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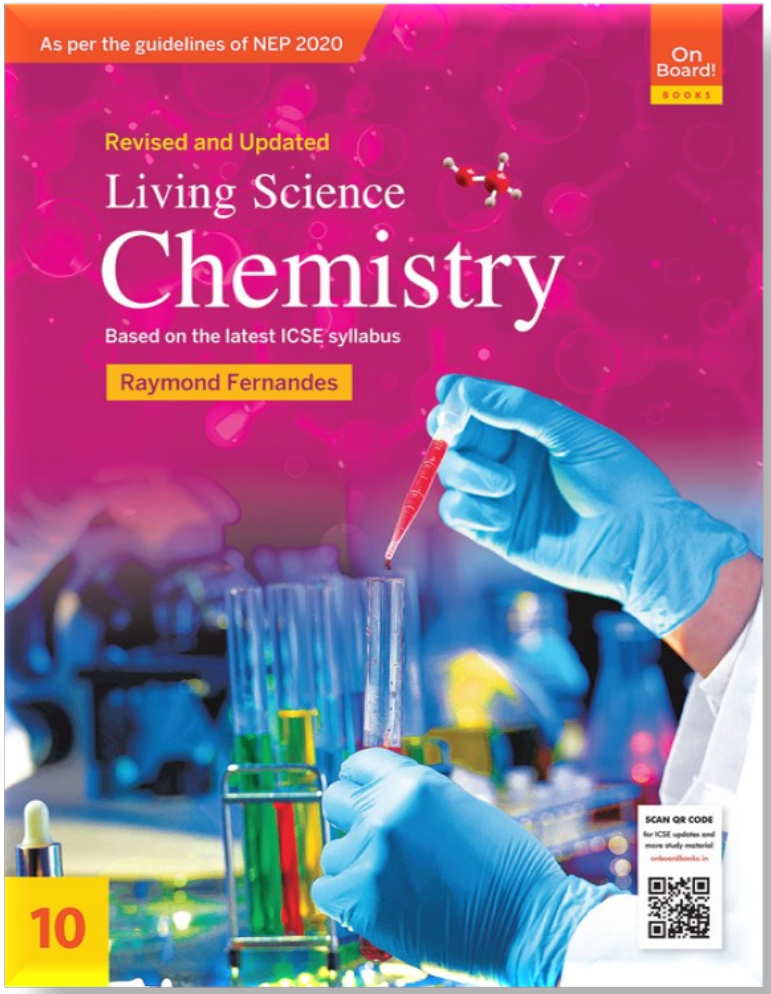
ICSE
Living Science
Chemistry

Class 10

Chapter-13 Organic Chemistry-II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On Board! BOOKS
Revised and Updated
Living Science
Chemistry
Based on the latest ICSE syllabus
Raymond Fernandes
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10

LEARNING OBJECTIVES

Alkanes

- Sources of alkanes
- Preparation of alkanes
- Properties of alkanes
- Uses of alkanes

Alkenes

- Sources of alkenes
- Preparation of alkenes
- Properties of ethene
- Uses of ethene

Alkynes

- Preparation of ethyne
- Properties of ethyne
- Uses of ethyne

Alcohols, Ethanol

Carboxylic acids

Chemical tests to distinguish alkanes, alkenes and alkynes

Alkanes

Alkanes are originally called paraffins because of their inertness towards usual laboratory reagents. They are saturated hydrocarbons with the general molecular formula C_nH_{2n+2}. The simplest hydrocarbon is methane. It is the first compound of the homologous series of alkanes.

Sources of alkanes

Lower alkanes are found naturally in association with coal and petroleum. Methane is the main constituent of marsh gas. A large number of hydrocarbons are present as a mixture in petroleum. Natural gas contains mainly methane, with smaller amounts of ethane, propane and butane.

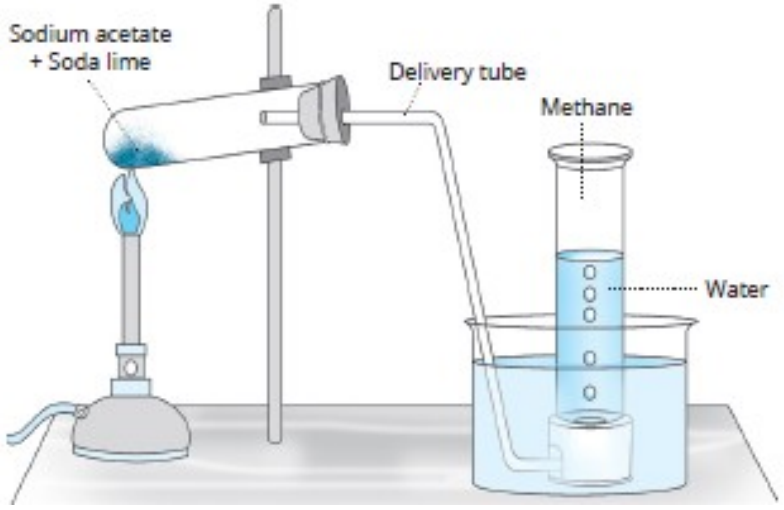
Preparation of alkanes

By the decarboxylation of acid salts

Methane: Methane is prepared in the laboratory by heating fused sodium acetate and soda lime in a hard glass test tube.

Reaction:

$$CH_3COONa + NaOH \xrightarrow[300\ ^\circ C]{CaO} CH_4 + Na_2CO_3$$



Collection of gas: The gas is collected over water, as it is insoluble in water. Calcium oxide is added to sodium hydroxide because sodium hydroxide is deliquescent.

The reaction is described as decarboxylation because the carboxyl group in sodium acetate is replaced by a hydrogen atom.

Ethane: Ethane is prepared in the laboratory by heating fused sodium propionate and soda lime in a hard glass test tube.

$$C_2H_5COONa + NaOH \xrightarrow[300\ ^\circ C]{CaO} C_2H_6 + Na_2CO_3$$

By reducing alkyl halides

When an alkyl halide is treated with zinc dissolved in dilute hydrochloric acid, nascent hydrogen is produced which reduces alkyl halides to the corresponding alkanes.

Iodomethane (methyl iodide) or bromoethane (ethyl bromide) is reduced by nascent hydrogen produced from Zn/HCl at ordinary room temperature.

$$\underset{\text{methyl iodide}}{CH_3I} + 2H \xrightarrow{Zn/HCl} \underset{\text{methane}}{CH_4} + HI$$

By Wurtz reaction

When alkyl halide (preferably bromide or iodide) is treated with metallic sodium in the presence of dry ether, an alkane with double the number of carbon atoms present in the alkyl group is formed. This reaction is called **Wurtz reaction**.

$$\underset{\text{methyl iodide}}{2CH_3I} + 2Na \xrightarrow{\text{dry ether}} \underset{\text{ethane}}{C_2H_6} + 2NaI$$

Methane cannot be prepared by this reaction. Alkanes containing odd number of carbon atoms like propane and pentane cannot be prepared by this method as a mixture of alkanes is produced which is difficult to separate.

Properties of alkanes

Physical properties

1. Lower alkanes like methane and ethane are colourless and odourless gases.
2. Alkanes are insoluble in water.
3. They dissolve readily in ether, benzene and petrol.
4. They float on water because they are lighter than water.
5. They are flammable.
6. Alkanes display isomerism from butane onwards.
7. The boiling and melting points of alkanes exhibit a regular increase with the increase in the number of carbon atoms.

Chemical properties

Alkanes do not react with concentrated acids, alkalis, oxidizing agents and reducing agents. However, by creating special condition of temperature, pressure and catalyst, alkanes can be made to undergo some useful reactions.

1. Pyrolysis of alkanes: Decomposition of a compound by the application of heat is called **pyrolysis**. Alkanes undergo pyrolysis at higher temperatures.

$$\underset{\text{Methane}}{2CH_4} \xrightarrow{1500\ ^\circ C} \underset{\text{acetylene}}{C_2H_2} + 3H_2$$

2. Combustion of alkanes: Alkanes undergo complete combustion in air to for carbon dioxide and water vapour.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

3. Catalytic oxidation: Different products are formed under different onditions: When a mixture of methane or ethane and oxygen (9 : 1 by volume) is passed through a copper tube at 200 °C, under a pressure of 120 atmospheres, corresponding alcohol is formed.

$$\underset{\text{Methane}}{2CH_4 + O_2} \xrightarrow[120\ \text{atm}]{\text{Cu tube at } 200\ ^\circ C} \underset{\text{methanol}}{2CH_3OH}$$

4. Substitution reactions: All saturated hydrocarbons undergo **substitution reactions**.

With methane

$$\underset{\text{methane}}{CH_4} + Cl_2 \xrightarrow{\text{UV light}} \underset{\text{methyl chloride}}{CH_3Cl} + HCl$$

With ethane

$$\underset{\text{ethane}}{C_2H_6} + Cl_2 \xrightarrow{\text{UV light}} \underset{\text{ethyl chloride}}{C_2H_5Cl} + HCl$$

Note: For more reactions see p. 232.

Uses of alkanes

1. Methane is mainly used as a fuel in the form of natural gas.
2. Methane can be used to make hydrogen, carbon black, carbon tetrachloride, acetylene and carbon disulphide.
3. Ethane is used as a fuel.
4. Ethane can also be used to prepare ethylene.

Methane

Methane does not allow the longwave infrared radiations radiating from the earth's surface to escape from the atmosphere. Thus, the heat of the earth is trapped in the atmosphere. This is called greenhouse effect. The resultant increase in earth's temperature is called global warming. Methane has a relatively short life time in the atmosphere (9–15 years), but its global warming potency is 20 times more effective than carbon dioxide (CO2) in trapping heat in the atmosphere, even though carbon dioxide is the most abundant greenhouse gas.

Methane concentration has increased considerably due to the following.

- Production and transport of fossil fuels
- Livestock like cattle and sheep
- Paddy fields
- Decay of organic wastes in landfills
- Coal mines, as well as oil and natural gas operations
- Biomass burning
- Wetlands

Alkenes

Alkenes are also called olefins which means oil-forming. Alkenes are unsaturated hydrocarbons containing a double covalent bond between the carbon atoms. Their general formula is C_nH_{2n}. The smallest alkene is ethene (C_2H_4). Alkenes do not occur free in nature because of their high reactivity. Alkenes are more reactive than alkanes due to the presence of a carbon-carbon doublebond

Sources of alkenes

Lower alkenes are found in minute quantities in coal gas. They are produced in large amounts by the cracking of petroleum.

Preparation of alkenes

By the dehydration of ethyl alcohol

Ethyl alcohol is mixed with concentrated sulphuric acid and heated to about 170 °C when the acid dehydrates the alcohol to form ethene.

$$C_2H_5OH \xrightarrow{\text{conc. } H_2SO_4 \text{ at } 170\ ^\circ C} H_2C{=}CH_2 + H_2O$$

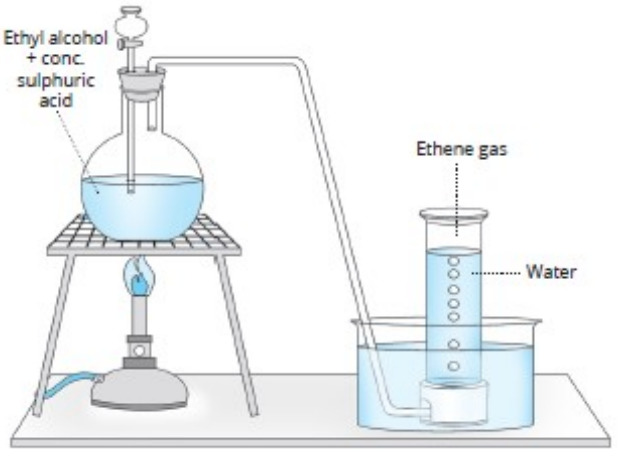
By the pyrolysis of ethane

When ethane is heated to 850 °C it forms ethene.

$$C_2H_6 \xrightarrow{850\ ^\circ C} C_2H_4 + H_2$$

By the dehydrohalogenation of alkyl halides

When an alkyl halide is heated gently in an alcoholic medium containing sodium hydroxide, it forms the corresponding alkene.



Properties of ethene

Physical properties

1. Ethene is a colourless and inflammable gas.

2. It boils at –102 °C and its melting point is –169 °C.

3. It has a sweet smell.

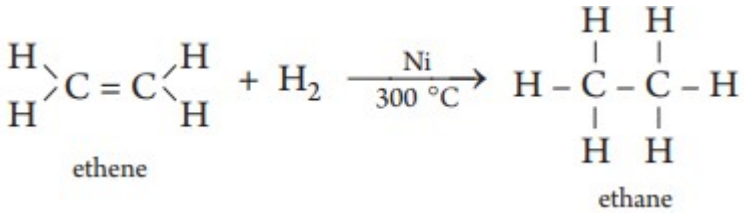
4. It is sparingly soluble in water but highly soluble in organic solvents.

5. When inhaled, ethene causes unconsciousness, i.e. it has anaesthetic effect.

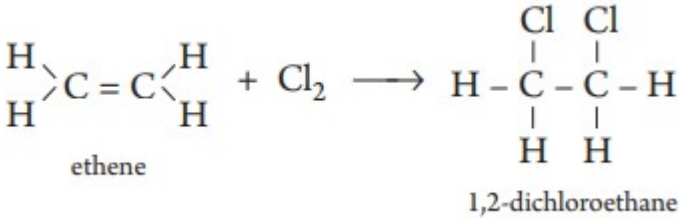
Chemical properties

1. **Addition reaction:** Being unsaturated, ethene undergoes addition reactions.

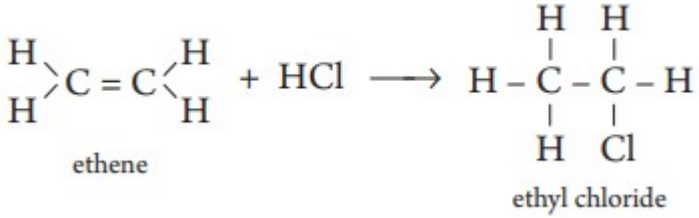
a. **Hydrogenation of ethene:** When vapours of ethene are mixed with hydrogen and passed over platinum or palladium at ordinary temperatures or nickel maintained at 300 ° C, two atoms of hydrogen molecule are added to the unsaturated molecu'



b. Addition of halogens: Ethene reacts with chlorine to form 1,2-dichloroethane. This reaction is carried out in carbon tetrachloride as a solvent. The order of the reaction with halogens is $F_2 > Cl_2 > Br_2 > I_2$.



c. Reaction of ethene with hydrogen chloride: Ethene reacts with hydrogen chloride at room temperature to form ethyl chloride. The order of reaction of hydrogen halides with alkanes is HI > HBr > HCl > HF.



d. Reaction with concentrated sulphuric acid: Ethene reacts with concentrated sulphuric acid to form ethyl hydrogensulphate. This reaction is important because on hydrolysis ethyl hydrogensulphate gives ethyl alcohol.

$$C_2H_4 + H_2SO_4 \longrightarrow C_2H_5{\cdot}HSO_4$$

$$C_2H_5{\cdot}HSO_4 + H_2O \longrightarrow C_2H_5OH + H_2SO_4$$

2. Oxidation

a. Combustion: Ethene burns in air with a smoky luminous flame forming carbon dioxide and water vapour.

$$C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O + \text{heat}$$

b. Reaction with potassium permanganate: Ethene decolourises cold alkaline potassium permanganate solution (Baeyer's reagent).

$$\underset{\text{ethene}}{H_2C = CH_2} + \underset{\substack{\text{cold alkaline}\\ KMnO_4 \text{ soln.}\\ \text{(oxidizing agent)}}}{H - OH + [O]} \longrightarrow \underset{\substack{\text{1,2-ethanediol}\\ \text{(ethylene glycol)}}}{\begin{matrix} H_2C - CH_2 \\ | \quad | \\ HO \quad OH \end{matrix}}$$

Note: This reaction is used as a test for unsaturation (Baeyer's test). Saturated hydrocarbons, can be distinguished from alkenes.

3. Polymerization

Polymerization is an addition reaction in which molecules of the same compound join together to form a single new compound when heated under pressure in the presence of a suitable catalyst.

Ethene yields the well-known polymer polythene.

$$n C_2H_4 \xrightarrow{\text{high pressure/ catalyst}} (-C_2H_4-)n$$

Uses of ethene

1. Major use of ethene is in the manufacture of polythene.
2. It is used in oxy-ethylene flame which is used for welding and cutting of metals.
3. It is used for artificial ripening of fruits such as mangoes, bananas, etc.
4. It is used in the manufacture of ethyl alcohol.
5. It is also used to manufacture ethyl benzene, which is later converted to synthetic rubber.

Alkynes

Alkynes are unsaturated hydrocarbons containing a carbon-carbon triple bond. Alkynes are also called acetylenes. Alkynes have the general formula of C_nH_{2n-2}. The first three members of the series are gases followed by liquids and solids. Alkynes are more reactive than alkenes and alkanes due to the presence of a carbon-carbon triple bond.

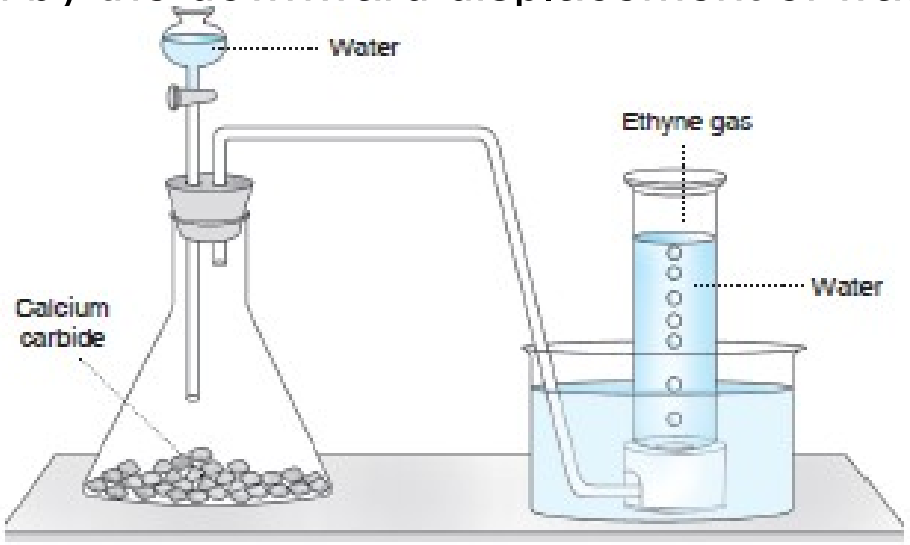
Preparation of ethyne

From calcium carbide

Ethyne is prepared by the action of water on calcium carbide.

$$CaC_2 + 2H_2O \rightarrow \underset{\text{ethyne}}{C_2H_2} + Ca(OH)_2$$

The gas is collected by the downward displacement of water as ethyne is insoluble in water.



From 1,2-dibromoethane

Ethyne of high purity can be obtained by the reaction of 1,2-dibromoethane and boiling ethanolic solution of potassium hydroxide.

Properties of ethyne

Physical properties

1. It is a colourless and odourless gas. Ethyne prepared from calcium carbide has garlic-like odour due to the presence of impurities like phosphine and hydrogen sulphide.

2. Acetylene boils at –84 °C.

3. It is sparingly soluble in water but soluble in organic solvents like alcohol and acetone.

4. Acetylene solution when stored in acetone under pressure is stable.

5. It is lighter than air.

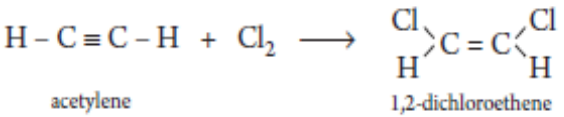
Chemical properties

1. Addition reaction

Like all unsaturated hydrocarbons, acetylene undergoes **addition reaction**. It undergoes addition reactions at triple bond in two steps.

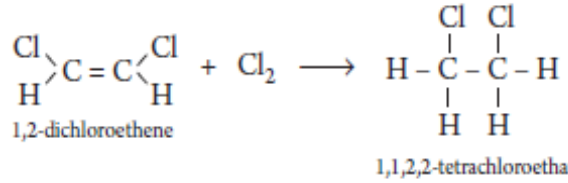
a. Hydrogenation of ethyne: In the presence of nickel as a catalyst, ethyne is heated to about 200 °C. It first adds on hydrogen to form ethane or ethylene and then goes on to form ethane on further addition of hydrogen.

b. Halogenation of ethyne: Ethyne also adds on halogens to form their di- and tetra- derivatives.

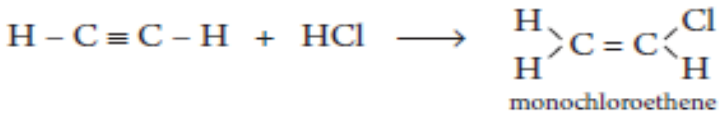


Reaction with chlorine

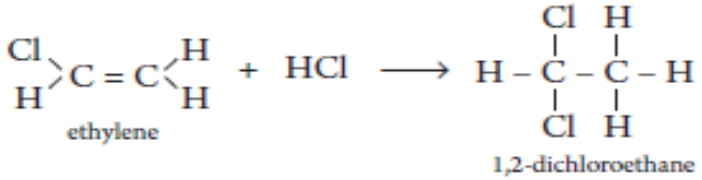
Acetylene in an inert solvent reacts with chlorine to give first dichloroethene and then tetrachloroethane.



Stage 1



Stage 2



c. Hydrohalogenation of ethyne: Hydrohalogenation takes place in two stages:

2. **Combustion**

Ethyne burns in air or oxygen with a sooty flame giving carbon dioxide and water.

$$2CH \equiv CH + 5O_2 \longrightarrow 4CO_2 + 2H_2O + \text{heat} + \text{light}$$

3. **Reaction with ozone:** Ethyne reacts with ozone at room temperature to form acetylene ozonide.

4. Polymerization reaction

When ethyne is passed through a red hot copper tube (873 K), three molecules of it combine to form benzene.

$$3C_2H_2 \xrightarrow{\text{red hot copper tube/ 873 K}} C_6H_6$$

ethyne — benzene

Note: For all reactions, please see p. 236.

Uses of ethyne

1. Ethyne is used in oxy-acetylene flames to cut and weld metals.
2. It is used in the manufacture of acetaldehyde and vinyl chloride.
3. It is used in the manufacture of synthetic fibres like polyacrylonitrile.
4. It is used in synthesis of industrial solvents such as trichloroethylene, tetrachloroethylene and carbon tetrachloride.
5. It is used for artificial ripening and preservation of fruits.

Alcohols

Alcohols are organic compounds containing the –OH functional group. The general formula of monohydric alcohols is $C_nH_{2n+1}OH$. Alcohols do not exist free in nature, they are often found with acids in esters. Ethyl alcohol or ethanol is by far the most important of all alcohols. It is commonly known as **alcohol**.

Ethanol

Preparation of ethanol: Industrial preparation

On a large-scale, ethanol is manufactured by fermentation of sugar and starch.

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

Laboratory preparation

Ethanol is widely available commercially and therefore its laboratory preparation is hardly of any consequence. Nevertheless, it can be prepared in the laboratory in the following ways:

1. Hydrolysis of ethyl iodide: The hydrolysis of ethyl bromide or ethyl iodide with dilute alkali like aqueous sodium hydroxide yields ethanol.

$$C_2H_5I + NaOH \longrightarrow C_2H_5OH + NaI$$

2. From hydrolysis of ethene: When concentrated sulphuric acid is added to ethene at 80 °C and 30 atmospheric pressure, ethyl hydrogensulphate is formed which on hydrolysis with boiling water forms ethanol. Similarly, ethanol is manufactured in the presence of phosphoric acid.

$$C_2H_4 + H_2SO_4 \xrightarrow[30\ atm]{80\,^\circ C} C_2H_5HSO_4$$

ethyl hydrogensulphate

$$C_2H_5HSO_4 + H_2O \xrightarrow{boiling} C_2H_5OH + H_2SO_4$$

Properties of ethanol

Physical properties

1. Ethanol is a colourless, inflammable liquid.
2. It dissolves in water in all proportions.
3. It boils at 78.3 °C.
4. It has a spirituous odour and burning taste.

Chemical properties

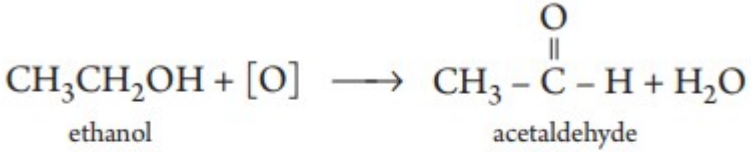
1. **Combustion:** Ethanol burns with a pale blue flame giving carbon dioxide and water vapour.

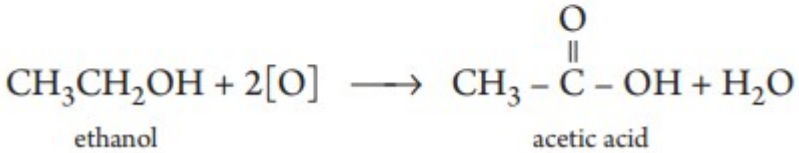
$$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

2. **Reaction with metals:** It reacts with metals like sodium and potassium to liberate hydrogen. This reaction is important because it is used as a reducing agent in organic chemistry

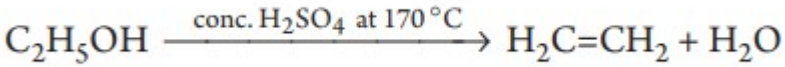
$$2C_2H_5OH + 2Na \longrightarrow \underset{\text{sodium ethoxide}}{2C_2H_5ONa} + H_2\uparrow$$

3. Oxidation in presence of oxidizing agents: Ethanol on controlled oxidation in the presence of acidified potassium dichromate or finely divided copper at 300 °C first forms acetaldehyde and then acetic acid.

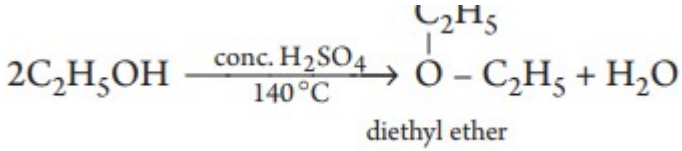




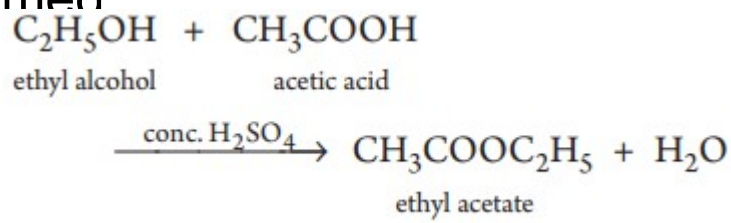
4. Reaction with concentrated sulphuric acid: Ethyl alcohol when mixed with concentrated sulphuric acid and heated to about 170 °C or when mixed with alumina at 350 °C forms ethylene.



If ethyl alcohol is in excess, then sulphuric acid at 140 °C dehydrates ethyl alcohol to give diethyl ether.



5. Reaction with acetic acid: Ethyl alcohol when reacts with acetic acid in the presence of concentrated sulphuric acid, a new type of organic compound called ester is formed



Uses of ethanol

1. Ethanol is an important solvent for resins, varnishes, soaps, perfumes, dyes and drugs.
2. It is used in the manufacture of other important organic compounds like acetaldehyde and chloroform.
3. It is used as a fuel.
4. It is used in alcohol thermometers because of its low freezing point.
5. It is present in many beverages.

Denatured alcohol

Ethyl alcohol is a good industrial solvent, it is also consumable. To prevent the misuse of commercial alcohol, it is mixed with poisonous substances like methanol and pyridine. This process is called **denaturing alcohol**.

Denatured alcohol is also called methylated alcohol. Consumption of denatured alcohol is extremely harmful; it causes blindness or death if consumed even in small doses. This denatured alcohol or spirit is called spurious or illicit alcohol.

Carboxylic Acids

All carboxylic acids contain the –COOH functional group. The name of this homologous series is derived by the conjunction of two words carbonyl and hydroxyl because the functional group consists of both these functional groups, i.e. C = O (carbonyl) and –OH (hydroxyl). The general molecular formula of this series is R-COOH. It can also be written as C*n*H2*n*+1COOH.

Acetic acid (Ethanoic acid)

The formula of acetic acid is CH_3COOH. A 5–8% solution of acetic acid in water is known as vinegar.

Preparation of acetic acid

1. From ethanol: In laboratory, acetic acid is prepared by the controlled oxidation of ethyl alcohol by concentrated sulphuric acid and potassium dichromate or sodium dichromate.

$$\underset{\text{ethanol}}{C_2H_5OH} \xrightarrow{[O]} \underset{\text{acetaldehyde}}{CH_3CHO} \xrightarrow{[O]} \underset{\text{acetic acid}}{CH_3COOH} + H_2O$$

Acetic acid can also be prepared by passing ethyl alcohol vapours over platinum black at 300 °C in the presence of oxygen.

$$C_2H_5OH + O_2 \xrightarrow[300\,^\circ C]{Pt} CH_3COOH + H_2O$$

2. From ethyne (or acetylene): Acetic acid can also be prepared from acetylene. Acetylene when passed through 42% sulphuric acid at 60 °C containing 1% mercuric sulphate gives acetaldehyde. This is oxidized to acetic acid by passing a mixture of air and acetaldehyde vapours over manganese acetate at 70 °C.

$$HC \equiv CH + H_2O \xrightarrow[HgSO_4]{H_2SO_4} H_3CCH = O \xrightarrow{[O]} CH_3COOH$$

Properties of acetic acid

Physical properties

1. Acetic acid is a colourless liquid.
2. It has a pungent smell.
3. It dissolves in water in all proportions.
4. It is hygroscopic and corrosive.
5. It melts at 17 °C and boils at about 120 °C.

Chemical properties

1.Reaction with carbonates and hydrogen carbonates: Acetic acid is a monobasic acid. It liberates carbon dioxide from carbonates and hydrogen carbonates.

$$2CH_3COOH + Na_2CO_3 \longrightarrow \underset{\text{sodium acetate}}{2CH_3COONa} + H_2O + CO_2\uparrow$$

$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + H_2O + CO_2\uparrow$$

2. Reaction with alkalis: It also neutralizes alkalis.

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

3. Reaction with metals: Acetic acid reacts with strongly electropositive metals, sodium and zinc to form respective acetates and liberate hydrogen.

$$2CH_3COOH + 2Na \longrightarrow \underset{\text{sodium acetate}}{2CH_3COONa} + H_2\uparrow$$

4. Reaction with alcohols: Acetic acid combines with alcohols to form sweet smelling esters in the presence of dehydrating agents like anhydrous zinc chloride or concentrated sulphuric acid. This phenomenon is called **esterification**.

$$CH_3COOH + C_2H_5OH \longrightarrow \underset{\text{ethyl ethanoate (ester)}}{CH_3COOC_2H_5} + H_2O$$

5. Reduction: Acetic acid is resistant to reduction, being unaffected by all reducing agents. However, it is reduced to ethyl alcohol by using lithium aluminium hydride.

$$CH_3COOH + 4[H] \xrightarrow{LiAlH_4} C_2H_5OH + H_2O$$

Uses of acetic acid

1. Acetic acid is used in the manufacture of cellulose acetate which is synthetic fibre, a film base in photography, etc.
2. It is also used as a solvent for making acetic anhydride, acetone and dyes.
3. It is used to coagulate rubber latex.
4. In dilute form, it is used as vinegar which is used for preserving and flavouring food. In the concentrated form, it is used as a solvent.
5. It is used in the form of organic esters as perfumes.

Chemical Tests to Distinguish Between Alkanes, Alkenes and Alkynes

1. Alkanes like methane and ethane will not decolourise bromine dissolved in carbon tetrachloride, whereas alkenes like ethene and alkynes like ethyne will decolourise bromine dissolved in carbon tetrachloride.
2. Alkenes will not show any characteristic reaction with ammoniacal cuprous chloride solution, whereas alkynes will form a red precipitate with ammoniacal cuprous chloride solution.

SUMMARY

1. Organic chemistry is the study of organic compounds.
2. The simplest organic compounds are hydrocarbons.
3. Hydrocarbons are compounds of carbon and hydrogen.
4. Formation of organic compounds is due to the bonding ability of carbon.
5. Carbon is a tetravalent element and can bond with four other elements or radicals.
6. Carbon can also bond with another carbon which leads to the formation of long chain compounds.
7. The general formula for alkanes is C_nH_{2n+2}.
8. Unsaturated double bonded hydrocarbons are called alkenes.
9. The general formula for alkenes is C_nH_{2n}.
10. The smallest member of the alkene family is ethene.
11. The structural formula of ethene is $H_2C = CH_2$
12. The common name for ethene is ethylene.
13. Unsaturated triple bonded hydrocarbons are called alkynes.
14. The general formula for alkynes is C_nH_{2n-2} .

15. The smallest member of the alkyne family is ethyne, also called acetylene.

16. The structural formula of acetylene is H – C ≡ C – H.

17. In a hydrocarbon, all hydrogens can be replaced by other elements or radicals.

18. These radicals are responsible for the change in properties of the hydrocarbon and such radicals are known as functional groups.

19. Examples of functional groups are as follows:

- Alkyl functional group $–CH_3$, $–C_2H_5$
- Halogen functional group –X [–F, –Cl, –Br, –I]
- Alcohol functional group –OH
- Aldehyde functional group –CHO
- Carboxylic acid functional group –COOH

20. Reactions in organic chemistry can be classified according to the carbon–carbon bonding.

- Saturated hydrocarbons undergo substitution reactions.
- Unsaturated hydrocarbons undergo addition reactions.

21. Laboratory preparation of hydrocarbons

- Methane from sodium acetate

$$CH_3COONa + NaOH \xrightarrow{CaO} CH_4 + Na_2CO_3$$

- Ethane from sodium propionate

$$C_2H_5COONa + NaOH \xrightarrow{CaO} C_2H_6 + Na_2CO_3$$

- Ethene from ethanol

$$C_2H_5OH \xrightarrow{\text{conc. } H_2SO_4 \text{ at } 170\ ^\circ C} H_2C = CH_2 + H_2O$$

This reaction occurs in the presence of concentrated sulphuric acid at 170 °C or Al_2O_3 at 350 °C.

- Acetylene from calcium carbide

$$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$$

THANK YOU