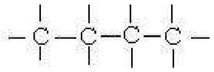
ORGANIC CHEMISTRY | S.3 Holiday Notes | ==> Copy into your books

Organic chemistry is a branch of chemistry dealing with carbon and its compounds except oxides of carbon, carbonates, hydrogen carbonates and carbides of metals.

These organic compounds contain carbon as the basic framework and other elements like hydrogen, nitrogen and chlorine are attached to it.

Carbon has a unique behaviour because:

1. It can form a very long chain of carbon atoms, which can be up to 2000 atoms.



These compounds consisting of chains of carbon atoms are called **aliphaticcompounds.** These compounds can be **saturated** (if all the carbon atoms are joined to each other by a single covalent bond e.g. ethane, $CH_3—CH_3$) or **unsaturated** (if it contains multiple covalent bonds i.e. either double or triple e.g. ethene, $CH_2=CH_2$and ethyne, $H-C\equiv C-H$

2. It can form a ring of carbon atoms. The compounds that form rings of carbon atoms are **alicyclic compounds.**

Because of these two unique behaviours, carbon can form very many and complex compounds which has made it necessary for its study under a separate branch called organic chemistry. However, for historical and conventional reasons some simpler compounds such as carbon dioxide (CO_2) and sodium carbonate (Na_2CO_3) are usually studied under non-carbon compound in inorganic chemistry.

Classification of organic compounds

Organic compounds can be classified into several groups. The simplest of the organic compounds are hydrocarbons. Other groups include alcohols, esters, carboxylic acids, amines, ketones, alcohols and ethers.

These groups are differentiated from each other by **functional groups**.

Functional groups are groups of atoms that are common to a given homologous series and are responsible for chemical reactions. Examples of functional groups include:

-OH for alcohols e.g. ethanol, CH_3CH_2OH; methanol, CH_3OH.
-COOH for carboxylic acids e.g. Ethanoic acid, CH_3COOH; methanoic acid HCOOH.
$-NH_2$ for amines e.g. amino ethane, $CH_3CH_2NH_2$, amino propane, $CH_3CH_2CH_2NH_2$

Homologous series

This is a series of organic compounds related to each other by the same functional group.

Characteristics of homologous series include:

i) All members conform to a general molecular formula e.g.

C_nH_{2n+2} for alkanes. If n=2, C_2H_6(ethane); if n=4, C_4H_{10} (butane)

C_nH_{2n} for alkenes. If n=2, C_2H_4 (ethene); if n=3, C_3H_6 (propene)

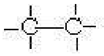
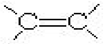
ii) Members of the same homologous series have the same chemical properties (though varying in vigour/speed)

iii) The physical properties of the members change gradually with increase in molecular mass. E.g. boiling point, melting point and density increase with increase in molecular mass; there is a gradual change in state down the group (methane is a gas, pentane is a liquid and decane is a solid); solubility decreases down the group as molecular mass increases.
iv) Members in each homologous series differ from the next by $-CH_2$ group (methylene group).
v) Members have the same general method of preparation

Hydrocarbons

These are compounds consisting of only hydrogen and carbon atoms. They have a general formula of C_xH_y where x and y can be any numerical whole numbers.

Hydrocarbons are classified into three main groups as alkanes, alkenes and alkynes. These three are differentiated by the following functional groups.

Alkanes,  $-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$ Alkenes,  $>C=C<$ Alkynes, $-C \equiv C-$

Alkanes

These are saturated hydrocarbons with the general formula of C_nH_{2n+2}. Where n is the number of carbon atoms. Alkane members are referred to as the paraffin i.e. they have little affinity to react.

Sources of alkanes

The main sources of alkanes include:
i) Natural gas. This contains mainly methane with small amounts of other gases like propane and butane. Methane is formed by anaerobic decomposition of organic matter and it is found in swamps, stagnant ponds and marshes.
ii) Petroleum. This contains a wide range of alkanes ranging from molecular gases to high molecular waxy solids (C_2-C_{40}). Petroleum is formed by anaerobic decomposition of sea plants and animals. The components of petroleum are separated by fractional distillation, a process known as refining.

Nomenclature of alkanes

According to IUPAC (International Union of Pure and Applied Chemistry), all members of alkanes have their names ending with the suffix –ane.

Value of n	**Formula**	**Name**
1	CH_4	Methane
2	C_2H_6	Ethane
3	C_3H_8	Propane
4	C_4H_{10}	Butane
5	C_5H_{12}	Pentane

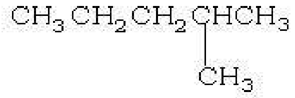
Straight chain alkanes have a prefix n before the normal name e.g.

$CH_3CH_2CH_2CH_3$	n-butane

In branched chains, the branch may be a hydrocarbon or other atoms like chlorine, and bromine.

The hydrocarbon side chains have one hydrogen less the parent alkanes and are generally referred to as **alkyl groups**. The alkyl groups derive their names from respective parent alkanes e.g.-CH_3 (methyl); -CH_2CH_3 (ethyl); -$CH_2CH_2CH_3$ (propyl); - $CH_2CH_2CH_2CH_3$ (butyl).

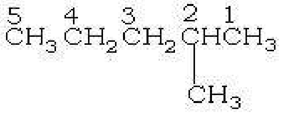
For branched alkanes e.g.



$CH_3CH_2CH_2\underset{\underset{\displaystyle CH_3}{|}}{C}HCH_3$

i) Name the longest unbranched carbon chain .i.e. the longest carbon chain consists of 5-carbon atoms, it is therefore a derivative of pentane

ii) Give the number showing position of the branch. Count from the side that will give the branch the lowest possible number. E.g. the branch is on the 2nd carbon atom (the branch replaces hydrogen on the 2nd carbon)



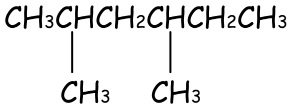
$\overset{5}{C}H_3\overset{4}{C}H_2\overset{3}{C}H_2\overset{2}{\underset{\underset{\displaystyle CH_3}{|}}{C}}H\overset{1}{C}H_3$

iii) Name the branch (substituent group) i.e. methyl group

So, write the name of the alkane starting with the carbon position on which the branch is located (2); put a dash (-); write the name of the branch/substituent group (methyl) followed by the name of the longest straight carbon chain.

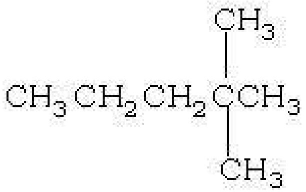
The above compound is therefore 2-methylpentane.

iv) If the branches of side chains are more than one and are similar, di, tri, etc are used.



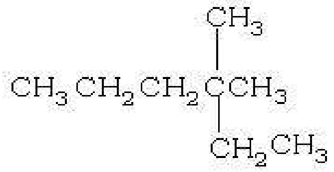
$CH_3\underset{\underset{\displaystyle CH_3}{|}}{C}HCH_2\underset{\underset{\displaystyle CH_3}{|}}{C}HCH_2CH_3$

2,4-dimethylhexane



$CH_3CH_2CH_2\overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}CH_3$

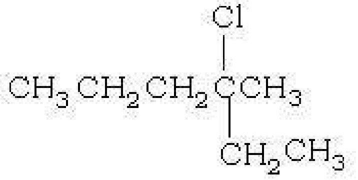
2,2-dimethylpentane



$CH_3CH_2CH_2\overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CH_2CH_3}{|}}{C}}CH_3$

3,3-dimethyl hexane

v)If the side chains are different, naming follows alphabetical order



$CH_3CH_2CH_2\overset{\overset{Cl}{|}}{\underset{\underset{CH_2CH_3}{|}}{C}}CH_3$

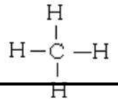
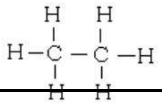
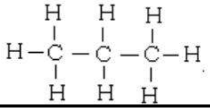
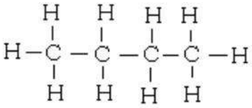
Note: the longest unbranched chain has 6-C atoms;it istherefore a derivative of hexane.

3-chloro, 3-methylhexane

Molecular and structural formulae
Molecular formula shows the number of each kind of atoms present in one molecule of a compound. It does not show the arrangement of atoms in the molecule.

Structural formula (graphical formula) shows the arrangement of atoms in one molecule of a compound.

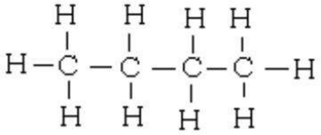
Alkanes like other hydrocarbons and other organic compounds have covalent bonds between the atoms. In alkanes, the carbon atoms use all the four outer most electrons to form covalent bonds by sharing with other carbon atoms and hydrogen atoms. Because all the electrons are used up in the formation of covalent bonds, they are called **saturated hydrocarbons**.

Compound	**Molecular formula**	**Structural formula**
Methane	CH_4	
Ethane	C_2H_6	
Propane	C_3H_8	
Butane	C_4H_{10}	

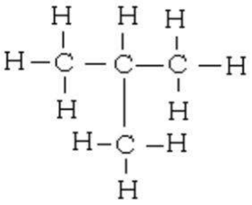
Isomerism
This is the existence of a compound with the same molecular formula but different structural formulae.

Isomers are compounds with the same molecular formula but different structural formulae.

All hydrocarbons with four or more carbon atoms per molecule possess isomers. E.g. butane (C_4H_{10})

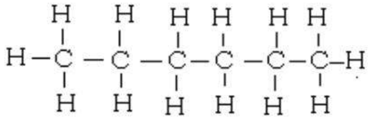


n-butane

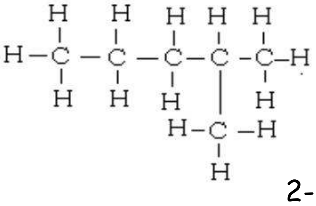


2-methyl propane

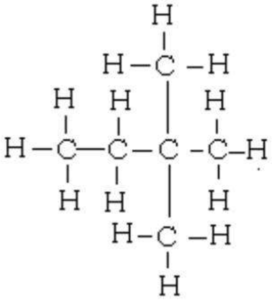
Hexane (C_6H_{14})

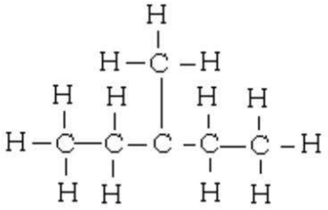


n-hexane



2-methylpentane





2,2 -dimethyl butane

3-methylpentane

Properties of alkanes

Alkanes are not so reactive and undergo combustion and chlorination reactions only.

1. Combustion

Alkanes undergo complete combustion in plenty of oxygen to form carbon dioxide and water vapour. For example, methane explodes in air/ oxygen on application of flame

$CH_4\ (g) + 2O_2\ (g) \longrightarrow CO_2\ (g) + 2H_2O\ (g) + \text{Heat.}$

Incomplete combustion of alkanes in limited supply of oxygen produces carbon monoxide, and sometimes carbon and water vapour.

$2CH_4\ (g) + 3O_2\ (g) \longrightarrow 2CO\ (g) + 4H_2O\ (g) + \text{Heat.}$

Or

$CH_4\ (g) + O_2\ (g) \longrightarrow C(s) + 2H_2O\ (g) + \text{Heat.}$

The combustion of alkanes produces considerable amount of heat. This explains why they are used as fuel for domestic and industrial uses.

The in complete combustion of carbon occurs in cylinders of petrol engines that results in to release of poisonous carbon monoxide and sometimes even carbon. It is therefore dangerous to run a car engine in a garage where there is no free air circulation.

2. Chlorination

Alkanes undergo substitution reaction with halogens. A substitution reaction is reaction in which an atom or a group of atoms in a compound is/are replaced by other atoms.

For the case of alkanes, this is only possible with halogens, e.g. when sunlight shines on a mixture of methane and chlorine, the chlorine replaces hydrogen in a chain reaction i.e. substitution reaction occurs as follows:

$$CH_4\,(g) + Cl_2\,(g) \longrightarrow \underset{\text{(Chloromethane)}}{CH_3Cl\,(g)} + HCl\,(g)$$

$$CH_3Cl\,(g) + Cl_2\,(g) \longrightarrow \underset{\text{(Dichloromethane)}}{CH_2Cl_2\,(g)} + HCl\,(g)$$

$$CH_2Cl_2\,(g) + Cl_2\,(g) \longrightarrow \underset{\text{(Trichloromethane)}}{CHCl_3\,(g)} + HCl\,(g)$$

$$CHCl_3\,(g) + Cl_2\,(g) \longrightarrow \underset{\text{(Tetra chloromethane)}}{CCl_4\,(g)} + HCl\,(g)$$

This reaction occurs rapidly in bright sunlight and when chlorine is in excess.

Petroleum (Crude oil)

Petroleum is formed by anaerobic decomposition of sea plants and animals. It is oil consisting of different alkanes normally ranging from C_5H_{12} to $C_{43}H_{88}$. The oil deposits are usually found with sand and brine.

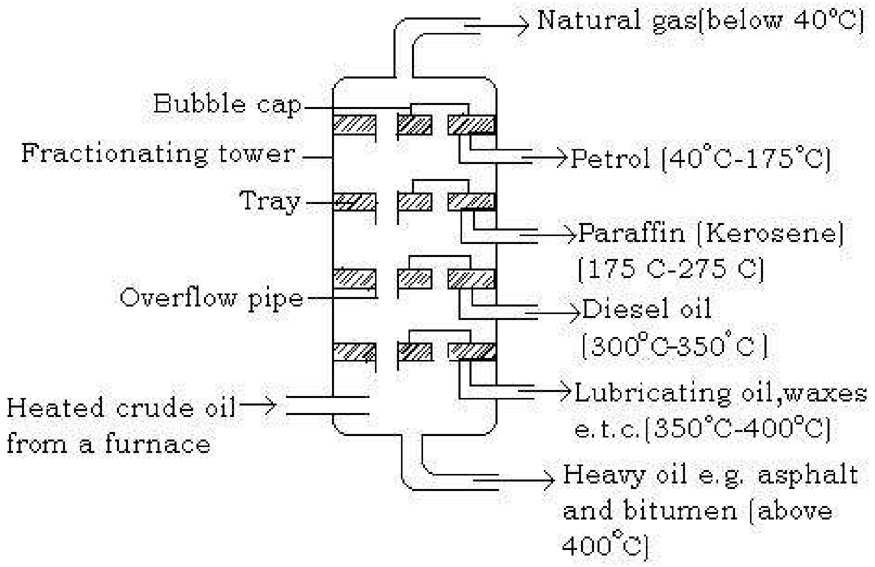
Refining fuel

The different alkanes that make up petrol can be separated by fractional distillation.
This is based on the boiling points of the different components.

After the removal of impurities mainly sulphur compounds, it is heated until when most of it vaporizes. The vapour is passed into the bottom of a tall fractionating tower. The fractionating tower is divided into several compartments each cooler than the one below it.

During fractional distillation, the fraction of petroleum that is most volatile settles at the top, the non-volatile heavy oil runs out, and the bottom of the column.

Fractionating tower



Crude oil is separated into the following fractions

Fraction	**Distilling temperature**	**Number of carbon atoms**	**uses**
Natural gas e.g methane,ethane,propane	Below 40 C	C_1-C_4	Fuel for lighting and heating purposes
Petrol + naphthalene	40 C to 175 C	C_5-C_{10}	Fuel; solvent for grease, paints and stain;vanish,dry cleaning
Paraffin	175 C to 275 C	C_{10}-C_{14}	Fuel
Diesel + gas oil	275 C to 350 C	C_{14}-C_{18}	Fuel
Lubricating oil+paraffin Wax+vaseline	Above 350 C	C_{18}-C_{40} and above	Lubrication, making candle, making Vaseline.

The gas oil fraction is cracked to yield more petrol.

Cracking of gas oil

Fractional distillation of crude oil above only yields 20% of the petrol. The cracking process produces more petrol.

Cracking is the breaking down of large complex hydrocarbons into smaller molecules (of short carbon chain) by use of heat or catalyst. Heavy alkanes are cracked to produce useful alkenes and fuel of high quality (relatively smaller alkanes). E.g.

$$C_{10}H_{22} \longrightarrow C_7H_{16} + C_3H_6$$

Cracking can be classified in to:

i) **Thermal cracking:** this involves heating of large hydrocarbons at highpressures to break them into smaller molecules.

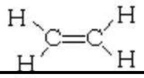
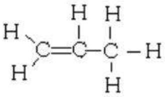
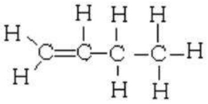
ii) **Catalytic cracking:** this involves the use of a catalyst to break down large andcomplex hydrocarbons in to simpler ones. Catalysts commonly used are silicon (IV) oxide and aluminium oxide. Catalytic cracking takes place at a relatively low temperature and pressure.

ALKENES

Alkenes are unsaturated hydrocarbons with a general formula of C_nH_{2n}. where n=2 or more. They are characterized by possession of a double bond between carbon atoms.

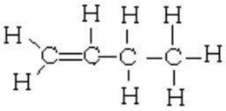
Nomenclature and structure

Alkenes are named as alkanes except that their names end with suffix –ene. Consider the table below.

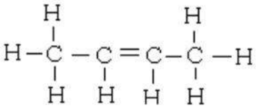
n	Molecular formula	Name	Structural formula
2	C_2H_4	Ethene	 or $CH_2{=}CH_2$
3	C_3H_6	Propene	 or $CH_2{=}CHCH_3$
4	C_4H_8	Butene	 or $CH_2{=}CHCH_2CH_3$

Isomerism

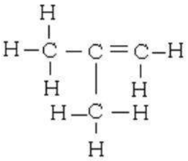
Isomerism in alkenes begins when n=4i.e from butene. Isomers of butane are:



But-1-ene



But-2-ene



2-methylpropene

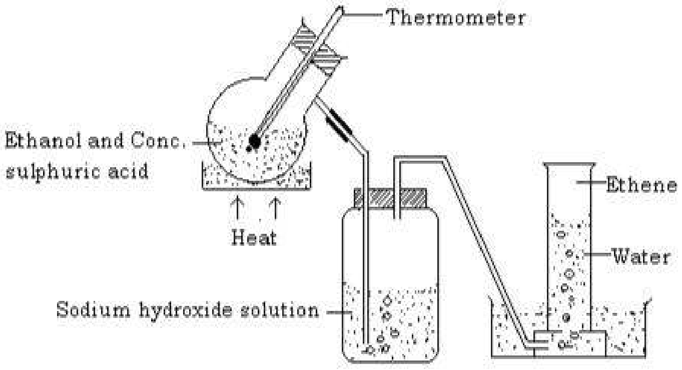
Ethene

This is the simplest alkene with molecular formula, C_2H_4.

Laboratory preparation

Ethene is prepared by dehydration of ethanol using excess concentrated sulphuric acid.

Set up



Procedure

- To 50cm^3 of ethanol, add 100cm^3 of concentrated Sulphuric acid slowly while shaking under a tap
- The apparatus is set as above and the mixture heated with care to 180°C. Ethene is evolved and is collected over water.

NB. The wash bottle of alkali solution removes sulphur dioxide produced in small quantity as ethanol reduces sulphuric acid slightly. The alkali also removes fumes of the acid.

$$CH_3CH_2OH(l) \xrightarrow[170^\circ C\text{-}180^\circ C]{\text{Excess Conc. } H_2SO_4} C_2H_4(g) + H_2O(g)$$

Sometimes aluminium sulphate is added to the reaction to reduce frothing.

Ethene can also be prepared by catalytic dehydration of ethanol. Here, ethanol vapour is passed over a heated catalyst to produce ethane.

Properties of ethene

Physical properties

- Is a colorless gas with a faint sweet smell
- It is insoluble in water but soluble in organic solvents eg benzene and methylbenzene
- It is slightly less dense than air

Chemical properties

Alkenes are generally more reactive than corresponding alkanes. They undergo the following reactions

a) Combustion

Ethene burns in excess oxygen with a smoky flame since it contains a relatively high percentage of carbon forming carbon dioxide and water vapour

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

b) Addition reaction of ethene

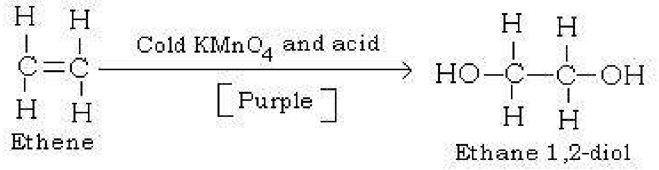
Ethene and other unsaturated compounds undergo addition reactions an addition reaction is one in which a molecule adds to an unsaturated compound by breaking the

double bond or triple bond
Examples;
i)When ethene gas is bubbled through bromine water, bromine water changes from red brown to colourless i.e. the red brown color of bromine is discharged

$CH_2=CH_2$ (g) + Br_2 (l) $\longrightarrow$ CH_2BrCH_2Br (l)

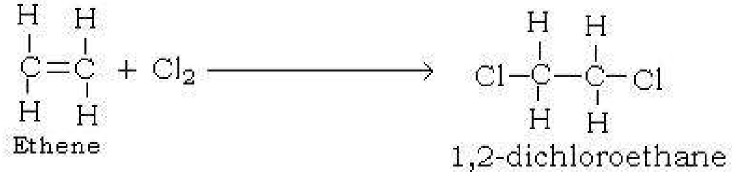
This is the common test for unsaturation.

ii) Acidified potassium manganate (VII) solution (purple) turns to colourless if ethene is bubbled through the solution



The above is alternative test for unsaturation.

When chlorine gas is mixed with ethane and the mixture left in sunlight, the two combine forming a colorless oily liquid called 1,2-dichloroethane



c) Hydrogenation (addition of hydrogen)

When hydrogen and ethane mixture is passed over a finely divided nickel catalyst, which is heated to about 200_{o}C ethane is formed

$CH_2=CH_2$ (g) + H_2 (g) $\longrightarrow$ CH_3CH_3 (g)

d) Reaction with sulphuric acid

Ethene undergoes an addition reaction with fuming concentrated sulphuric acid to form an oily liquid called ethyl hydrogen sulphate

$CH_2=CH_2$ (g) + H_2SO_4 (l) $\longrightarrow$ $CH_3CH_2HSO_4$ (l)

When the liquid formed above is boiled with water, ethanol is produced

$CH_3CH_2HSO_4$ (l) +H_2O (l) $\longrightarrow$ CH_3CH_2OH(l) + H_2SO_4 (l)

e) Polymerization

Ethene under a very high pressure becomes a liquid. When this liquid is strongly heated to about 200°C in the presences of a little oxygen catalyst, a white waxy solid (Polyethene) is obtained.

$nCH_2=CH_2 \longrightarrow - \ CH_2CH_2 \ _n -$

Uses of ethene

- it is used in the manufacture of ethanol
- it is used in the ripening of fruits
- it is used in the manufacture of plastics (synthetic polymers e.g. polythene)
- it is also used in preparing other solvents

Polymerization

Is the combination of many molecules of the same compound with relatively small molecular masses to form one complex molecule with very large molecular mass.

The complex molecule with a large molecular mass formed by the combination of many molecules of relatively small molecular masses is called the **polymer.** The small molecules from which a polymer is built are called **monomers**

Types of polymerization

These are mainly two i.e. addition and condensation

Addition polymerization

This is a combination of many small but unsaturated molecules to form a large molecule without any other product. In this case, the polymer possess the same empirical formula as the monomer. E.g. in the formation of Polyethene

$nCH_2{=}CH_2 \ -(CH_2-CH_2)_n- \longrightarrow$

(Monomer-ethene) (Polymer-Polyethene)

Condensation polymerization

In the condensation polymerization, two different molecules combine to form one large molecule with consequent loss of simple molecules like water, hydrogen chloride etc. so the empirical formula of the monomer and the polymer are not the same e.g. formation of starch from glucose and formation nylon 6,6

Types of polymers

Polymers can broadly be divided into two groups namely **natural polymers** and **synthetic polymers**

Natural polymers

Polymer	**Monomer**	**Use**
Starch	Glucose	Source of energy
Proteins	Amino acids	Repair of worn out tissues
Cellulose	Glucose	Cell walls
Glycogen	Glucose	Source of energy
Lipids (fats and oil)	Fatty acids and glycerol	Source of energy,
Natural rubber	Isoprene	Making foot wears

Synthetic (artificial) polymers

Polymer	Monomer	Use
Polyethene	ethene	-Making containers, eg plastics bowls and dust bins -used as wrapping materials
Polyvinyl chloride (PVC)	Chloro ethene	-Making rain coats -Electrical insulation -making pipes and films
Polystyrene	styrene	-making packing materials - making house hold items such as combs, plastic cups and a common lining in refrigerators

Classes of addition polymers

There are two main classes of addition polymers i.e. plastics and rubber.

Plastics

A plastic is a substance, which when soft can be formed into different shapes

Plastics are minor products formed by cracking of crude oil eg poly ethene. Polyvinyl chloride. Melamine

All synthetic polymers are plastics in nature

Advantages of plastics

-They are good thermal and electrical insulators
- They can easily be shaped and molded (they are ductile)
- They resistant to acids and alkalis and they do not rust
-plastics can be coloured when they are being manufactured and they do not need repainting
- They are light and therefore
portable -They are cheap

Disadvantages

- Produce poisonous fumes when they are burnt
- They are non-biodegradablei.e they do not decay naturally
- Where serious fire hazards occur, molten plastics can inflict very severe burn

Types of plastics

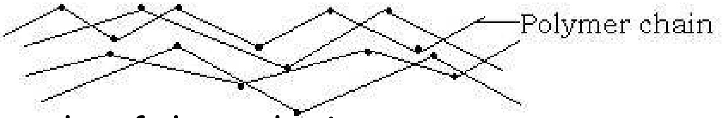
Plastics can be put into two types depending on their behavior upon heating i.e thermo-softening plastics and thermo-setting plastics

a) Thermo- softening plastics (Thermo-plastics)

These are plastics that soften or melt when heated and can be therefore be moulded into any shape while they are still soft. The plastics only harden when they cool.

Structure of thermo-plastics

The long polymer chains in thermoplastics lie alongside each other. They may be entwined on each other but the polymer chains are not linked (not bonded to each other). When heated, the chains slide over each other making them soft and runny.



Examples of thermoplastics

1. Polythene

Polythene is a polymer of ethene. There are two types of polythene i.e. low-densityPolyethene and high-density polythene.

i) Low density polythene

This is made by polymerizing ethene at a high pressure of 1000-2000 atmospheres and temperature of 200°C. Oxygen is used as a catalyst. It has a lower softening temperature of 105°C-120°C. The low density is due to poor packing of the branched polymer chains. The low-density polythene is soft, light and flexible

Uses:

For making polythene bags; insulation of electric cables because they can withstand bad weather conditions; making of squeeze bottles such as wash bottles; making plastic bags.

Disadvantage:

At boiling water temperature, they become soft so much that they become flappy and lose shape.

ii) High density polythene

It is made by polymerizing ethene at low pressure (5-25 atmospheres) and low temperature (20-50°C) in the presence of a Ziegler catalyst. It has a higher softening temperature of about 140°C. The high density is due top the close packing of the unbranched polymer chains. Very few of these polymers may be branched.

They are much harder, stiff, and do not lose shape at boiling water temperature.

Uses

For making crates e.g. of beer and sodas, bowls, toys, buckets, food boxes, etc.

2. Polyvinyl chloride (PVC)/Polychloroethene

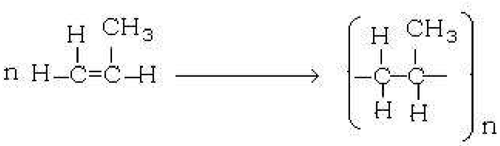
PVC is made by polymerization of vinyl chloride (chloroethene).

$$\underset{\text{(Monomer-chloroethene)}}{nCH_2{=}CHCl} \xrightarrow{\qquad\qquad} \underset{\text{(Polymer-polychloroethene)}}{-(CH_2CHCl)n-}$$

PVC are more rigid than Polyethene and are used for making water pipes, light switches and sockets, insulation for electric cables,, carpets, plastic rain coats etc.

3. Polypropene

This is made by polymerizing propene at a high pressure in the presence of a Ziegler catalyst.



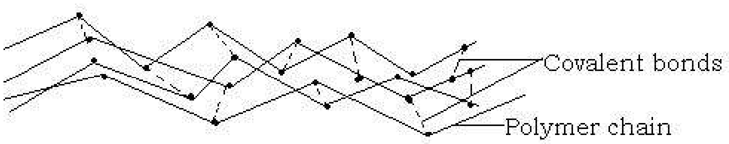
$$n\ H-\overset{H}{\overset{|}{C}}=\overset{CH_3}{\overset{|}{C}}-H \longrightarrow \left[-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{CH_3}{C}}-\right]_n$$

It is used for making ropes and for packaging.

b) Thermosetting plastics

These are plastics, which do not soften or melt on heating and therefore cannot be remoulded into different shapesonce they are set. They simply decompose upon heating. Thermosetting plastics have polymer chains, which are bonded/ linked to each other. This is called cross-linking.

Structure



Examples of thermosetting plastics include: Bakelite (used for making electric plugs, saucepan handler, switches); melamine (used for making cups and children dishes).

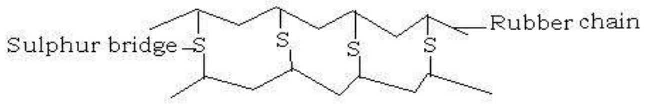
Natural rubber

Natural rubber is obtained from a rubber tree as a milky liquid called latex. Latex can be coagulated by addition of a little ethanoic acid to form a solid of high molecular weight.

The monomer of rubber is isoprene (2-methylbuta-1,3-diene)

Vulcanization of rubber

Rubber in its natural state is not strong or elastic enough and it is made more strong and useful by vulcanization, which involves heating the rubber with sulphur. The sulphur combines with rubber forming cross linkages between natural rubber chains.



Vulcanized rubber is stronger, more elastic and more durable.

Uses of vulcanized rubber

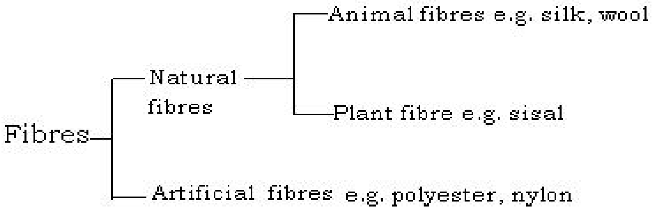
- It is used in the manufacture of tyres
- Used in the manufacture of foot wears

Condensation polymers

Fibres

These are polymers, which can be drawn into threads. This is because, the forces of attraction between the linear molecules are weak but those between individual atoms are strong.

Classification of fibres



Advantages of synthetic/artificial polymers

- Relatively low production cost compared to the cost of extracting natural polymers.
- They are usually stronger and more resistant to corrosive substances like acids compared to natural polymers.
- They can easily be modified depending on the purpose for which the polymer is required unlike natural polymers, which are hard to modify. As well, their quality can easily be improved in terms of appearance, strength etc.

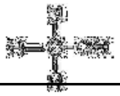
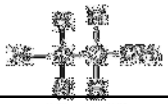
Disadvantages of synthetic polymers

- Many are non-biodegradable causing pollution to the environment.
- When burnt, they produce toxic gases like hydrogen cyanide (from polypropenenitrile) thus endangering lives of the people working in the factories.

Alcohols/Alkanols

These are organic compounds with hydroxyl (-OH) group attached to the hydrocarbon. Alcohols have a general formula of $C_nH_{2n+1}OH$.

Members of the series

n	Molecular formula	Structural formula	Name
1			Methanol
2			Ethanol
3			Propanol

Alcohols are named by placing –ol in the place of –e in the corresponding alkane members.

Ethanol

Physical properties

- It is a colourless liquid with a strong characteristic smell
- It is a volatile liquid and boils at 78°C
- It is very soluble in water

Chemical properties

1. Combustion

Ethanol burns completely in air with a blue non-luminous flame producing carbon dioxide and water vapour.

$C_2H_5OH\ (l) + 3O_2\ (g) \longrightarrow 2CO_2\ (g) + 3H_2O\ (l)$

2. Dehydration

When a little concentrated sulphuric acid is added to ethanol, an oily liquid called ethyl hydrogensulphate is produced and the reaction is exothermic.

$C_2H_5OH\ (l) + H_2SO_4\ (l) \longrightarrow C_2H_5HSO_4\ (l) + H_2O\ (l) + \text{Heat}$

When concentrated sulphuric acid is heated with ethanol, it produces ethene.

$CH_3CH_2OH\ (l) \xrightarrow[170°C\text{-}180°C]{\text{Conc. } H_2SO_4} C_2H_4\ (g) + H_2O\ (g)$

Preparation of ethanol

Ethanol is manufactured/ prepared by the process of fermentation of carbohydrates such as starch and sugars.

Fermentation

This is a process in which carbohydrates like starch and sugars are converted to alcohol by enzymes. The enzymatic break down of glucose yields simple compounds like ethanol and carbon dioxide. Some heat is as well generated. Fermentation takes place in the absence of oxygen (anaerobic process).

Preparation from starch

Starch is heated with malt at a temperature of 60°C. Malt contains an enzyme diastase, which hydrolyses starch to maltose.

$\underset{\text{(Starch)}}{2C_6H_{10}O_5\ (aq)} + H_2O\ (l) \longrightarrow \underset{\text{(Maltose)}}{C_{12}H_{22}O_{11}\ (aq)}$

Yeast is added at room temperature to the mixture and left to ferment for 2-3 days. Yeast contains two enzymes, maltase and zymase. Maltase catalyses the hydrolysis of maltose to glucose as below.

$\underset{\text{(Maltose)}}{C_{12}H_{22}O_{11}\ (aq)} + H_2O\ (l) \longrightarrow \underset{\text{(Glucose)}}{2C_6H_{12}O_6}$

Zymase catalyses the breakdown of glucose into ethanol, carbon dioxide, producing heat in the process.

$C_6H_{12}O_6\ (aq) \longrightarrow 2C_2H_5OH\ (l) + 2CO_2\ (g) + \text{Heat}$

(Glucose) (Ethanol)

The crude ethanol produced can then be concentrated or purified by fractional distillation.

Preparation of ethanol from millet

- Millet flour is mixed with little water to form paste. The mixture is then put under ground for about 8 days.
- It is then removed, roasted and dried under the sun.The dried material is then mixed with germinated millet flour (yeast).
- Water is added and the mixture allowed to ferment for about 3 days in a warm place. This forms a local drink known as —Malwa.

Preparation of ethanol from ripe bananas

- Ripe bananas are squeezed to obtain the juice.
- The juice is filtered to remove the solid particle.
- The juice is mixed with roasted sorghum flour and the mixture allowed to ferment for 1-3 days in a warm place. A crude form of ethanol locally known as —Tonto is obtained.

Beer is made by the fermentation of the starch in barley; wine by the fermentation of sugars in grapes. Spirits are obtained by distillation of dilute solutions produced by fermentation and therefore have an increased alcoholic content.

Uses of ethanol

- It is used as an alcoholic beverage e.g. beers, wines and spirits
- It is used as a solvent for paints, varnishes etc.
- It is used as a fuel
- It is used as a preservative and for sterilization
- It is used as a thermometric liquid especially in minimum and maximum thermometers.