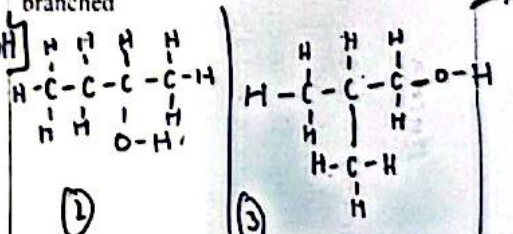
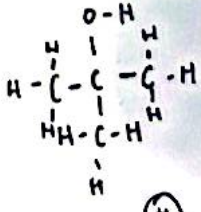
oxygen has 2 bonds

Bond between O and H atom must be drawn

Alcohol Homologous Series ($C_nH_{2n+1}OH$)

No. of carbon atoms in one molecule	Prefix	Chemical name	Molecular formula	M_r	Physical state at r.t.p	Full Structural formula (unbranched)	Structural formula	Full structural formula of isomers (shift position of –OH group)
1	Meth	methanol	CH_3OH	32	liquid		CH_3OH	-NIL-
2	Eth	ethanol	C_2H_5OH	46	liquid		CH_3CH_2OH	-NIL-
3	Prop	propanol	C_3H_7OH	60	liquid		$CH_3CH_2CH_2OH$	
4	But	Butanol	C_4H_9OH	74	liquid		$CH_3CH_2CH_2CH_2OH$	Butanol has 4 isomers: 2 unbranched and 2 branched 



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Chemical reactions of Alcohol

(A) Complete Combustion

(B) Incomplete Combustion

Same as alkanes and alkenes

(C) Oxidation (gain oxygen)

- alcohols are **oxidised** to form carboxylic acid (organic acids)
- there are **2 ways** to oxidize alcohols:

(i) alcohols oxidized by oxygen (O_2) in the air (natural phenomenon)

- conditions required:
  - presence of **air** (need **atmospheric oxygen**)
  - at **room temperature** by **bacteria** in the air

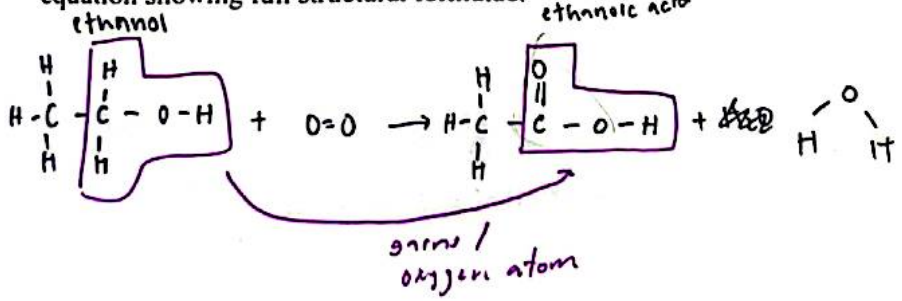
- general equation: alcohol + oxygen gas → carboxylic acid + water

example

word equation: ethanol + oxygen gas → ethanoic acid + water

chemical equation: $CH_3CH_2OH + O_2 \rightarrow CH_3COOH + H_2O$

equation showing full structural formulae:



Application of Oxidation of Ethanol to daily life
Alcoholic drinks contain ethanol as a key ingredient. When alcoholic drinks are exposed to air, the ethanol is oxidized to ethanoic acid, making the drink taste sour which indicates that it is spoiled. Therefore, we should place alcohol drinks in the fridge if we cannot finish drinking.

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(ii) alcohols oxidized by adding a chemical reagent which is an oxidizing agent (chemical test for presence of alcohol)

- conditions required:
  - add an oxidizing agent: acidified potassium (VII) manganate ($KMnO_4$) — MnO_4^- => Mn^{7+} ox. state of Mn is +7
  - warm/heat/boil the mixture of alcohol and oxidizing agent (↳ water bath)

-alcohol is flammable

- (a) Observation:
  - solution turns from purple to colourless (positive test)

  Conclusion: Compound is an alcohol

$x + (-2)4 = -1$
$x = -1 + 8$
$= +7$

- (b) Observation:
  - Solution remains purple (negative test)

  Conclusion: Compound is NOT an alcohol

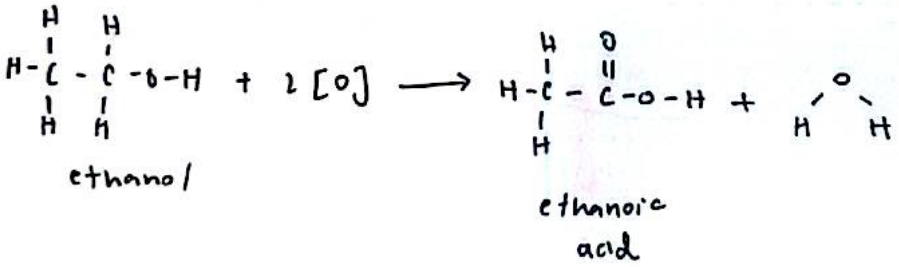
- general equation: alcohol + oxidizing agent → carboxylic acid + water

example

word equation: ethanol + 2[O] (oxidizing agent) → ethanoic acid + water

chemical equation: $CH_3CH_2OH + 2[O] \rightarrow CH_3COOH + H_2O$

equation showing full structural formulae:



IMPORTANT: No. of carbon atoms remains the same in a the oxidation of alcohol to carboxylic acid

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Formation of ethanol

- there are 2 ways to produce ethanol:

(i) by catalytic addition of steam to ethene
(i.e. hydration of ethene)

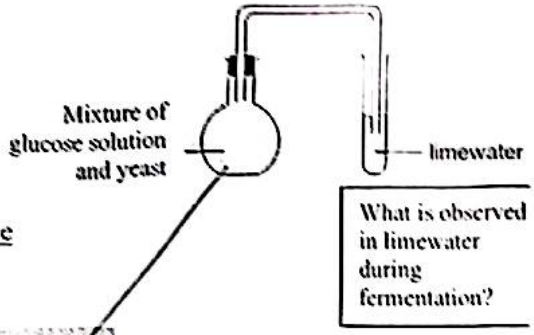
steam + alkene

Conditions: 300°C, 60 atm, phosphoric(V) acid (H_3PO_4) catalyst

$$\text{ethene} + \text{steam} \xrightarrow[H_3PO_4]{300^\circ C,\ 60\ atm} \text{ethanol}$$

(ii) by fermentation of glucose/sugar/starch solution ($C_6H_{12}O_6$)

- experimental conditions (37GAY):
  - temperature of 37°C
  - in the absence of oxygen
  - add yeast (solid state) as a catalyst
  - refer to TB pg 455 Figure 23.2



- product: (dilute) ethanol solution and carbon dioxide

$$\text{glucose} \xrightarrow{\text{yeast}} \text{dilute ethanol} + \text{carbon dioxide}$$

- A dilute solution of ethanol (15% alcohol) is produced. A higher alcohol content is not produced as it causes the yeast to die and fermentation to stop.

- IMPORTANT: dilute ethanol solution obtained has to be **purified into pure ethanol** using **fractional distillation**

  - Note: fermentation must take place at a temperature of 37°C (optimal temp) whereby the enzymes (micro-organisms) in the yeast work best. At HIGHER temperatures, the enzymes are denatured and can no longer act as catalyst, speed of reaction will DECREASE

word equation: glucose solution → dilute ethanol solution + carbon dioxide gas

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

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Chapter 23: Carboxylic Acids

Name: Huena (12) Class: 4A Date: ~~3~~ 3 · 6 · 25

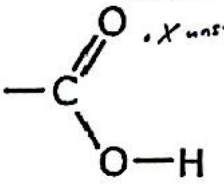
At the end of the lesson, you should be able to:

- Describe the carboxylic acid homologous series as containing the $-CO_2H$ group
- Draw the structures of carboxylic acids, methanoic acid to butanoic acid and name the unbranched acids, methanoic to butanoic acids
- Describe carboxylic acids as weak acids, reacting with carbonates, bases and some metals
- Describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or acidified potassium manganate(VII)
- Describe the chemical reactions of a carboxylic acid with an alcohol to form an ester e.g. ethyl ethanoate
- State some commercial uses of esters, e.g. perfumes; flavourings; solvents

Carboxylic acid homologous series

- also known as **organic** acids
- are **simple molecular** (covalent) compounds containing carbon, oxygen and hydrogen atoms
- consists of ONLY carbon-carbon single bonds (C-C), therefore they are **saturated** compounds
- functional group: $-CO_2H$ or $-COOH$ carboxyl group
- spelling end with **–anoic**

· saturation comes from c-c bond
· X unsaturated



General formula: $C_{n-1}H_{2n-1}COOH$ where n = number of carbon atoms, positive integer starting from 1

① $HCOOH$
② CH_3COOH
③ C_2H_5COOH

Physical property of Carboxylic acids

- The carboxylic acids homologous series has the same physical properties as alkanes and alkenes: mp. bp ↑, flammability ↓, viscosity ↑

Additional physical property of Carboxylic acids: Solubility in water

- **Very soluble** in water (only methanoic acid to butanoic acid)
- Solubility **decreases** as the number of carbon atoms in the molecule increases as size of molecule increases ↑
- the trend in the physical properties of alcohol such as (i) melting and boiling points, (ii) viscosity and (iii) flammability is the same as that in alkane and alkene ↑ ↓

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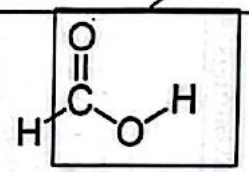
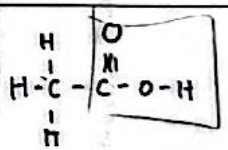
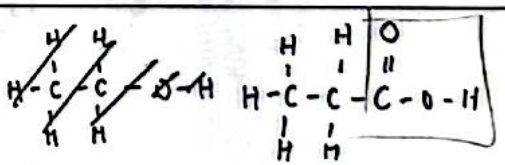
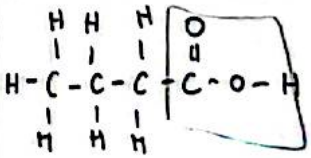
All bonds in the –COOH group must be shown

Carboxylic acid Homologous Series ($C_{n-1}H_{2n-1}CO_2H$) / $C_nH_{2n}O_2$

No. of carbon atoms in one molecule	Prefix	Chemical name	Molecular formula	M_r	Physical state at r.t.p	Full Structural formula	Structural formula
1	Meth	Methanoic acid	HCOOH	46	liquid		HCOOH
2	Eth	ethanoic acid (common in vinegar)	CH_3COOH / $C_2H_4O_2$	60	liquid		CH_3COOH
3	Prop	propanoic acid	C_2H_5COOH	74	liquid		CH_3CH_2COOH
4	But	butanoic acid	C_3H_7COOH	88	liquid		$CH_3CH_2CH_2COOH$

+14 +14 +14

. ensure to draw all carbons atoms first

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Chemical properties (reactions) of Carboxylic acids

(A) Complete Combustion (same as alkane)

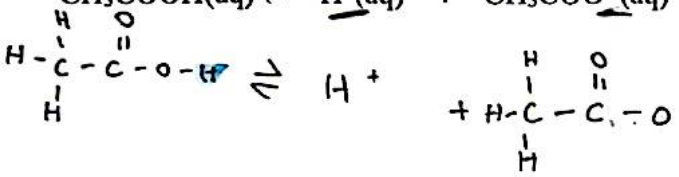
(B) Incomplete Combustion (same as alkane)

(C) Reaction with water (acids dissociate in water to form H+ ions – depends on strength)

- Carboxylic acids are **weak** acids as they **partially dissociate** in water to produce a **low concentration** of **hydrogen ions** (H^+).
- Carboxylic acids have acidic properties due to the **hydrogen ions** produced.
- Note: ethanoic acid is a weak acid known as vinegar

c.g. ethanoic acid ⇌ hydrogen ion + ethanoate ion

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



(D) Reaction with reactive metals

- reactive metals: all metals except the Group I metals (too reactive, unsafe) and unreactive metals (below H)
- general equation: carboxylic acid + metal → salt + hydrogen
- example: magnesium + ethanoic acid → magnesium ethanoate + hydrogen

$$Mg\,(s) + 2CH_3COOH(aq) \rightarrow (CH_3COO)_2Mg\,(aq) + H_2(g)$$

(E) Reaction with bases

- bases: includes metal hydroxides and metal oxides
- general equation: carboxylic acid + base → salt + water
- example: sodium hydroxide + methanoic acid → sodium methanoate + water

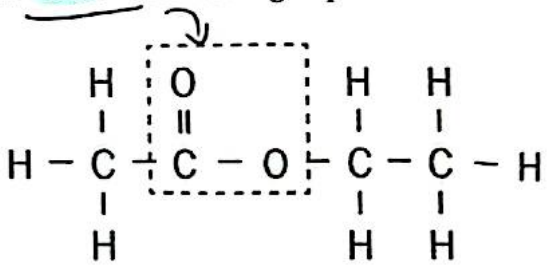
(F) Reaction with carbonates

- general equation: carboxylic acid + carbonate → salt + carbon dioxide + water
- example: calcium carbonate + dilute propanoic acid → calcium propanoate + carbon dioxide + water

(G) Reaction with alcohols (to form esters)

What are esters?

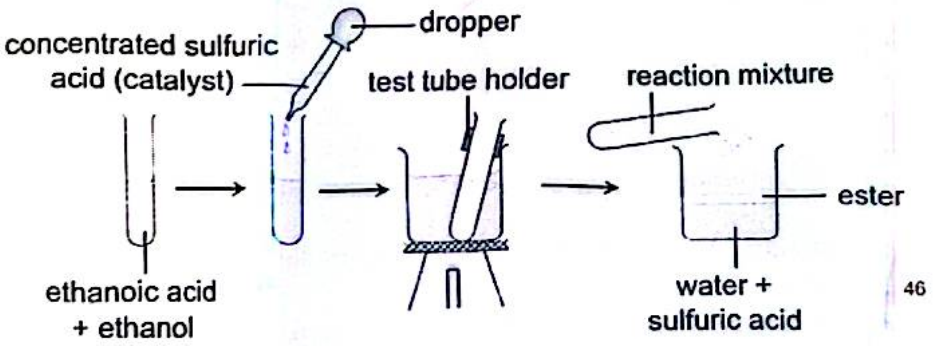
- Esters are sweet-smelling, colourless liquids that are **insoluble** in water.
- Esters contain the –COO– functional group.



- An ester is formed by reacting a carboxylic acid with an alcohol. This reaction is known as esterification.
- carboxylic acids react with alcohols to produce an ester in a reversible reaction
- general equation: carboxylic acid + alcohol ⇌ ester + water
- conditions required:
  - catalyst is **concentrated sulfuric acid** (add a few drops)
  - warm/heat/boil the mixture of carboxylic acid and alcohol
- how to make esters in the lab: refer to TB page 461, Figure 23.7

Esterification

- An ester is formed when a mixture of an alcohol and a carboxylic acid is warmed together with a few drops of concentrated sulfuric acid.
- Concentrated sulfuric acid acts as a catalyst for the reaction.



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How to name an ester?

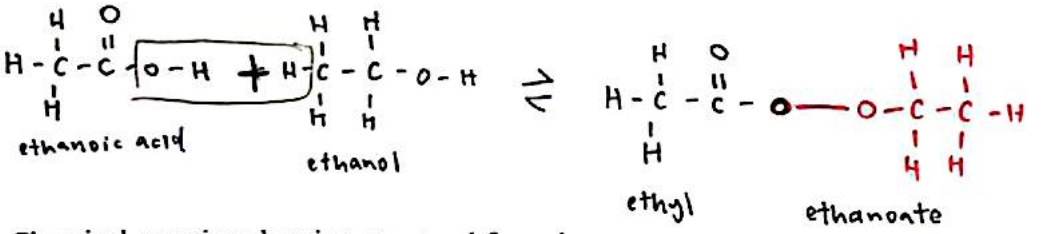
- General name: alkyl alkanoate
- Alkyl group belongs to the alcohol
- Alkanoate group belongs to the carboxylic acid

methyl ethanoate
methanol (alcohol) — ethanoic acid (carboxylic acid)

Example 1: ethanol + ethanoic acid → ethyl ethanoate + water

Equation showing full structural formula:

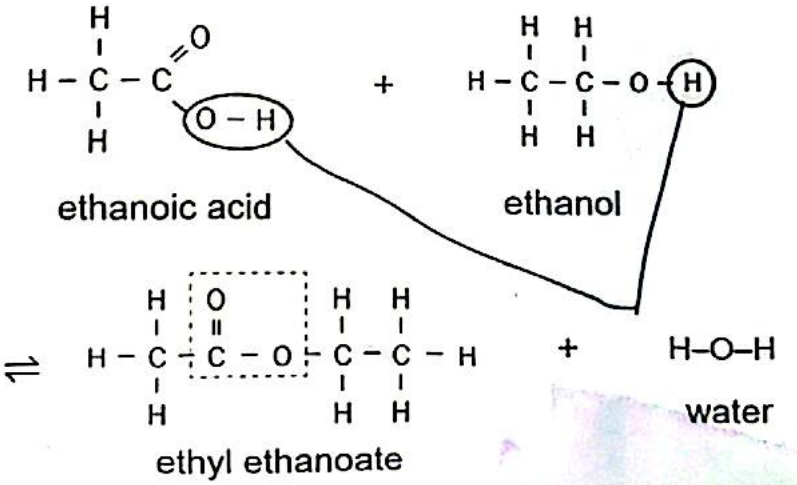
Thinking process: remove –OH group from acid and -H from alcohol



Chemical equation showing structural formula:

$$CH_3CH_2OH + CH_3COOH \rightarrow CH_3COOCH_2CH_3 + H_2O$$

Note: For writing of structural formula of esters, it MUST be carboxylic acid first then alcohol. But for drawing of FULL structural formula of esters, can be either.



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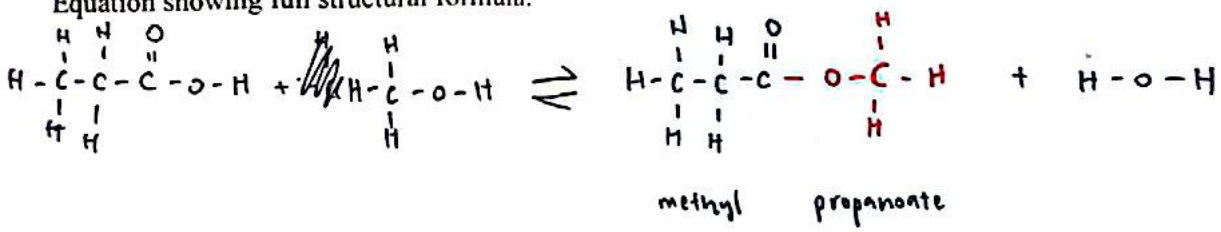
CH_3OH C_2H_5COOH

Example 2: methanol + propanoic acid → methyl propanoate + water

(2) (1) (3)

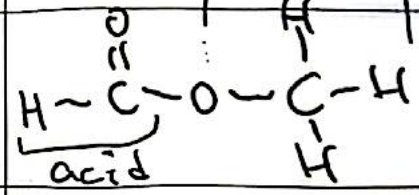
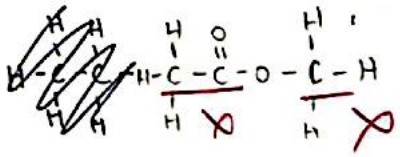
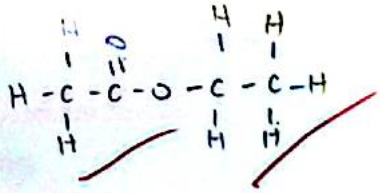
Equation showing full structural formula:



Chemical equation showing structural formula:

$$CH_3CH_2COOH + CH_3OH \rightleftharpoons CH_3CH_2COOCH_3 + H_2O$$

$C_nH_{2n+1}OH$ $C_{n-1}H_{2n-1}COOH$

Alcohol	Carboxylic acid	Ester formed	Full structural formula
Methanol C_2H_5	Methanoic acid CH_3COOH	Methyl methanoate	
Ethanol	ethanoic acid methanoic acid	Ethyl methanoate	
Ethanol	ethanoic acid	ethyl ethanoate	

Naming: alcohol - acid
Drawing: acid - alcohol