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Class 10th

Chapter 4

CARBON AND ITS COMPOUND

Carbon is an element. It is a non-metal. The amount of carbon present in the earth's crust and atmosphere is very small. all the living things, plants and animals, are made up of carbon-based compounds which are called organic compounds.

Bonding In Carbon – Covalent Bond

Elements forming ionic compounds achieve this by either gaining or losing electrons from the outermost shell. In the case of carbon, it has four electrons in its outermost shell and needs to gain or lose four electrons to attain noble gas configuration.

- **(i) It could gain four electrons forming C^{4-} anion. But it would be difficult for the nucleus with six protons to hold on to ten electrons, that is, four extra electrons.**
- **(ii) It could lose four electrons forming C^{4+} cation. But it would require a large amount of energy to remove four electrons leaving behind a carbon cation with six protons in its nucleus holding on to just two electrons.**

Carbon overcomes this problem by sharing its valence electrons with other atoms of carbon or with atoms of other elements.

Covalent Bond

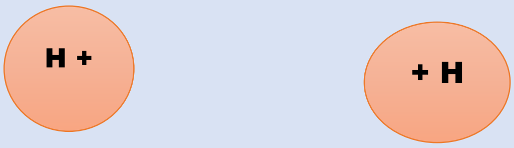
Such bonds which are formed by the sharing of an electron pair between two atoms are known as covalent bonds. Covalently bonded molecules are seen to have strong bonds within the molecule, but inter-molecular forces are weak. This gives rise to the low melting and

boiling points of these compounds. Since the electrons are shared between atoms and no charged particles are formed, such covalent compounds are generally poor conductors of electricity.

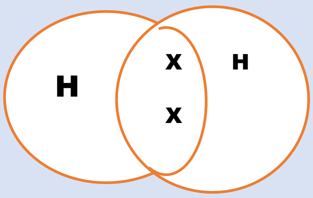
Single Covalent Bond

The atomic number of hydrogen is 1. Hence hydrogen has one electron in its K shell and it requires one more electron to fill the K shell. So two hydrogen atoms share their electrons to form a molecule of hydrogen, H2. This allows each hydrogen atom to attain the electronic configuration of the nearest noble gas, helium, which has two electrons in its K shell.

The shared pair of electrons is said to constitute a single covalent bond between the two hydrogen atoms. A single covalent bond is also represented by a line between the two atoms.



Hydrogen atom



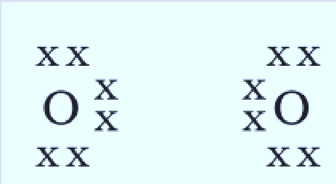
H_2 molecule

H —— H

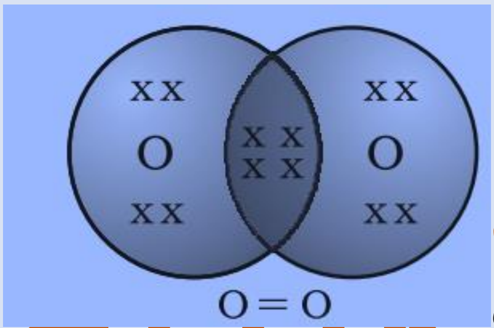
Double Covalent Bond

oxygen has six electrons in its L shell (the atomic number of oxygen is eight) and it requires two more electrons to

complete its octet. So each atom of oxygen shares two electrons with another atom of oxygen to give us the structure . The two electrons contributed by each oxygen atom give rise to two shared pairs of electrons. This is said to constitute a double bond between the two atoms .



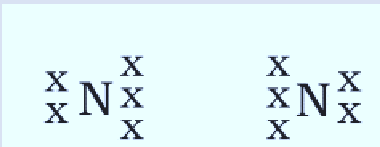
Oxygen atom

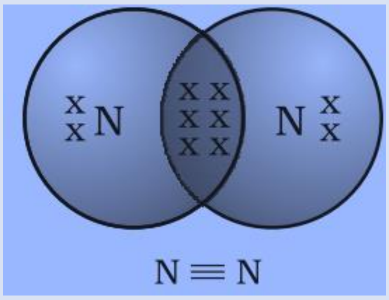


O_2 **MOLECULES**

<u>Triple Covalent Bond</u>

Nitrogen has the atomic number 7. What would be its electronic configuration and its combining capacity? In order to attain an octet, each nitrogen atom in a molecule of nitrogen contributes three electrons giving rise to three shared pairs of electrons. This is said to constitute a triple bond between the two atoms.





Allotropes of carbon

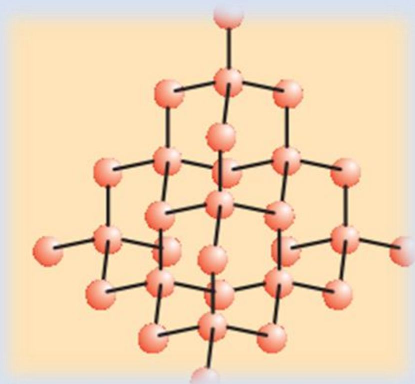
The various physical forms in which an element can exist are called allotropes of the element.

Diamond

In diamond, each carbon atom is bonded to four other carbon atoms forming a rigid three-dimensional structure.

Diamond is the hardest substance known.

Diamonds can be synthesised by subjecting pure carbon to very high pressure and temperature. These synthetic diamonds are small but are otherwise indistinguishable from natural diamonds

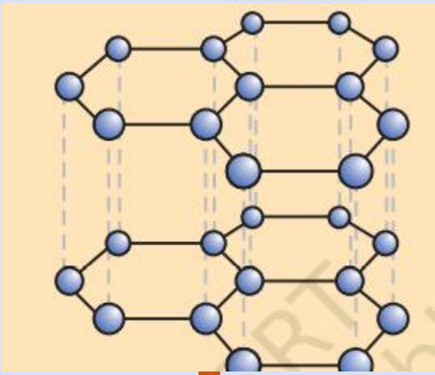


Graphite

In graphite, each carbon atom is bonded to three other carbon atoms in the same plane giving a hexagonal array. One of these bonds is a double-bond, and thus the valency

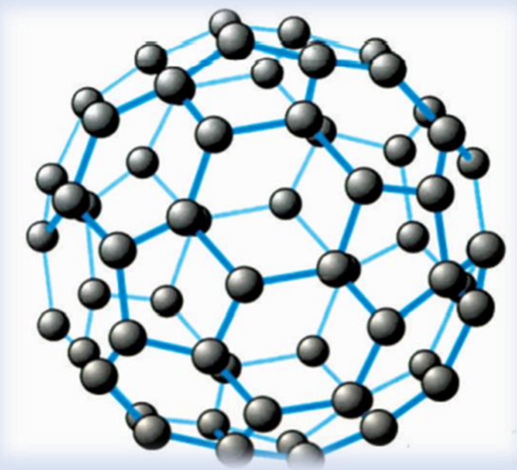
of carbon is satisfied. Graphite structure is formed by the hexagonal arrays being placed in layers one above the other.

graphite is smooth and slippery. Graphite is also a very good conductor of electricity unlike other non-metals.



Buckminsterfullerene

Buckminsterfullerene is an allotrope of carbon containing clusters of 60 carbon atoms joined together to form spherical molecules. Since there are 60 carbon atoms in a molecule of buckminsterfullerene, so its formula is C_{60} (C-sixty).



<u>**ORGANIC COMPOUNDS**</u>

The compounds of carbon are known as organic compounds. , most of the organic compounds contain hydrogen and many organic compounds contain oxygen or other elements. So, most of the organic compounds are hydrocarbons (containing only carbon and hydrogen), or their derivatives.

Some of the examples of organic compounds are : Methane (CH_4), Ethane (C_2H_6), Ethene (C_2H_4), Ethyne (C_2H_2), Trichloromethane ($CHCl_3$), Ethanol (C_2H_5OH), Ethanal (CH_3CHO), Ethanoic acid (CH_3COOH).

The two characteristic properties of carbon element which lead to the formation of a very large number of organic compounds (or carbon compounds) are :

(i) catenation
(ii) tetravalency (four valency).

1. **carbon atoms can link with one another by means of covalent bonds to form long chains (or rings) of carbon atoms. The property of carbon element due to which its atoms can join with one another to form long carbon chains is called 'catenation'.**

When carbon atoms combine with one another, three types of chains can be formed. These are :

(i) straight chains,

(ii)branched chains

(iii)closed chains or ring type chains

2. **Due to large valency of 4, a carbon atom can form covalent bonds with a number of carbon atoms as well as with a large number of other atoms such as hydrogen, oxygen, nitrogen, sulphur, chlorine, and many more atoms. This leads to the formation of a large number of organic compounds.**

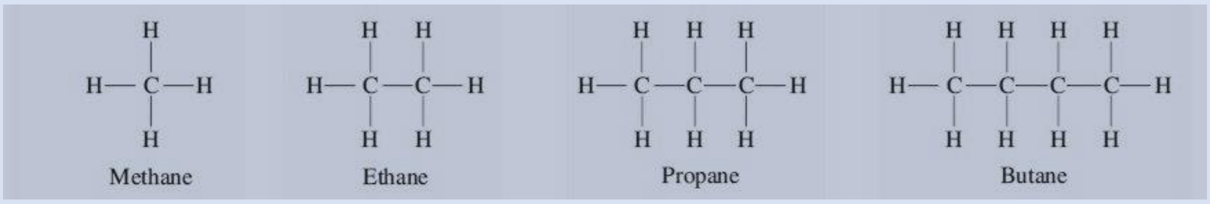
Saturated & Unsaturated Carbon Compounds

A compound made up of hydrogen and carbon only is called hydrocarbon.

Hydrocarbons are of two types:
Saturated hydrocarbons
Unsaturated hydrocarbons

Saturated hydrocarbons

A hydrocarbon in which the carbon atoms are connected by only single bonds is called a saturated hydrocarbon. Saturated hydrocarbons are also called alkanes. Methane (CH_4), ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}), are all saturated hydrocarbons which contain only carbon-carbon single bonds



Unsaturated hydrocarbons

A hydrocarbon in which the two carbon atoms are connected by a 'double bond' or a 'triple bond' is called an unsaturated hydrocarbon.
Ethene ($H_2C{=}CH_2$) and ethyne ($HC{\equiv}CH$) are two important unsaturated hydrocarbons, because ethene

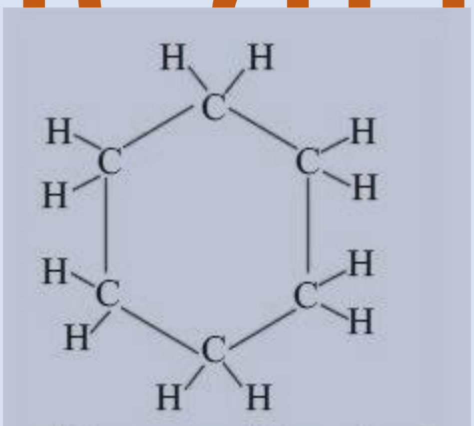
contains a double bond and ethyne contains a triple bond between two carbon atoms

Ethene (Contains a double bond)   Ethyne (Contains a triple bond)

There are some other hydrocarbons in which the carbon atoms are arranged in the form of a ring. Such hydrocarbons are called cyclic hydrocarbons. The cyclic hydrocarbons may be saturated or unsaturated.

A saturated cyclic hydrocarbon is ‘cyclohexane’

The formula of cyclohexane is C_6H_{12}. A molecule of cyclohexane contains 6 carbon atoms arranged in a hexagonal ring with each carbon atom having 2 hydrogen atoms attached to it.

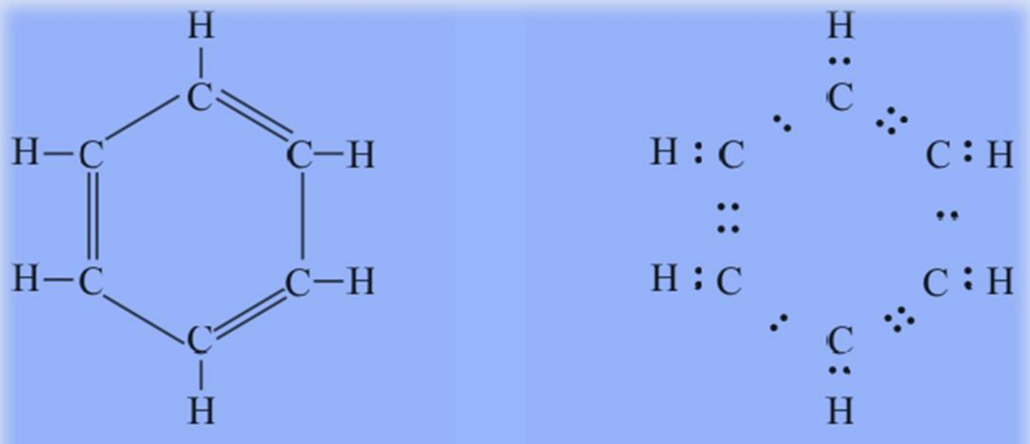


(*a*) Structural formula of cyclohexane, C_6H_{12}

An unsaturated cyclic hydrocarbon is ‘benzene’.

The formula of benzene is C_6H_6. A molecule of benzene is made up of 6 carbon atoms and 6 hydrogen atoms.
the electron-dot structure of benzene has been obtained by putting two electron dots in place of every single bond

and four electron dots in place of every double bond in its structural formula.



(*a*) Structural formula of benzene, C_6H_6

(*b*) Electron-dot structure of benzene, C_6H_6

All these carbon compounds which contain only carbon and hydrogen are called hydrocarbons.
Among these, the saturated hydrocarbons are called alkanes.
The unsaturated hydrocarbons which contain one or more double bonds are called alkenes.
Those containing one or more triple bonds are called alkynes.

FUNCTIONAL GROUPS

An 'atom' or 'a group of atoms' which makes a carbon compound (or organic compound) reactive and decides its properties (or functions) is called a functional group.

1. Halo Group : —X (X can be Cl, Br or I)

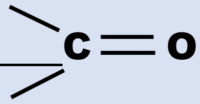
The halo group can be chloro, —Cl ; bromo, —Br ; or iodo, —I, depending upon whether a chlorine, bromine or iodine atom is linked to a carbon atom of the organic compound.

2. Alcohol Group : —OH

The alcohol group is made up of one oxygen atom and one hydrogen atom joined together. The alcohol group is also known as alcoholic group or hydroxyl group.

3. <u>Aldehyde Group : —CHO</u>

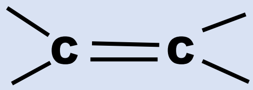
The aldehyde group consists of one carbon atom, one hydrogen atom and one oxygen atom joined together.

<u>4. Ketone Group :</u> 

The ketone group consists of one carbon atom and one oxygen atom. The oxygen atom of the ketone group is joined to the carbon atom by a double bond. The carbon atom of the ketone group is attached to two alkyl groups.

<u>5.Carboxylic Acid Group : —COOH</u>

Carboxylic acid group is present in methanoic acid, H—COOH and ethanoic acid, CH_3—COOH. The carboxylic acid group is also called just carboxylic group or carboxyl group.

<u>6. Alkene Group :</u> 

The alkene group is a carbon-carbon double bond. The alkene group is present in ethene ($CH_2=CH_2$), and propene ($CH_3–CH=CH_2$). The compounds containing alkene group are known as alkenes.

<u>7. Alkyne Group :</u> —C≡C —

The alkyne group is a carbon-carbon triple bond. The alkyne group is present in ethyne and propyne. The compounds containing alkyne group are known as alkynes.

HOMOLOGOUS SERIES

A homologous series is a group of organic compounds having similar structures and similar chemical properties in which the successive compounds differ by CH_2 group.

Homologous Series of Alkenes

The general formula of the homologous series of alkenes is C_nH_{2n} where n is the number of carbon atoms in one molecule of alkene.

1. **Ethene** C_2H_4
2. **Propene** C_3H_6
3. **Butene** C_4H_8
4. **Pentene** C_5H_{10}
5. **Hexene** C_6H_{12}

Homologous Series of Alkynes

The general formula of the homologous series of alkynes is C_nH_{2n-2} where n is the number of carbon atoms in one molecule of alkyne.

1. **Ethyne** C_2H_2
2. **Propyne** C_3H_4
3. **Butyne** C_4H_6
4. **Pentyne** C_5H_8
5. **Hexyne** C_6H_{10}

Nomenclature Of Carbon Compound

Naming a carbon compound can be done by the following method

- **Identify the number of carbon atoms in the compound.**

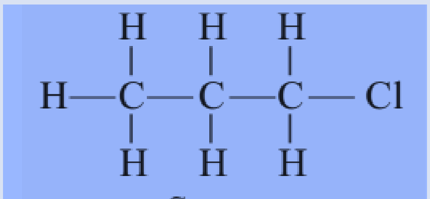
- In case a functional group is present, it is indicated in the name of the compound with either a prefix or a suffix
- If the name of the functional group is to be given as a suffix, and the suffix of the functional group begins with a vowel a, e, i, o, u, then the name of the carbon chain is modified by deleting the final ‘e’ and adding the appropriate suffix.
- If the carbon chain is unsaturated, then the final ‘ane’ in the name of the carbon chain is substituted by ‘ene’ or ‘yne’

Example

HALOALKANES

When one hydrogen atom of an alkane is replaced by a halogen atom, we get haloalkane.
The general formula of haloalkanes is C_nH_{2n+1}–X (where X represents Cl, Br or I).

C_3H_7Cl
This compound contains 3 carbon atoms so its parent alkane is propane. It also has a chloro group. So, the IUPAC name of C_3H_7Cl becomes chloropropane.

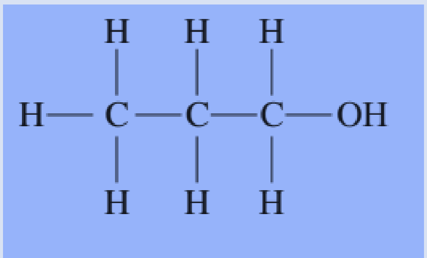


Structure

ALCOHOLS

The hydroxyl group attached to a carbon atom is known as alcohol group.
The general formula of the homologous series of alcohols is C_nH_{2n+1} —OH

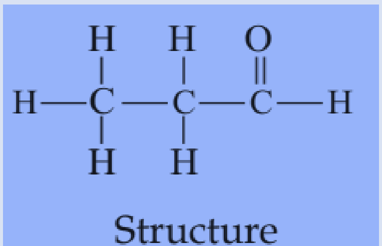
C_3H_7OH contains 3 carbon atoms, so its parent alkane is propane (C_3H_8). It also contains alcohol group (OH group) which is indicated by using ‘ol’ as ending. So, replacing the last ‘e’ of propane by ‘ol’, the name becomes propanol



Structure

ALDEHYDES
The general molecular formula of aldehydes is $C_nH_{2n}O$. Aldehydes are the compounds containing, —CHO group. Now, in the name ‘aldehyde’, the first two letters make ‘al’. So, the word ‘al’ is used as a suffix to show the presence of an aldehyde group in an organic compound.

CH_3CH_2CHO contains 3 carbon atoms so its parent alkane is propane. Now, CH_3CH_2CHO also contains an aldehyde group (–CHO group) which is indicated by writing ‘al’ as suffix or ending. So, by replacing the last ‘e’ of propane by ‘al’ we get the name propanal.

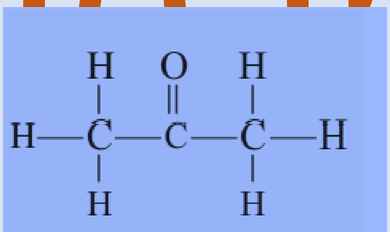


Structure

<u>KETONES</u>

The general molecular formula of ketones is $C_nH_{2n}O$.

CH_3COCH_3 contains 3 carbon atoms, so its parent alkane is propane (because propane also contains 3 carbon atoms). Now, CH_3COCH_3 also contains a ketone group (—CO— group) which is indicated by using ‘one’ as ending. So, by replacing the last ‘e’ of propane by ‘one’, we get the name propanone



Structure

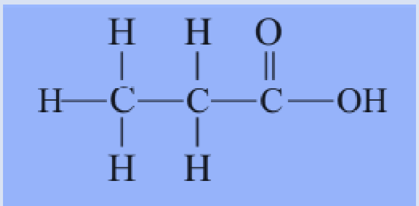
<u>CARBOXYLIC ACIDS</u>

The general formula of the homologous series of carboxylic acids is R— COOH where R is an alkyl group like methyl, CH_3, ethyl, C_2H_5, etc.

CH_3CH_2COOH

This compound contains 3 carbon atoms, so its parent alkane is propane. It also contains a carboxylic acid group (—COOH group). The name of this compound can be obtained by replacing the last ‘e’ of propane by ‘oic acid’

which gives us propanoic acid (propan + oic acid = propanoic acid).



Structure

CHEMICAL PROPERTIES OF CARBON COMPOUNDS

Combustion

The process of burning of a carbon compound in air to give carbon dioxide, water, heat and light, is known as combustion.
alkanes burn in air to produce a lot of heat due to which alkanes are excellent fuels.
carbon and its compounds are used as fuels because they burn in air releasing a lot of heat energy.
Saturated hydrocarbons will generally give a clean flame while unsaturated carbon compounds will give a yellow flame with lots of black smoke, limiting the supply of air results in incomplete combustion of even saturated hydrocarbons giving a sooty flame. The gas/kerosene stove used at home has inlets for air so that a sufficiently oxygen-rich mixture is burnt to give a clean blue flame.

Why do Substances Burn with a Flame or without a Flame

All the gaseous fuels burn with a flame but only those solid and liquid fuels which vaporise on heating (to form a gas), burn with a flame.

Flames are of two types : blue flame and yellow flame. When fuels burn, the type of flame produced depends on the proportion of oxygen (of air) which is available for the burning of fuel or combustion of fuel.

1. When the oxygen supply (or air supply) is sufficient, then the fuels burn completely producing a blue flame. This blue flame does not produce much light, so it is said to be non-luminous flame.

2. When the oxygen supply (or air supply) is insufficient, then the fuels burn incompletely producing mainly a yellow flame. The yellow colour of flame is caused by the glow of hot, unburnt carbon particles produced due to the incomplete combustion of fuel.

Formation of coal and petroleum

Coal and petroleum have been formed from biomass which has been subjected to various biological and geological processes. Coal is the remains of trees, ferns, and other plants that lived millions of years ago. These were crushed into the earth, perhaps by earthquakes or volcanic eruptions. They were pressed down by layers of earth and rock. They slowly decayed into coal. Oil and gas are the remains of millions of tiny plants and animals that lived in the sea. When they died, their bodies sank to the sea bed and were covered by silt. Bacteria attacked the dead remains, turning them into oil and gas under the high pressures they were being subjected to. Meanwhile, the silt was slowly compressed into rock. The oil and gas seeped into the porous parts of the rock, and got trapped like water in a sponge.

Substitution Reactions

The reaction in which one (or more) hydrogen atoms of a hydrocarbon are replaced by some other atoms (like chlorine), is called a substitution reaction.
Substitution Reaction of Methane with Chlorine.
Methane reacts with chlorine in the presence of sunlight to form chloromethane and hydrogen chloride:
$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ (in the presence of sunlight

Addition Reactions

The reaction in which an unsaturated hydrocarbon combines with another substance to give a single product is called an addition reaction. Addition reactions (like the addition of hydrogen, chlorine or bromine) are a characteristic property of unsaturated hydrocarbons.
Ethene reacts with hydrogen when heated in the presence of nickel catalyst to form ethane

$$CH_2 = CH_2 + H_2 \xrightarrow[\text{Heat}]{\text{Ni catalyst}} CH_3 - CH_3$$

ETHANOL (OR ETHYL ALCOHOL)

Properties of Ethanol

Ethanol is a liquid at room temperature. Ethanol is commonly called alcohol and is the active ingredient of all alcoholic drinks.
because it is a good solvent, it is also used in medicines such as tincture iodine, cough syrups, and many tonics.

Chemical Properties of Ethanol

Reaction with sodium

Alcohols react with sodium leading to the evolution of hydrogen. With ethanol, the other product is sodium ethoxide.

$$2C_2H_5OH + 2Na \longrightarrow 2C_2H_5O^{-}\ Na^{+} + H_2$$

When ethanol is heated with excess of concentrated sulphuric acid at 170°C (443 K), it gets dehydrated to form ethene

$$CH_3{-}CH_2OH \xrightarrow{\text{Conc.H SO ; 170°C}} CH_2{=}{=}CH_2 + H_2O$$

How do alcohols affect living beings

When large quantities of ethanol are consumed, it tends to slow metabolic processes and to depress the central nervous system.

This results in lack of coordination, mental confusion, drowsiness, lowering of the normal inhibitions, and finally stupor.

The individual may feel relaxed without realising that his sense of judgement, sense of timing, and muscular coordination has been seriously impaired.

Methanol is oxidised to methanal in the liver. Methanal reacts rapidly with the components of cells. It coagulates the protoplasm; in much the same way an egg is coagulated by cooking. Methanol also affects the optic nerve, causing blindness.

ETHANOIC ACID

1. Ethanoic acid is a colourless liquid having a sour taste and a smell of vinegar.
2. The boiling point of ethanoic acid is 118°C (391 K).
3. When pure ethanoic acid is cooled, it freezes to form a colourless, ice-like solid.
4. Ethanoic acid is miscible with water in all proportions.

Reactions of ethanoic acid:

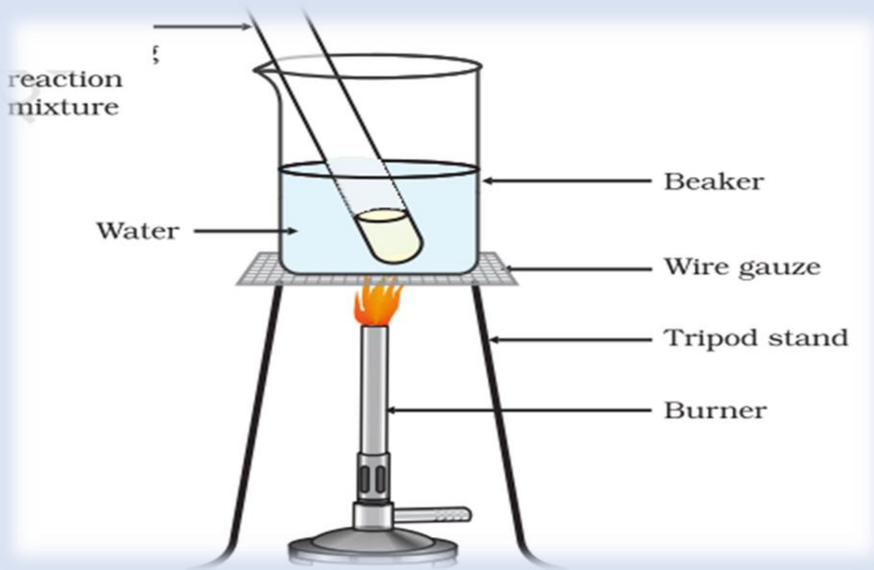
Esterification reaction:

Esters are most commonly formed by reaction of an acid and an alcohol. Ethanoic acid reacts with absolute ethanol in the presence of an acid catalyst to give an ester

Take 1 mL ethanol (absolute alcohol) and 1 mL glacial acetic acid along with a few drops of concentrated sulphuric acid in a test tube.
Warm in a water-bath for at least five minutes.
Pour into a beaker containing 20-50 mL of water and smell the resulting mixture

$$CH_3COOH + C_2H_5OH \xrightarrow{\text{Conc. } H_2SO_4} CH_3COOC_2H_5 + H_2O$$

Ethanoic acid   Ethanol   Ethyl ethanoate   Water



On treating with sodium hydroxide, which is an alkali, the ester is converted back to alcohol and sodium salt of carboxylic acid. This reaction is known as saponification because it is used in the preparation of soap. Soaps are sodium or potassium salts of long chain carboxylic acid

$$CH_3COOC_2H_5 + NaOH \xrightarrow{\text{Heat}} CH_3COONa + C_2H_5OH$$

Reaction with a base

Like mineral acids, ethanoic acid reacts with a base such as sodium hydroxide to give a salt (sodium ethanoate or commonly called sodium acetate) and water:

$$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$$

CH_3COOH	$NaOH$	CH_3COONa	H_2O
Ethanoic acid	Sodium hydroxide	Sodium ethanoate	Water

Reaction with carbonates and hydrogen carbonates:

Ethanoic acid reacts with carbonates and hydrogen carbonates to give rise to a salt, carbon dioxide and water. The salt produced is commonly called sodium acetate.

$$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$$

$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$$