ORGANIC CHEMISTRY

Introduction

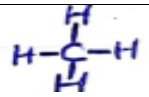
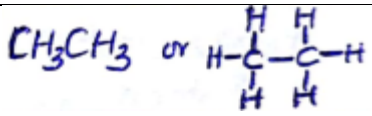
- **Definition**: Organic chemistry is a branch of chemistry that deals with the study of compounds of carbon **except** the oxides of carbon, and the carbonates, hydrogencarbonates and carbides of metals.
- Carbon is unique and forms this branch of chemistry because:
  Carbon:
  (i) atom has a valency of 4. This enables it to form 4 covalent bonds with many different groups hence leading to a wide variety of compounds being formed.
  (ii) atoms can join together. This gives rise to long chains and rings of carbon atoms. For example, octane (C_8H_{18}), one of the constituents of petrol, has eight atoms in a chain.
- Organic compounds are made up of carbon together with elements such hydrogen, oxygen, nitrogen, sulphur and the halogens (fluorine, chlorine, bromine and iodine).
- The simplest class of the organic compounds are the **hydrocarbons**.
- **Definition**: A hydrocarbon is a compound containing hydrogen and carbon atoms **only**.
- Hydrocarbons have the general formula C_xH_y where x and y are whole numbers.
- The main classes of hydrocarbons of interest at this level are the alkanes and alkenes.

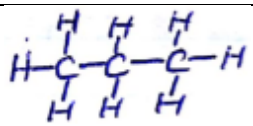
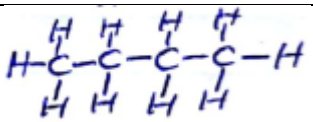
HOMOLOGOUS SERIES

- This is a family/group of related organic compounds in which each member differs from the next in molecular formula by a CH_2 group. Members in a homologous series:
  - conform to the same general molecular formula.
  - can be prepared by similar methods.
  - have/show similar chemical properties, although varying in vigour.
  - show a gradual change of physical properties.

ALKANES

- Alkanes are saturated hydrocarbons with the general formula C_nH_{2n+2}, where n is 1,2,3 and so on.
- The names of alkanes end with the suffix $-\boldsymbol{ane}$.
- Examples of some alkane are:

Value of n	**Alkane**		**Name**
	Molecular formula	**Structural formula**	
1	CH_4		Methane
2	C_2H_6		Ethane

3	C_3H_8	$CH_3CH_2CH_3$ **or** 	Propane
4	C_4H_{10}	$CH_3CH_2CH_2CH_3$ **or** 	Butane

- Alkanes are covalent compounds; each dash (−) represents a covalent bond with a pair of electrons shared between the bonded atoms.
- In alkanes, the $carbon - carbon$ bonds are all **single covalent bonds**. Both the carbon and hydrogen atoms exert their **normal valency**. These explain why alkanes are saturated compounds.
- **Definition**: A saturated compound is one in which all its atoms show their usual valency with other atoms and whose molecules contain neither double nor triple bonds.

- The table below gives some physical properties of some straight chain alkanes:

Alkane	**Boiling point (°C)**	**Melting point (°C)**	**State at room temperature**	**Solubility in water**	**Density ($g\ cm^{-3}$)**
Methane, CH_4	−162	−183	gas	all are insoluble in water	0.424
Ethane, C_2H_6	−89	−172			0.546
Propane, C_3H_8	−42	−188			0.582
Butane, C_4H_{10}	……	−135			0.579
Pentane,C_5H_{12}	36	−130	liquid		0.626
Hexane, C_6H_{14}	69	−95			0.659

Questions:

Use the above table of physical properties to answer the following questions:

(a) Plot a graph of boiling point (*vertical axis*) against the number of carbon atoms (*horizontal axis*).
  (i) From your graph, determine the boiling of the alkane with four carbon atoms.
  (ii) What is the shape of your graph?
  (iii) State the relationship between the boiling point of an alkane and the number of carbon atoms in the alkane.

(b) The density of water is 1.0 $g\ cm^{-3}$. What general conclusion can you draw from the density of alkanes compared to that of water?

(c) State:
  (i) what would be observed if 50 cm^3 of pentane is shaken with 100 cm^3 of water in a glass beaker and the mixture allowed to stand.
  (ii) how the mixture in (c)(i) can be separated.

(d) Draw a well labelled setup of the apparatus to support your answer in (c)(ii).

(e) What general name is used to describe a mixture of pentane and water in (c)(i).

(f) Alkanes are generally soluble in organic solvents. State what the statement suggests about the type of bond in alkanes.

Natural sources of alkanes

- Methane is widely obtained from:
  (i) natural gas, coal gas and crude petroleum (crude oil).
  (ii) atmosphere surrounding swamps, marshes and stagnant pounds (where it is seen as gas bubbles). Hence, the name marsh gas.
  (iii) anaerobic (bacterial) decomposition of large complicated organic matter e.g. cellulose.
- Natural gas mainly contains methane and small quantities of ethane, propane and some other higher alkanes.
- Fractional distillation of crude oil/petroleum give methane and other higher alkanes.

Case study: Methane

- Methane is a colourless, odourless gas. It is almost insoluble in water.
- In plentiful supply of air (oxygen), methane burns with a blue flame and produces water (steam) and carbon dioxide. This is called **complete combustion**.
  $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$; $\Delta H = -890\ kJ\ mol^{-1}$
  This reaction is highly exothermic (produces a lot of heat) and because of this, methane is used as a **fuel**. In fact, methane is a constituent of town gas used for domestic and industrial heating purposes.
- In a limited (little) supply of air (oxygen), methane burns and forms carbon monoxide, unburnt carbon (soot) and water. This is called **incomplete combustion**.
  $2CH_4(g) + 3O_2(g) \longrightarrow 2CO(g) + 4H_2O(g)$ **and** $CH_4(g) + 3O_2(g) \longrightarrow C(s) + 2H_2O(g)$

Note:

- The other alkanes (e.g. petrol, diesel, paraffin, candle wax etc) give the same products during both complete and incomplete combustion.
- Thus, it is **not advisable** to burn hydrocarbons (e.g. alkanes) in poorly ventilated rooms (e.g. garage). This is because poorly ventilated rooms have **limited supply of air** and this leads to production of **poisonous** carbon monoxide.

Questions:

1. (a) Name the products of complete and incomplete of ethane.
   (b) Write equation to show complete combustion of ethane and butane.
   (c) Pentane, a constituent of petrol, burns in air according to the following equation:
   $C_5H_{12}(g) + 8O_2(g) \longrightarrow 5CO_2(g) + 6H_2O(g)$; $\Delta H = -3509\ kJ\ mol^{-1}$
   (i) What does $-3509\ kJ\ mol^{-1}$ mean?
   (ii) Calculate the mass of pentane required to produce of 17.545 kJ heat. (C=12; H=1)
   (d) It is **not** advisable to burn petrol in a living room with closed doors and windows. Give a reason.
2. The molecular formula of an organic compound **Q** is C_3H_8.
   (a) (i) Write the structural formula of **Q**.

(ii) Name the group of organic compounds to which **Q** belongs.
(iii) Name **Q**.

(b) It is **not** wise to burn **Q** in a living room with closed windows and doors. Give a reason.

(c) State **one** uses of **Q**.

PETROLEUM

- It is also called 'rock oil'.
- The petroleum (*natural gas and crude oil*) was formed from the remains of plants and animals which lived millions of years of ago and decomposed.
- Petroleum is a mineral made up of different chemical substances with hydrocarbons as the main constituent. The minor components are oxygen, nitrogen and, sometimes, sulphur.
- The different useful products in petroleum can be obtained can be obtained by refining it.
- The process of refining petroleum (crude oil) includes **fractional distillation** and purification of the fractions; all of which are carried out in oil refineries.
- The components in petroleum (crude oil) can be separated by **fractional distillation**. This because the components have **different boiling points**.
- The table below gives products (fractions) from fractional distillation of crude oil/petroleum and their uses.

Fraction	**Distilling temperature (℃)**	**Uses**
Natural gas (e.g. methane, ethane propane and butane)	• *Below* 40 • *Most volatile* (*lowest boiling point fraction*)	• Bottled gas • Fuel
Petrol/motor gasoline/naphtha	40 – 175	• Solvent for grease, stains and paints • Motor and aviation fuel
Paraffin oil/kerosene	175 – 250	• Fuels for stoves and jet engines in aeroplanes • Lighting and heating
Gas oil	250 – 300	• To make petrol • Heating buildings
Diesel oil	300 – 350	• Fuel for diesel engines (in lorries, tractors and trains) and furnaces
Lubricating oil and waxes	350 – 400	• Lubrication in machine parts/ make grease • Make petroleum jelly (e.g. Vaseline) • Make candles

Asphalt and bitumen	• *Above* 400 • *Less volatile* (*highest boiling point component*) • *Residue left*	• Road and runway surfacing • Binding agents for roofing sheets • Protective coatings for concrete roof tops

- ❖ One major use of petroleum products is as **fuel**. This is because their combustion process is **highly exothermic**.
- ❖ In a plentiful (excess) supply of air (oxygen), complete combustion occurs forming water and carbon dioxide.
- ❖ However, if limited (insufficient) supply of air (oxygen) is present, incomplete combustion occurs forming poisonous carbon monoxide instead of carbon dioxide. In addition, some unburnt carbon is formed. In fact, this is a common situation in cylinders of petrol engines due to limited supply of oxygen.
- ❖ Exhaust fumes from motor cars, factories and industries contain poisonous carbon monoxide and some unburnt carbon (***which makes exhaust pipes black***). This explains why it's advisable **not** to run a car engine inside a garage with little supply of air (oxygen).
- ❖ In addition, carbon monoxide and carbon formed pollute the air/atmosphere.
- ❖ The other pollutants from petroleum products are:
  (i) Lead compounds in leaded petrol (petrol containing lead); cause lead poisoning in the body. However, the sale of leaded petrol was stopped in 2000.
  (ii) Sulphur dioxide and sulphur trioxide (due to the presence of sulphur in petroleum); these are poisonous and responsible for acids rains in many major cities.

Uses of alkanes

- ❖ They include:
  - As fuels. For example, butane is used in cigarette lighters.
  - As solvent
  - Road surfacing/making
  - As binding agents for roofing sheets
  - To make lubricants and Vaseline
  - As a source of carbon (if heated) for printers ink, paints and carbon paper.

Note:
Natural gas is preferred as a fuel because it is non-poisonous and has no smell.
However, natural gas is non-renewable and it emits carbon dioxide and steam when burnt. Both carbon dioxide and steam lead to climate change and also global warming.

CRACKING OF OILS (PETROLEUM)

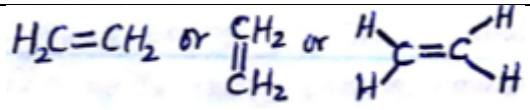
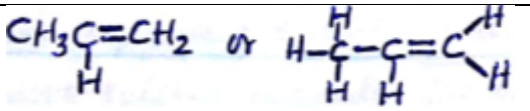
- Cracking as an alternative means of getting petrol (and other useful products) from oils. This is because fractional distillation of crude oil alone cannot effectively meet the ever increasing demands for petrol.
- Cracking means breaking down the large molecules of oils (hydrocarbons) into smaller molecules of petrol and gases.
- For example: $\underbrace{C_{10}H_{22}(l)}_{in\ oil} \longrightarrow \underbrace{C_7H_{16}(l)}_{petrol} + \underbrace{C_3H_6(g)}_{propene}$
- There are **three** ways of performing cracking process namely:
  (a) **Thermal cracking;** involves use of high temperatures (of about 500- 700°C) and high pressures (of about 30 atmospheres) to obtain petrol.
  (b) **Steam cracking;** involves heating a mixture of oil and steam at high temperatures (of about 900°C) for a short period of time (less than a second) to obtain petrol.
  (c) **Catalytic cracking;** involves use of catalysts (e.g. a mixture of silicon(IV) dioxide and aluminium oxide) at lower temperatures and pressures to produce petrol.
- The gases produced during cracking of oils include; hydrogen, ethane, ethene, propene and propane.
  The gases are useful in other process for example:
  (i) Hydrogen is used in the Haber process for the manufacture of ammonia
  (ii) The alkenes are converted into plastics

Trial questions:

1. Describe the process of cracking oils.
   In your description include:
   - Importance of cracking in oil industry.
   - The types of cracking/how cracking can be performed.
   - **Two** useful items apart from petrol obtained and for each item, state **one** use.
2. Crude oil is a mixture
   (a) Define the term **mixture**.
   (b) (i) Name **one** method by which the components in the crude oil can be separated.
   (ii) Give a reason for your answer in (b)(i)
   (c) Describe briefly how the components in crude oil can be separated by the named method in (b)(i). (*No diagram is required*)
   (d) Name any **two** useful products from crude oil and for each product, states **one** use.

ALKENES

- Alkenes are hydrocarbons with the general formula C_nH_{2n}, where n is 2,3, 4 and so on.
- They are named by dropping the suffix $-ane$ of the corresponding alkanes and replacing it with the suffix $-ene$.
- Examples of some alkenes are**:**

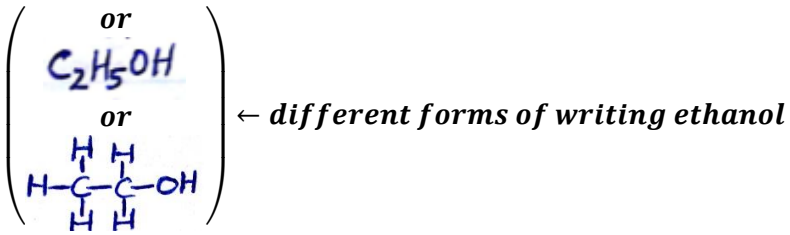
Value of n	Molecular formula	Structural formula	Name
2	C_2H_4		Ethene
3	C_3H_6		Propene

- Important to note that alkenes differ from alkanes in structure. This is because alkenes contain a double bond between two carbon atoms whereas alkanes contain single bonds **only** between two carbon atoms.
- Because molecules of alkenes contain a double bond between two carbon atoms, they are described as **unsaturated compounds**.
- **Definition**: An unsaturated compound is one in which some atom (or atoms) is (are) not exerting all its (their) combining power with other atoms.

Case study: Ethene

Laboratory preparation of ethene.

- One common method involves dehydration of ethanol (i.e. removal of water from ethanol)



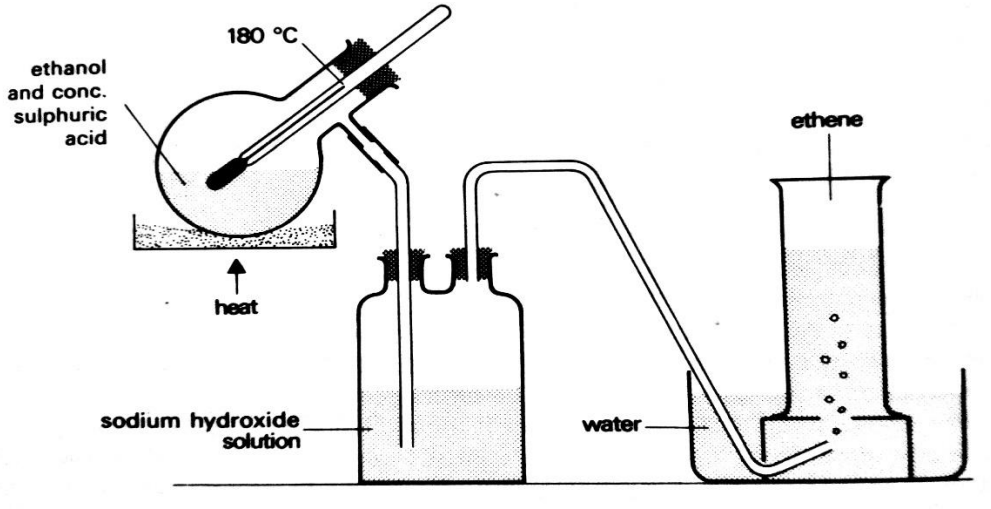
← ***different forms of writing ethanol***

Note: The molecular formula of ethanol is C_2H_6O

- The conditions for the above reaction are; **hot**, **excess concentrated** sulphuric acid (or excess concentrated sulphuric acid and heating at 180°C)
- **Procedure:**
  - A mixture of excess concentrated sulphuric acid and ethanol in a flask carrying a thermometer and a gas tube is heated up to 180°C via a sand bath. The mixture should be heated because no ethene is formed at room temperature.
  - Ethene produced is passed through sodium hydroxide solution to remove sulphur dioxide formed because ethanol reduces the sulphuric acid slightly.

- The gas is collected over water since it is insoluble in water.

❖ The setup of apparatus is as follows**:**



Note

❖ When ethanol vapour is passed over hot aluminium oxide (or broken pot), dehydration also occurs to form ethene.

❖ On a large scale, ethene is obtained by cracking of oils (petroleum).

❖ **Properties of ethene**

(A) Physical:

Ethene:

- is a colourless and sweet smelling gas
- is insoluble in water but dissolves in organic solvents.
- is slightly less dense than air
- has no effect on litmus

(B) Chemical:

(i) Combustion

In excess/plenty of oxygen, ethene burns with a yellow smoky flame to form carbon dioxide and water.

$C_2H_4(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(l)$

The flame is ***smoky*** because ethene has a ***high percentage of carbon***. The smoky flame makes ethene **not** a suitable fuel.

(ii) With hydrogen

In presence of hot nickel catalyst, ethene reacts with hydrogen to form **ethane**.

$C_2H_4(g) + H_2(g) \longrightarrow C_2H_4(g)$

(iii) With liquid bromine

Ethene turns **red** liquid bromine to **colourless**.

$H_2C = CH_2(g) + Br_2(l) \longrightarrow \underbrace{BrCH_2CH_2Br(l)}_{1,2-dibromoethane}$

If **bromine water** is used, ethene turns the solution from **reddish-brown** to **colourless**.
This reaction is used in the laboratory to:

- ✓ test for alkenes/unsaturated compounds/presence of a double bond in a compound.
- ✓ distinguish alkenes from alkanes which are saturated and give no observable change.

(iv) With acidified potassium manganated(VII) solution

Ethene turns the **purple solution** to **colourless**.

$$H_2C = CH_2(g) \xrightarrow{KMnO_4/H^+} \underbrace{HOCH_2CH_2OH(l)}_{ethane-1,2-diol}$$

This reaction also serves in the laboratory to:

- ✓ test for alkenes/unsaturated compounds.
- ✓ distinguish alkenes from alkanes which give no observable change.

(v) Polymerization

Under suitable conditions (*e.g. traces of oxygen, heat and high pressure of about 100 atmospheres*), several (many) molecules of ethene combine repeatedly to form a giant (complex) molecule (or macromolecules) called **polythene** or **poly(ethene)**.

The above reaction/process is called **polymerization** and the polythene is a **polymer** (in particular addition polymer). The many small molecules undergoing polymerization are called **monomers**.

Polythene has a wide range of uses which include; making buckets, bowls, carrier bags, funnels, dustbins, toys, car carpets, ropes wash-bottles, and bottles for milk and fruit juices. Polythene is used to make sacks to hold fertilizers, chemicals, animal feedstuffs, solid fuel and agricultural products. It is also used as an electrical insulator (coat for electrical wires).

Uses of ethene

- ❖ Ethene is used in the:
  - manufacture of plastics for example polythene.
  - manufacture of ethanol and automotive antifreeze agent.
  - process of ripening of fruits.

POLYMERISATION

- ❖ **Definition**: Polymerisation is the formation of a single giant molecule by the repeated combination of many small molecules of the same kind/same compound.
- ❖ A polymer is a giant molecule (complex molecule/macromolecule) formed by combination of small molecules many times of the same kind/same compound.
- ❖ There are **two** main types of polymerization namely:
  - (i) **Addition polymerization**; involves unsaturated molecules (monomers) of the same kind and no loss or gain of matter.
    Examples of polymers formed by this process are: polythene, Perspex and rubber.

(ii) **Condensation polymerization**; involves many molecules (monomers) of different kinds or same kind and loss of water molecules occurs.
Examples of polymers formed by this process are: nylon, Terylene, starch and cellulose.

❖ There are **two** types polymers namely:
(i) **Natural polymers**. These exist in nature and man has no influence over their formation. Thus, natural polymers are God-made polymers.
Examples of natural polymers are; starch, proteins, natural rubber, cellulose (e.g. paper, wood and cotton), silk, wool etc.
(ii) **Artificial polymers**. These are man-made polymers.
Examples of artificial polymers are; polythene, Perspex, nylon and artificial rubber.

❖ The uses of some common polymers are:

Polymer	**Uses**	**Desirable properties (if any)**
Perspex	• Replacement (substitute) for glass in aircraft, helicopters and buildings in which glass windows would be dangerous. • Making lenses and reflectors. **Note**: One disadvantage of Perspex is that it scratches easily.	• Colourless and transparent
Nylon	• Making clothes, ropes, curtains, carpets, parachutes and belting	• Strong, flexible, tough and durable
Polythene	• Making toys, carrier bags, bottle etc. • As an insulator	• Tough, insoluble in all solvents at room temperature and a good electrical insulator
Wool	• Making suits and blankets	• Absorbs and releases moisture quickly • Resistant to dirt, flame and wear and tear. Thus, it is durable • Is an insulator and thus very warm
Silk	• Clothing such as shirts, suits, ties, blouses, lingerie, pajamas and jackets	• Soft, low density (light weight), smooth, resistant to deformation (strong) • Good insulation and affinity for dyes • Shines and shimmers
Starch	• As food/provides energy	•
Proteins	• As food, act as enzymes/hormones	•

❖ One major disadvantage of artificial polymers over natural polymers is that artificial polymers are **non-biodegradable** and thus, **pollute** the atmosphere when carelessly disposed.

❖ Advantages of artificial polymers over natural polymers are:

- Artificial polymers are durable, weather resistant , easy to manufacture, stronger, tougher and do not react with common chemicals reagents
- Some artificial polymers are attractive.

RUBBER

- There are **two** forms of rubber namely; **natural** rubber and **synthetic** (artificial) rubber
- Natural rubber has many disadvantages over synthetic rubber.
  Natural rubber is/has:
  - soft
  - sticky
  - not elastic
  - low tensile strength
- The above physical properties of natural rubber can be improved by a process called **vulcanization** of rubber.
- Vulcanization of rubber involves **heating** natural rubber with **sulphur** to form **vulcanized rubber**.
- Vulcanized rubber has the following properties:
  - Has greater tensile strength
  - Is strong
  - Is durable
  - Is (more) elastic
- Vulcanized rubber is used in the making of tyres, shoe soles, erasers, carpets, gloves, condoms, belts and tubes.

Trial question:
Describe the process of vulcanization of rubber.
In your description include:
(i) Importance of vulcanization in rubber industry.
(ii) **Two** useful items of vulcanized rubber.

PLASTICS

- These are man-made materials composed of giant molecules (macromolecules) based on carbon atoms.
- There are **two** types of plastics namely:
  (i) **Thermoplastics (thermosoftening plastics);** these become soft on heating (warming) and rigid on cooling and thus, can be moulded into new shapes.
  Examples of thermoplastics are; polythene, Perspex and nylon.
  (ii) **Thermosets (thermosetting plastics);** these decompose when heated and thus, cannot be moulded into new shapes. Examples of thermosets are; bakelite and rubber

Advantages of plastics

- Plastics are:
  - light and thus, portable
  - colourful and thus, attractive
  - resistant to chemical and weather attack
  - do not corrode
- Some plastics can be moulded into new shapes.

Disadvantages of plastics

- Plastics:
  - have low tensile strength
  - have poor resistant to heat
  - are non-biodegradable and hence disposal problem. Therefore they **pollute** the environment
  - produce poisonous gases when burnt

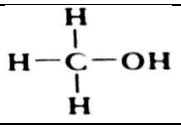
FIBRES

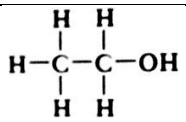
- A fibre is a solid whose length can be thousands of times greater than its width and which is strong and flexible enough to make cloth, ropes, belting etc.
- A fibre can be:
  (i) Artificial/synthetic. For example; nylon and Terylene.
  (ii) Natural. For example; silk, cotton, sisal and wool.
- Monomers of some common polymers are shown in the table below:

Polymer	**Monomer**
Polythene	Ethene
Starch	Glucose
Proteins/wool/silk	Amino acids
Cellulose	Glucose

ALCOHOLS (ALKANOLS)

- Alcohols are organic compounds which possess a hydroxyl group ($-OH$) on the carbon chain and have the general formula, $C_nH_{2n+1}OH$.
- They are named by dropping the suffix $-ane$ of the corresponding alkanes and replacing it with the suffix $-ol$.
- The two simplest members in this family are:

n (number of carbon atoms per molecule**)**	**Formula**	**Structural formula**	**Name**
1	CH_3OH		Methanol

2	CH_3CH_2OH **or** C_2H_5OH		Ethanol

Case study: Ethanol

- On a large scale, ethanol is obtained by **fermentation** of sugars and starch.
- **Definition**: Fermentation is the breakdown of complex sugars and starch to form ethanol and carbon dioxide by action of enzymes.
- Common sources of starch are; bananas, maize, cassava, potatoes, millet, sorghum, rice and barley.
- The sugar is mainly got from molasses (residues from purification of cane sugar or beet sugar).
- During the fermentation process, both sugars and starch are broken down to **glucose** ($C_6H_{12}O_6$)
- The glucose solution is mixed with yeast and the mixture covered for about two days at room temperature.
- Enzyme, **zymase** present in yeast catalyses the conversion of glucose to crude ethanol and carbon dioxide (seen as bubbles of colourless gas).
  $C_6H_{12}O_6(aq) \longrightarrow 2C_2H_5OH(aq) + 2CO_2(g)$
- The crude ethanol formed is filtered to remove solid residues.
- The filtrate is fractionally distilled at 78°C to obtain pure and concentrated ethanol.
- The ethanol formed can be dried by use of calcium oxide (which does not react with the alcohol) and then re-distilled.

Assignment:
Using internet or text books, make research and describe how ethanol is obtained by **fermentation** from:
(a) Starch
(b) Sugar
Your description should include:

- Relevant sources of starch and sugar.
- Equations and enzymes involved.

Properties of ethanol

(A) Physical

- Ethanol;
  (i) is a colourless liquid at room temperature and pressure.
  (ii) is volatile.
  (iii) is hygroscopic liquid.
  (iv) has a pleasant smell and burning taste.
  (v) is miscible with water to form a colourless solution.

(B) Chemical

(i) **Combustion**

- Ethanol burns with a blue flame in plenty of supply of air forming **carbon dioxide** and **water**.
  $C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$
- The reaction is **highly exothermic** (produces a lot of heat energy) and this explains why ethanol is used as **fuel**.

(ii) **Dehydration**

- Hot, excess concentrated sulphuric acid removes water (or the elements of water) from ethanol to form ethene.
  $C_2H_5OH(l) \longrightarrow C_2H_4(g) + H_2O(l)$
- This reaction is used in the laboratory preparation of ethene (*see page 7 for details*).

Uses of ethanol

❖ Ethanol is:
- a constituent of beers, wines and spirits.
- used a solvent (in stains, polishes and for iodine).
- used as a thermometric liquid.
- used in the manufacture of perfumes, flavours, drugs, varnishes etc.
- used as a petrol additive.

SOAPS

❖ Soaps are obtained by breaking down oils and fats; a process known as **saponification**.
❖ Oils and fats are naturally occurring esters of **long chain carboxylic acids** and **glycerol**.
❖ **Definition**: A soap is a sodium or potassium salt of a long chain carboxylic (organic) acid used as a cleansing agent.
❖ Chemically we shall represent soap with the formula $\boldsymbol{NaSt}$ (*sodium stearate*) and $\boldsymbol{KSt}$ (*potassium stearate*); where St^- is the group from the organic acid.
❖ The main difference between fats and oils is that oils are **liquids** at room temperature while fats are **solids** at **room temperature**.
❖ Common sources of oils are: Simsim, groundnuts, cashewnuts, cotton seeds, palm seeds, olive seeds, castor seeds and sunflower seeds.
❖ Common examples of oils are: palm oil, groundnut oil, cashewnut oil, castor oil, coconut oil, olive oil, corn oil etc.
❖ Common examples of fats are: lard from pigs and mutton fat.

How soap is obtained in a laboratory

❖ A mixture of oil (or fat) and sodium hydroxide solution (or potassium hydroxide solution) is boiled while stirring until no further change.
❖ Brine (or saturated sodium chloride solution/concentrated sodium chloride solution) is added into the mixture to **precipitate** (or salt out) soap form the solution mixture. The mixture is stirred and allowed to cool.

- Solid soap is skimmed off/filter off, washed and dried.

Note: If the desired soap is to be used as a toilet soap, then dyes and perfumes are added.

How soap works (washes)

- Soap cleanses/washes by dissolving in water and loosening the particles of dirt/grease on the fabric being washed.
- Soap consists of two parts; water-soluble part which dissolves in water and fat-soluble part which dissolves the dirt/grease.
- With constant agitation, the dirt/grease splits into tiny globules (droplets) and is dispersed into water which is then poured away.
- One major **disadvantage** of soaps is that their used in hard water is limited due to formation of **scum** (seen as a white precipitate). The scum leads to soap wastage and marks dirt marks on clothes during washing. Scum also damages silk and nylon.

$$\underbrace{Ca^{2+}(aq)}_{in\ hard\ water} + \underbrace{2St^{-}(aq)}_{from\ soap} \longrightarrow \underbrace{CaSt_2(s)}_{\substack{calcium\ stearate \\ (scum)}}$$

$$\underbrace{Mg^{2+}(aq)}_{in\ hard\ water} + \underbrace{2St^{-}(aq)}_{from\ soap} \longrightarrow \underbrace{MgSt_2(s)}_{\substack{magnesium\ stearate \\ (scum)}}$$

Note: Scum is an insoluble magnesium (or calcium) salt formed by the reaction between dissolved magnesium (or calcium) ions in hard water and soap.

SYNTHETIC (SOAPLESS) DETERGENTS

- **Definition**: A detergent is any substance that facilitates the emulsification and removal of grease.
- Common detergents are marketed as Omo, Surf, Tide, Brytex, Nomi, Magic, Ariel, Mama, Toss, and Sunlight.
- Detergents have been introduced to replace soaps for domestic and laundry use and are **better** than soaps because of the following reasons:

  Detergents:

  (i) do not form scum with hard water. This is because calcium (or magnesium) salt of the detergent is **soluble** in water.

  (ii) are obtained from petroleum products so fats and vegetable oils are saved for other uses such as the manufacture of margarine.

  (iii) are more soluble in water and thus wash brighter than soap.
- Detergents wash in a similar way like soaps.
- The major **disadvantages** of detergents are:

  (i) They contain **phosphates** which are fertilizers. Thus, when released/discharged into water bodies (lakes/rivers/swamps/seas/oceans), they accelerate the growth algae which depletes dissolved oxygen in water. This makes make the aquatic organisms to die and rot in water. Hence, causing **water pollution**.

(ii) Some detergents are **non-biodegradable** (i.e. cannot be broken down by bacteria) and hence, their foam pollutes the streams and rivers.

How a detergent is obtained in a laboratory

- About 2 cm^3 of concentrated sulphuric acid is carefully added to about 1 cm^3 of castor oil/coconut oil with stirring.
- 10 cm^3 of distilled water is added to the resultant mixture. The mixture is stirred and solid detergent is obtained by decantation. The solid is washed with distilled water.

Trial Questions:

1. Using a suitable yeast, glucose can be converted to ethanol and carbon dioxide according to the following equation.

   $C_6H_{12}O_6 \xrightarrow{yeast} 2CH_3CH_2OH + 2CO_2$

   (a) Name the:
   (i) enzyme in yeast that converts glucose to ethanol.
   (ii) process by which glucose is converted to ethanol in the presence of yeast.
   (iii) process by which ethanol obtained can be concentrated.
   (b) Draw a diagram for the step up of apparatus that can be used in the named process in (a)(iii) and state **one** method that can be used to determine the purity of the ethanol.
   (c) Write equation to show how ethanol burns in excess air.
   (d) State **one** use of ethanol as a result of the reaction in (c).
2. (a) Write the molecular formula and structural formula of (i) ethane (ii) ethene

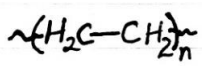
(a) State the structural difference between ethene and ethane.
(b) Name **one** reagent which can be used to distinguish between ethene and ethane. State what would be observed if each of the compounds was separately treated with the named reagent.
(c) Write equation for the polymerization of ethene.
(d) State **one**:
(i) use of the product in (d). (ii) disadvantage of the product in (d).
(e) Name **one** compound from which ethene can be prepared.

3. The molecular formulae of some organic compounds **Q** and **R** are C_3H_8 and C_3H_6.
   (a) Write the name and structural formula of **Q** and **R**.
   (b) Name **one** other reagent other bromine that can be used to distinguish between **Q** and **R**. State what would be observed if the reagent you have named was separately treated with **Q** and **R**.
   (c) Name the products of both complete and incomplete combustion of **Q**.
4. The molecular formula of compound T is C_2H_6O.
   (a) When compound **T** was heated with excess concentrated sulphuric acid, a colourless gas **Z**, which turned bromine to colourless was evolved.
   Identify: (i) **T** (ii) **Z**
   (b) Write equation:
   (i) for the formation of **Z** from **T**. (ii) to show how **Z** reacts with bromine.
   (c) Name **one** other reagent apart from bromine that can be used to identify **Z**. and state what would be observed if **Z** was treated with the named reagent.

(d) State the property of the sulphuric acid shown in the reaction in (a).
(e) The combustion of **T** is highly exothermic. State a possible use of **T**.
(f) An organic compound, **J** has a molecular formula $C_6H_{12}O_6$. When a mixture of aqueous solution of J and yeast was kept at room temperature for about two days, ethanol was formed.
(i) State the role of yeast
(ii) Write equation for the reaction leading to the formation of ethanol.

5. Fats and oils can be used to make soap.
(a) State:
(i) **one** difference between fats and oils.
(ii) what is meant by the term **soap**.
(iii) **one** word, which means "**formation of soap**".
(iv) **two** natural sources of vegetable oils.
(b) Briefly describe soap can be prepared from a named oil.
(c) Soap was used for washing in hard water.
(i) State what was observed.
(ii) Write equation for the reaction that took place.
(d) A detergent can be used for washing instead of soap. State **one** advantage and **one** disadvantage of using detergents.
(e) Soap was solution was shaken with a solution containing magnesium hydrogencarbonate.
(i) State what was observed. (ii) Explain your answer in (e)(i).
(f) State what would be observed if a solution of soapless detergent was used in (e) instead of soap solution. Give a reason for your answer.
(g) Briefly explain how soapless detergents cause water pollution.

6. Ethanol can be converted to ethene by dehydration.
(a) (i) State the conditions under which the reaction takes place.
(ii) Write equation for the reaction leading to the formation of ethene from ethanol.
(iii) State how ethene can be identified.
(b) Under suitable conditions, ethene can be converted to a compound, **W** with the following general formula:



(i) State what **n** stands for in the formula?
(ii) What is the change from ethene to **W** called?
(iii) Name compound **W**.
(iv) Write equation for the reaction leading to the formation of **W**.
(v) State **one** use and **one** disadvantage of **W**.
(c) Name **one** other compound of the category of **W** which is not man-made.
(d) State **one**
(i) use of the compound you have named in (c)(i).
(ii) advantage of compound you have named in (c)(i) over **W**.
(e) Write equation to show the reaction of ethene leading to formation of
(i) 1,2-dibromoethane (ii) water and carbon dioxide

(f) State **one** use of ethanol other preparation of ethene.

7. (a)Differentiate between:
   (i) **natural polymer** and **natural polymer**.
   (ii) **thermosetting polymer** and **thermosoftening** (**thermoplastic**) **polymer**.
   (b) Polythene is an example of a synthetic polymer.
   (i) What is meant by the term **polymer**?
   (ii) Name **one** other synthetic polymer apart from polythene.
   (g) Briefly describe how polythene causes water pollution.
8. Natural rubber is soft and it is normally made hard before use.
   (a) (i) Name **one** process by which natural rubber is made hard.
   (ii) State how natural rubber is made is made hard by the process you have named in (a)(i).
   (b) State **two**:
   (i) reasons why natural rubber is made hard before use. (ii) uses of rubber.
9. The general formulae of some hydrocarbons **T** and **V** are C_nH_{2n+2} and C_nH_{2n} respectively.
   (a) Write the molecular formula and name of the hydrocarbons for $n = 3$.
   (b) Name a reagent that can be used to distinguish between **T** and **V**. state what would be observed if the reagent you have named was treated separately with **T** and **V**.
   (c) Write equation to show how **T** burns plentiful of supply of air.
   (d) Name products of incomplete combustion of **T**.
10. (a) Outline how a sample of a concentrated solution of ethanol can be prepared by fermentation of glucose. (*No diagram is required, but your answer should include equation of reaction*)
   (b) Briefly describe and explain how a sample of ethene can be prepared from ethanol using sulphuric acid. (No diagram is required, but your answer should include condition(s) and equation(s))
   (c) When reacted together, ethene molecules can form a polymer.
   (i) Name the polymer.
   (ii) Write equation for reaction leading to the formation of the polymer.
   (d) State **one**
   (i) use of the polymer.
   (ii) disadvantage of the polymer.