

## 8.26.0 ORGANIC CHEMISRTY

### 8.14.0 CLASSIFICATION AND NOMENCLATURE OF ORGANIC COMPOUNDS

TOPIC	OBJECTIVES Learners should be able to:	CONTENT (ATTITUDES, SKILLS AND KNOWLEDGE)	SUGGESTED ACTIVITIES AND NOTES	SUGGESTED RESOURCES
8.14.1 Homologous series	<ul style="list-style-type: none"> <li>define the term homologous series</li> <li>name systematically organic compounds</li> <li>classify organic compounds as hydrocarbons, alcohols and carboxylic acids up to six carbon atoms</li> </ul>	<ul style="list-style-type: none"> <li>homologous series                             <ul style="list-style-type: none"> <li>hydrocarbons</li> <li>alcohols</li> <li>carboxylic acids</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Making molecular models up to six carbon atoms</li> <li>Drawing structures of organic molecules up to six carbon atoms</li> <li>Simulations of organic molecules</li> </ul>	<ul style="list-style-type: none"> <li>Plasticine</li> <li>Molecular model kits</li> <li>Models of organic molecules</li> <li>ICT Tools/Braille Jaws software</li> </ul>

### 8.14.0 CLASSIFICATION & NOMENCLATURE OF ORGANIC COMPOUNDS

#### BASICS:

- ❖ Organic compounds are a family of compounds that have chains or rings of carbon atoms bonded to atoms of hydrogen and sometimes oxygen, nitrogen, and other elements.
- ❖ Examples of organic compounds are hydrocarbons (alkanes and alkenes), alcohols, carboxylic acids, polymers, esters, starch, cellulose and proteins.
- ❖ Hydrocarbons are compounds which contain carbon and hydrogen only.
- ❖ Alkanes and alkenes are examples of hydrocarbons.
- ❖ A **homologous series** is a group/family of compounds with a **general formula**, **similar chemical properties** and showing a **gradation (gradual change)** in **physical properties** as a result of **increase** in the **size and mass** of the molecules, e.g. melting and boiling points; viscosity; flammability.
- ❖ **CHARACTERISTICS OF A HOMOLOGOUS SERIES:**
  - All members of homologous series have same general formula.
  - All members have the same functional group - the part of the substance where reactions happen.
  - Formula of each member differs to the next by  $\text{-CH}_2$ .
  - Physical properties change gradually as carbon atoms increase.
  - The members have similar chemical properties
- **Alkanes, alkenes, alcohols and carboxylic acids** are examples of individual homologous series.
- ❖ The group that identifies an organic molecule and gives it its chemical properties is called its **functional group**.
- ❖ **Alkane** - general formula  $\text{C}_n\text{H}_{2n+2}$
- ❖ **Alkene** - general formula:  $\text{C}_n\text{H}_{2n}$  and the **C=C** bond is the functional group.
- ❖ **Alcohol** - have the general formula:  $\text{C}_n\text{H}_{2n+1}\text{OH}$ . The **-OH** group (hydroxyl group) is the **functional group** of alcohols.

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- ❖ Carboxylic acid - have the general formula:  $C_nH_{2n+1}COOH$  and  $-COOH$  group (carboxyl group) is the functional group.
- ❖ Polymers are macromolecules made of repeating units called monomers.
- ❖ Addition polymerisation is which small molecules (monomers) join together to form one molecule as the only product. All atoms in the monomer are used to form the polymer, double bonds in molecules break in order to form new bonds.
- ❖ Condensation polymerisation - 2 different monomers join, double bonds are not broken. In order for the monomers to join, a small molecule has to be expelled like  $H_2O$  (water) or  $HCl$ .
- ❖ Esters are produced when carboxylic acids react with alcohols; the functional group is the ester link ( $-COO-$ , a carbon with a double bond to oxygen and a single bond to another oxygen).
- ❖ Organic compounds may have straight chains or branched chains.

## NOMENCLATURE OF ORGANIC COMPOUNDS

### 1. Naming straight chain organic compounds

- ❖ Nomenclature is the assigning of names to members in families of organic compounds.
- ❖ Organic compounds are named according to the number of carbon atoms in the molecule (see the table below).

Number of Carbon Atoms	Name Prefix	Alkane	Alkene	Alcohol	Carboxylic acid
1	meth	methane	-----	methanol	methanoic acid
2	eth	ethane	ethene	ethanol	Ethanoic acid
3	prop	propane	propene	propanol	Propanoic acid
4	but	butane	butene	butanol	Butanoic acid
5	pent	pentane	pentene	pentanol	Pentanoic acid
6	hex	hexane	hexene	hexanol	Hexanoic acid
7	hept	heptane	heptene	heptanol	Heptanoic acid
8	oct	octane	octene	octanol	Octanoic acid

The prefix denotes the number of the carbon atoms and the suffix denotes the family name.

- ♥ The name begins with a prefix that tells you how many Carbons are in the chain.
- ❖  $C_1 = \text{Meth-}$ ,  $C_2 = \text{Eth-}$ ,  $C_3 = \text{Prop-}$ ,  $C_4 = \text{But-}$ ,  $C_5 = \text{Pent-}$
- ❖ After 5 the prefixes are the same as for Polygons in Maths (Hex-, Hept-, Oct-, Non-, Dec- and so on).
- ❖ We can remember the first 5 as: **My Evil Plane Bombed Paris.**
- ♥ The name ends with a suffix that tells you the family name of the organic compound

Suffix (Name ending) → Family name

“ane” → alkane

“ene” → alkene

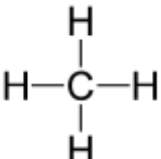
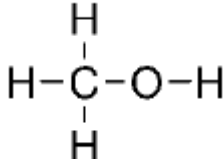
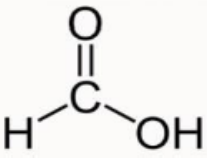
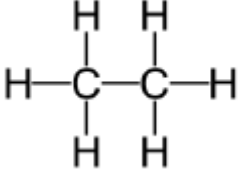
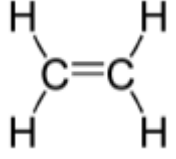
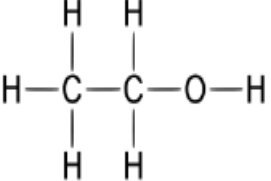
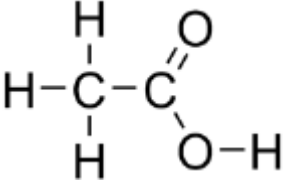
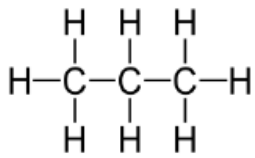
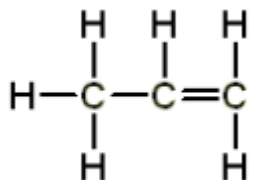
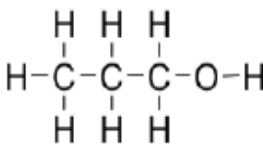
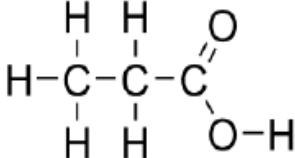
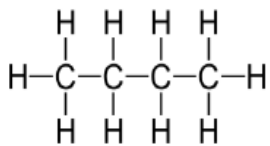
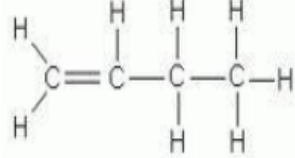
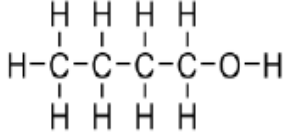
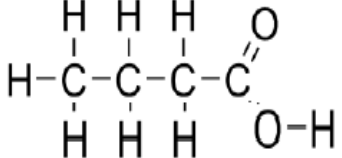
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“ol” → alcohol

“oic acid” → carboxylic acid

“yl”, “oate” → ester (as in ethyl ethanoate)

**TABLE:** The nomenclature of some straight chain organic compounds

	<b>NAME OF FAMILY, FORMULA &amp; STRUCTURE</b>			
NUMBER OF CARBON ATOMS	Alkane	Alkene	Alcohol	Carboxylic acid
	Functional group -----	Functional group: C=C	Functional group -OH	Functional group -COOH
1	Methane CH <sub>4</sub> 	NB. Methene, CH <sub>2</sub> , does not exist.	Methanol CH <sub>3</sub> OH 	Methanoic acid HCOOH 
2	Ethane C <sub>2</sub> H <sub>6</sub> 	Ethene C <sub>2</sub> H <sub>4</sub> 	Ethanol C <sub>2</sub> H <sub>5</sub> OH 	Ethanoic acid CH <sub>3</sub> COOH 
3	Propane C <sub>3</sub> H <sub>8</sub> 	Propene C <sub>3</sub> H <sub>6</sub> 	Propanol C <sub>3</sub> H <sub>7</sub> OH 	Propanoic acid C <sub>2</sub> H <sub>5</sub> COOH 
4	Butane C <sub>4</sub> H <sub>10</sub> 	Butene C <sub>4</sub> H <sub>8</sub> 	Butanol C <sub>4</sub> H <sub>9</sub> OH 	Butanoic acid C <sub>3</sub> H <sub>7</sub> COOH 
5	Pentane	Pentene	Pentanol	Pentanoic acid
6	Hexane	Hexene	Hexanol	Hexanoic acid

**EXERCISE:** Please complete the last two rows of this table by writing the formulae and drawing in the structures of the missing organic compounds. Substitute the number of carbon atoms (n) into the general formulae so as to get the formulae of the compounds.

## 2. The nomenclature of branched chain organic compounds

Naming any organic molecule is straightforward if you follow these rules:

1. Find the longest carbon chain and name it. For example, a chain of five carbon atoms will have a name based on pentane.
2. Number the carbon atoms in the chain so that the functional group has the lowest possible number.
3. Identify any branches joined onto the main chain and name them.
4. Identify each branch by a number indicating its position. If more than one branch is present then a prefix must be used (**Di** = 2 branches, **Tri** = 3 branches, **Tetra** = 4 branches).

**NB.** Be careful when naming molecules to number the longest possible carbon chain, and that when writing the name, you follow the convention of using commas between numbers and dashes between numbers and words.

### Examples:

Name the following organic compounds:

<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <b style="color: red;">1.</b> <pre>       H   H   H   H                     H - C - C - C - C - H                           H   H       H               H - C - H                                       H                     </pre> <p style="color: red;">Branch on 2<sup>nd</sup> carbon = 2  Branch is methyl group = <b>methyl</b>  Longest chain is 4 carbons long = <b>butane</b></p> <p>Therefore name is <b>2-methylbutane</b></p> </div>	<pre>       H   H   H   H                     H - C - C - C - C - H                           H   H       H               CH<sub>3</sub>                     </pre> <p style="color: blue;">2-methylbutane can also be represented as shown above or as shown below.</p> <p style="color: blue;">CH<sub>3</sub> - CH<sub>2</sub> - CH - CH<sub>3</sub>  <span style="margin-left: 100px;"> </span>  <span style="margin-left: 100px;">CH<sub>3</sub></span></p>
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**2.**

```

          H
          |
        H - C - H
          |
      H   H   |   H
      |   |   |   |
H - C - C - C - C - H
      |   |   |   |
      H   H   |   H
              H - C - H
                  |
                  H
                    
```

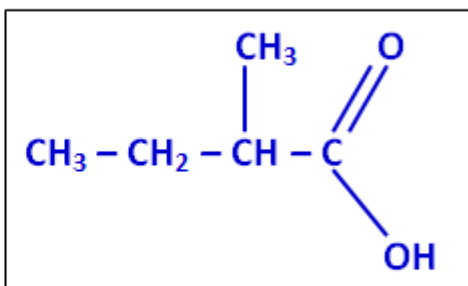
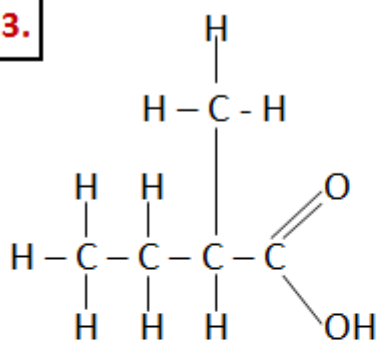
```

          CH3
          |
CH3 - CH2 - C - CH3
          |
          CH3
                    
```

Branch on 2<sup>nd</sup> Carbon = 2  
Another branch on 2<sup>nd</sup> carbon = 2  
Both branches are methyl groups = **dimethyl**  
Longest chain is 4 carbons long = **butane**

Therefore name is **2,2-dimethylbutane**

**3.**



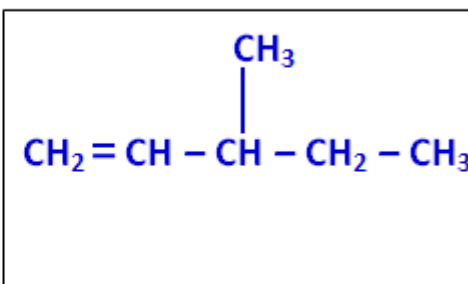
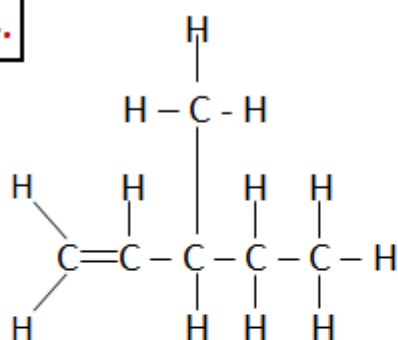
Branch on 2<sup>nd</sup> Carbon = 2

Branch is methyl group = **methyl**

4 carbon long chain with carboxyl group = **butanoic acid**

Therefore name is **2-methylbutanoic acid**

**4.**



Branch on 3<sup>rd</sup> carbon = 3

Branch is methyl group = **methyl**

5 carbon long chain = **pent**

Alkene group (double bond) on 1<sup>st</sup> carbon = **1-ene**

Therefore name is **3-methylpent-1-ene**

## EXERCISE

Name the following organic compounds.

## 8.27.1 ISOMERISM

TOPIC	OBJECTIVES Learners should be able to:	CONTENT (ATTITUDES, SKILLS AND KNOWLEDGE)	SUGGESTED ACTIVITIES AND NOTES	SUGGESTED RESOURCES
8.27.1 Isomerism	<ul style="list-style-type: none"> <li>describe the term isomerism</li> <li>identify structural isomers of alkanes</li> <li>draw the structures of the isomers</li> </ul>	<ul style="list-style-type: none"> <li>structures of isomers of alkanes up to 6 carbon atoms</li> </ul>	<ul style="list-style-type: none"> <li>discussing isomerism</li> <li>making models of isomers of alkanes</li> <li>simulating isomerism</li> </ul>	<ul style="list-style-type: none"> <li>models</li> <li>ICT tools and Braille/Jaws software</li> </ul>

### ISOMERS

- Isomers are compounds with the same molecular formula but different structural formulae.
- Due to different chain length, isomers have different physical properties (e.g. boiling point).
- Isomerism is the existence of two or more molecules that are isomers.

### STRUCTURAL ISOMERS OF ALKANES

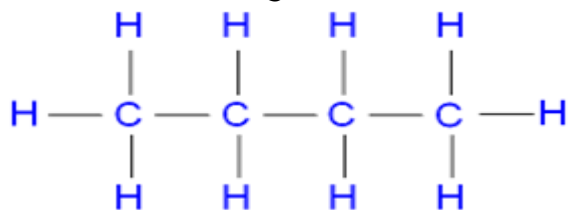
- ❖ **What is a structural formula?** The structural formula (also called the displayed formula) shows how the atoms are joined together in the molecule.
- ❖ Isomers of hydrocarbons have the same number of carbon and hydrogen atoms but the carbon atoms are joined to each other in different ways. Simply changing the shape of the molecule does not make it a different isomer.
- ❖ The isomers of some alkanes are shown below.
- ❖ Different isomers are different molecular compounds.
- ❖ They will have different physical properties (for example different boiling points).
- ❖ The more carbon atoms a compound has, the greater the number of isomers there can be.
  - Methane (1 carbon atoms) has 0 isomers.
  - Ethane (2 carbon atoms) has 0 isomers.
  - Propane (3 carbon atoms) has 0 isomers.
  - Butane (4 carbon atoms) has 2 isomers.
  - Pentane (5 carbon atoms) has 3 isomers.
  - Hexane (6 carbon atoms) has 5 isomers.
  - Heptane (7 carbon atoms) has 9 isomers.
  - Octane (8 carbon atoms) has 15 isomers.
- ❖ There are also isomers of alkenes and alcohols.

### What are the Isomers of Butane?

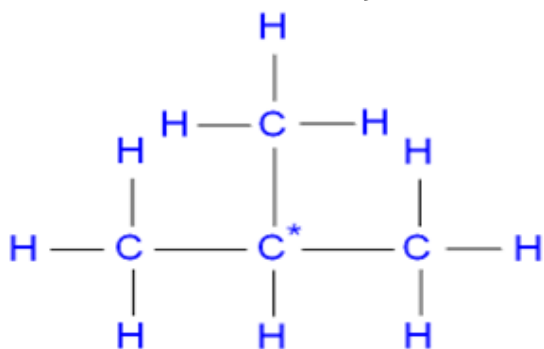
- ♦ Butane (C<sub>4</sub>H<sub>10</sub>) has two structural isomers:
  - 1) n-butane
  - 2) 2-methylpropane.

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- ♦ **Isomer 1** is the straight chain normal structure for **butane** (called **n-butane**).



- ♦ **Isomer 2** (called **2-methylpropane**) is a different structure with a branched chain which has a **carbon\* atom** joined onto **three** other **carbon atoms**.



### Nomenclature (how to name this isomer)

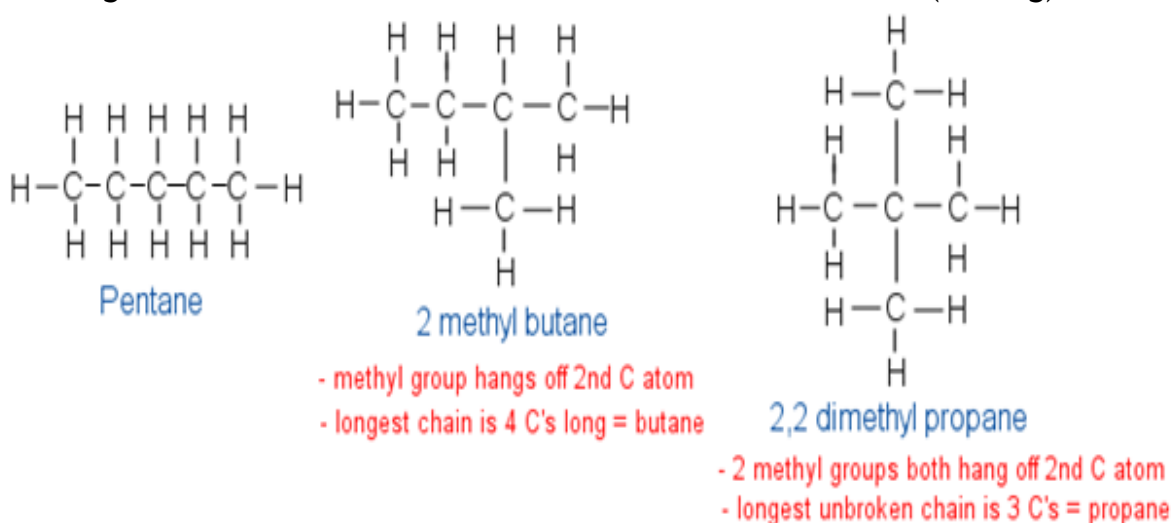
**Name: 2-methylpropane**

- The **2** means the **methyl** group ( $-\text{CH}_3$ ) is attached to (or branching off) the **2<sup>nd</sup>** **carbon** atom.
- **Propane** means the longest chain is **3** **carbons** long.

- ♦ The **two isomers** are **different compounds** with different boiling points.
- ♦ Note that for **both isomers**, each **carbon atom** has four bonds (**valency 4**), and each **hydrogen atom** has **one bond** (**valency 1**).  
Valency is the **combining power** of an **atom**. You **cannot change** the **number** of **bonds** which **each atom** has.
- ♦ **Changing** the **shape** of the **molecule** does **not** produce a **different isomer**.

### What are the Isomers of Pentane?

- ♥ Pentane ( $\text{C}_5\text{H}_{12}$ ) has **three structural** isomers: pentane, **2-methylbutane** and **2,2-dimethylpropane**.
- ♥ The fig below shows the three isomers and their nomenclature (naming).



**Assignment:** Draw the structural formulae of the five isomers of hexane and name each isomer appropriately.



## 8.28.0 HYDROCARBONS

TOPIC	OBJECTIVES Learners should be able to:	CONTENT (ATTITUDES, SKILLS AND KNOWLEDGE)	SUGGESTED ACTIVITIES AND NOTES	SUGGESTED RESOURCES
8.28.1 Alkanes and Alkenes	<ul style="list-style-type: none"> <li>describe the manufacture of alkanes and alkenes</li> <li>distinguish between alkanes and alkenes</li> <li>describe the</li> </ul>	<ul style="list-style-type: none"> <li>Cracking of long chain alkanes</li> <li>Combustion of alkanes and alkenes</li> </ul>	<ul style="list-style-type: none"> <li>Making models of alkenes and alkanes</li> <li>Drawing structures of alkanes and alkenes</li> <li>Burning</li> <li>Experimenting with</li> </ul>	<ul style="list-style-type: none"> <li>Hydrocarbon</li> <li>Burner</li> <li>Sand</li> <li>Cooking oil</li> <li>Bromine water</li> <li>Boiling tube</li> </ul>
	<ul style="list-style-type: none"> <li>chemical properties of alkanes as exemplified by methane</li> <li>describe the chemical properties of alkenes as exemplified by ethene</li> </ul>	<ul style="list-style-type: none"> <li>Reaction with chlorine in the presence of UV light and in darkness</li> <li>Reaction with bromine water</li> <li>Reaction of ethene with steam and hydrogen</li> </ul>	<ul style="list-style-type: none"> <li>cooking oil to demonstrate cracking</li> <li>Hydrocarbons</li> <li>Discussing the production of margarine and ethanol</li> </ul>	<ul style="list-style-type: none"> <li>Delivery tubes</li> </ul>

### 8.28.1 ALKANES & ALKENES

- ❖ **Hydrocarbons** are compounds which contain carbon and hydrogen only.
- ❖ **Alkanes** and **alkenes** are examples of hydrocarbons.
- ❖ **Alkanes are saturated hydrocarbons.** **Saturated** means they only have single bonds (i.e. they do not have double or triple bonds).
- ❖ **Alkenes are unsaturated hydrocarbons.** **Unsaturated** means they have double bonds between some of their carbon atoms.

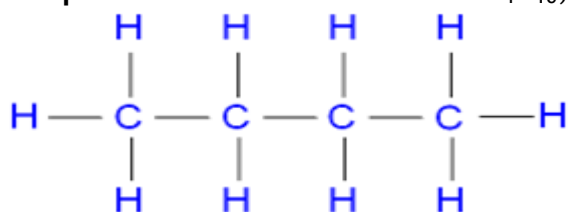
#### ALKANES

- Usually found in fuels, **examples:** *natural gas, petrol, diesel, paraffin and kerosene.*
- Are a homologous series
- Have a general formula of  $C_nH_{2n+2}$
- **Example:** propane has three carbon atom, thus  $n=3$ . Then the formula of propane is  $C_3H_8$
- Ends with suffix **-ane**
- Next alkane formula differ by  $-CH_2$  atoms. E.g. methane:  $CH_4$ , ethane:  $C_2H_6$

#### Structure of Alkanes

Shows how all atoms in a molecule joined together by drawing lines between atoms to represent the bonds

**Example:** butane has a formula of  $C_4H_{10}$ , therefore the structural formula is:





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- It has 4 carbon atoms bonded together with 10 hydrogen atoms
- Organic compound containing single bonds only is **saturated**. E.g. *methane*.
- All alkanes are saturated. All alkenes are unsaturated

### Physical Properties of Alkanes

Name	Molecular formula	M.p. (°C)	B.p. (°C)	State at r.t.p.*	Density (g/cm <sup>3</sup> )
methane	CH <sub>4</sub>	-182	-162	gas	0.000 68
ethane	C <sub>2</sub> H <sub>6</sub>	-172	-89		0.001 27
propane	C <sub>3</sub> H <sub>8</sub>	-187	-42		0.001 86
butane	C <sub>4</sub> H <sub>10</sub>	-138	-0.5		0.002 45
pentane	C <sub>5</sub> H <sub>12</sub>	-130	36	liquid	0.63
hexane	C <sub>6</sub> H <sub>14</sub>	-95	69		0.66
⋮	⋮	⋮	⋮		⋮
heptadecane	C <sub>17</sub> H <sub>36</sub>	22	292		0.77
octadecane	C <sub>18</sub> H <sub>38</sub>	28	308	solid	0.78
nonadecane	C <sub>19</sub> H <sub>40</sub>	32	320		0.78

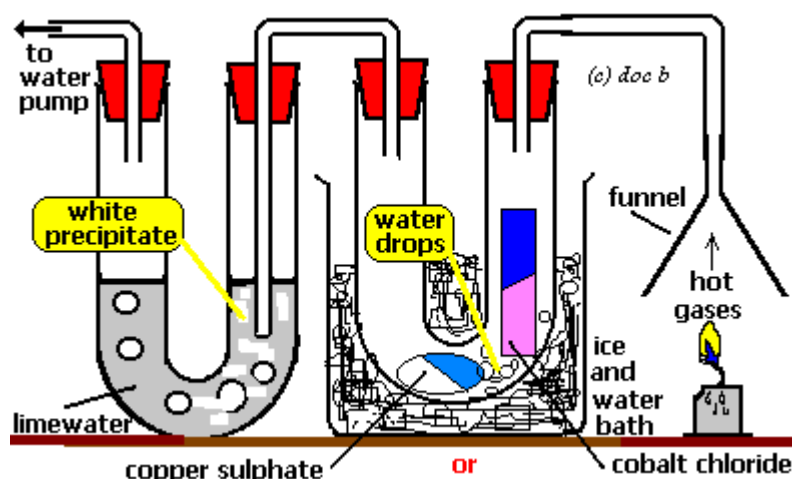
- **Melting points and boiling points increase** as the molecules become larger and heavier which increases the intermolecular forces of attraction between molecules so more energy (from heat) is needed.
- Alkanes are **insoluble** in water but **soluble** in organic solvents such as tetrachloromethane (CCl<sub>4</sub>).
- Alkane density **increases** down the series; all alkenes are less than 1g/cm<sup>3</sup>
- Alkanes become more **viscous** (uneasily flow) going down the series as the longer molecules tangles together when it flows.
- Alkanes become **less flammable** down the series as B.P. becomes larger
- Alkanes are **unreactive** with either metals, water, acids or bases because the C - C and C - H covalent bonds are harder to break.

### REACTIONS OF ALKANES

- Each carbon atoms in an **alkane** has four covalent single bonds - this makes them quite unreactive.
- **They only have two reactions:**
- **1. COMBUSTION** this can either be **complete combustion** or **incomplete combustion**.  
**Complete combustion:** meaning there is enough oxygen supply so water and carbon dioxide form.  
e.g.  $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$

**EXPERIMENT:** To demonstrate the complete combustion of a hydrocarbon, such as alkane, produces **water** and **carbon dioxide**.

- ♦ When Hydrogen atoms in alkanes react with Oxygen it always forms **Water Vapour (H<sub>2</sub>O)**



- If there is enough Oxygen for **complete combustion** then each Carbon atom will bond to **two** Oxygen atoms to form **Carbon Dioxide (CO<sub>2</sub>)**.
- ❖ We can show this by drawing the gases from a burning Hydrocarbon (a candle) through a cold U-tube and another filled with **Limewater**.
- The Limewater turns milky, showing the presence of Carbon dioxide.
- A colourless liquid **condenses** in the tube. This liquid will turn dry **Cobalt Chloride paper** from blue to pink, or **Anhydrous Copper sulphate** powder from white to blue. This shows that the liquid is water.
- Conclusion: carbon dioxide and water are the products of the complete combustion of hydrocarbons such as alkanes.

**Incomplete combustion:** meaning there is not enough oxygen to burn them cleanly so either carbon monoxide and water or carbon and water form.

e.g.  $2\text{CH}_4 + 3\text{O}_2 \rightarrow 2\text{CO} + 4\text{H}_2\text{O}$  **or**  $\text{CH}_4 + \text{O}_2 \rightarrow \text{C} + 2\text{H}_2\text{O}$

## RESEARCH ASSIGNMENT

- (a).** Write the balanced equations for the complete and incomplete combustion of the following alkanes:
- Propane
  - Butane
  - Pentane
  - Octane (petrol).
- (b).** Burning of fossil fuels in engines and industries produces carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>) and oxides of nitrogen (NO<sub>x</sub>). What are the undesirable effects of each of these oxides on the environment and living organisms?

- **2. CHLORINE SUBSTITUTION:** sunlight is necessary.  
A chlorine atom replaces a hydrogen atom in an alkane in the presence of sunlight or uv. This can happen to all of the hydrogen atoms if there is enough chlorine.  
e.g.  $\text{CH}_4 + \text{Cl}_2 \xrightarrow{\text{light}} \text{HCl} + \text{CH}_3\text{Cl} / \text{CH}_2\text{Cl}_2 / \text{CHCl}_3 / \text{CCl}_4$  these compounds are called chloromethane / dichloromethane / trichloromethane / tetrachloromethane.  
In darkness chlorine substitution does not occur. This means sunlight or uv is needed to initiate the reaction.

## ALKENES

- Are a homologous series
- have general formula  $C_nH_{2n}$ .
- all alkene names end with **-ene**.
- the formula of one alkene differs from the next by  $-CH_2$ .
- have similar properties like alkane going down the series.

### Structure of Alkenes

Is organic compound containing  $C = C$  double bond, said to be **unsaturated**

*Reason:* not all C atoms are bonded to the maximum no. of 4 other atoms.

For more detail on alkenes, see topic **8.14.0 on classification & nomenclature of organic compounds**.

### The Importance of Ethene

Ethene is an alkene used to manufacture:

**Ethanol** - solvent & fuel

**Poly(ethene)** - PE plastic variations

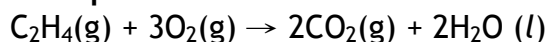
**Ethanoic acid** - vinegar

## REACTIONS OF ALKENES

### 1. COMBUSTION

Burns in air to form carbon dioxide and water (**complete combustion**).

**Example:** Ethene burns in air. Write the balanced equation for the reaction



**Incomplete combustion** forms soot and CO. Its produced more than alkane.

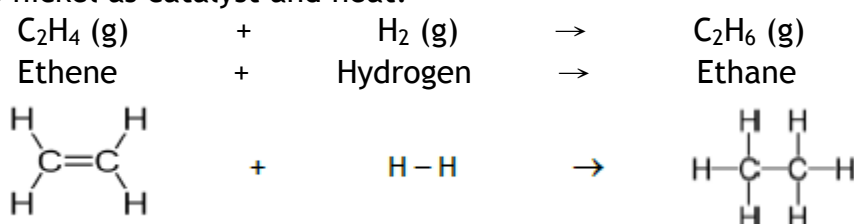
### 2. ADDITION REACTIONS OF ALKENES

Addition reaction is the reaction of 2 or more molecules to form a single product.

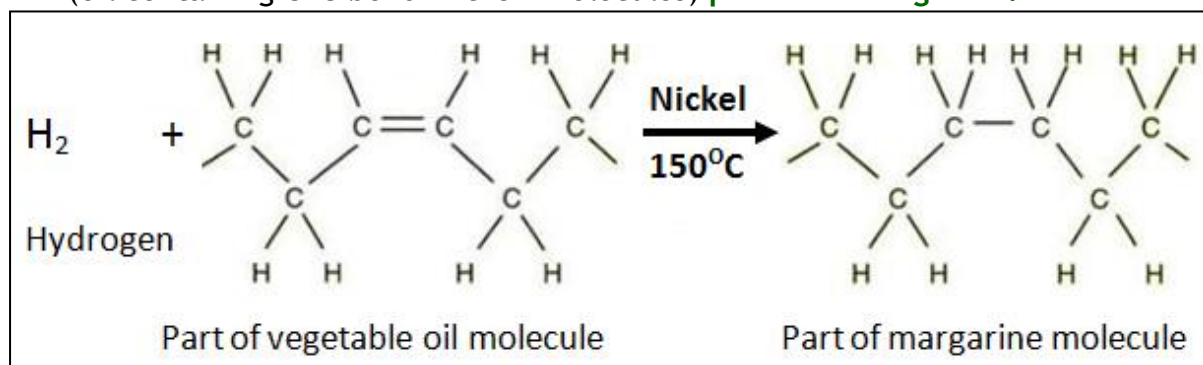
The following are examples of addition reactions of alkenes:

#### Addition of hydrogen (hydrogenation)

- Alkenes react with **hydrogen** to form **alkanes**. This is called **hydrogenation**. Must use nickel as catalyst and heat.



**The Manufacture of Margarine** - **Hydrogenation** of polyunsaturated vegetable oils (oil containing  $C=C$  bond in their molecules) **produces margarine**.

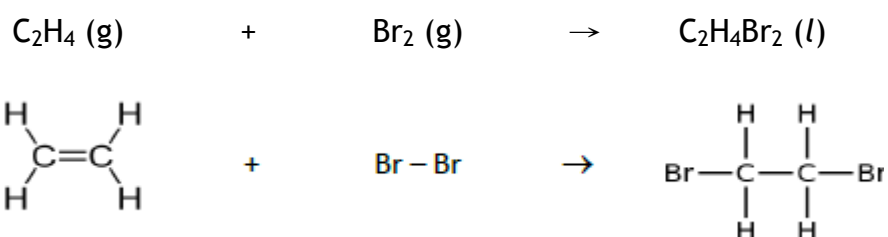


## ORGANIC CHEMISTRY

- Hydrogen is reacted with vegetable oil in the presence of nickel catalyst and heat. Hydrogen adds to C=C bond, increasing the molecular mass of the compound
- With increase in mass, the compound has higher boiling point. Therefore, margarine is solid at room temperature.
- Since only some C=C bonds react with hydrogen, margarine is partially hydrogenated and each type of margarine has different hardness, depending on the number of C=C bonds remaining.

### Addition of bromine

- Bromine adds to C = C double bond of alkane molecules. Phosphoric acid (H<sub>3</sub>PO<sub>4</sub>), high temperature of 300°C and 60-70 atm pressure are needed as catalyst.
- E.g. ethene to 1,2 -dibromoethene

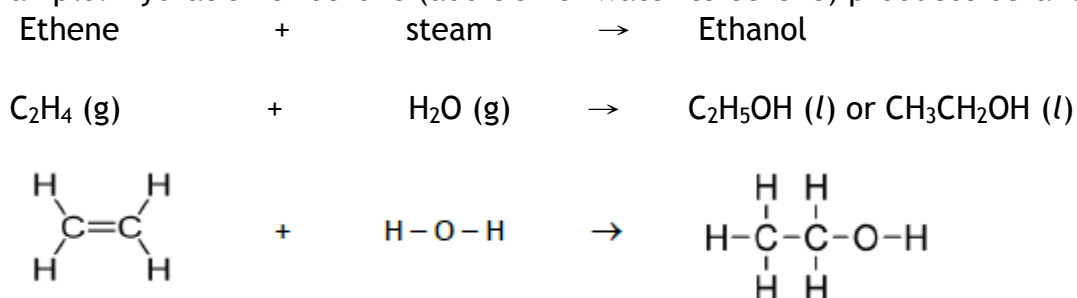


### Nomenclature

(n) + (bromo) + (alkene name), where n is the number of bromine atoms.  
E.g. Above, Ethene reacts with 2 bromine atoms producing DI(2)BROMO(Bromine) ETHENE(alkene name). Hence we call the product DIBROMOETHENE.

### Hydration of alkenes - Addition of water to alkenes (reaction of alkenes with steam to form alcohol)

- Alkene reacts with water, in the form of steam, to produce alcohol.
- Alkene and steam are passed over phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) catalyst at a temperature of 300°C and pressure of 60 atmospheres. H<sub>2</sub>O molecules add to C=C bonds to form alcohol.
- Example: Hydration of ethene (addition of water to ethene) produces ethanol:



### Addition Polymerization

- The joining of several identical alkene molecules to form a polymer (large molecule)
- E.g. (Ethene)<sub>n</sub> → Poly(ethene)
- (See full notes on Addition polymerisation is which small molecules (monomers) join together to form one molecule as the only product.).

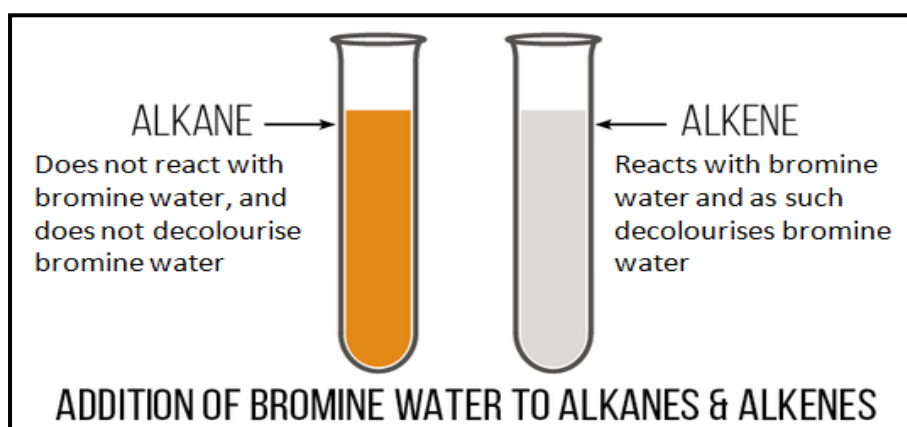
### Testing for Unsaturated Compounds

## ORGANIC CHEMISTRY

Mix bromine solution with alkene (for liquid alkenes - shake). Reddish-brown colour of bromine disappears. This shows that the compound is an alkene i.e. is unsaturated [contains double bond(s)].

How to Tell an Alkane from an Alkene? - *Alkenes decolourise bromine water whereas alkanes do not.*

- An alkene e.g. **ethene** may be distinguished from an alkane e.g. **ethane** by shaking the hydrocarbons with bromine water.
- Bromine water is brown or orange, and will lose its colour when it reacts with the double bond of an alkene.
- Bromine water will stay brown with an alkane because an alkane has no double bonds.
- Bromine adds across the double bond of an alkene to form a colourless dibromo alkane. This is an example of an addition reaction.



What is the Cracking of Hydrocarbons?

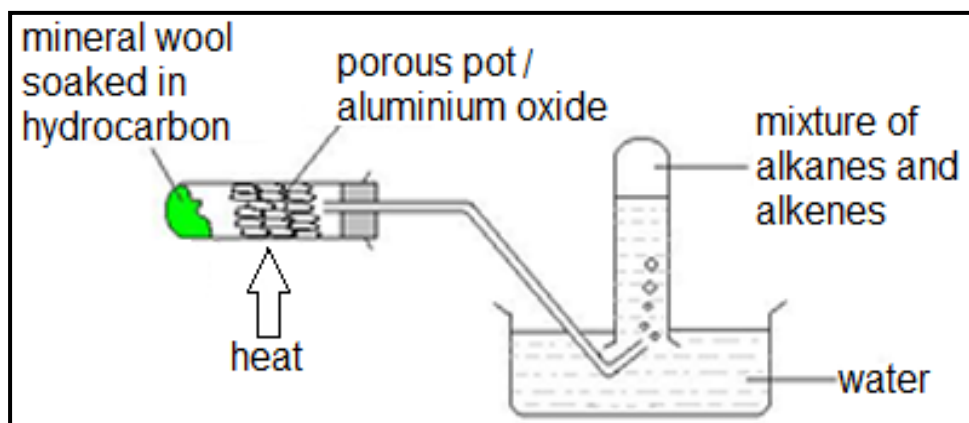
- After the fractional distillation of crude oil there are too many large hydrocarbons and not enough small hydrocarbons to meet the public's demand.
- Some of the large hydrocarbons (the heavier fractions) are broken down into more useful smaller hydrocarbons (lighter fractions) by a process known as catalytic cracking.
- The fractional distillation of crude oil produces mainly large alkanes.
- The purpose of cracking larger alkanes is to produce smaller, more useful alkanes (such as petrol), and even more useful alkenes (such as ethene)
- Cracking is the main source of alkenes.
- See also the dehydration of ethanol to produce ethene.

What is the Chemistry of the Cracking of Hydrocarbons?

- Catalytic cracking of hydrocarbons involves thermal decomposition of large alkane molecules into smaller molecules in the presence of a catalyst.
- The hydrocarbons are boiled and the hydrocarbon gases are either mixed with steam and heated to a very high temperature or passed over a hot powdered catalyst of aluminium oxide (alumina), silica (silicon dioxide) or porous pot.
- The catalyst works by providing the hydrocarbon gases with a convenient surface for the cracking to take place.

## ORGANIC CHEMISTRY

- In the laboratory the catalytic cracking of a hydrocarbon such as cooking oil can be done using the set up below. Do not crack highly flammable alkanes such as octane in the lab for safety reasons. Crack cooking oil instead.

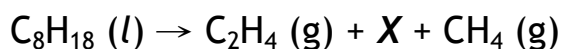


- For example, decane (an alkane with 10 carbons) can be cracked to produce octane and ethene.



- Octane is used as petrol.
- Ethene is used in the manufacture of polymers.
- Cracking an alkane produces a smaller alkane plus an alkene.
- If you add up the number of hydrogen atoms in the above reaction, you will see that there are 22 on each side.
- An alkene is produced because the original alkane does not have enough hydrogen atoms to produce two more alkanes.
- NB. The total number of carbon and hydrogen atoms in cracked alkane should equal the total number of carbon and hydrogen atoms in the products.

E.g. Octane can be cracked into simpler hydrocarbons such as the reaction below. Suggest the possible identity of product x.



$$\text{Number of C atoms in X} = 8 - 2 - 1 = 5$$

$$\text{Number of H atoms in X} = 18 - 4 - 4 = 10$$

Therefore, product X is  $\text{C}_5\text{H}_{10}$



## 8.29.0 ALCOHOLS

### 8.29.0 ALCOHOLS

TOPIC	OBJECTIVES Learners should be able to:	CONTENT	SUGGESTED ACTIVITIES AND NOTES	SUGGESTED RESOURCES
8.29.1 Fermentation	<ul style="list-style-type: none"> <li>describe the conditions necessary for the fermentation process</li> <li>describe the industrial production of ethanol by fermentation</li> </ul>	<ul style="list-style-type: none"> <li>Conditions for fermentation</li> <li>Fermentation                             <ul style="list-style-type: none"> <li>- ethanol</li> <li>- mahewu</li> <li>- Indigenous beer brewing</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Discussing conditions necessary for fermentation</li> <li>investigating the conditions necessary for fermentation</li> <li>visiting sites e.g. breweries, ethanol production plants</li> </ul>	<ul style="list-style-type: none"> <li>Glucose</li> <li>Yeast</li> <li>Sugarcane</li> <li>Malt, hops, maize, barley, rapoko, sorghum</li> </ul>
8.29.2 properties of ethanol	<ul style="list-style-type: none"> <li>describe the properties of ethanol</li> <li>describe the uses and social effects of ethanol</li> </ul>	<ul style="list-style-type: none"> <li>Solubility</li> <li>Boiling point</li> <li>Combustion</li> <li>Oxidation to carboxylic acids</li> <li>Dehydration of ethanol to ethene</li> <li>Uses of ethanol                             <ul style="list-style-type: none"> <li>- Solvents</li> <li>- Fuels (blend petrol)</li> <li>- Perfumes</li> <li>- Alcoholic beverages</li> </ul> </li> <li>Social effects</li> </ul>	<ul style="list-style-type: none"> <li>Burning of ethanol</li> <li>Testing for ethanol using potassium dichromate</li> <li>Dehydrating ethanol using concentrated sulphuric acid</li> <li>Discussing the uses and social effects of using ethanol</li> </ul>	<ul style="list-style-type: none"> <li>Science kit</li> </ul>

## CONTENTS

### What is an Alcohol?

- \* Molecular Formula
- \* Structural Formula
- \* Functional Group
- \* Isomers
- \* Reaction with Carboxylic acids - Oxygen - Sodium

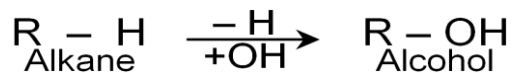
### Ethanol

- \* Combustion - Dehydration – Formation
- \* *Fermentation-ethanol, mahewu, indigenous beer brewing.*
- \* *Testing for ethanol using potassium dichromate*
- \* *Properties and Uses*



## ALCOHOLS

- Alcohols are the organic compounds containing hydroxyl group (-OH) attached to a carbon atom. These are obtained by replacing one or more hydrogen atoms of hydrocarbons by hydroxyl group (-OH).



- The general formula of alcohol is  $\text{C}_n\text{H}_{2n+1}\text{OH}$ .
- Following are the molecular formulae and structural formulae of first five members of homologous series of alcohol.

Number of carbon atoms	Name	Molecular Formula	Structural Formula
1.	Methanol	$\text{CH}_3\text{OH}$	<pre>       H         H — C — OH               H           </pre>
2.	Ethanol	$\text{C}_2\text{H}_5\text{OH}$	<pre>       H   H             H — C — C — OH                   H   H           </pre>
3.	Propanol	$\text{C}_3\text{H}_7\text{OH}$	<pre>       H   H   H                 H — C — C — C — OH                       H   H   H           </pre>
4.	Butanol	$\text{C}_4\text{H}_9\text{OH}$	<pre>       H   H   H   H                     H — C — C — C — C — OH                           H   H   H   H           </pre>
5.	Pentanol	$\text{C}_5\text{H}_{11}\text{OH}$	<pre>       H   H   H   H   H                         H — C — C — C — C — C — OH                               H   H   H   H   H           </pre>

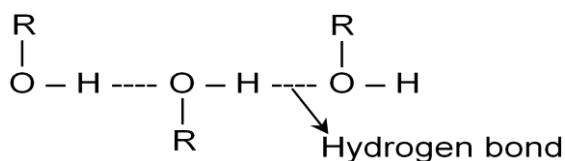
### Physical Properties of Alcohols

The important physical properties of alcohols are:

- The lower members of alcohols are colourless liquids having a characteristic smell and burning taste. While the higher members are colourless, odourless, wax like solids.
- Alcohols exist as associated molecules having inter molecular hydrogen bonding as shown below:

## ORGANIC CHEMISTRY

3. The lower members have low boiling points but higher members of alcohol have high melting point.



4. The lower members are soluble in water but as the size of alcohol molecule increases solubility in water decreases.  
5. These are volatile and easily combustible.  
6. These are bad conductors of electricity.  
7. These are generally lighter than water.  
8. Alcohols have intoxicating effect i.e. these are poisonous.

### NOMENCLATURE OF ALCOHOLS

Alcohols are named by replacing 'e' in the name of the parent alkane by 'ol'.

The following rules are followed in naming alcohols:

1. The longest continuous chain containing the carbon bonded to OH group is selected as the parent chain.
2. The carbon atoms in the chain are numbered in such a way that the carbon atom carrying the hydroxyl group gets the lowest number. For example,

Name	Structural Formula
Propan-1-ol	$\begin{array}{ccccc} & 3 & 2 & 1 & \\ & \text{CH}_3 & - \text{CH}_2 & - \text{CH}_2 & - \text{OH} \end{array}$
Propan-2-ol	$\begin{array}{ccccc} & 1 & & 2 & 3 \\ & \text{CH}_3 & - & \text{CH} & - \text{CH}_3 \\ & & &   & \\ & & & \text{OH} & \end{array}$
Butan-1-ol	$\begin{array}{ccccc} & 4 & 3 & 2 & 1 \\ & \text{CH}_3 & - \text{CH}_2 & - \text{CH}_2 & - \text{CH}_2 - \text{OH} \end{array}$
Butan-2-ol	$\begin{array}{ccccc} & 4 & 3 & 2 & 1 \\ & \text{CH}_3 & - \text{CH}_2 & - \text{CH} & - \text{CH}_3 \\ & & &   & \\ & & & \text{OH} & \end{array}$
Pentan-1-ol	$\begin{array}{ccccc} & 5 & 4 & 3 & 2 & 1 \\ & \text{CH}_3 & - \text{CH}_2 & - \text{CH}_2 & - \text{CH}_2 & - \text{CH}_2 - \text{OH} \end{array}$

Pentan-2-ol	$  \begin{array}{ccccccc}  & 5 & & 4 & & 3 & & 2 & & 1 \\  & \text{CH}_3 & - & \text{CH}_2 & - & \text{CH}_2 & - & \text{CH} & - & \text{CH}_3 \\  & & & & & & &   & & \\  & & & & & & & \text{OH} & &   \end{array}  $
Pentan-3-ol	$  \begin{array}{ccccccc}  & 5 & & 4 & & 3 & & 2 & & 1 \\  & \text{CH}_3 & - & \text{CH}_2 & - & \text{CH} & - & \text{CH}_2 & - & \text{CH}_3 \\  & & & & &   & & & & \\  & & & & & \text{OH} & & & &   \end{array}  $

## Ethanol (C<sub>2</sub>H<sub>5</sub>OH)

The formula for ethanol is **C<sub>2</sub>H<sub>5</sub>OH**

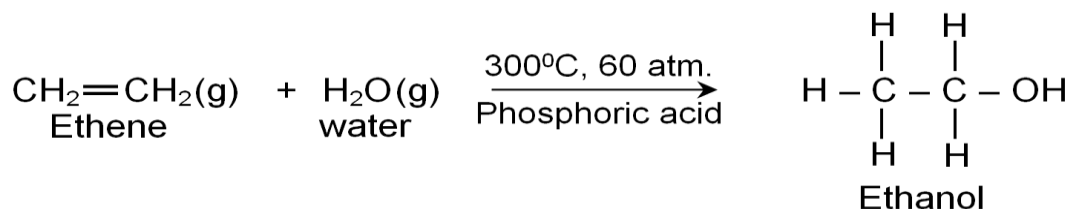
### Manufacture of Ethanol

Ethanol can be prepared by the following two methods-

1. By hydration of ethene
2. By fermentation of carbohydrates

#### a. Manufacture of Ethanol by Hydration of Ethene

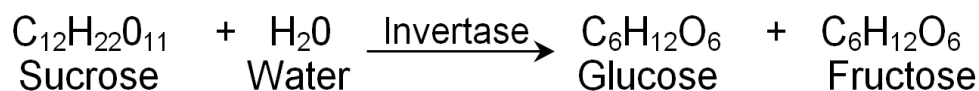
Ethene and steam are passed over phosphoric acid catalyst at a temperature of 300°C and a pressure of 60 atmospheres to form ethanol.



Hydration is an addition reaction. Water, in the form of steam, is added to C=C bond in ethene to form ethanol.

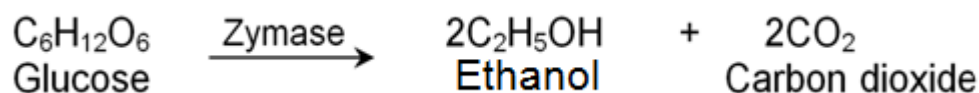
#### b. Manufacture of Ethanol by Fermentation of sugar (carbohydrates)

- Sugar/starch is dissolved in water and the fungi called yeast is added to the solution.
- The mixture is left to ferment in warm conditions (25-40°C) for several days in anaerobic conditions (in the absence of air/oxygen).
- Fresh air is not allowed to enter the vessel in which fermentation is taking place because air can oxidize ethanol into vinegar.
- The yeast produces two enzymes (biological catalysts), **invertase** and **zymase**.
- The enzyme invertase hydrolyses sucrose present in sugar solution to glucose and fructose as given below :



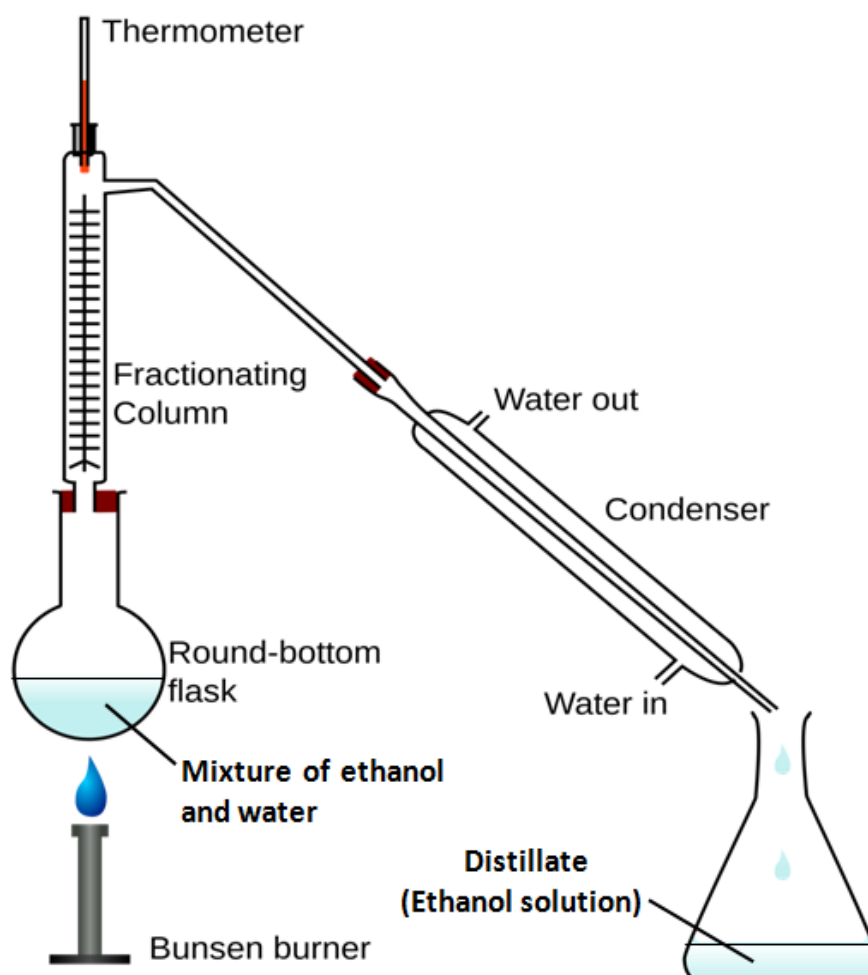
## ORGANIC CHEMISTRY

- The enzyme zymase then converts glucose and fructose to ethanol and carbon dioxide gas.



- The excess yeast is filtered off to obtain a dilute solution of ethanol.
- If the ethanol content in the solution rises to around 15%, the yeast is killed, so it is impossible to make pure alcohol by fermentation.
- If a more concentrated solution of ethanol is required it is purified through fractional distillation.
- Fractionally distilling the ethanol takes advantage of the difference in boiling point between ethanol and water. Water boils at 100°C while ethanol boils at 78°C.
- The liquid distilling at 78°C is 96% pure ethanol, it is impossible to get it to 100% because the rest is water and this cannot be removed by simple distillation.

### FRACTIONAL DISTILLATION OF DILUTE ETHANOL IN THE LABORATORY



**Fig.** Fractional distillation of dilute ethanol in the laboratory.

- ❖ Beads or glass columns in the fractionating column increase surface area for condensation and evaporation.
- ❖ Ethanol, having a lower boiling point (78°C) than water (96°C), vaporises first.
- ❖ The vapour is cooled in the condenser and condenses into liquid.
- ❖ The liquid is collected as the distillate.

- ❖ The amount of water in the distillate increases as the boiling point of water is approached.
- ❖ The fraction of ethanol distilled around 78°C is more flammable because it contains less water.

### THE HARMFUL EFFECTS OF ALCOHOL (ETHANOL)

In spite of its widest use as a useful product, ethanol, taken as an alcoholic beverage, has a lot of detrimental health effects. Some of the effects of alcohol are as follows:

#### 1. Impairment of coordination and judgement.

It is one of the many causes of road accident as it leads to blurred vision and reduced reaction time.

2. It leads to **lack of muscular control** (e.g. drunken stagger) and ultimately to **coma**, the state in which a person is said to be dead-drunk.
3. **Liver cirrhosis** (damage and deterioration of liver).

Prolonged and excessive consumption of alcohol causes liver cirrhosis which can cause liver failure and death.

4. Also heavy drinking eventually **damages the muscle tissue of the heart and long-term damage to the brain.**

All these health effects accelerate death.

#### 5. Alcohol is a **depressive drug and can be addictive.**

Occasional drinking may lead to alcohol addiction, a condition during which a person is said to be alcoholic. When a drunkard finds him/herself in such a condition it is very difficult to go without drinking. This can eventually lead to poverty as a drunkard spends most of his/her time and money drinking (buzzing).

6. **Alcohol can make someone aggressive.** This accounts for many arrests, conviction and jail sentences.
7. **Excessive drinking causes depression and other mental disorders.**
8. It can lead to **gastric ulcers, high blood pressure and cancer of the mouth, throat, and gullet.** People who smoke as well are at greater risk from these cancers.
9. **Alcohol lowers the resistance of body towards diseases.**

### SOCIAL EFFECTS OF USING ALCOHOL

1. *Abuse of alcohol leads to addiction and Alcoholism. Alcoholics are admitted for treatment in institutions such as the Alcoholic synonymous and mental hospitals.*
2. *Social problems e.g. bankruptcy, lack of self control, domestic violence, divorces, public fighting, prostitution, accidents, absenteeism from work, loss of jobs, poor performance at school and workplace etc.*
3. *Abuse of alcohol in cough medicines: Children may become addicted from an early age.*

## USES OF ETHANOL

### 1. **Solvents**

Ethanol is very important solvent which is used in industries for preparation of paints, lacquers, dyes, varnishes, cosmetics and perfumes etc.

### 2. **Fuels**

Ethanol is a constituent of blend petrol and methylated spirits.

### 3. Preparation of **Perfumes**.

### 4. **Alcoholic beverages**

Ethanol is used for drinking purpose in the form of beer, whisky, rum and gin.

To avoid the misuse of ethanol meant for industrial processes, it is made unfit for drinking purpose by adding small amount of  $\text{CuSO}_4$ , methanol and pyridine in it.

### 5. As an **antiseptic** in the form of rectified spirit.

### 6. **Antifreeze in car radiators**.

The mixture of ethanol and water is called antifreeze. Its freezing point is lower than the freezing point of water. So, a solution containing antifreeze cannot solidify even at very low temperature. So, antifreeze mixture is used in radiators of cars in very cold countries.

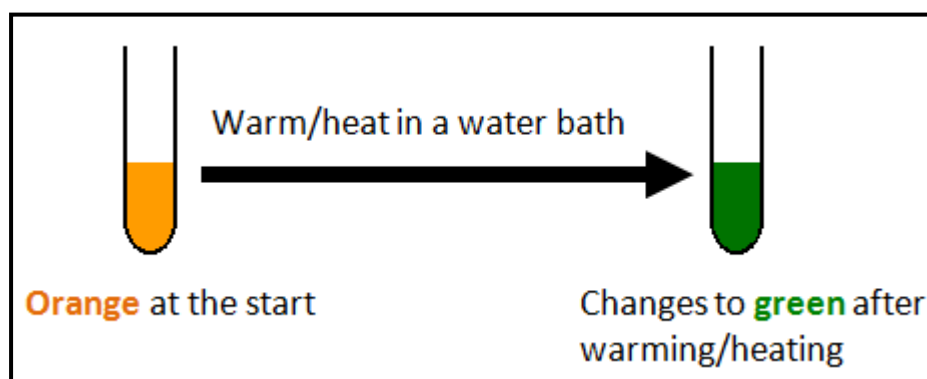
### 7. **For preparing ethanoic acid, ethene and esters.**

## Testing for ethanol using potassium dichromate

1. Add a few drops of the ethanol to a test tube containing potassium dichromate (VI) solution acidified with dilute sulphuric acid.
2. Warm/heat test tube in a hot water bath.

### Result

The orange solution turns green after heating:



### Conclusion

Change of acidified potassium dichromate from orange to green shows the presence of ethanol (alcohol).

## PROPERTIES OF ETHANOL

### Physical Properties

## ORGANIC CHEMISTRY

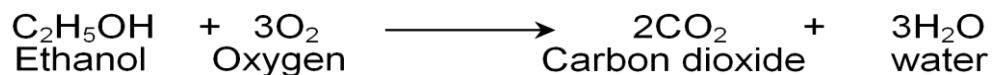
1. It is a colourless, volatile liquid with characteristic pleasant odour.
2. It has boiling point of 78°C.

### Chemical Properties

Following are the important chemical properties of ethanol.

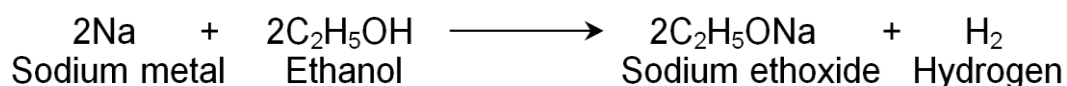
#### 1. Combustibility

Ethanol can easily burn in air to produce carbon dioxide and water.



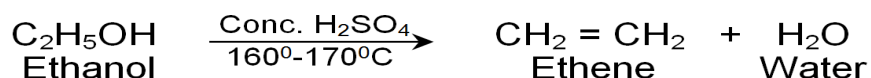
#### 2. Reaction with Na Metal

Ethanol Reacts With Sodium Metal To Produce Sodium Ethoxide And Hydrogen Gas



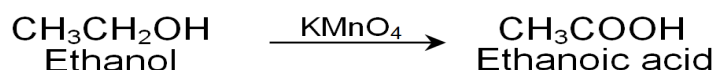
#### 3. Dehydration of Ethanol

When ethanol is heated to 1600-1700C in the presence of sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) then a molecule of water is liberated and ethene is formed.



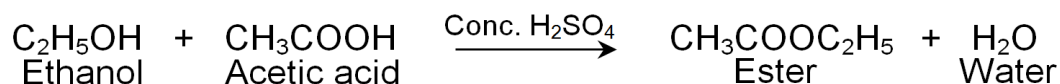
#### 4. Oxidation of Ethanol by Potassium Permanganate

Ethanol can be converted into ethanoic acid by oxidation by KMnO<sub>4</sub> as follows:



### Esterification

Ethanol reacts with carboxylic acids in the presence of conc. H<sub>2</sub>SO<sub>4</sub> as catalyst to form sweet smelling substance called esters having general formula (RCOOR). This process is called **esterification**.



## INDIGENOUS BEER BREWING

### SORGHUM BEER RECIPE

Source: <https://www.kiva.org/blog/sorghum-beer-recipe>



Author: Austin Harris.

## Ingredients:

1 kg. (2.2 lbs.) Sorghum  
7g (1/4-ounce) Baking Yeast

## Instructions:

1. Soak sorghum in water, allowing it to begin germination.  
This process is called malting. The following are the purposes of malting the sorghum:
  - Develops enzymes which break down the grain's starches into fermentable sugars such as glucose and maltose.
  - Develops protease enzymes which break down the proteins in the grain into forms that can be fermented by yeast.
2. Dry the malt or chimera (partially germinated grains).
3. Crush the sorghum malt (chimera) and boil in water for about 15 minutes.
4. Drain and put into a large vessel. Add 4 litres of hot water and let sit for 1 hour.
5. Transfer liquid portion of mash to a large vessel and add 8 litres of hot water. Let the mixture cool naturally until reaching room temperature.
6. Add the yeast and one cup of additional crushed sorghum malt (from germinated grains). Stir vigorously.
  - The yeast contains zymase enzyme which ferments glucose in the grain to ethanol:
$$\text{C}_6\text{H}_{12}\text{O}_6 \xrightarrow{\text{Zymase}} \text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2$$

Glucose                      Ethanol                      Carbon dioxide
  - Natural enzymes which develop during malting also ferment the sugars in the grain to ethanol.
7. Ferment for 2 days at room temperature then strain beer into storage vessels. Serve to thirsty customers.

## Sorghum Beer

African sorghum beer is a brownish-pink beverage with a slightly tangy and sour taste. It has an alcohol content that can vary between 1% and 8%. Its appearance is cloudy hence it is referred to as opaque beer. Traditionally it is consumed at room temperature. Sorghum beer is known by the following names in Zimbabwe: *doro*, *hwahwa* etc and the commercial version is called *chibuku*, *scud* etc.

## MAHEWU

- **Mahewu** (a.k.a. *magada*) is a non-alcoholic home-brewed drink made of thin, slightly fermented finger millet malt porridge or maize-meal porridge, often with wheat flour added.
- **Mahewu** is a fermented **gruel** commonly consumed as a staple among black Zimbabweans.
- The **gruel** is a **thin drinkable porridge** made from **fermented cereal malt** such as finger millet malt, maize-meal or sorghum/rapoko malt.

- A similar, commercially manufactured mahewu drink is sold in cartons, or in the form of an instant ready-mix.
- Finger millet is **zviyo** in Shona.
- Malt is **chimera** in Shona.
- So, finger millet malt in Shona is called **chimera chezviyo**.

### How to make Mahewu (Finger Millet Malt Drink)

Source: <http://www.zimbokitchen.com/how-to-make-mahewu-finger-millet-malt-drink/>

Author: Rumbie.

#### Ingredients Required

- 200g finger millet malt
- 2 1/2 litres hot water
- 1 1/2 litres cold water
- Extra cold water to make paste

#### Equipment Required

- Large pot
- Flat rounded wooden spoon
- Measuring jug

#### Instructions

1. The ingredients you'll need for this are (200g finger millet malt 2 1/2 litres hot water; 1 1/2 litres cold water; and Extra cold water to make paste) Put the finger millet malt in large pot.
2. Add a bit of cold water to make a smooth paste.
3. Put pot on stove top on medium-high heat. Add the boiling water whilst stirring simultaneously and bring to the boil.
4. As soon as it is boiling, reduce heat to a gentle simmer and allow it to simmer until cooked (about 40 minutes).
5. After about 40 minutes, it should now be cooked through and ready for the next stage.
6. When it is cooked, remove from the heat and allow it to cool.
7. When it has cooled, add the cold water, again, whilst stirring simultaneously. Do this until you get a "thinnish" liquid. (Thin enough to drink).
8. Your mahewu are now ready to be brewed!
9. Place your pot in a warm dry place until the beverage brews, stirring at least once a day to ensure that nothing settles in the bottom
10. Your mahewu (finger millet drink) should be ready in about 4 days depending on how warm the place was where you were putting it. You will know that it is ready when it has a pungent flavour.

## 8.30.0 CARBOXYLIC ACIDS

### 8.30.0 CARBOXYLIC ACIDS

TOPIC	OBJECTIVES Learners should be able to:	CONTENT	SUGGESTED ACTIVITIES AND NOTES	SUGGESTED RESOURCES
8.30.1 Chemistry of carboxylic acids	<ul style="list-style-type: none"> <li>describe the formation of ethanoic acid</li> <li>describe the chemical properties of carboxylic acids</li> <li>describe the uses of ethanoic acids</li> <li>describe the process of saponification</li> </ul>	<ul style="list-style-type: none"> <li>Oxidation of ethanol (refer to alcohols)</li> <li>Properties of carboxylic acids                             <ul style="list-style-type: none"> <li>Esterification</li> <li>Reaction with carbonates</li> </ul> </li> <li>Uses of ethanoic acids                             <ul style="list-style-type: none"> <li>Manufacture of perfumes</li> <li>Food preservation</li> <li>Flavouring</li> </ul> </li> <li>Soap manufacturing</li> <li>Structure of soap molecule</li> <li>Glycerine/glycerol</li> </ul>	<ul style="list-style-type: none"> <li>Experimenting on chemical properties of ethanoic acid</li> <li>Discussing the uses of ethanoic acids</li> <li>Making soap in the laboratory</li> </ul>	<ul style="list-style-type: none"> <li>Science kit</li> <li>Perfume samples</li> <li>Vinegar</li> <li>Animal fat</li> <li>Sodium chloride</li> <li>Sodium hydroxide</li> </ul>

### CONTENTS

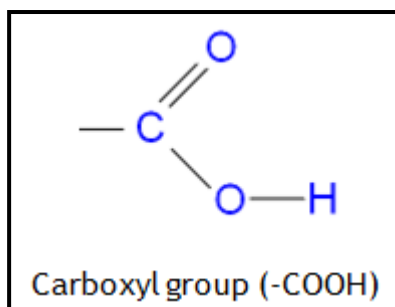
- What is a Carboxylic Acid?
- Examples of Carboxylic Acids
- What is the Functional Group for a Carboxylic Acid?
- What is the Structural Formula of a Carboxylic Acid?
- What is Ethanoic Acid?
- How is Ethanoic Acid Formed?
- What are the Uses of Ethanoic Acid?
- The Reaction of Carboxylic Acids with Alcohols, Alkalis, Carbonates and Metals
- *Saponification*

## CARBOXYLIC ACIDS

### Carboxylic Acids

What is a **Carboxylic Acid**?

- **Carboxylic acids** are organic molecules which form a homologous series with the general formula  $C_nH_{2n+1}COOH$ .
- The **-COOH group (carboxyl group)** is the **functional group** of carboxylic acids.



- **Carboxylic acids** are weak acids which **react** in the **same way** as dilute mineral acids.
  - **Carboxylic acids are weak acids** (partially ionises in water).
- They are **named** (like hydrocarbons) according to the **number** of **carbon atoms** in the **molecule**.

<b>Methanoic acid</b> $\text{HCOOH}$ , has $n=1$ .	<b>Butanoic acid</b> $\text{C}_3\text{H}_7\text{COOH}$ , has $n=4$ .
<b>Ethanoic acid</b> $\text{CH}_3\text{COOH}$ , has $n=2$ .	<b>Pentanoic acid</b> $\text{C}_4\text{H}_9\text{COOH}$ , has $n=5$ .
<b>Propanoic acid</b> $\text{C}_2\text{H}_5\text{COOH}$ , has $n=3$ .	<b>Hexanoic acid</b> $\text{C}_5\text{H}_{11}\text{COOH}$ , has $n=6$ .

Other examples of **carboxylic acids** are:

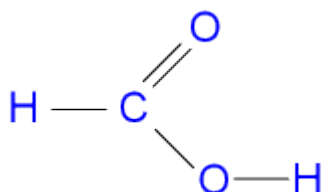
1. **Aspirin** - taken as a **pain killer** and to **prevent blood clots**
2. **Citric Acid** - found in **oranges**, **lemons** and some **soft drinks**
3. **Tartaric Acid** - used in baking powder for **cooking**
4. **Vitamin C** - called **ascorbic acid**, is found in **fresh fruit** and **vegetables**.

The four **acids** listed above are examples of acids that are **solid** when they are **pure**.

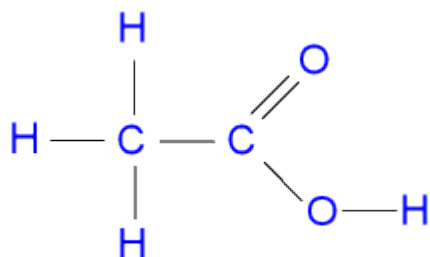
## The Structure of Carboxylic Acids

What is the **Structure** of **Carboxylic Acids**?

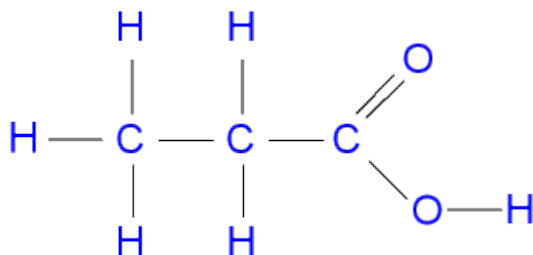
**Methanoic acid** ( $\text{HCOOH}$ ) has the structural formula



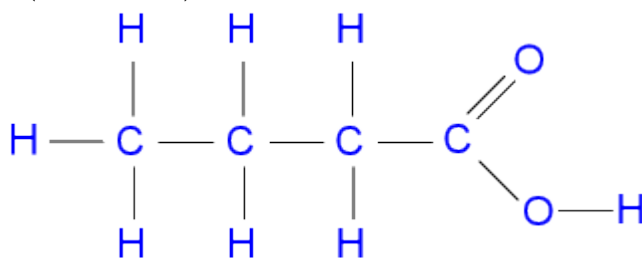
**Ethanoic acid** ( $\text{CH}_3\text{COOH}$ ) has the **structural formula**



Propanoic acid ( $\text{C}_2\text{H}_5\text{COOH}$ ) has the structural formula



Butanoic acid ( $\text{C}_3\text{H}_7\text{COOH}$ ) has the structural formula



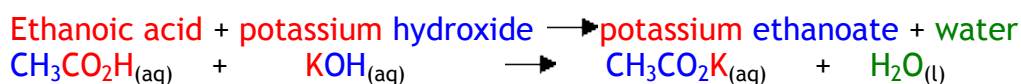
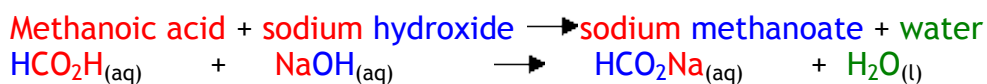
## The Reactions of Carboxylic Acids

What are the Reactions of Carboxylic Acids?

- Carboxylic acids react in the same way as dilute mineral acids.

1. Carboxylic acids react with bases/alkalis to form salt and water (neutralization)

Carboxylic acids are neutralised by alkalis, for example



2. Carboxylic acids react with carbonates and bicarbonates to form salt, carbon dioxide and hydrogen.

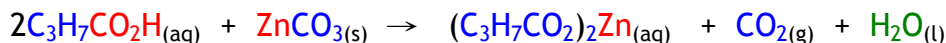
Carboxylic acids are neutralised by carbonates, for example

## ORGANIC CHEMISTRY

Ethanoic acid + sodium carbonate  $\rightarrow$  sodium ethanoate + carbon dioxide + water



Butanoic acid + zinc carbonate  $\rightarrow$  zinc butanoate + carbon dioxide + water.



3. Carboxylic acids react with metals to form metal ethanoate (salt) and hydrogen

Magnesium + ethanoic acid  $\rightarrow$  magnesium ethanoate + hydrogen



zinc + propanoic acid  $\rightarrow$  zinc propanoate + hydrogen.

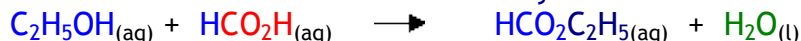


4. Carboxylic acids react with alcohols in the presence of concentrated sulfuric acid, to form sweet smelling substances called **esters**.

The reaction is called **esterification**. Concentrated sulfuric acid is a catalyst for this reaction.

E.g. Methanoic acid will react with ethanol in the presence of concentrated sulfuric acid, to form an ester called ethyl methanoate

Ethanol + methanoic acid  $\rightarrow$  ethyl methanoate + water.



### Ethanoic Acid.

#### Preparation of ethanoic acid

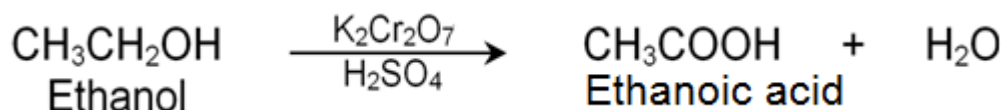
1. Oxidation of alcohol in the presence of bacteria such as Acetobacter:

- When ethanol reacts with oxygen in air it forms a weak acid called ethanoic acid. In an open bottle of beer or wine, the reaction happens naturally in the presence of bacteria such as Acetobacter, and it is the ethanoic acid that can make beer or wine taste sour.

Ethanol + oxygen  $\rightarrow$  ethanoic acid + water.



- Ethanoic acid can also be prepared by oxidation of ethanol in the presence of oxidizing agent potassium dichromate ( $\text{K}_2\text{Cr}_2\text{O}_7$ ) or potassium manganate (VII) ( $\text{KMnO}_4$ ) and (sulphuric acid)  $\text{H}_2\text{SO}_4$ .



- Ethanoic acid is a weak acid.  
It is found in vinegar ("vinegar" is old French for "sour wine").
- Vinegar is used as a food flavouring and preservative.

## Physical Properties

Following are the physical properties of ethanoic acid:

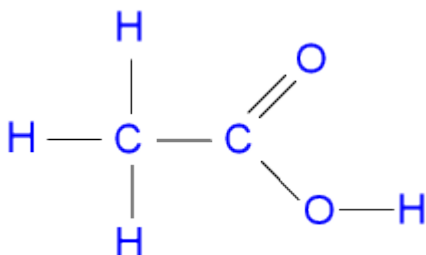
- It is a colourless liquid with pungent odour.
- It freezes below  $16.5^{\circ}\text{C}$ .
- Its boiling point is  $118^{\circ}\text{C}$ .
- It is soluble in water.

## Uses of ethanoic acids

1. Manufacture of perfumes
2. Food preservation
3. Flavouring
4. **Ethanoic acid** is used to make a polymer called **acetate rayon**.  
**Acetate rayon fibres** can be woven to make **clothing** and **fabrics**.

## What is the Structure of Ethanoic Acid?

- The **structure** of **ethanoic acid** is shown in the **picture** below.



**Ethanoic acid** will **react** with alcohols, alkalis, carbonates and metals (see Reactions of carboxylic acids).

**Question:** Write balanced equations to represent the reactions of ethanoic acid with:

- (a). Sodium hydroxide
- (b). Sodium carbonate
- (c). Sodium
- (d). Butanoic acid.

## PREPARATION OF CARBOXYLIC ACIDS

### 1. From natural gas

Natural gas is passed over air and catalyst to form ethanoic acid and water.

E.g. production of ethanoic acid from methane

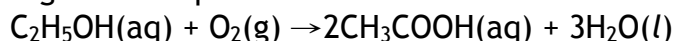


### 2. Oxidation of alcohol



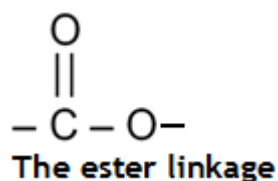
Alcohol can be oxidized when left in air with bacterial enzymes as catalyst. The products are carboxylic acid and water.

E.g. ethanol produces water and ethanoic acid when left in air.



## ESTERIFICATION

- An **Ester** is a sweet smelling organic compound made from carboxylic acid and alcohol with the removal of one molecule of water. **Sulphuric acid** is added as **catalyst** then the mixture is heated.
- The reaction is called **esterification**.
- The carboxylic acid and alcohol are joined by an **ester linkage** (-COO-) with the release of water.
- The general formula of esters is  $\text{C}_n\text{H}_{2n+1}\text{COOC}_n\text{H}_{2n+1}$ .
- The functional group of esters is the ester linkage (-COO-, a carbon with a double bond to oxygen and a single bond to another oxygen):



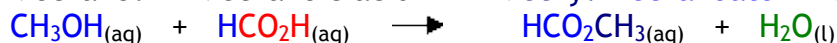
## EXAMPLES OF ESTERIFICATION REACTIONS

### 1. The reaction between Methanoic Acid with Alcohols to make Esters

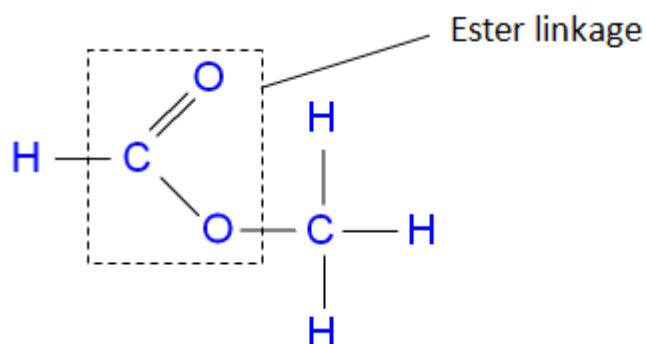
Methanoic acid will react with alcohols in the presence of concentrated sulfuric acid, to form esters.

Concentrated sulfuric acid is a catalyst for this reaction.

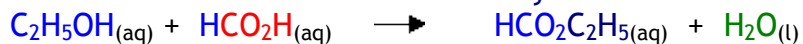
Methanol + Methanoic acid  $\rightarrow$  Methyl methanoate + water.



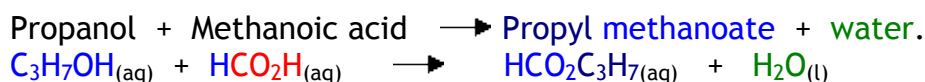
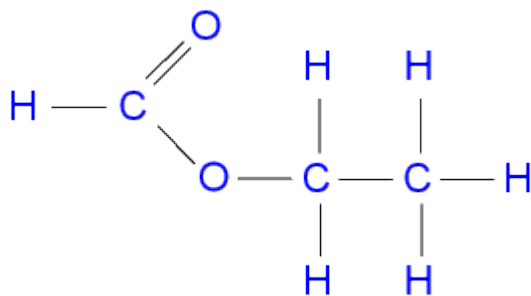
The structure of methyl methanoate:



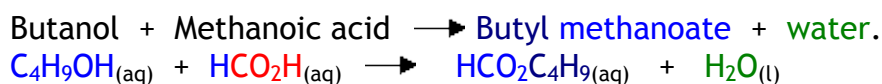
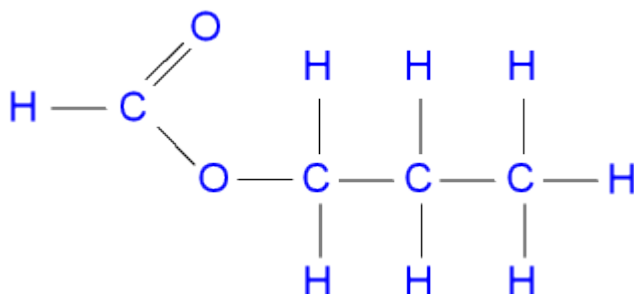
Ethanol + Methanoic acid  $\rightarrow$  Ethyl methanoate + water.



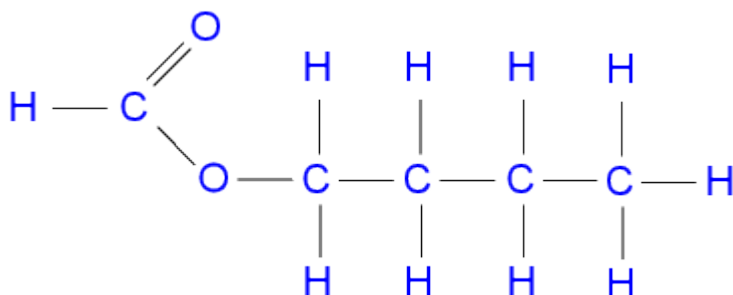
The structure of ethyl methanoate:



The structure of propyl methanoate:



The structure of butyl methanoate.



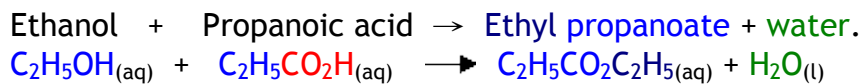
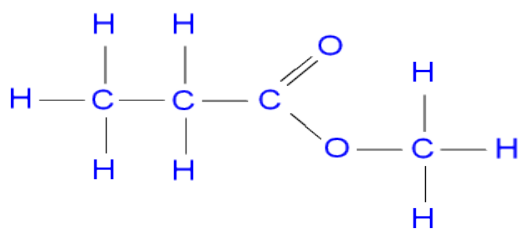
## 2. The Reaction of Propanoic Acid with Alcohols to make Esters

Propanoic acid will react with alcohols in the presence of concentrated sulfuric acid, to form esters.

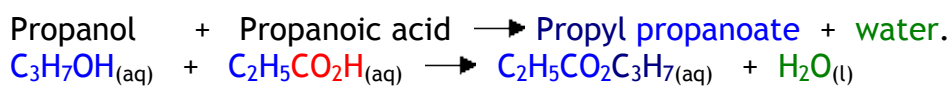
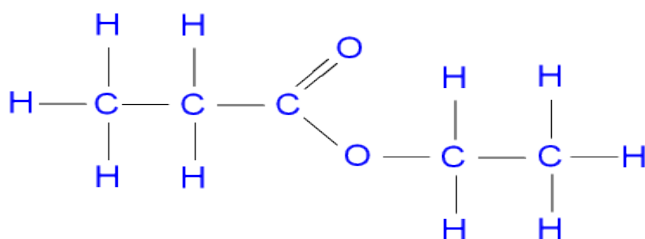
Concentrated sulfuric acid is a catalyst for this reaction.



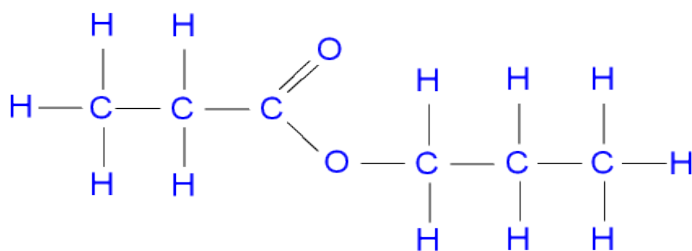
The structure of methyl propanoate.



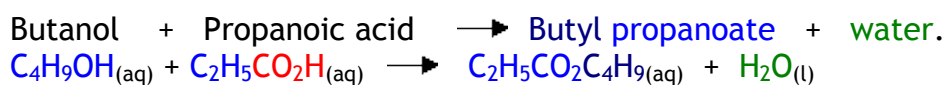
The structure of ethyl propanoate:



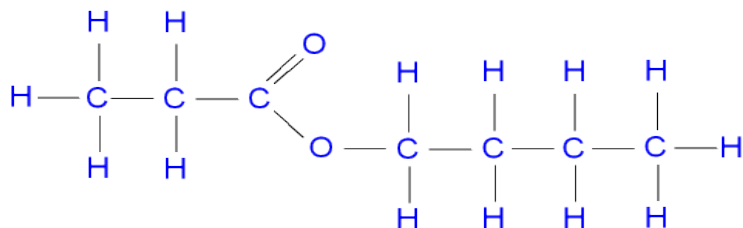
The structure of propyl propanoate:



**Question:** Identify and encircle the ester linkage (ester bond) in this structure.



The structure of butyl propanoate:

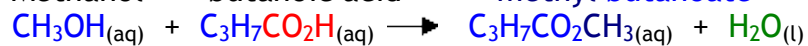


### 3. The Reaction of Butanoic Acid with Alcohols to make Esters

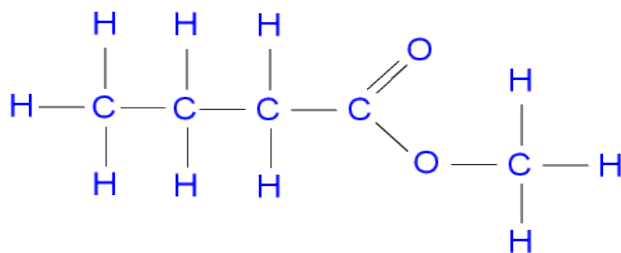
Butanoic acid will react with alcohols in the presence of concentrated sulfuric acid, to form esters. Concentrated sulfuric acid is a catalyst for this reaction.

## ORGANIC CHEMISTRY

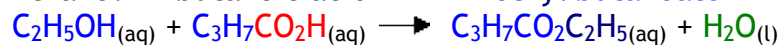
Methanol + butanoic acid  $\rightarrow$  methyl butanoate + water.



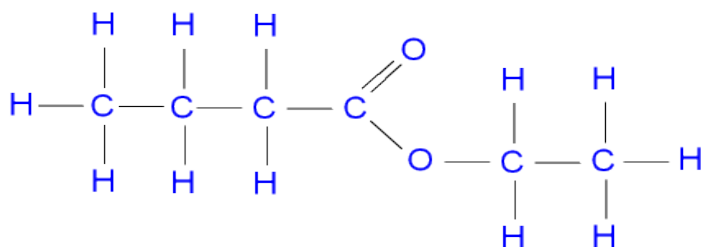
The structure of methyl butanoate:



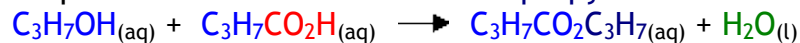
Ethanol + butanoic acid  $\rightarrow$  ethyl butanoate + water.



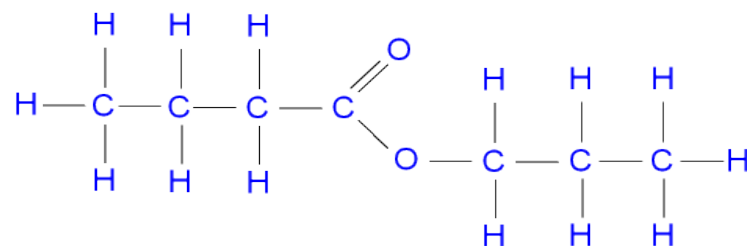
The structure of ethyl butanoate.



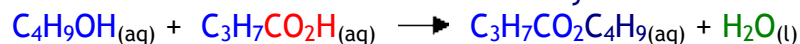
Propanol + butanoic acid  $\rightarrow$  propyl butanoate + water.



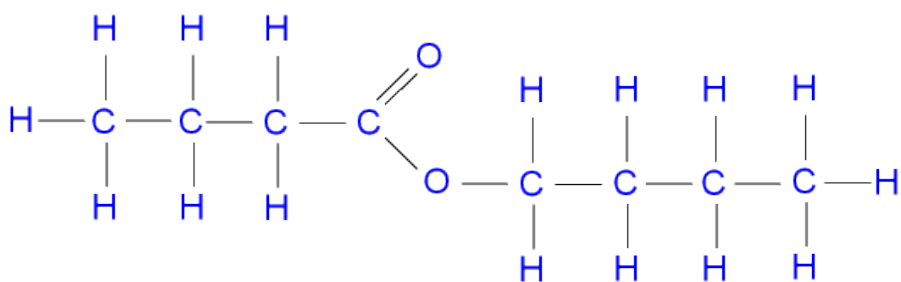
The structure of propyl butanoate:



Butanol + butanoic acid  $\rightarrow$  butyl butanoate + water.



The structure of butyl butanoate.



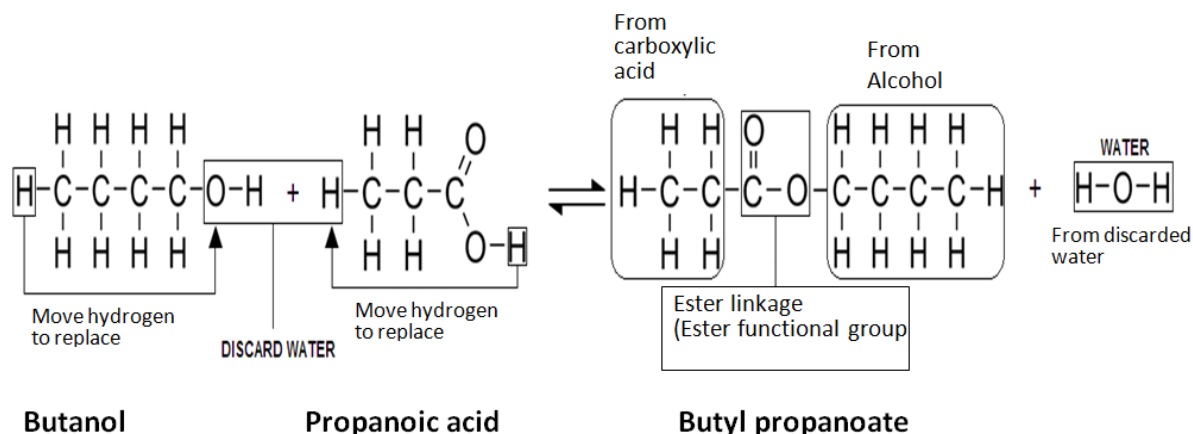
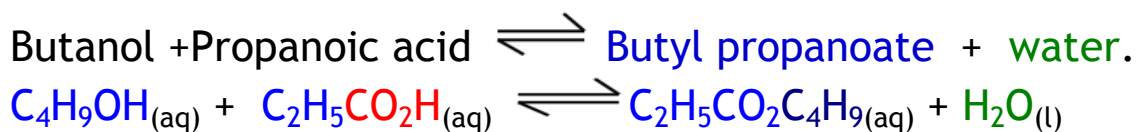
## NAMING ESTERS (ESTER NOMENCLATURE)

Ester name is [alcohol]yl [carboxylic acid]oate. For instance, example above is *butyl butanoate*, where “butyl” is from butanol; “butanoate” is from butanoic acid

## Hydrolysis of esters

- **Esterification is reversible.** We can add **sodium hydroxide** and heat mixture to obtain carboxylic acid and alcohol from ester with the release of water. This is **HYDROLYSIS**.

E.g. Propanoic acid reacts with butanol to form butyl propanoate in the presence of sulphuric acid catalyst. This reaction is reversed by adding sodium hydroxide. The butyl propanoate is hydrolysed back to butanoic acid and propanol



## USES OF ESTERS

An **ester** is a **sweet smelling** substance.

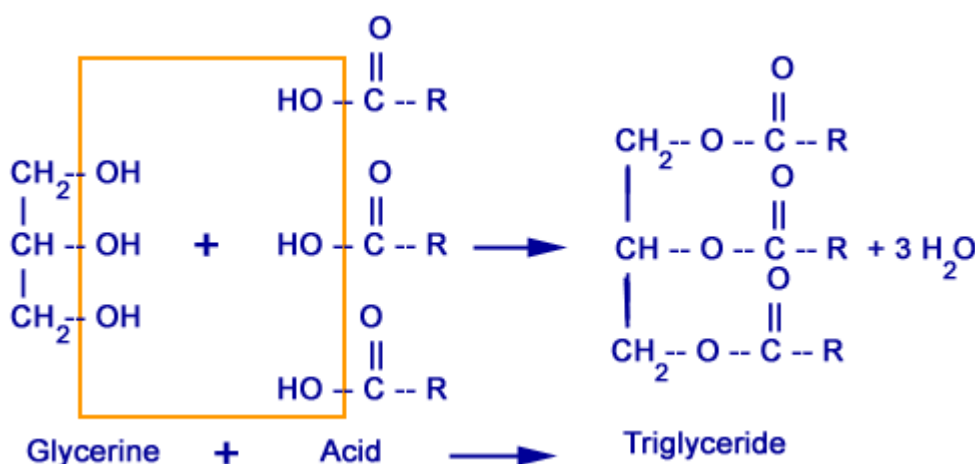
Following are the uses of esters:

1. Artificial fruit/food flavours in cold drinks, ice-creams and sweets etc.
2. Solvents for oils, fats and varnishes.
3. Making artificial perfumes.
4. Esters are used to make polymers called polyesters.

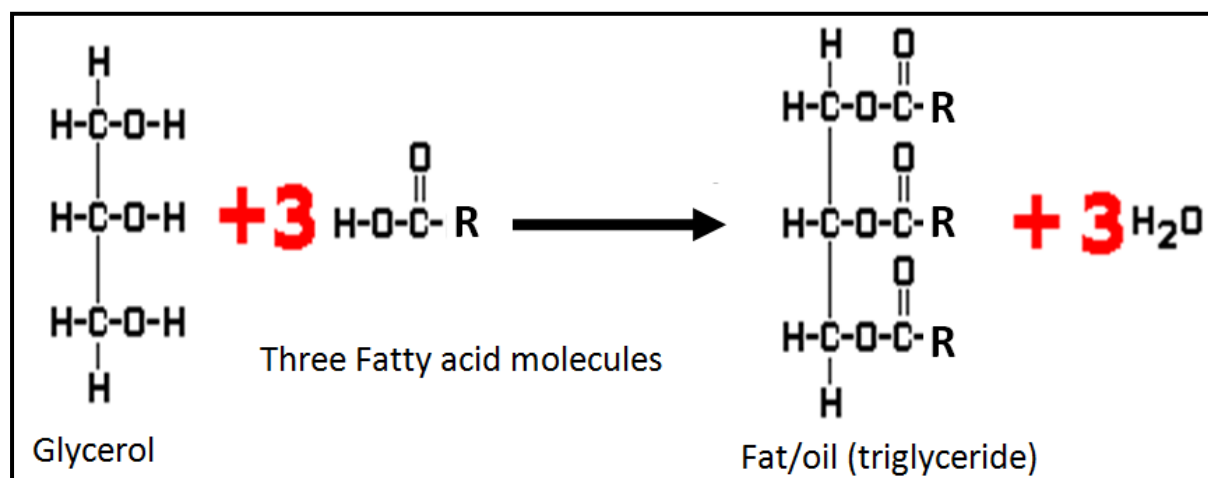
Polyesters can be used to make plastic bottles or polyesters can be made into fibres to make clothing. Recycled polyesters are used to make fleece clothing.

## FATS/OILS (a.k.a. Lipids or tryglycerides)

- Fats and oils (**triglycerides**) are **ester** molecules with three ester linkages, hence they are **triesters**.
- Fats and oils are **esters** formed by a glycerol molecule reacting with 3 fatty acid molecules.



This can be simplified as shown below:



- Since glycerol is an alcohol, while fatty acids are carboxylic acid, the process is called **esterification**, and it is a **condensation** reaction.
- Fats and oils (Triglycerides) are used to make soaps in a process called **saponification**.

## SAPONIFICATION

- The process of making soap by the hydrolysis of fats and oils with sodium hydroxide is called **saponification**:

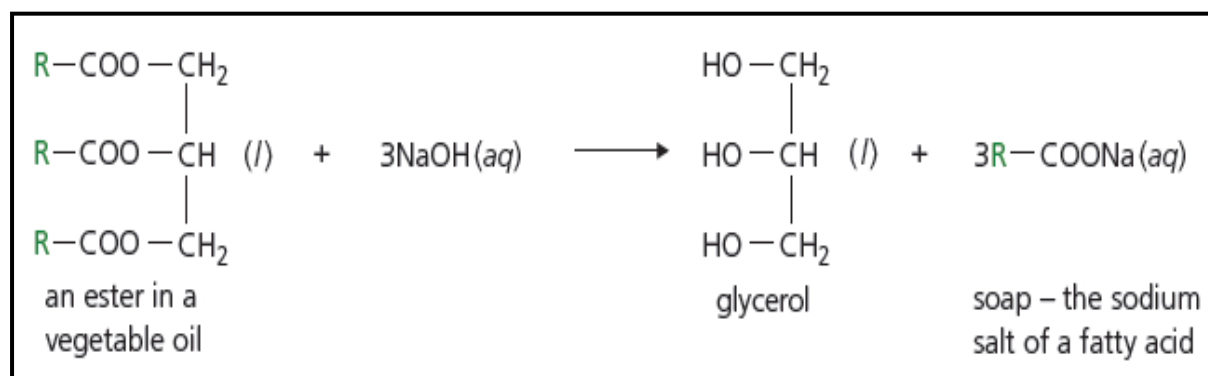


## ORGANIC CHEMISTRY

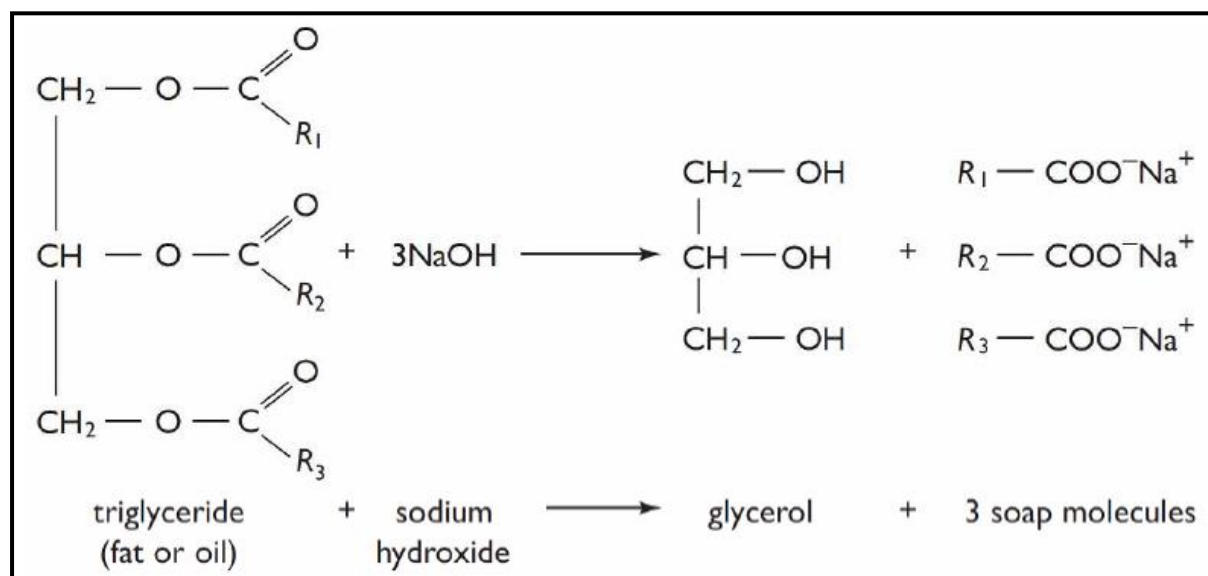
- These fats and oils, called **triglycerides**, are **ester** molecules with three ester linkages.



- Soap is made in factories by boiling fats and oils with sodium hydroxide. The three ester linkages in fats/oils are broken down in the presence of water. This is a hydrolysis reaction.
- Glycerol and a sodium salt of a fatty acid ( **$R-COO^-Na^+$** ) are formed.
- The sodium salt of fatty acid is used as **soap**. For example:



This can also be represented as shown below:

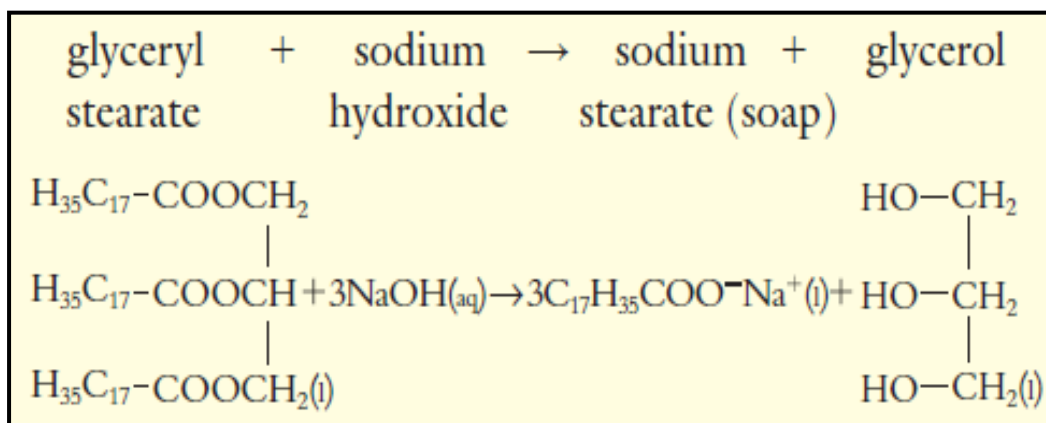




Where **R** is a long chain of carbon atoms.

- This process of making soap by the hydrolysis of fats and oils with sodium hydroxide is called **saponification**.
- The soap you buy may be made from vegetable oil - like palm oil or coconut oil - or even from fish oil or animal fat.
- Artificial esters are added to make the soap smell nice.

**Saponification of glyceryl stearate (a fat) gives a soap called sodium stearate:**

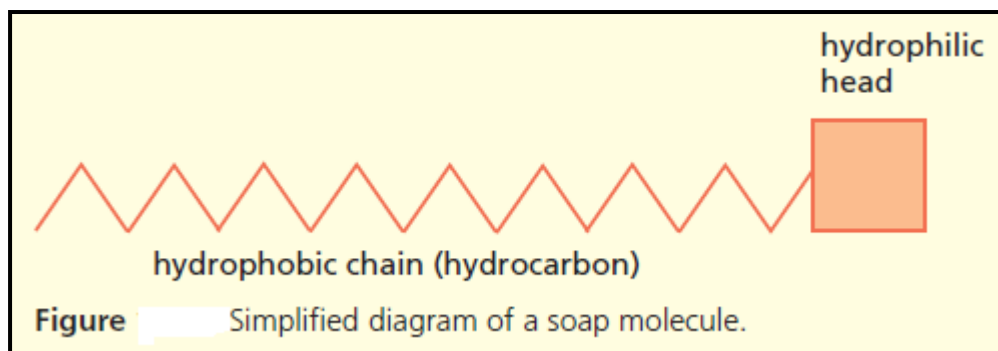


- There are many different types of triglycerides (fats and oils) used for saponification:

Triglyceride	Details
Tallow (fat)	An <b>animal fat</b> derived from beef (or sheep) processing . Soaps commonly made from tallow are hard, greasy soaps due to the long chain length of tallow
Lard (fat)	An <b>animal fat</b> derived from pigs. Produces hard soaps which lather quickly but do not dissolve readily in water
Coconut oil	A <b>vegetable oil</b> derived from the coconut fruit. Produces soaps that are soft and which lather in salty or hard water
Palm oil	A <b>vegetable oil</b> derived from the palm fruit. Produces soaps that are similar to those made from tallow (hard and greasy) due to the long chain length

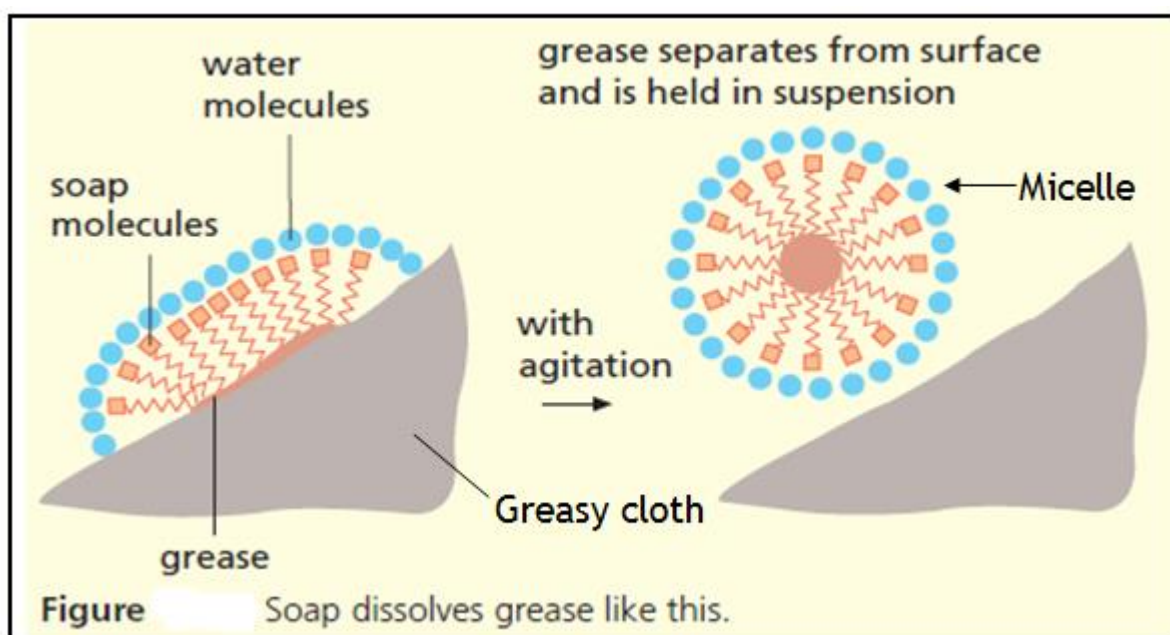
**The cleaning action of soap is explained as follows:**

Soap molecule consists of a long hydrocarbon chain which is hydrophobic (water hating) attached to an ionic 'head' which is hydrophilic (water loving) (see Figure below).



When soap is put into water which has a greasy dish (or a greasy cloth) in it, the hydrophobic hydrocarbon chain on each soap molecule becomes attracted to the grease and becomes embedded in it (Figure).

On the other hand, the hydrophilic ionic head group is not attracted to the grease but is strongly attracted to the water molecules. When the water is stirred, the grease is slowly released and is completely surrounded by the soap molecules to form structures called micelles. The grease is, therefore, 'solubilised' and removed from the dish. The soap is able to remove the grease because of the combination of the covalent and ionic bonds present.



## The Saponification Experiment (Soap making experiment)

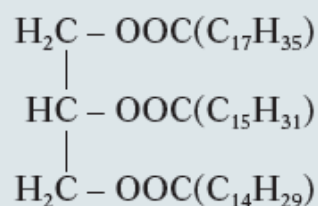
1. Place 5g of NaOH pellets in a 100ml beaker.
2. Add 30ml of water
3. Add 5ml of vegetable oil e.g. coconut oil, cotton seed oil etc or animal fat e.g. mutton fat or lard.
4. Using a Bunsen burner, bring the solution to a boil, taking care to stir constantly so as to provide a uniform temperature.
5. Allow the solution to cool once the layer of oil has fully disintegrated.
6. Add 10g of NaCl and bring the solution once more to a boil, again taking care to stir constantly.
7. Allow the solution to cool; lumps of soap should appear on top.
8. Decant the solution taking care to keep the product.
9. Flush the beaker with NaCl and decant successively.

10. Place the soap on filter paper and allow the soap to dry in the fume cupboard.

## TRY THIS QUESTION

**9** Soaps are salts of fatty acids.

- a** Name one fatty acid.
- b** In which way is a fatty acid different from ethanoic acid? In which way is it similar?
- c** Below is one example of a compound found in vegetable oil, and used to make soap.



- i** This compound is an *ester*. Explain that term.
  - ii** To make soap, the oil is usually reacted with a sodium compound. Which one?
  - iii** Which type of reaction takes place?
- d**
- i** The reaction in c will give *four* different products. Write down their formulae.
  - ii** Which ones can be used as soap?
  - iii** One product is an alcohol. Name it.
  - iv** In which way is this product similar to ethanol? In which way is it different?
- e** Name three vegetable oils used to make soap.

## 8.31.0 POLYMERS

TOPIC	OBJECTIVES Learners should be able to:	CONTENT	SUGGESTED ACTIVITIES AND NOTES	SUGGESTED RESOURCES
8.31.1 Synthetic polymers	<ul style="list-style-type: none"> <li>describe the formation of polythene</li> <li>describe the formation of nylon and terylene</li> <li>draw structures to represent synthetic polymers</li> <li>identify repeat units for polymers</li> <li>deduce the structure of the monomer from a given polymer and vice-versa</li> </ul>	<ul style="list-style-type: none"> <li>Addition polymerisation</li> <li>Structures of:                             <ul style="list-style-type: none"> <li>Polythene</li> </ul> </li> <li>Condensation polymerisation                             <ul style="list-style-type: none"> <li>Nylon</li> <li>Terylene</li> </ul> </li> <li>Uses of synthetic polymers</li> </ul> <p><b>N.B:</b> Use block diagrams to represent condensation polymers</p>	<ul style="list-style-type: none"> <li>Discussing polymerisation</li> <li>Identifying and naming linkages in synthetic polymers</li> <li>Drawing repeat units for polymers</li> <li>Drawing structures to represent monomers and polymers</li> <li>Discussing on the uses of synthetic polymers</li> <li>Visiting sites                             <ul style="list-style-type: none"> <li>Saltrama plastics</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Models and images to represent structures of monomers</li> <li>ICT tools and Braille/Jaws software</li> <li>Samples of different polymers</li> <li>Resource persons</li> </ul>
	<ul style="list-style-type: none"> <li>describe the uses of synthetic polymers</li> </ul>	<ul style="list-style-type: none"> <li>Nylon</li> <li>Terylene</li> <li>Uses of synthetic polymers</li> </ul> <p><b>N.B:</b> Use block diagrams to represent condensation polymers</p>	<ul style="list-style-type: none"> <li>Treger plastics</li> </ul>	
8.31.2 Natural Polymers	<ul style="list-style-type: none"> <li>name the type of linkages in each of the polymers</li> <li>draw structures to represent natural polymers</li> <li>deduce structure of the monomer from a given polymer and vice-versa</li> <li>describe the hydrolysis of natural polymers</li> </ul>	<ul style="list-style-type: none"> <li>Natural polymers                             <ul style="list-style-type: none"> <li>Starch</li> <li>Proteins</li> </ul> </li> <li>Hydrolysis of natural polymers</li> </ul>	<ul style="list-style-type: none"> <li>Discussing structures of natural polymers</li> <li>Drawing structures of natural polymers</li> <li>Discussing hydrolysis of natural polymers</li> <li>Experimenting on acid hydrolysis of natural polymers</li> </ul>	<ul style="list-style-type: none"> <li>Science kit</li> </ul>

### 8.31.1 SYNTHETIC POLYMERS

#### WHAT ARE POLYMERS

❖ **Polymers are macromolecules made of repeating units called monomers.**

#### CLASSIFICATION OF POLYMERS

Polymers can be classified in two ways as given below:

1. Classification based on source of availability.
2. Classification based on method of synthesis.

## 1. Classification based on source of availability

According to this classification polymers are of two types:

1. Natural polymers
2. Synthetic polymers

### Natural Polymers

The polymers obtained from **nature** are called natural polymers. For example, proteins, starch, cellulose, natural rubber, nucleic acids, etc. are common examples of natural polymers.

### Synthetic Polymers

The polymers which are **manmade** are called synthetic polymers. They are prepared in laboratories by man. Examples of synthetic polymers are polythene, nylon, Terylene, teflon, polyvinyl chloride (PVC) and synthetic rubber.

## 2. Classification of polymers on the basis of method of synthesis

On the basis of method of synthesis, the polymers are also of two types:

1. Addition polymers
2. Condensation polymers

**Addition Polymers** - A polymer formed by direct addition of repeated monomers without the elimination of any molecule is called an **addition polymer**. Addition polymers are prepared from unsaturated compounds especially alkenes. An example of an addition polymer is poly(ethene) a.k.a. polythene.

**Condensation Polymers** - These polymers are formed by the condensation of two or more different monomers with the elimination of small molecules, usually water ( $H_2O$ ) or  $HCl$ . Polyesters and polyamides (e.g. nylon) are in this class of polymers.

**SYNTHETIC POLYMERS** are manufactured by Addition polymerisation in which small molecules (monomers) join together to form one molecule as the only product. e.g. polythene or by *condensation polymerisation* e.g. Terylene and Nylon.

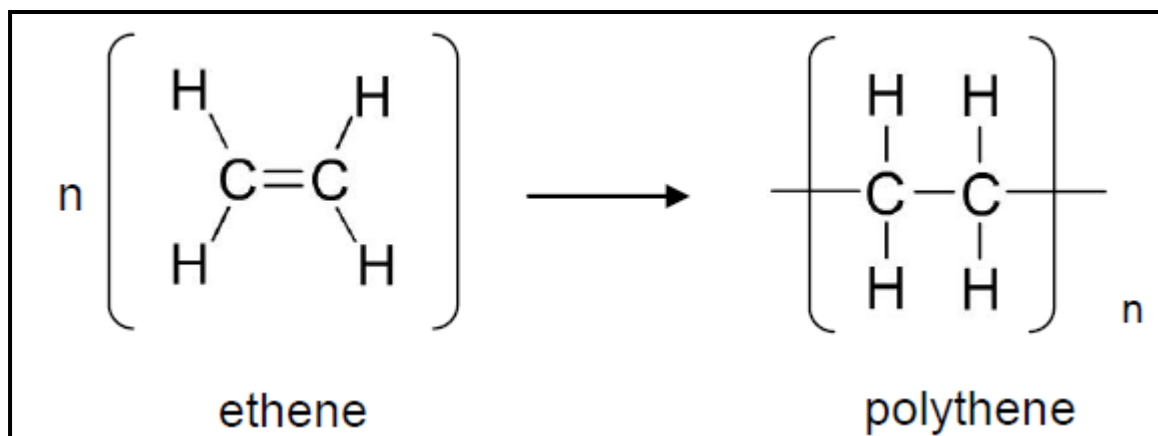
## 1. ADDITION POLYMERISATION

- ❖ Addition polymerisation is reaction in which small molecules (monomers) join together to form one molecule as the only product.
- ❖ **Atoms in the monomer are used to form the polymer, double bonds in molecules break in order to form a new bond.**

### MAKING POLYTHENE by addition polymerisation

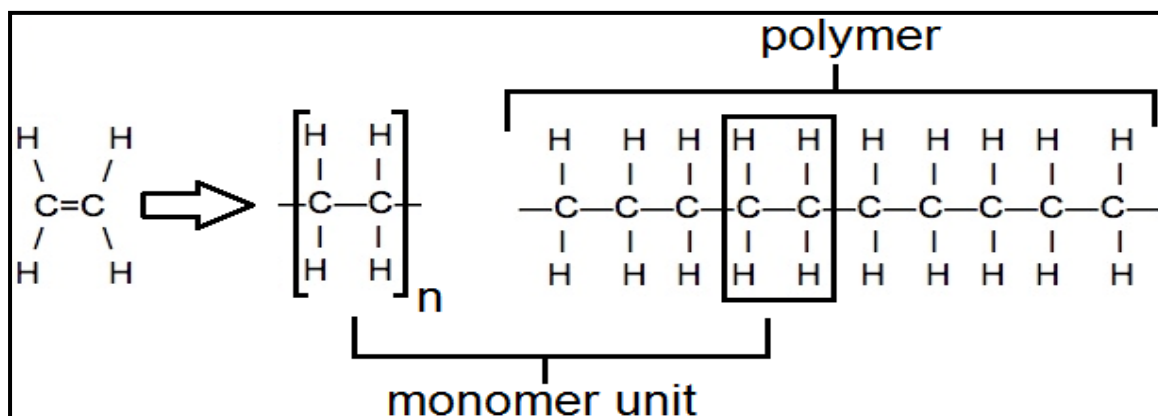
Addition polymerisation is in which small molecules (monomers) join together to form one molecule as the only product.

- Many **ethene** molecules can be made to join together to form the polymer called **poly(ethene)** or **polythene**.
- High temperature and high pressure are needed for the reaction to occur.



- In this reaction the double bond is opened up, to form a link either side to another molecule: note that double bonds are *not* present in the long chain polymer. The polythene is actually an alkane and it is saturated.

❖ Use the diagram below to deduce the structure of a monomer (e.g. ethene) from a polymer (e.g. polythene) and vice versa.



**Uses of polythene:** for plastic bags, plastic bottles (since it forms a flexible film and is transparent), gloves, clingfilm, mugs, bowls, chairs and dustbins.

## 2. CONDENSATION POLYMERISATION

- ❖ **Condensation polymerisation** - 2 different monomers join, double bonds are not broken. In order for the monomers to join, a small molecule has to be expelled (lost) like  $\text{H}_2\text{O}$  (water) or  $\text{HCl}$  (hydrogen chloride).
- ❖ Hence the name condensation since water is expelled.
- ❖ In condensation polymerisation **two products are formed**, the **polymer** and the **expelled small molecule**.

### MAKING NYLON by condensation polymerisation

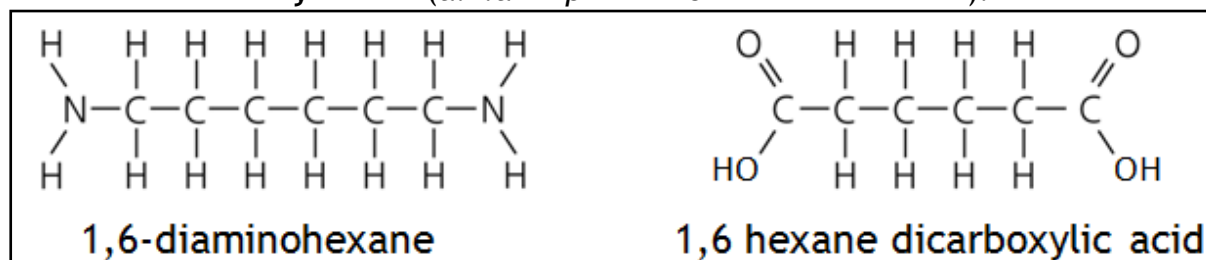
Nylon is a synthetic condensation polymer produced from two different monomers. One of the monomers has an amide group ( $\text{NH}_2$ ) and the other has a carboxylic acid group ( $-\text{COOH}$ ). Each time a link is made a molecule of water is lost. The link formed is called an amide (or peptide link) so the resulting polymer is a polyamide (polypeptide)

#### 1. Making nylon (a polyamide/polypeptide) in *industry*:



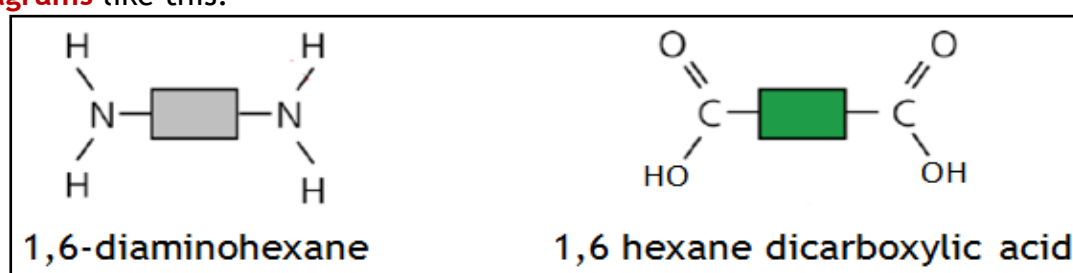
## ORGANIC CHEMISTRY

- ❖ The monomers are **1,6-diaminohexane** (a.k.a *hexane-1,6-diamine*) and **1,6 hexane dicarboxylic acid** (a.k.a *adipic acid* or *hexanedioic acid*).

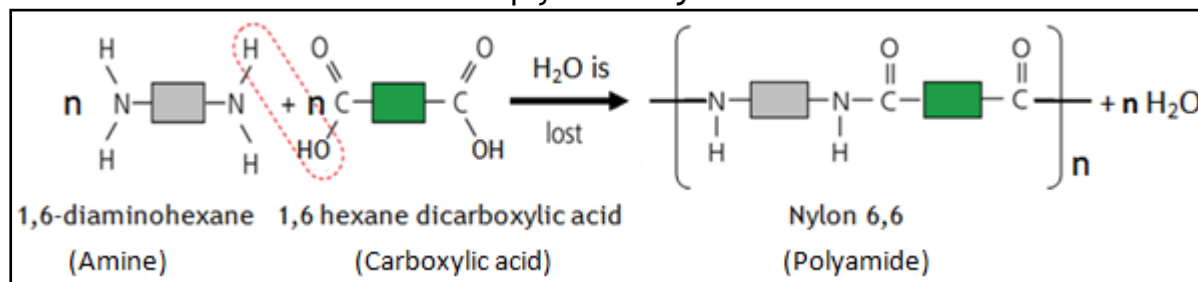


- 1,6-diaminohexane is an organic compound called an **amine**. It is a **diamine** because it has two amino (-NH<sub>2</sub>) groups at both ends.
- 1,6 hexane dicarboxylic acid is **carboxylic acid**. It is a **dicarboxylic acid** because it has two carboxylic (-COOH) groups at both ends.

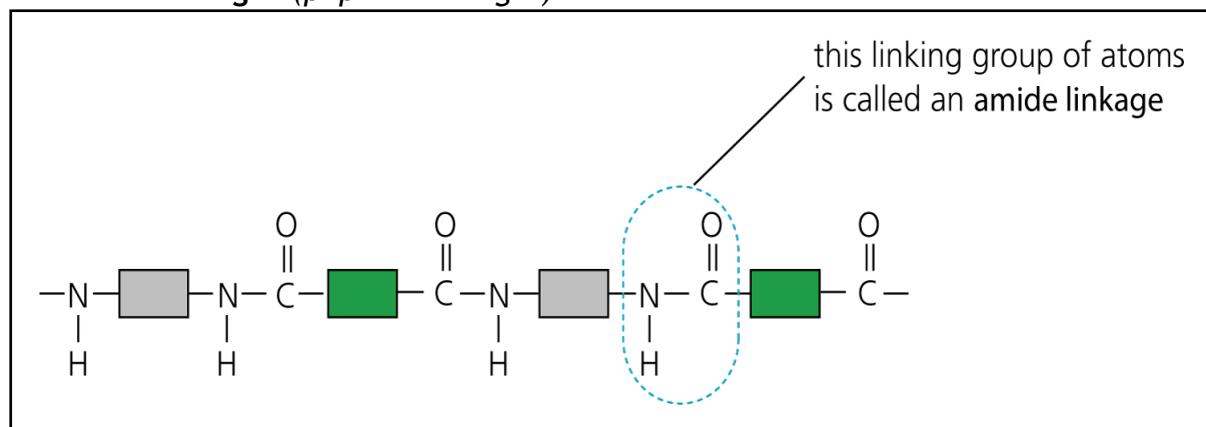
**NB.** According to your *syllabus* these monomers should be *simplified* by using **block diagrams** like this:



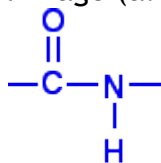
- ❖ In industry, the monomers join to each other by eliminating a small molecule: H<sub>2</sub>O (water). This is a condensation polymerisation. The industrial conditions are **350°C** in the *presence* of **hydrogen and a nickel catalyst**.
- ❖ Thousands of monomers join together, giving a polymer called Nylon 6,6.
- ❖ The polymer is called *Nylon 6,6* because it comes from *two six-carbon monomers*. Some textbooks simply call it *Nylon*.



- ❖ Nylon is a polymer called a **polyamide** (polypeptide) since it has repeating **amide linkages** (*peptide linkages*).

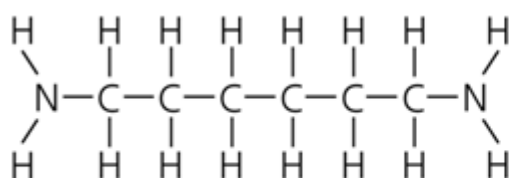


- An amide linkage (a.k.a peptide linkage) has this structure:

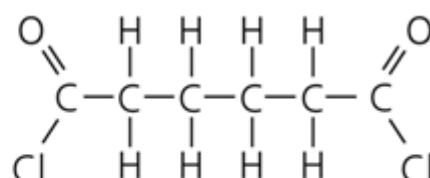


## 2. Making nylon (a polyamide) in the laboratory:

- The monomers are 1,6-diaminohexane and hexan-1,6-dioyl chloride.

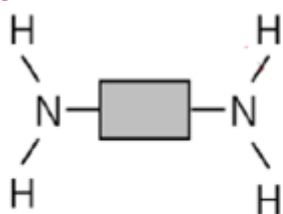


1,6-diaminohexane

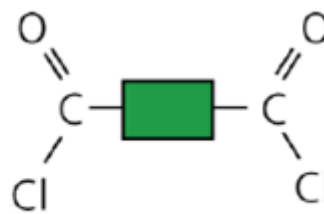


hexan-1,6-dioyl chloride

**NB.** According to your *syllabus* these monomers should be *simplified* by using **block diagrams** like this:

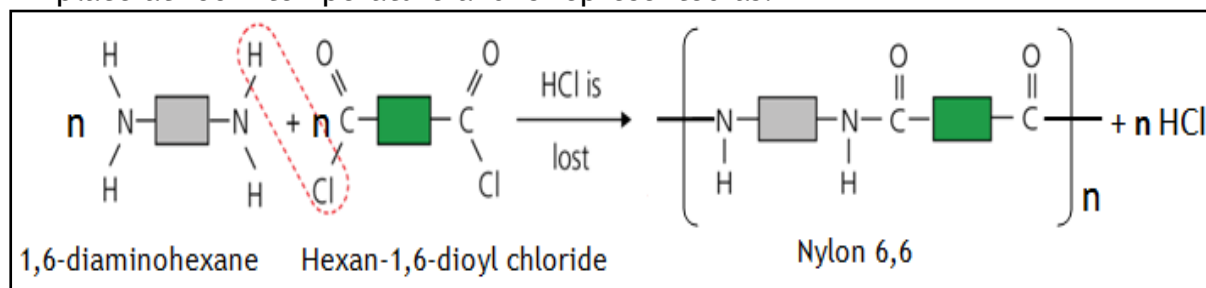


1,6-diaminohexane



hexan-1,6-dioyl chloride

- The condensation polymerisation to make Nylon 6,6 in the laboratory takes place at room temperature and is represented as:



- HCl is expelled as a by-product.
- Nylon makes very strong fibres because of very strong intermolecular forces between its chains in the form of hydrogen bonding.
- Uses of nylon:** fabrics, carpet fibres, airbags, tyre cords, ropes, stockings, seat belts, ballistic cloth, fishing lines and nylon can also be cast into solid shapes for cogs and bearings in machines. Nylon melts instead of burning and so has many military applications.

### TRY THIS QUESTION

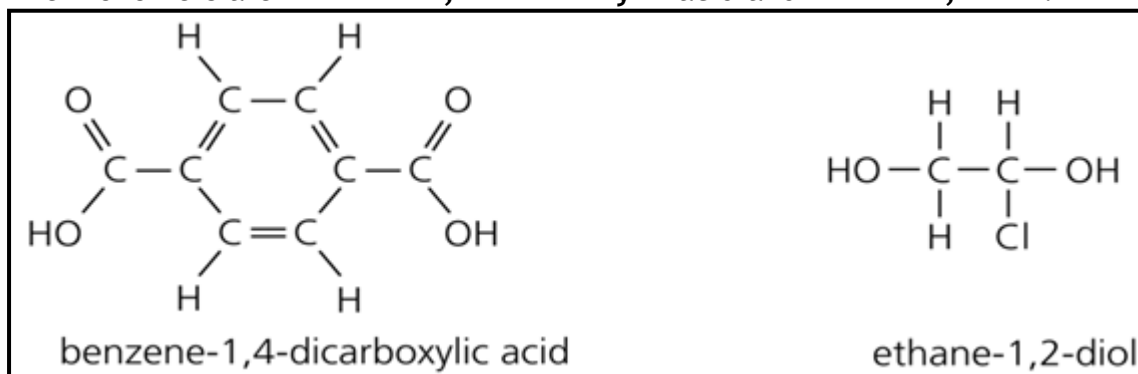
*Describe the similarities and differences between the industrial and laboratory manufacture of nylon.*



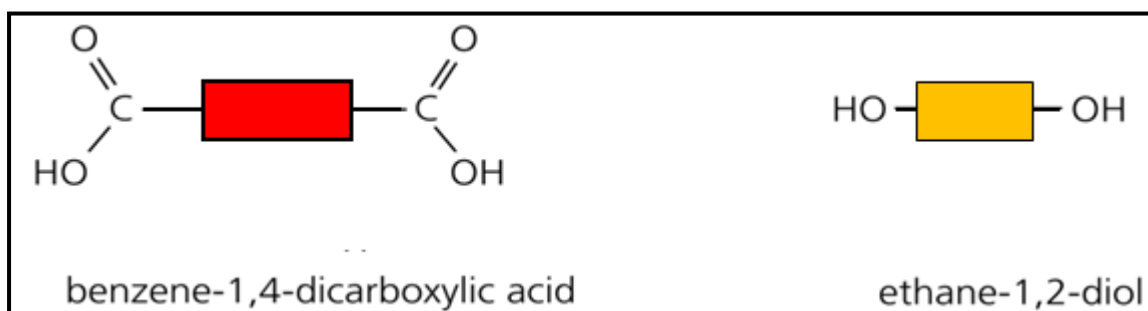
## MAKING TERYLENE by condensation polymerisation

Making Terylene (a polyester):

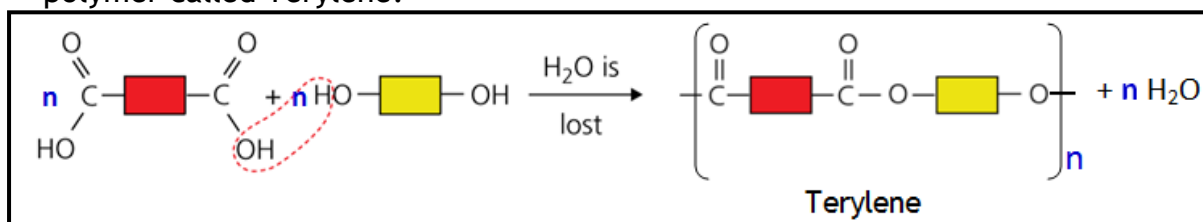
The monomers are **benzene-1,4-dicarboxylic acid** and **ethane-1,2-diol**.



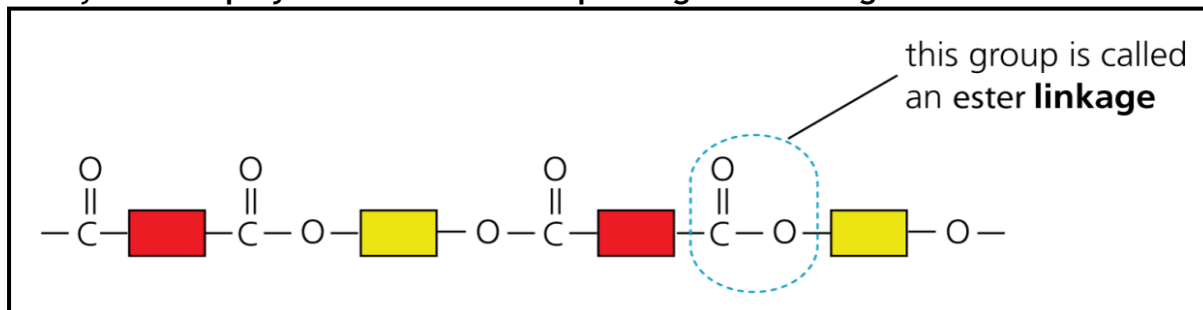
**NB.** According to your *syllabus* these monomers should be *simplified* by using **block diagrams** like this:



❖ The monomers join by eliminating a water molecule. This is condensation polymerisation since water is lost. Thousands of molecules join up, giving a polymer called Terylene.



▪ Terylene is a **polyester** since it has **repeating ester linkages**.



### Uses of Terylene:

1. Making clothes, dress materials and curtains.
2. Making conveyor belts.
3. Making sails of sail boats.

### 8.31.2 NATURAL POLYMERS

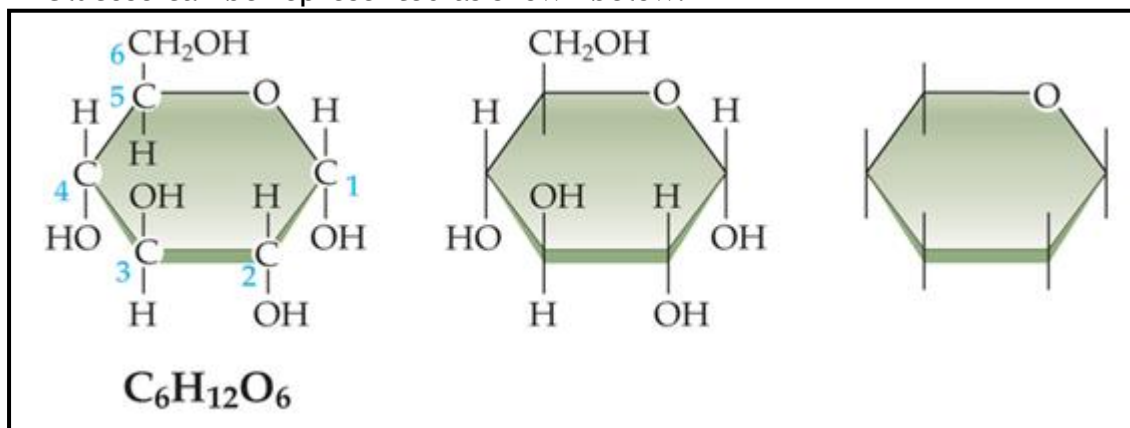
SUB TOPIC	LEARNING OBJECTIVES Learners should be able to:	CONTENT	SUGGESTED NOTES AND ACTIVITIES	SUGGESTED RESOURCES
8.31.2 Natural Polymers	<ul style="list-style-type: none"> <li>name the type of linkages in each of the polymers</li> <li>draw structures to represent natural polymers</li> <li>deduce structure of the monomer from a given polymer and vice-versa</li> <li>describe the hydrolysis of natural polymers</li> </ul>	<ul style="list-style-type: none"> <li>Natural polymers                             <ul style="list-style-type: none"> <li>- Starch</li> <li>- Proteins</li> </ul> </li> <li>Hydrolysis of natural polymers</li> </ul>	<ul style="list-style-type: none"> <li>Discussing structures of natural polymers</li> <li>Drawing structures of natural polymers</li> <li>Discussing hydrolysis of natural polymers</li> <li>Experimenting on acid hydrolysis of natural polymers</li> </ul>	<ul style="list-style-type: none"> <li>Science kit</li> </ul>

#### Content

- STARCH
- PROTEIN

#### CARBOHYDRATES

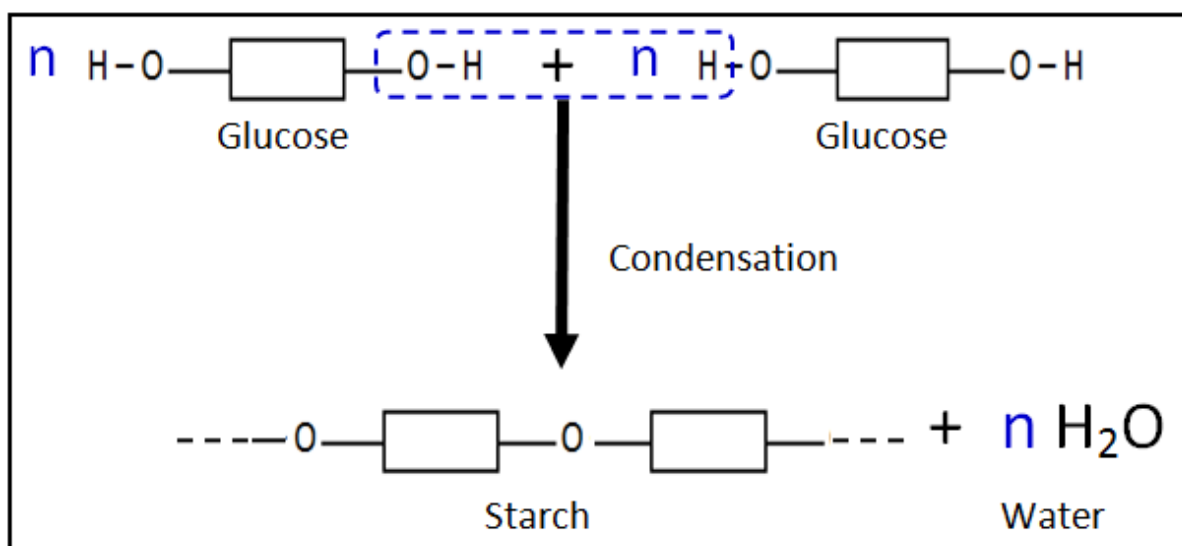
- Carbohydrates** (a.k.a **saccharides**) are organic compounds which contain carbon, hydrogen and oxygen. Their general formula is  $C_n(H_2O)_n$ .
- Carbohydrates** are natural condensation polymers made from simple sugars. Starch, cellulose and glycogen are all polymers of glucose. The simple sugar monomers are called **monosaccharides** and the polymers are called **polysaccharides**. All monosaccharides have OH groups and it's these groups that join together to make the polymer with the elimination of water.
- The simplest carbohydrate is **glucose**, formula  $C_6H_{12}O_6$ .
- Glucose can be represented as shown below:



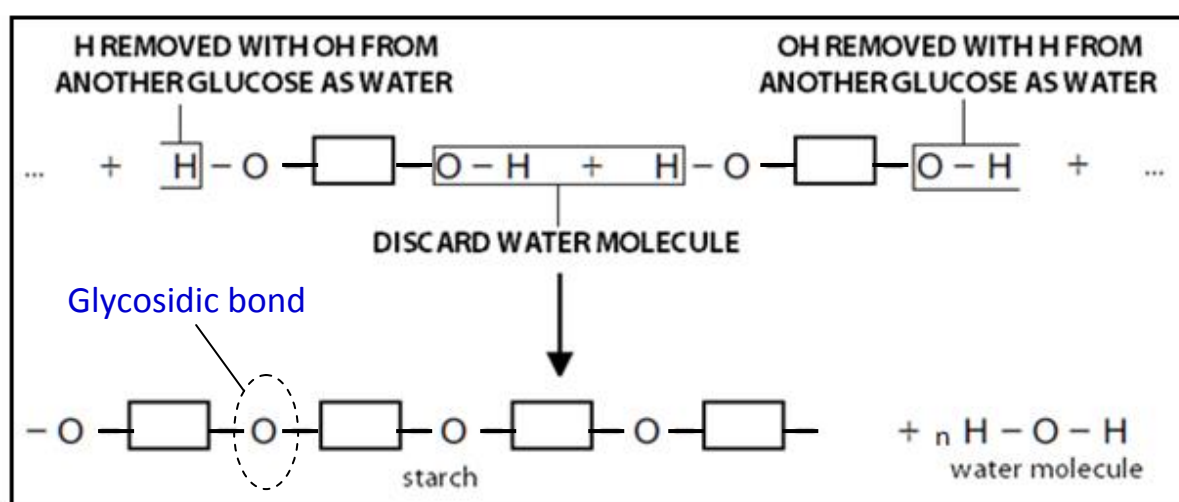
- ❖ The structure of glucose is simplified using block diagrams as shown below:



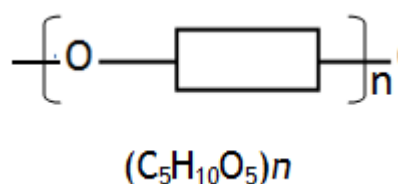
- Glucose** monomers polymerise to form **starch** with the elimination of water in a reaction called **condensation polymerisation**:



- ❖ The overall condensation reaction is:  $n\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow (\text{C}_5\text{H}_{10}\text{O}_5)_n + n\text{H}_2\text{O}$
- ❖ This can also be represented as shown below.



The starch repeat unit is as follows:



- ❖ The repeat units are held together by linkages called **glycosidic bonds** ( $-\text{O}-$ ).
- ❖ In plants the glucose made during photosynthesis is converted into starch for storage.

## Hydrolysis of carbohydrates in the laboratory

- *Starch can also be broken down into glucose by heating with sulphuric acid.* This adds water molecule into the polymer.
- Water molecules break apart the glycosidic bond of the starch molecule, leaving separate glucose molecules. **This is hydrolysis which is the reverse of condensation:**

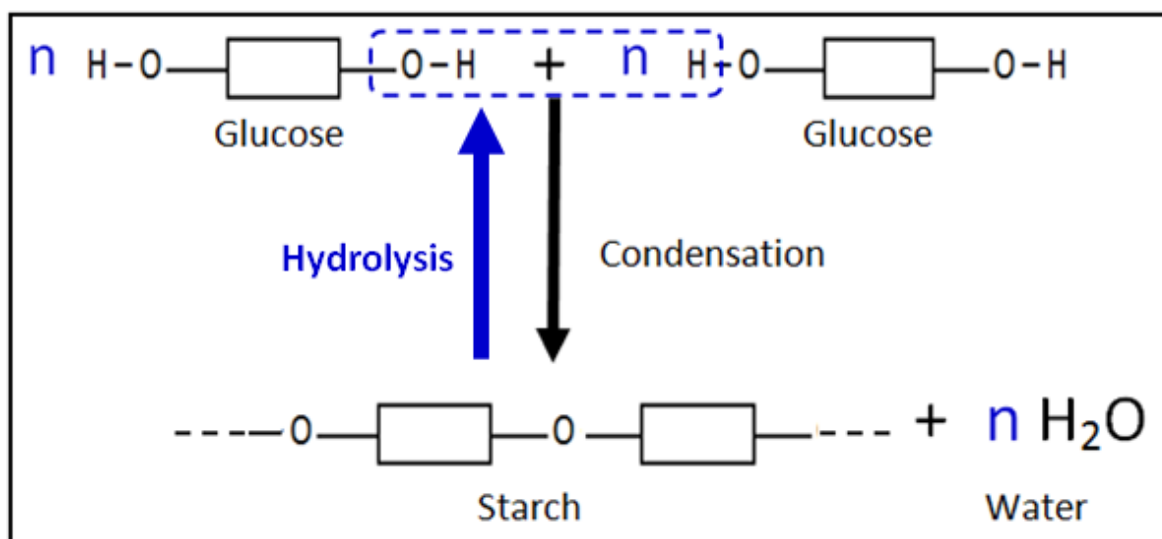


FIG. Hydrolysis of starch is the reverse of condensation polymerisation.

❖ The overall hydrolysis reaction is:  $(C_5H_{10}O_5)_n + nH_2O \rightarrow nC_6H_{12}O_6$

## Hydrolysis of starch during digestion

- During digestion enzymes, by hydrolysis, break down the starch we eat into glucose molecules.
- These glucose molecules are transported around the body by blood. In the bloodstream during assimilation, condensation reactions build the glucose molecules up to produce glycogen for storage in the liver. Some of the glucose is used in respiration to produce energy for metabolism.

## TRY THESE QUESTIONS

Starch, a complex carbohydrate, is a natural macromolecule or polymer. It can be formed from its monomer by condensation polymerisation.

(a) (i) Explain the terms:

*monomer* .....

.....

*condensation polymerisation* .....

..... [2]

(ii) Draw the structural formula of starch to include three monomer units.

Glucose, the monomer, can be represented as  $HO-\square-OH$ .

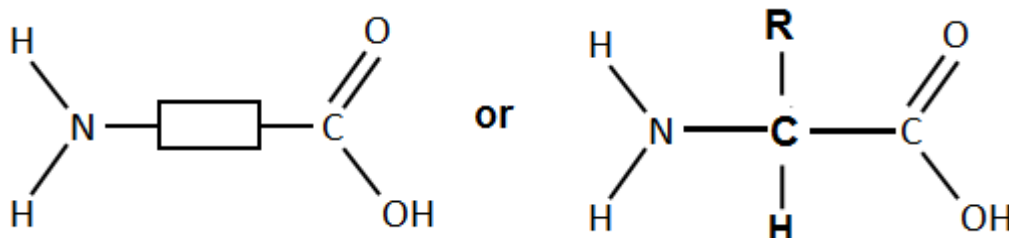
- 7** Starch is a carbohydrate. It is a natural polymer.  
This shows part of a starch macromolecule:



- a What is a *macromolecule*?
- b What is a *carbohydrate*?
- c Which type of polymerisation gives starch?
- d What do the blocks represent, above?
- e
  - i Draw a diagram showing the structure of the monomer for starch. (Use a block.)
  - ii Name this monomer.
- f Starch is also called a *polysaccharide*. Why?
- g Starch can be broken down by hydrolysis.
  - i Describe two ways in which the hydrolysis is carried out. (One occurs in your body.)
  - ii One takes place at a far lower temperature than the other. What makes this possible?

## PROTEINS

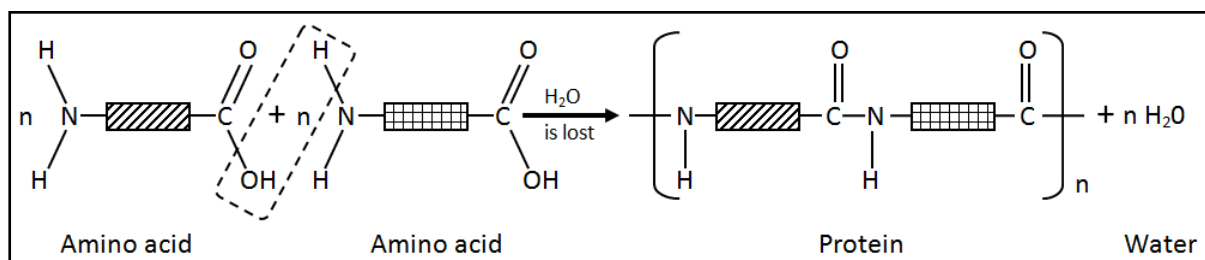
- Proteins are **natural condensation polymers** made up from **amino acid** monomers.
- Proteins are **natural polymers** made up of amino acids monomers by condensation polymerisation.
- Different amino acid molecules are joined together in different orders within our bodies to form different proteins.
- The body cannot make all the amino acids required to build different proteins. It relies on protein intake from our **diet** to supply the **essential amino acids**.
- Amino acids have an **amine group** ( $\text{-NH}_2$ ) at one end and a **carboxyl group** ( $\text{-COOH}$ ) at the other end.



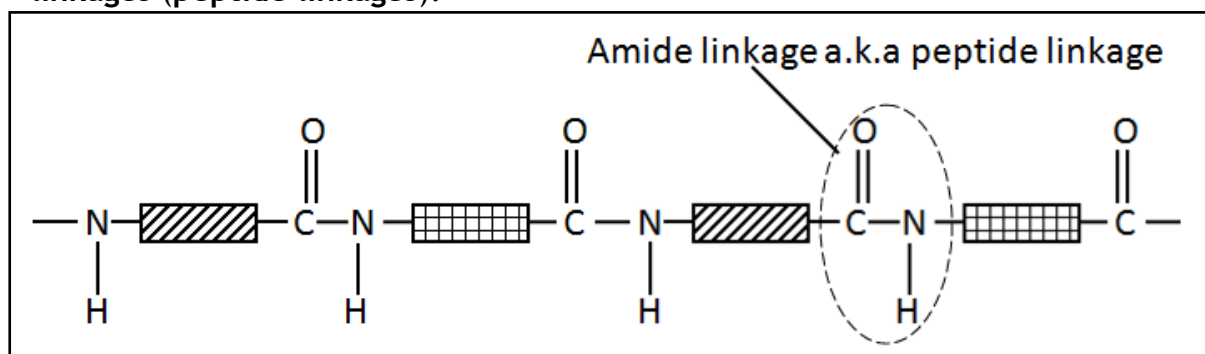
- Amino acids can be represented as shown above where the **box** or **R** represents an alkyl group.
- When R is hydrogen the protein is called **glycine**. When R is  $\text{-CH}_3$  the protein is called **alanine**.

## ORGANIC CHEMISTRY

- When amino acids react they form an **amide linkage** (peptide linkage) like in nylon. Water is lost. This is a condensation reaction.

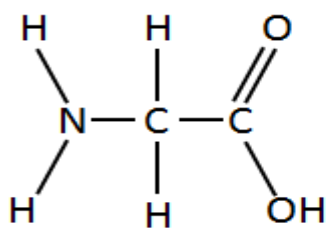


- NB.** An **amide linkage** is also called a *peptide linkage*.
- Proteins are **polyamides** (**polypeptides**) since they have repeating **amide linkages** (**peptide linkages**).

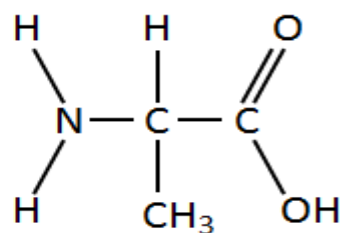


### TRY THESE QUESTIONS:

- Using the diagram of the protein above identify and draw the following:
  - The two monomers (amino acids) that make up the protein.
  - The protein repeat unit.
- The structural formulae of the two simplest amino acids, glycine and alanine, are shown below.



Glycine



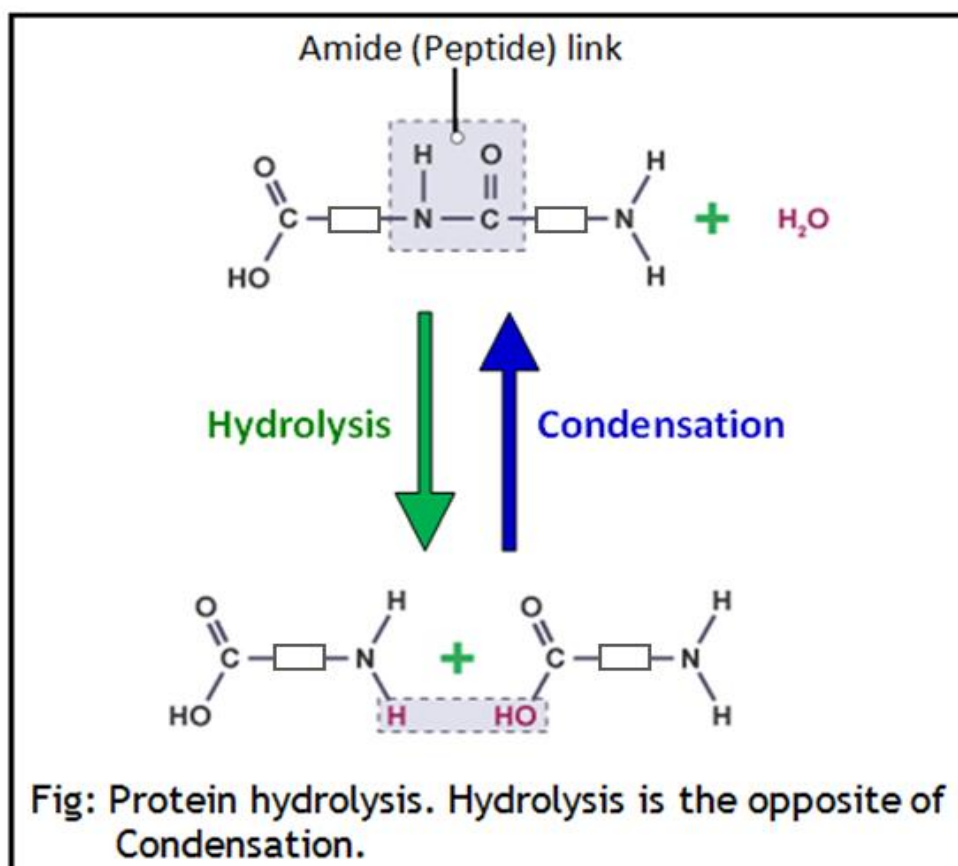
Alanine

- Encircle and label the following on any one of the amino acids:
  - The amine group.
  - The carboxyl group.
- Using the structures of these two amino acids draw a diagram to show the condensation polymerisation in which the two form a protein.
- Encircle and label the peptide linkage on your diagram in (b) above.

## Hydrolysis of proteins - Breaking down proteins

### Hydrolysis of proteins in the laboratory

- Proteins can also be broken down by hydrolysis into amino acids by boiling protein with sulphuric acid. This adds water molecule into the polymer.
- Water molecules break apart the peptide links of the protein molecule, leaving separate amino acid molecules.
- The hydrolysis is the *opposite* of condensation polymerisation.



- Given the structure of a protein molecule, the structures of the amino acids used to form it can be shown by simply breaking every peptide link to leave amine and carboxyl groups.

### Hydrolysis of proteins during digestion

- During digestion, enzymes by hydrolysis break down the proteins we eat into amino acids.
- These amino acids are transported around the body by blood. In the bloodstream during assimilation, condensation reactions build the amino acids up to produce proteins required by the body.

