بسم اللہ الرحمن الرحیم

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Chemistry 10

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Appeal,

Balochistan Textbook Board is a dedicated organization committed to undertake publication of quality textbooks in line with the curriculum. These books are the fruits of efforts by renowned educationists and experts. Despite our constant endeavours, chances of inadvertent mistakes cannot be ruled out, and there is always room for improvement. Therefore, we look forward to valuable suggestions to enhance the quality of the textbooks.

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Preface

In continuation of the developing new text books that have the challenge to accept new challenges of new and modern era, the Chemistry 10 is here which has been designed to meet the needs of this changing world. This again is in according to new curriculum for courses which has been set by the Ministry of Education in 2006;

The new curriculum offers a radical shift from the traditional curriculum is based upon the multi text book system, creating the students being able to think independently, asking questions and looking for the answers at their own. The understanding of subject must be more developed in them rather than the traditional remembering procedures,

This chemistry '10' book is also the part of new curricula system, and has been written in very simple language, so the learner feel easy in understanding the basic concepts of chemistry, and cope with the challenging demands of the todays world.

Some of the main aims of this book are:

(i) Writing the chemistry in an easy and approachable mannar so the students from the remote and backward areas feel easy to understand the important ideas, concepts of the subject.

(ii) An overview of the basic principles involved in the subject.

(iii) Knowledge of the practical approach in the subject, for this purpose many activities and interesting informations have been introduced in the book.

(iv) Most of the topics also explain the role of chemistry tools in our society so the reader be able to understand the importance of the subject and its role for improving the life standard of us.

(v) There are also solved examples to guide the students how to cope with the problems on the topic.

(vi) Each chapter is accompanied with an exercise at the end to check the learing ability of the students.

As it is obvious that a text book can do nothing alone and the most important part of studies is the role of Teachers and Instructors , so the teachers are requested to apply the aims of this book in the light of the SLOs (Students learning objectives) which are stated at the beginning of each chapter, that describes the time to be allotted to each chapter, tests and assignments of the chapter and the main areas that they should focus on. At the end we are thankful to all those0 who helped us in writing this book, and made it possible for us to try to bring a change in the traditional education system.

We also appreciate for further suggestions from readers and educators to improve the quality of this text in future,

Thanking you all in anticipation.

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Contents

Chapter

9

CHEMICAL EQUILIBRIUM

Conceptual Linkage

Before reading this chapter, the student must know the:

- Representation of chemical reactions and chemical equation.
- Balancing of chemical equations.
- Basic mathematics.

Time Allocation

Teaching periods =08

Assessment periods =03

Weightage =05%

LEARNING OUTCOMES

Students will be able to:

- Define chemical equilibrium in terms of a reversible reaction. (Understanding)
- Write both the forward and the reverse reactions and describe the macroscopic characteristics of each. (Applying)
- Define law of mass action. (Understanding)
- Derive an expression for the equilibrium constant and its units. (Applying)
- State the necessary conditions for equilibrium and the ways that equilibrium can be recognized. (Understanding)
- Write the equilibrium constant expression of a reaction.

Introduction

The word "equilibrium" which is Latin origin literally means "balance of forces", This is the state when there seems no change in any system. e.g. a pencil which is kept on finger, when at rest is said to be in equilibrium state.

The equilibrium is generally of two types, the static equilibrium and the dynamic equilibrium. The static equilibrium is the type of equilibrium in which the different phases of equilibrium remain in the state of rest, e.g. in case of the fulcrum and fauna or the playground seesaw.

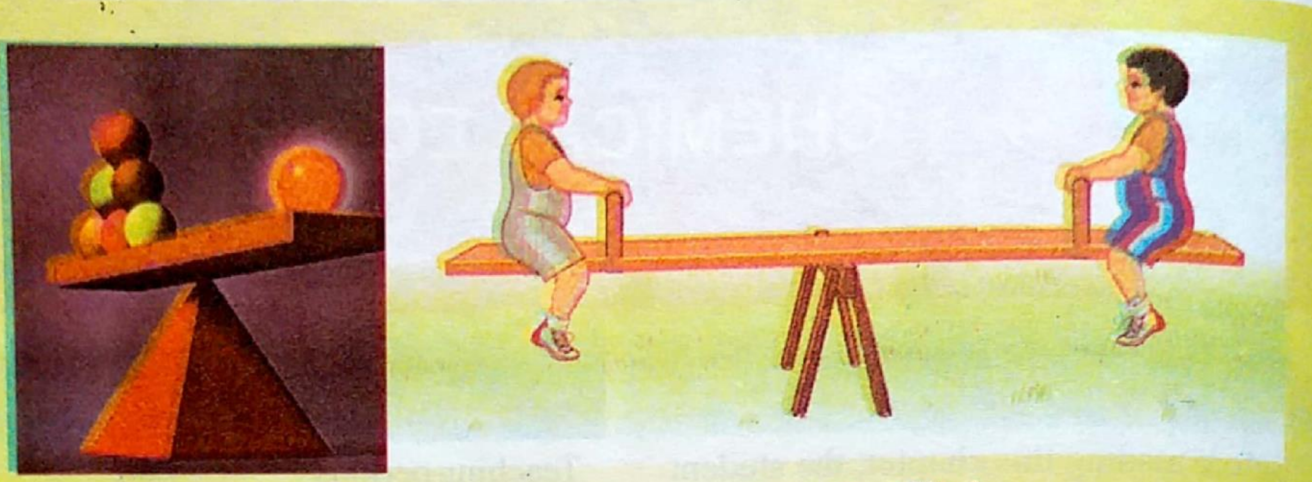


Fig.9.1: Common examples Static Equilibrium

The second type of equilibrium is the dynamic equilibrium which is the state of equilibrium in which the different phases readily interconvert in each other, for example during the vapour pressure the rate of evaporation and the rate of condensation remains equal so the net change in the system is zero and we say that the system is in equilibrium.

The chemical reactions are mostly reversible and the product of a chemical reaction can be transformed into the reactants through which they are formed. The general representation for such reversible chemical reactions is as:

$$A + B \rightleftharpoons C + D$$

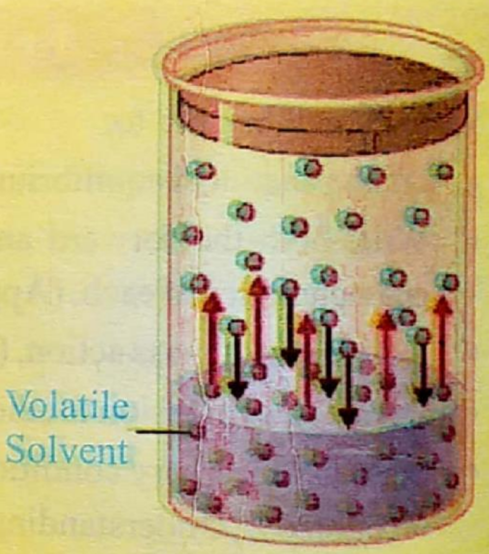


Fig. 9.2: Vapour Pressure of a volatile solvent, an example of dynamic equilibrium

Here 'A' and 'B' are initial reactants and 'C' and 'D' are the products. The double headed half arrow sign shows that change is taking place in both directions, such equilibrium where the rate at which the product C & D are produced is equal to the rate of reactants A & B are reproduced is called chemical equilibrium, e.g ammonia which is formed by the reaction between hydrogen and nitrogen, it can be again converted into its constituting elements i.e. the hydrogen and the nitrogen.

$$3H_{2(g)} + N_{2(g)} \longrightarrow 2NH_{3(g)}$$

$$2NH_{3(g)} \longrightarrow 3H_{2(g)} + N_{2(g)}$$

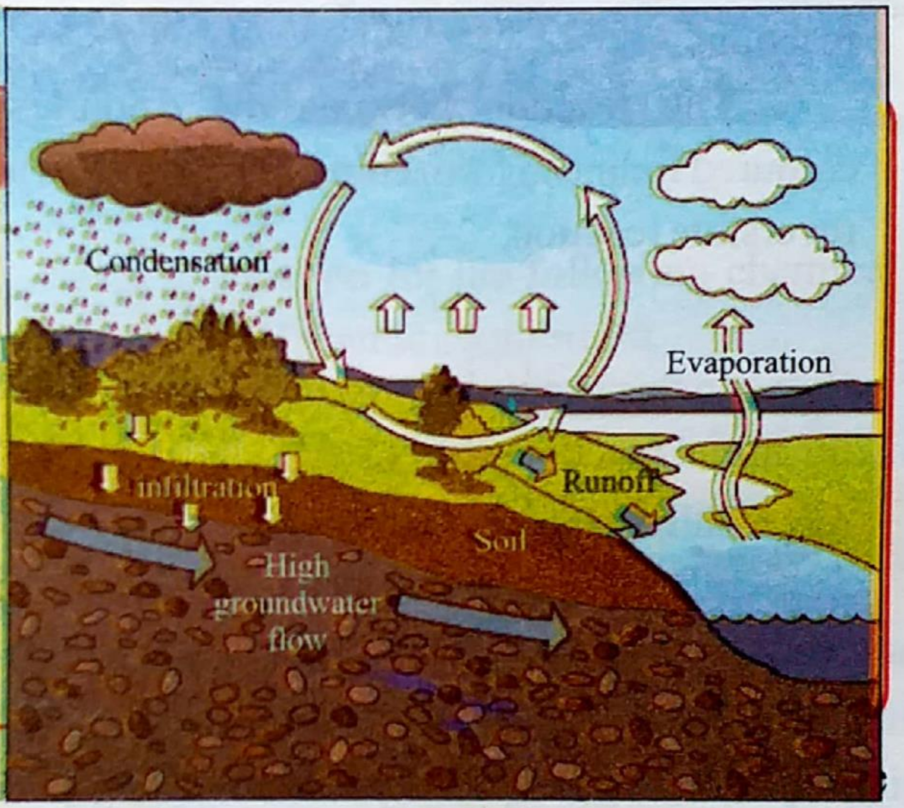
Collectively both these reactions are written as:

$$3H_{2(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

This special arrow sign "$\rightleftharpoons$" indicates that the reaction can proceed in both directions. The NH_3 produced is an important constituent of urea fertilizer.

Interesting Information

This is interesting to know that different stages in the natural water cycle and the other natural processes like nitrogen cycle, Carbon dioxide cycle, Ozone cycle etc exist in dynamic equilibrium.



Many of the chemical can be converted back into the initial reactants, and this is done by selecting suitable reaction conditions. There are many chemical reactions which can proceed in both the directions at almost the same conditions.

Another important example of such chemical reactions includes formation of NO_2 gas, which is reddish brown in colour from N_2O_4 gas (which is pale yellow).

$$\underset{\text{(Liquid)}}{\underset{\text{Pale Yellow}}{N_2O_{4(l)}}} \xrightleftharpoons{140^\circ C} \underset{\text{(Gas)}}{\underset{\text{Reddish Brown}}{2NO_{2(g)}}}$$

Such reversible chemical reaction is actually do exist in dynamic manner and all the species involved in chemical reaction readily interconvert in a fashion that the net change remains zero, so the equilibrium establishes in all these cases. Such systems are called chemical equilibrium.

9.1 Reversible reactions and Dynamic Equilibrium

As already described, the chemical reactions involve a unique type of equilibrium where the concentration of reacting species that include both the initial reactants and the products remain unchanged in a dynamic manner. This means that the reactants and the product of the reaction reunite to yield the corresponding species of the reaction. This can be easily understood by considering the following examples of reversible dynamic chemical reactions.

The reaction between the colourless hydrogen gas with purple coloured Iodine to form colourless hydrogen iodide is a good example of such reversible reaction.

$$H_{2(g)} + I_{2(g)} \underset{\text{Reverse Reaction}}{\overset{\text{Forward Reaction}}{\rightleftharpoons}} 2HI_{(g)}$$

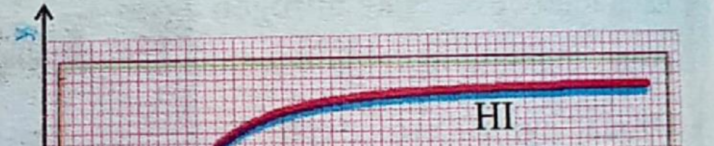


Fig. 9.3: Reaction between H_2 and I_2 showing equilibrium achievement

In this particular reaction the initial reactants the H_2 and I_2 react with each other to form HI. Subsequently, the product of this reaction decomposes and again converted into the initial used reactants i.e. the hydrogen and the Iodine. Hence this is the reversible reaction. A dynamic equilibrium establishes after a certain time. This can be seen in the graphical representation of the reaction in figure 9.3.

This is to be noted that at the point of equilibrium all three species of the reaction found in specific concentration. The reaction at this point does not stops but the all species of the reactio interconvert in a manner that their quantities remain unchanged and becaus the rate of forward reaction is equal to the rate of reverse reaction that is why this is called dynamic equilibrium.

Important example of such reactions is the formation of SO_3 from the oxidation of SO_2 gas,

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

This should be clearly understood that the all chemical reactions are reversible but the extent of their reversibility varies greatly for each type, and all reversible reactions show dynamic equilibrium.

Activity 9.1

Write down the balanced chemical equation for the following chemical compounds when they attain the state of dynamic equilibrium.

N_2 and O_2 N_2 and H_2 H_2 and I_2 NO and O_2 CO_2 and H_2

9.2 Law of mass action and Derivation of the expression for the equilibrium constant

Uptill now you have learnt that there exists a dynamic equilibrium between reactants and products during reversible chemical reactions, in 1864 two scientists Guldberg and Waage studied the relation of dynamic equilibrium between the quantities or concentration and put forwarded their research work as law of mass action, according to the law of mass action.

"The rate of a chemical reaction is directly proportional to the product of active masses (or concentration) of reactants at constant temperature".

e.g for a general reaction.

$$A + B \rightleftharpoons C + D$$

Here, two reaction are included, one is the forward phase in which A and B changes into C and D.

$$A + B \longrightarrow C + D$$

The second reaction is the reverse phase of the process which is actually the conversion of the product of the initial reaction the C and D into the reactants of the initial reaction, i.e. into A and B.

$$C + D \longrightarrow A + B$$

According to the law of mass action;

Rate of forward reaction = $(R_f) \alpha [A] [B]$

(Where sign "α" shows a direct relation among different species of the reaction, and [ ] shown the molar concentration.)

And the rate of reverse reaction = $(R_r) \alpha [C] [D]$

or it can be written as:

$$R_f = K_f[A] [B]$$

And

$$R_r = K_r [C] [D]$$

Where K_f and K_r are the proportionality constants.

At the dynamic equilibrium the rate of both the forward and the reverse reactions are equal.

$$R_f = R_r$$

or it can also be written as,

$$K_f [A] [B] = K_r [C] [D]$$

And by rearranging this:

$$\frac{K_f}{K_r} = \frac{[C][D]}{[A][B]}$$

Because K_f and K_r both are constant so they are combined to get one single constant, i.e.

$$\frac{K_f}{K_r} = K_c$$

Where K is the equilibrium constant and C is the molar concentration.

Therefore:

$$K_c = \frac{[C][D]}{[A][B]} \quad \ldots\ldots\ldots\ldots\ldots (i)$$

Where 'K_c' is called **equilibrium constant.**

For more general form, i.e.

$$aA + bB \rightleftharpoons cC + dD$$

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b} \quad \ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

Where 'a, b, c' and 'd' are written at the top of the brackets, are the reaction coefficients.

The equation (ii) is a general form for describing chemical equilibrium. But remember, in gaseous systems partial pressure of gases is taken which describes of their concentration in solutions. For this reason we substitute 'K_p' rather than 'K_c' in such gaseous systems, hence for:

$$aA_{(g)} + bB_{(g)} \rightleftharpoons cC_{(g)} + dD_{(g)}$$

The

$$K_p = \frac{\overbrace{(pC)^c(pD)^d}^{\text{Coefficient}}}{\underbrace{(pA)^a(pB)^b}_{\text{Coefficient}}}$$

Where 'p' is the partial pressure of any gas and 'K_p' represents equilibrium constant for gaseous systems where concentration is measured using partial pressure of gases.

9.3 Equilibrium constant and its units

The equilibrium constant actually tells us the concentration of different species of the reaction at both the reactant and the product sides of the reaction, it is denoted by the symbol "K_c" and by some simple calculations we can get easily the information about the constitution of any chemical reaction at the time of equilibrium.

$$K_c = \frac{\text{Product of the concentration of products raised to the power of coefficient}}{\text{Product of the concentration of reac tan ts raised to the power of coefficient}}$$

This not only helps us in calculating the concentration of species of a chemical reaction but with some suitable applications we can enhance the quantity of the desired species of a reversible chemical reaction.

The equilibrium constant (K_c) depends upon the temperature, and if temperature is changed its value also changes, but its value does not depends upon the initial concentration of reactants or products.

Because the equilibrium constant (K_c) is a ratio and likewise all the other ratios, it also have no units, (as all the units in both the reactant(s) and the product(s) are same and are cancelled by each other in the expression). e.g. in the reaction between H_2 and I_2.

$$H_{2(g)} + I_{2(g)} \xrightleftharpoons{450^{\circ}C} 2HI_{(g)}$$

$$K_c = \frac{[HI]^2}{[H_2][I_2]}$$

$$\text{Units} = \frac{\cancel{(\text{mol dm}^{-3})^2}}{\cancel{(\text{mol dm}^{-3})}\cancel{(\text{mol dm}^{-3})}} = \textbf{No units}$$

Thus K_c has no units in this case.

In case when the number of moles of reactants and products are not equal then K_c has units. e.g. for the reaction between N_2 and H_2 to form NH_3.

$$N_{2(g)} + 3H_{2(g)} \xrightleftharpoons{450^{\circ}C} 2NH_{3(g)}$$

In this case, the units will be:

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

And

$$\text{Units} = \frac{(\text{mol dm}^{-3})^2}{(\text{mol dm}^{-3})(\text{mol dm}^{-3})^3} = \frac{1}{(\text{mol dm}^{-3})^2} = (\text{mole dm}^{-3})^{-2}$$

Thus in this case it has some units too, it means that the units of K_c varies from case to case.

9.4 Importance of Equilibrium constant

The equilibrium constant has many applications in chemistry. The value of K_c is used to calculate many important phenomenon of the reversible reactions used in industries, e.g. it is used to calculate the amount of reactants or products of a reversible chemical reactions of industrially important compounds like sulphuric acid (H_2SO_4), nitric acid (HNO_3), urea or $CO(NH_2)_2$. For example in the preparation of NH_3 gas which is used in synthesis of urea fertilizer, the reaction is:

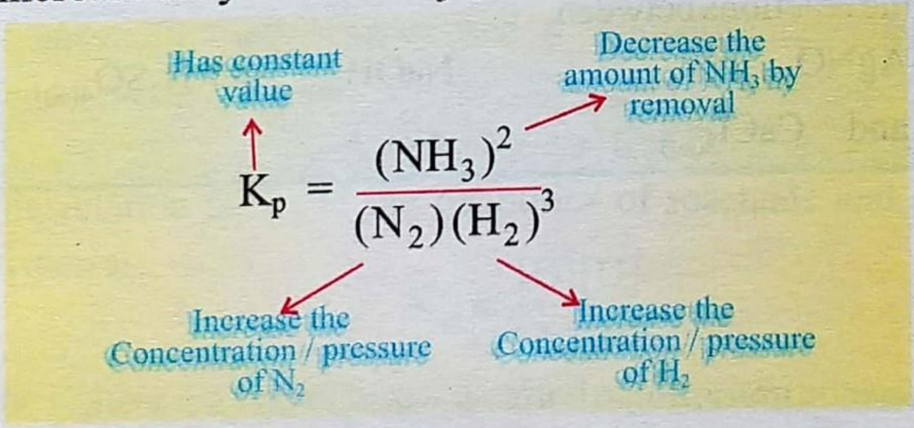
$$N_{2(g)} + 3H_2 \xrightleftharpoons{450^{\circ}C} 2NH_{3(g)}$$

to increase amount of NH_3 gas the knowledge of 'K_c' is used, according to which the concentrations of N_2 or H_2 or both has to be increased or concentration of NH_3 has to be decreased which result in the formation of more NH_3 and hence more urea can be formed.

In this process 'K_c' or more properly 'K_p' is:

$$K_p = \frac{(NH_3)^2}{(N_2)(H_2)^3}$$

So, to increase the yield of 'NH_3' gas we can do the following steps:



K_c is also used to predict the direction of a chemical reaction, and after a specific time period the extent of a chemical reaction. When the value of equilibrium constant is known which is done experimentally, it is used in many ways. For example, if the value of 'K_c' is very high for a reaction, it means that the desired product can be easily made from this reaction, as the concentration of the products is very high at the time of equilibrium, which makes the 'K_c' very high.

Similarly, if the 'K_c' is very low for a given reaction, it means that the concentration of the initial reactants is high at the time of equilibrium of a reaction, so it means that the reaction is not feasible.

The knowledge of equilibrium constant expression is used to calculate and enhance the yield of products in the field of many of industrially important compounds like H_2SO_4, HNO_3, Urea etc are prepared through the chemical reactions which are reversible, in all such cases the application of some simple rules of Science increases the yield of these chemical reactions up to a great extent, and hence expenditure of the preparation decreases as a result of which the prices of the products can be controlled to a desired level.

The value of 'K_c' is also helpful in calculating the effect of changing the conditions upon a chemical reaction, and hence the yield of a chemical reaction can be controlled.

Activity 9.2

Write down the balanced chemical equation and equilibrium constant expression for the reactions between,

$NaCl_{(aq)}$ and $AgNO_{3(aq)}$

$NaOH_{(aq)}$ and $H_2SO_{4(aq)}$

$(NH_4)_2CO_{3(aq)}$ and $CaCl_{2(aq)}$

Summary of the Chapter

- A system is said to be in the state of equilibrium when there seems no change in that system.
- The Equilibrium is basically of two types, the static equilibrium and the dynamic equilibrium.
- When the different states or phases of an equilibrium established system do not move and remain constant at a place, such equilibrium is called static equilibrium e.g. Fulcrum and Fauna equilibrium and the equally balanced playground seesaw etc.
- A dynamic equilibrium is that type of equilibrium when different constituents of the system change in the manner that there occurs no change in the overall process.
- Most chemical reactions are reversible but tendency of reversibility varies for each system and equilibrium establishes in all these.
- The type of equilibrium in the chemical processes is of dynamic nature.
- In the state of dynamic equilibrium of a chemical reaction, there exists a simple relation between the concentration of reactants and the products, this relation can be represented by an equation.
- The Rate of a chemical reaction is directly proportional to the product of active masses (or concentration) of reactants, this statement is called Law of mass action and was proposed by Guldberg and Waage in 1864.
- For a general reaction

$$A + B \longrightarrow C + D$$

The relation between the quantities of reactants and products can be written as,

$$K_c = \frac{[C][D]}{[A][B]}$$

The K_c here is a constant and is called equilibrium constant.

- The Value of K_c can be used to predict the concentration of any reactant or product of a system which is at dynamic equilibrium.

Exercise

Q1: Fill in the blanks.

i) There are .... types of equilibrium.

ii) Vapour pressure is an important example of .... equilibrium.

iii) The equilibrium constant shows .... of products and reactants in a dynamic chemical process.

iv) All chemical reactions show .... type of equilibrium.

v) The Law of mass action was put forward by .... in ....

vi) All natural cycles show .... type of equilibrium.

vii) NH_3 gas is used for manufacture of .... fertilizer.

viii) In gaseous systems the .... is taken in consideration instead of concentrations.

ix) The value of K_c is .... of initial concentrations of reactants.

x) In the gaseous systems .... is replaced by K_p.

Q2: Tick the correct answer from the given list.

i) The types of equilibrium found in nature could be of

(a) 2 (b) 3 (c) 4 (d) 5

ii) The type of equilibrium found in fulcrum and fauna is

(a) Static (b) Dynamic

(c) Depends on conditions (d) Shows no equilibrium

iii) Most chemical reaction show

(a) Reversibility (b) Static equilibrium

(c) Heat energy (d) Pressure

iv) The value of K_c is dependent upon the

(a) Only on initial concentration of reactants

(b) Only on initial concentration of products

(c) Final concentration of reactants

(d) Does not depends upon initial concentration of reactants and products

v) The value of K_c can be used

(a) To increase the products of a chemical reaction.

(b) To predict the reaction pathway

(c) To reduce the heat supply of system

(d) To calculate the pressure of system

vi) The K_c is obtained by the data of

(a) initial concentration of reactants

(b) Initial concentration of products

(c) Concentration of both the reactants and the products at equilibrium state.

(d) Final concentration of products.

vii) The Value of K_c depends upon:

(a) Temperature of system

(b) Pressure of system

(c) Initial concentration of reactants

(d) Concentration of reactants and products at equilibrium

viii) Pressure of system effects the equilibrium of

(a) Liquids (b) Solids

(c) Gases (d) All of these

ix) The Carbon dioxide cycle involves

(a) Static equilibrium

(b) Dynamic equilibrium

(c) Does not related with equilibrium

(d) Related with atmospheric pressure

x) If for the general reaction

$A+B \rightleftharpoons C+D$

increase in concentration of D will result in the:

(a) Decrease in concentration of A

(b) Decrease in concentration of B
(c) Decrease in concentration of C
(d) Increase in the concentration of A and B.

Q3: Answer the following questions briefly.

i) What types of equilibrium are there in nature?
ii) Write down the equilibrium constant expression for the reaction.

$$NH_{3(g)} + HCl_{(g)} \rightleftharpoons NH_4Cl_{(s)}$$

iii) What are the units of K_c?"
iv) Explain the term Dynamic equilibrium?"
v) Define the term 'rate of a chemical reaction'.

Q4: What do you understand by the equilibrium?" Describe the types of equilibrium with examples.

Q5: Explain the reversible reaction with examples.

Q6: Describe the law of mass action and derive an expression for the equilibrium constant.

Q7: What do the K_c means? Explain its importance and applications.

Q8. In the reaction between:

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

How you can increase the production of So_3?

Chapter

10

ACIDS, BASES, AND SALTS

Conceptual Linkage

Before reading this chapter, the student must know the:

- Types of matter.
- Difference between elements and compounds.
- Molecular formulae and chemical equations.

Time Allocation

Teaching periods = 16
Assessment periods = 03
Weightage = 07%

LEARNING OUTCOMES

Students will be able to:

- Define and give examples of Arrhenius acid and bases. (Understanding)
- Use of Bronsted-Lowry theory to classify substances as acids or bases, or as proton donors or proton acceptors. (Applying)
- Classify substances as Lewis acids or bases. (Analyzing)
- Write the equation for the self-ionization of water. (Remembering)
- Given the hydrogen ion or hydroxide ion concentration, classify a solution as neutral, acidic, or basic. (Applying)
- Complete and balance a neutralization reaction. (Applying)

Introduction

Acids, bases and salts are the three main categories of chemical compounds. They show very interesting characters. Acids, bases and salts are very common chemical compounds that we use frequently in many ways in our daily life. Most of the citrus as well as the fruit that is not ripen fully contain acids and their sour taste gives a peculiar taste to each fruit.

Not only the acids but bases also constitute some important fraction of our daily life usage. The soft drinks contain base sodium bicarbonate ($NaHCO_3$) which is used to reduce the acidity level of stomach. The salts which constitute another very important class of chemical compounds are formed when an acid reacts with some base. For example, the typical table salt NaCl results by the reaction of NaOH and HCl.

$$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

Other salts are also formed by such similar chemical reactions.

Other common examples include Epsom salts($MgSO_4$), used as purgative in medicines, ammonium nitrate (NH_4NO_3) used as fertilizer, sodium carbonate ($Na_2CO_3.10H_2O$) which is used in washing cloths and baking soda ($NaHCO_3$) used in cooking. Moreover KNO_3 which is seen as white precipitates on salty (callar) soils is also a salt. Remember that these are just few examples of common salts and there found thousands other salts and are used in many ways.

In this chapter we will study these three important and common classes of chemical compounds in detail.

10.1 Concepts of Acids and Bases

The acids and bases are although common chemical compounds, and unlike our general concept that they are very corrosive and dangerous when touched (especially the acids which are considered very corrosive) they are commonly used in our daily life as well as in our daily diet.

Many scientists tried to explain these compounds in different ways, which will be discussed in following section in detail.

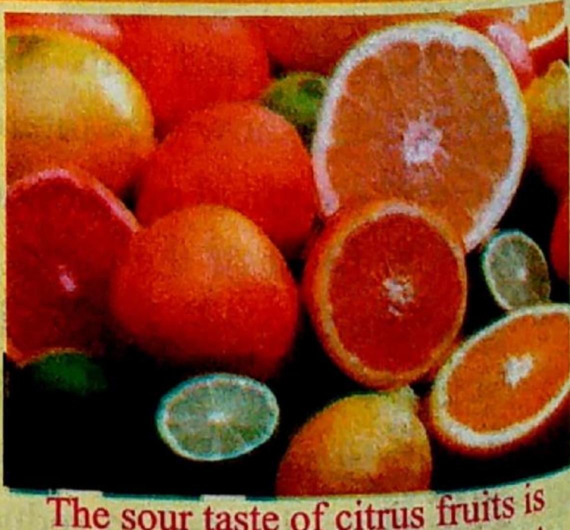
The Acids

The word "acid" comes from the Latin "acidus" meaning "sour" and they have got this name due to their sour taste. The acids in general have the following characteristics.

- **Acids taste sour**

You taste many acids in your daily life, e.g. acetic acid is the acid ingredient

Interesting Information



The sour taste of citrus fruits is due to natural acids such as citric acid and ascorbic acid.

in vinegar. Citrus fruit such as lemons, grapefruit, orange, and limes have citric acid in their juices. Sour milk, sour cream, yogurt, and cottage cheese have lactic acid which is formed by the fermentation of the lactose sugar present in the milk.

- **Acids turn blue litmus red**

Litmus is one of a large number of organic compounds that change colour when a solution changes acidity. Litmus is the oldest known pH indicator. It is red in acid and blue in base. Litmus is often impregnated onto paper to make 'litmus paper.'

- **Acids corrode active metals**

Even gold, the least active metal, is attacked by an acid. A mixture of acids called 'aqua regia,' or 'royal liquid.' You may have seen the effect of corroded metal by leakage of build from battery of car. When an acid reacts with a metal, it produces a compound with the cation of the metal and the anion of the acid and hydrogen gas.

When acids are mixed in water they can pass electricity easily. This is because acids ionize water and due to presence of ions the electricity can pass easily.

Contrarily, the bases have the following important characteristics

- **Bases taste bitter**

Although the bases are bitter in taste but when we eat or drink, we use their dilute solutions mixed with flavouring agents that is why we do not feel their bitter taste.

- **Bases turn red litmus blue**

Contrary to acids, when litmus paper or solution is treated with a base it turns into blue colour from red.

- **They have slippery touch**

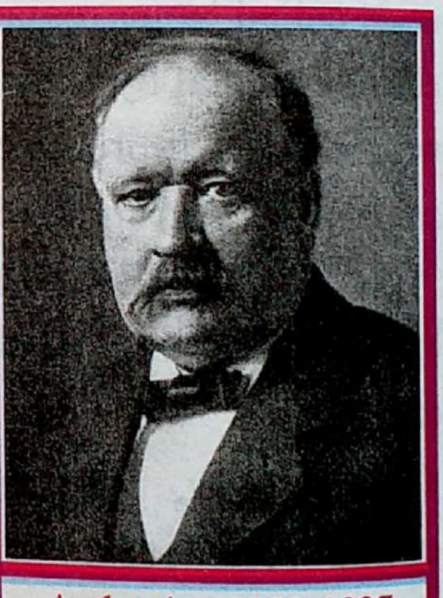
You can feel the slippery touch of bases when their dilute solutions are handled. (but remember the strong concentrated solutions of these are corrosive and must not be touched directly.) soap has slippery touch due to presence of base.

Considering these characters of acids and bases different scientists explained the acids in different ways, the important of these concepts are explained in following.

10.1.1 Concepts of Acids and Bases

Although the general properties for the acids and bases are described in the previous pages, but these do not define the terms acids and the bases in a satisfactory manner. To describe the nature of the acids and bases, different scientists proposed theories of acids and bases on different occasions. The three important theories are as follows.

The Arhenius concept of Acids and Bases



Arrhenius 1859-1927
(Swedish)

In 1884, a Swedish chemist Svante Arrhenius described that acid is a hydrogen containing compound which can gives hydrogen ion (H^+) in aqueous solution. For example, Hydrochloric acid (HCl) gives H^+ ion in its aqueous solution.

$$HCl_{(aq)} \xrightleftharpoons{H_2O} H^+_{(aq)} + Cl^-_{(aq)}$$

As water accepts H^+ ion, it forms H_3O^+, so this reaction can also be written in the following manner.

$$HCl_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)}$$

Similarly, the H_2SO_4 is an acid, because it also furnishes H^+ ion to water, as described in following reaction.

$$H_2SO_{4(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + HSO^-_{4\,(aq)}$$

And HNO_3 is also an acid because it gives hydrogen ions H^+ when dissolved in water.

$$HNO_{3(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + NO^-_{3(aq)}$$

Arrhenius defined, bases are the substances that produce OH^- ions when dissolved in water. e.g. NaOH is a base because it produces OH^- ions when it is dissolved in water.

$$NaOH_{(s)} \xrightleftharpoons{H_2O} Na^+_{(aq)} + OH^-_{(aq)}$$

The Arrhenius concept of acids and bases explains both these two common classes relatively in simple form. The theory explains many common acidic and basic compounds and also explain how acid and base react with each other yielding a neutral product called salt.

$$\underset{\text{Acid}}{HCl_{(aq)}} + \underset{\text{Base}}{NaOH_{(s)}} \longrightarrow \underset{\text{Salt}}{NaCl_{(aq)}} + H_2O_{(l)}$$

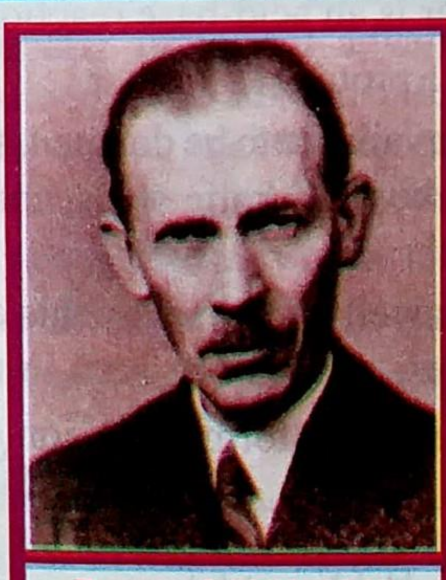
Although the Arrhenius theory helped to explain acids and bases in a simple way, there were still several drawbacks in this theory, like:

i) The theory can only classify these substances when dissolved in water.

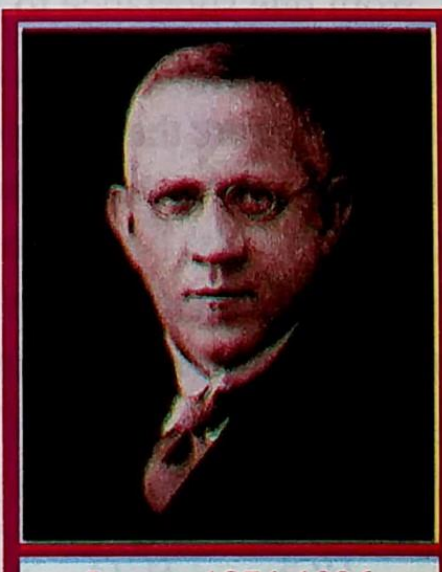
ii) Arrhenius theory fails to explain acids such as $AlCl_3$ and BF_3 which have no 'H' atom.

iii) The theory can only classify substances as bases if they contain the OH^- ion and cannot explain the bases having no OH^- ions such as Na_2CO_3.

10.1.2 The Bronsted-Lowry concept of Acids and Bases



Bronsted 1879-1947
(Denmark)



Lowry 1874-1936
(England)

The Arrhenius theory applies only when water is used as the solvent. It restricts the term acid to substances yielding hydronium ions and the term base to those yielding hydroxide ions. In 1923 J.N. Bronsted and T.M. Lowry independently proposed a much broader and more useful concept of acids and bases. According to their model, *acid is any substance capable of donating a hydrogen ion or proton (H^+) to another substance* e.g. HCl is an acid because it gives proton, e.g.

$$\underset{\text{Acid}}{HCl_{(aq)}} + \underset{\text{Base}}{H_2O_{(l)}} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)}$$

Similarly:

$$\underset{\text{Acid}}{H_2SO_{4(aq)}} + \underset{\text{Base}}{H_2O_{(l)}} \rightleftharpoons H_3O^+_{(aq)} + HSO^-_{4(aq)}$$

In the Brønsted-Lowry concept we usually refer to a hydrogen ion as a **proton**. That is because a proton is left when a **hydrogen atom** loses an electron to become an **ion**. According to this concept a base is any substance capable of accepting a proton or hydrogen ion (H^+) from another substance.

e.g.

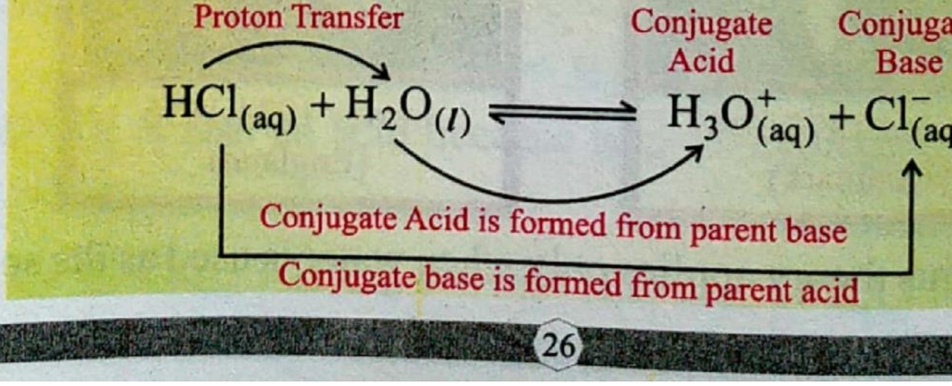
$$\underset{\text{Acid}}{HCl_{(aq)}} + \underset{\text{Base}}{H_2O_{(l)}} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)}$$

Here water (H_2O) is a base as it accept H^+ ions.

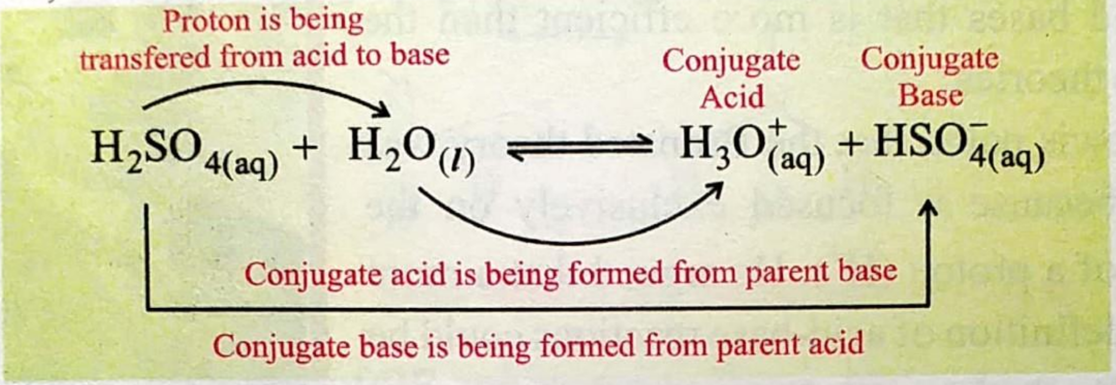
In other words, acids are proton (H^+) donors, and bases are proton (H^+) acceptors. According to this concept, any reaction involving the transfer of a proton or H^+ from one substance to another is an acid-base reaction where a base is a proton (H^+) acceptor and an acid is a proton (H^+) donor.

There may be more than one proton available to be donated, such acids that can donate more protons are said to be polyprotic acids, for example H_2SO_4, H_3PO_4.

Another interesting feature which is well explained by this concept is the formation of conjugate acids and bases, as it can be seen in the above examples that when HCl transfers H^+ ion to H_2O, it forms H_3O^+ ion.



This H_3O^+ ion has a great tendency of donating H^+ ion and is thus a very strong acid, such formed acid is called conjugate acid.



The HSO_4^- and Cl^- ions are the conjugate bases in above cases which have strong ability to accept H^+.

Activity 10.1

Identify the species in the given reactions as acids, bases, conjugate acids and conjugate bases reactions.

$$NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH^+_{4(aq)} + OH^-_{(aq)}$$

$$HNO_{3(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + NO^-_{3(aq)}$$

$$CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$$

Another important advantage of this theory is the explanation of relative strength of acids and bases, for example it is common observation that HCl is very strong acid which citric acid which is found in lemon is relatively weaker and can be used easily in food. According to this theory the acid that have the strong tendency of donating proton (H^+) are more stronger acids than those who have less tendency, similarly the bases which have strong tendency of accepting proton (H^+) are more basic in nature than those who have less tendency.

The Bronsted-Lowry theory does not explain the nature of acidic character of non-metal oxides like SO_2, NO_2 etc. and the compounds like Aluminum chloride ($AlCl_3$), and Boron trifluoride (BF_3). In the similar way this theory is also unable to explain the basic character of metallic oxides like CaO, MgO etc.

10.1.3 The Lewis concept


Gilbert Newton Lewis
(1875 –1946)

In 1923, G. N. Lewis introduced a theory of acids and bases that is more efficient than the previous theories.

Lewis noted that the Brønsted theory was limited because it focused exclusively on the transfer of a proton (H^+). He argued that a more general definition of acid-base reactions could be obtained by looking at what happens when an H^+ ion combines with an OH^- ion to form water.

$$H^+ + :\ddot{\underset{\cdot\cdot}{O}} - H^- \longrightarrow H - \ddot{\underset{\cdot\cdot}{O}} - H$$

Lewis argued that the H^+ ion picks up (or accepts) a pair of electrons from the OH^- ion to form a new covalent bond. As a result, any substance that can act as an electron-pair acceptor is a **Lewis acid.** Therefore, Lewis acid an electron-pair acceptor, such as the H^+ ion.

The pair of electrons that went into the new covalent bond were donated by the OH^- ion. Lewis therefore argued that any substance that can act as an electron-pair donor is a **Lewis base**. Therefore, Lewis base is an electron-pair donor, such as the OH^- ion.

The Lewis acid-base theory doesn't affect the category of compounds we have called "bases" because any Bronsted base must have a pair of nonbonding electrons in order to accept a proton. This theory, however, vastly expanded the family of compounds that can be called "acids." Anything that has one or more empty valence-shell orbitals can now act as Lewis acid.

This theory explains why BF_3 reacts instantaneously with NH_3. The nonbonding electrons on the nitrogen in ammonia are donated into an empty orbital on the boron to form a new type of covalent bond called co-ordinate covalent bond, as shown in the equation in figure-10.1.

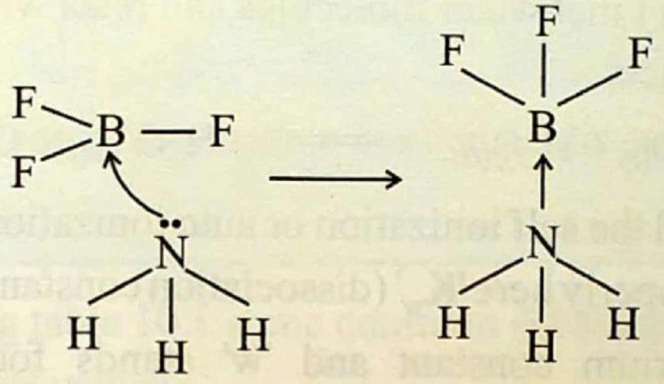


Figure-10.1: Reaction involving electron pair transfer between BF_3 and NH_3

The vacant orbital of BF_3 are shown in figure-10.2, where transfer of lone electron pair of NH_3 takes place is also elaborated.

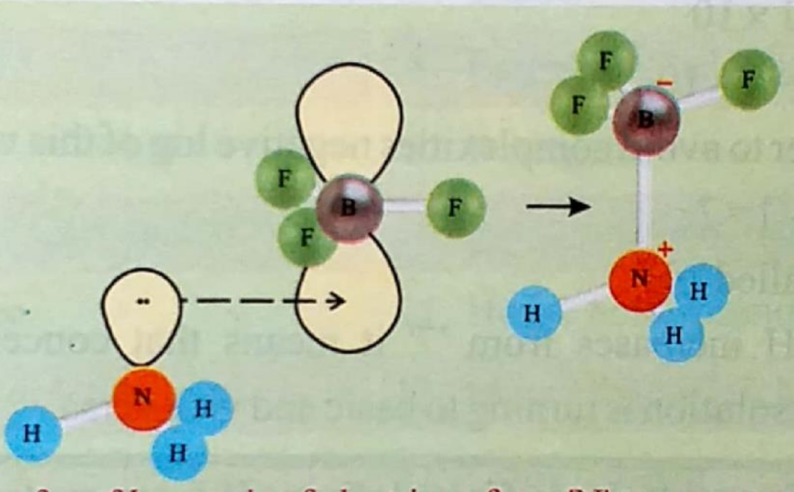


Figure-10.2: Transfer of lone pair of electrions from 'N' to vacant orbitals of Boron

The Lewis concept of acids and bases has a marked edge over previous theories as it explains not only the hydrogen containing acids but covers also other species that lack this hydrogen ion (H^+). This also explains bases as well in comprehensive manner.

10.2 The pH scale (Hydrogen ion concentration)

So far we have discussed the acidic and basic properties of chemical compounds, now we will discuss the relative strengths of acids / bases.

In order to understand and compare the relative strength of different acids and bases, scientists have developed a scale which easily describe the required information in figures 10.3, this makes it very easy to understand and compare the relative strength of different acids or bases. This scale has been created from the fact that water molecules can react with each other to form the following products.

$$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

This is called the self ionization or auto ionization of water molecules. The 'K_c' or more properly here 'K_w' (dissociation constant for water), where 'K' represents equilibrium constant and 'w' stands for water. The K_w is calculated experimentally.

$K_w = 1\times10^{-14}$

Where $[H^+][OH^-] = 1\times10^{-14}$

And $[H^+] = 1\times10^{-7}$

And $[OH^-] = 1\times10^{-7}$

In order to avoid complexities negative log of this value is taken.

i.e. $-\log[H^+] = 7$

This is called 'pH'.

If the pH increases from '7' it means that concentration of H^+ is decreasing and solution is turning to basic and vice versa.

Example-10.1: Calculating pH from molarity

Calculate pH of a solution where concentration of hydrogen ions is 0.0001 moles/lit.

Solution:

As $pH = -\log[H^+]$ put the value from question

$pH = -\log 1\times10^{-4}$ where $\log m\times n = \log$ of $m + \log$ of n

$pH = -(\log 1 + \log10^{-4})$ where $\log 1 = 0$

$pH = -(0 + \log10^{-4})$ but $\log m^n = n\log^m$

$pH = -(-4\times\log10)$

$pH = +4\log10$ where $\log10 = 1$

So,

$pH = 4\times1$

$pH = 4$

This '4' is the pH of the given solution.

Activity 10.2

Calculate hydrogen ion concentration in of an acidic solution whose pH is '3'.

In the following table 10.1 some common substances of our daily life are written with their pH values.

pH	Substance	pH	Substance
1	Hydrochloric Acid / Battery Acid	7.4	Blood
2	Gastric Fluid	8	Egg white, baking soda
3	Lemon Juice, Vinegar	9	Detergents
4	Soda Water / Carbonated Water	10	Soapy solutions, milk of magnesia
5	Black Coffee	11	House hold Ammonia
6	Tomato Juice, Urine	12	House hold Bleach
6.7	Milk	13	Drain Cleaner
7	Pure Water	14	Caustic Soda

Table 10.1: Some household species with their pH values

10.2.1 Indicators

Scientists use different chemicals to identify the different ranges of pH, e.g. the Phenolphthalein shows pink or purple colour in basic media and is colourless in acidic media, similarly the litmus shows blue colour in base and red colour in acids, methyl orange shows yellow colour in basic media and red colour in acidic media.

The universal indicator (which is obtained by mixing various indicators provides a good tool for identification of pH, the figure-10.3 shows various colours in different pH ranges by the universal indicator.

The pH scale is very helpful in understanding and calculating the relative strength of acids and bases, e.g. in the table 10.1 acid/basic character of some of the commonly used substances of our life. You can see that how easy it is to compare the relative acidic and basic strengths of each substance in a comprehensive manner.

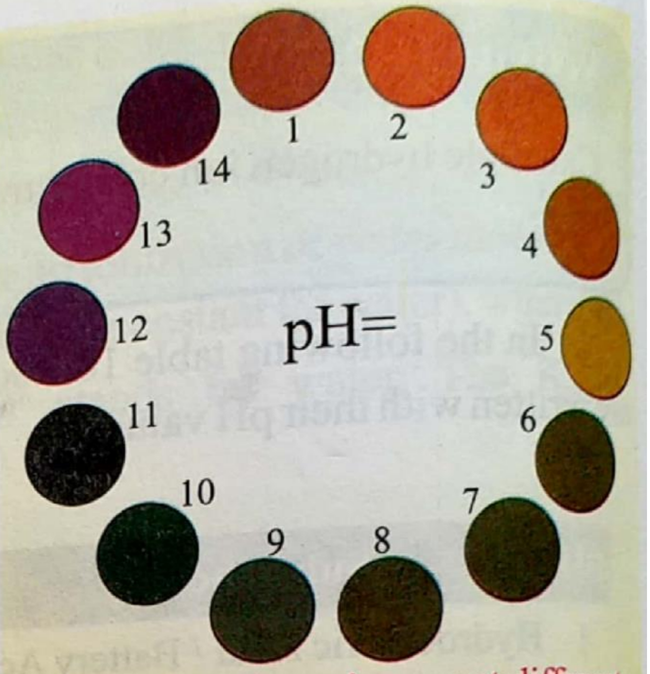


Fig. 10.3: Colour changes at different pH of Universal indicator solution

Interesting Information

Many fruits and vegetables contain pigments that change colour in response to pH, making them natural and edible pH indicators. Most of these pigments are anthocyanins (found in beet root and red cabbage), which commonly range in colour from red to purple to blue in plants, depending on their pH. Plants containing anthocyanins include acai, currant, chokeberry, eggplant, orange, blackberry, raspberry, blueberry, cherry, grapes and coloured corn. Any of these fruits can be used as pH indicators.

Activity 10.3

One of the natural indicator Flavin which belongs to Anthocyanin family is found in red cabbage, which is a water soluble compound. In order to extract this, boil some well pieced leaves of red cabbage and then take the water solution, this is the required indicator solution from red cabbage. Try this indicator solution with the items specified in the table and record your results.

10.3 The Salts

Salts are the neutralization products when an acid reacts with a base.

$$HCl_{(aq)} + NaOH_{(s)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

Here the NaCl is a salt which is used in our food frequently. You can see that in this reaction a water molecule is also produced.

Similarly sulphuric acid when reacts with potassium hydroxide which is a base it also gives a salt.

Fig. 10.4: Crystal lattice of table salt (NaCl)

$$H_2SO_{4(aq)}+2KOH_{(aq)}\rightarrow K_2SO_{4(aq)}+2H_2O_{(l)}$$

There are thousands of other salts and the majority of inorganic compounds are included in this class of chemical compounds. They are used in a variety of ways and not only they are used in food but even they could have deadly effects for livings.

The salts are the ionic compounds, and have high melting and boiling points. e.g the common table salt, the NaCl has the melting point 801°C.

The salts have the following important characters.

In the given table 10.2 some common salts are listed alongwith their usage in daily life.

Some common salts

Name	Formula	Usage
Sodium Chloride	$NaCl$	Used in food
Potassium Sulphate	K_2SO_4	Found in salinity effected areas, also used in making explosives
Ammonium Chloride	NH_4Cl	Used in cough medicines
Ammonium Phosphate	$(NH_4)_3PO_4$	Used as fertilizer
Sodium Nitrate	$NaNO_3$	Used as flavoring agent and as fertilizer
Silver Nitrate	$AgNO_3$	Used in photography

Name	Formula	Usage
Silver Bromide	$AgBr$	Used in photography
Copper Sulphate	$CuSO_4$	A poisonous salt, used in medicines in very little quantity
Washing Soda	$Na_2CO_3.10H_2O$	Used in laundry
Baking Soda	$NaHCO_3$	Used in bakery, cooking

Table 10.2: Names and uses of some common salts

Colour

Mostly salts appear to be clear and transparent (sodium chloride), opaque, and even metallic and lustrous (iron disulfide). While poly-crystalline aggregates look like white powders. Many salts exist in different colours, e.g. yellow (sodium chromate), orange (potassium dichromate), red (mercury sulfide), mauve (cobalt chloride hexahydrate), blue (copper sulfate pentahydrate, ferric hexacyanoferrate), colourless (magnesium sulfate), white, and most minerals and inorganic pigments as well as many synthetic organic dyes are salts.

Taste

Different salts can bring all five basic tastes, e.g. salty (sodium chloride), sweet (lead diacetate Warning: lead diacetate is extremely toxic and therefore should not be ingested), sour (potassium bitartrate), bitter (magnesium sulfate), and umami or savory (monosodium glutamate).

Odour

Salts of strong acids and strong bases ("strong salts") are non-volatile and odourless, while salts of either weak acids or weak bases ("weak salts") may smell after the conjugate acid (e.g. acetates like acetic acid (vinegar) and cyanides like hydrogen cyanide (almonds) or the conjugate base (e.g. ammonium salts like ammonia) of the component ions.

Activity 10.3

Write down the balanced chemical reaction among following acids and bases.

$HCl_{(aq)}$ and $KOH_{(aq)}$

$CH_3COOH_{(aq)}$ and $NaOH_{(aq)}$

$HNO_{3(aq)}$ and $Ca(OH)_{2(aq)}$

10.3.1 Preparation of Salts

The salt found in nature in a variety of sources naturally, from where they can be isolated using proper chemical techniques, and if required they can also be prepared by a number of methods, largely dependent upon the type of the salt which is to be prepared.

From natural source mostly the salts are obtained through mining process e.g. calcium carbonate ($CaCO_3$) which is commonly known as lime and marble, table salt or Halite (NaCl), Gypsum ($CaSO_4.2H_2O$), Sodium Carbonate ($Na_2CO_3.10H_2O$), Sodium bicarbonate ($NaHCO_3$) etc. are obtained mostly by this mining process. In Pakistan the world's second largest mine of Halite is situated near Jhelum at Khewra.

Some salts are obtained by evaporating the sea water, e.g. the table salt (NaCl) is obtained by the evaporating the sea water, which leaves behind the salty deposits of sea water in large ponds. By this method a great quantity of table salt is obtained and the packed table salt pouches we use commonly comes through this source.

Moreover this table salt is also obtained by mining process.

Chemically, A number of methods are available for preparing the salts artificially, and these methods depend largely upon the type of salts.

There are two main categories of the salts according to their solubility, one of these is the water soluble and the other one is the water insoluble salts.

Various methods are available for the preparation of the water soluble salts, these include.

i) **By the action of an acid and a base:** Salt are prepared by famous acid-base neutralization reactions. e.g

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow \underset{\text{Sodium Chloride Salt}}{\underline{NaCl_{(aq)}}} + H_2O_{(l)}$$

And

$$HNO_{3(aq)} + NaOH_{(aq)} \longrightarrow \underset{\text{Sodium Nitrate Salt}}{\underline{NaNO_{3(aq)}}} + H_2O_{(l)}$$

ii) **By the action of an acid upon a metal:** When a reactive metal (generally the metals of Groups 1 and 2) are reacted with an acid, a salt is produced, along with the evolution of hydrogen gas e.g.

$$H_2SO_{4(aq)} + 2Na_{(s)} \longrightarrow \underset{\text{Sodium Sulphate Salt}}{\underline{Na_2SO_{4(aq)}}} + H_{2(g)}$$

And

$$2HCl_{(aq)} + Ca_{(s)} \longrightarrow \underset{\text{Calcium Chloride Salt}}{\underline{CaCl_{2(aq)}}} + H_{2(g)}$$

iii) **By the action of an acid with a metallic oxide:** When a metal oxide is reacted with a dilute acid, the salts are produced, e.g.

$$2HCl_{(aq)} + CuO_{(aq)} \longrightarrow \underset{\text{Copper-II Chloride Salt}}{\underline{CuCl_{2(aq)}}} + H_2O_{(l)}$$

And

$$H_2SO_{4(aq)} + MgO_{(aq)} \longrightarrow \underset{\text{Magnesium Sulphate Salt}}{\underline{MgSO_{4(aq)}}} + H_2O_{(l)}$$

iv) **When a dilute acid is reacted with a metal carbonate, a salt is produced along with the evolution of CO_2,** e.g.

$$H_2SO_{4(aq)} + Na_2CO_{3(aq)} \longrightarrow \underset{\text{Sodium Sulphate Salt}}{\underline{Na_2SO_{4(aq)}}} + H_2O_{(l)} + CO_{2(g)}$$

The water insoluble salts are relatively more easy to be prepared by simple precipitation reactions (precipitate is a solid compound which is formed during the aqueous reaction of some species). This is because the separation of the prepared salt is quite easy by the use of simple filtration, moreover the raw materials used are normally not corrosive and thus are easy to handle.

The general methods employed for this purpose involve the mixing of solutions of two suitable water soluble salts proceeded by the filteration of the reaction mixture, some examples of such preparations are stated in the following equations.

$$CaCl_{2(aq)} + K_2SO_{4(aq)} \longrightarrow 2KCl_{(aq)} + CaSO_{4(s)}$$

$$MgSO_{4(aq)} + Na_2CO_{3(aq)} \longrightarrow Na_2SO_{4(aq)} + MgCO_{3(s)}$$

$$PbCl_{2(aq)} + CuSO_{4(aq)} \longrightarrow CuCl_{2(aq)} + PbSO_{4(s)}$$

It is to be noted that there are two types of the salts formed by such displacement reactions, one of the salt is soluble (or in aqueous form, denoted as "aq"), and the other is the insoluble, which is denoted as (s) in the above reaction equations, this insoluble solid salt is precipitated and can be separated through the simple filtration process, while the soluble salt can be separated by evaporating the solvent from filtrate.

Interesting Information

The salts are not only the inorganic compounds but many organic substances do also have salts, and many organic daily usage substances and drugs are converted into their salts because of the fact that the organic compounds are generally insoluble in water but their salts are soluble in water and thus are easy to use. Many fruit salts (used to treat acidity of stomach), Monosodium glutamate (Chinese salt), Tartarates, Oxalates include in this organic salt category.

10.3.2 Types of Salts

The salt comprise vast class of chemical compounds. Generally they are inorganic compounds, but even they may contain organic part too. They can be classified by several ways, e.g on the basis of their organic or inorganic nature. On the basis of their composition or properties, and the most famous and accepted classification is based on the basis of their solubility, according to which they are of two types,

(i) Soluble in water (ii) Insoluble in water

Activity 10.4

- On the basis of their solubility, list at least 10 salts into various classes.
- On the basis of their organic and inorganic nature, list at least 10 salts into two of described classes.

On the basis of their composition and properties they can be classified into several types, important of which are described here:

(i) Normal or neutral salts
(ii) Acidic salts
(iii) Basic salts
(iv) Double salts

i) Normal or neutral salt: A normal or neutral salt which is neutral in properties and they contain the ions that neutralize the effect of each other. Upon dissolving in water they do not produce H^+ or HO^- ions. The examples of such salts include NaCl, KCl, $NaNO_3$, K_2SO_4 etc

ii) Acidic salts: These salts when dissolved in water dissociate partially to produce either H^+ ions or tend to accept lone pair of electrons during chemical reactions. Examples of such salts are $KHSO_4$, $AlCl_3$, NH_4Cl etc

iii) Basic salts: This is the class of salts which show basic character due to the fact that during solvation they produce HO^- ions or tend to accept the H^+ ion, the examples of such salts include carbonates (e.g Na_2CO_3)$10H_2O$. bicarbonates (e.g. $NaHCO_3$) and sodium acetate (CH_3COONa).

iv) Double salts: These are the salts that contain the ions of more than two types, e.g Mohr's salt, $FeSO_4.(NH_4)_2SO_4.6H_2O$, potash alum, $K_2SO_4.Al_2(SO_4)_3.24H_2O$ etc. They are actually made up of two salts.

10.3.3 Uses of Salts

The salts are used in many field of life, e.g. they are important constitute of our daily food intake and not only provide taste to our food but are also essential for normal body processes, e.g the NaCl, monosodium glutamate, sodium citrate, sodium tartarate, sodium bicarbonate.

Many salts are used as colour pigments, some examples of such salts include Potassium dichromate ($K_2Cr_2O_7$) which is orange in colour, nickel chloride ($NiCl_2$) which is green in colour, cadmium sulphide (CdS) which is yellow in colour, tetraamine copper sulphate which is intense blue in colour. Lead chromate ($PbCrO_4$) which is yellow in colour.

Salts are also used in preserving the food items, e.g. Sodium metabisulphite $Na_2S_2O_5$, table salt (NaCl), sodium acetate (CH_3COONa), etc.

The salts are also used in many medicinal preparations, e.g $MgSO_4.7H_2O$ epsom salt in purgative preparations, sodium and potassium salts in blood pressure regulating, fluoride salts are used in tooth decay problems, calcium salts are good source of calcium which is necessary for animal bones growth,etc

Besides these different salts are used in other fields, e.g $CaSO_4.2H_2O$ gypsum Salt, KNO_3 nitre, ammonium phosphate, $(NH_4)_3PO_4$ are used in fertilizers, sodium silicate (Na_2SiO_3) is used in glass making, bleaching powder, Ca(OCl)Cl is used for bleaching purposes, Calcium sulphate as plaster of paris

Interesting Information

Although salts do a lot for us, but at the same time they also cause some problems for us too, e.g. oxalate salts produce kidney stone, the salt in sea water makes it unusable for drinking and cultivating lands. There are various methods available for desalinating sea water which contains about 35,000ppm of salt as compared to fresh water which has almost below 1000ppm of salts. The desalination commercially is brought about by reverse osmosis technique in which a semipermeable membrane is used to filter off the salts, nonotubes are also used for the same function. Besides these particulate material like fine sand has also been used for desalinating sea water.

Summary of the Chapter

- Acids and bases constitute two important classes of chemical compounds which are common in our daily life.
- Acids are sour in taste and they turn litmus red from blue.
- The bases are bitter in taste and they turn litmus blue from red.
- In order to explain the behaviour of acids and bases, many scientists proposed various theories, among these theories the Arhenius theory, the Bronsted-Lowry theory and the Lewis theory are important.
- Arrhenius defined Acids as the substance which donates H^+ ions when dissolved in water, and he defined bases as the substances which donates $H\bar{O}$ ions in water.
- Two scientists Bronsted and Lowry described the acids as the species which donate or tend to donate H^+ ions in water and the bases as the substances that accept or tend to accept H^+ ions when dissolved in water.
- According to Lewis concept the bases are the substances that donate electron pair during chemical reactions and the acids are the substances that accept electron pair in chemical reactions.
- Salts are the neutralized products of chemical reactions between acids and the bases.
- The salts are prepared by a number of methods, for example by reacting acids and bases together, by the action of acids on metals or metallic oxides or metallic carbonates.
- The salts are of different types; there classification is based upon different criteria, e.g. on the basis of their solubility in water, on the basis of their composition and properties etc.
- On the basis of solubility salts fall in two categories, i.e. water soluble and water insoluble salts.
- On the basis of their composition and properties they can be divided

into, normal, neutral, acidic, basic and double salts.

- A concept of pH is used to describe the relative strength acids and bases in much easier way.
- pH is defined as the $-\log[H^+]$, (negative log of hydrogen ion concentration).
- According to this system the substance having pH from 1-6.9 are acidic, from 7.1 to 14.0 pH the substances are basic in nature, and the substance that have pH 7.0 are neutral in this sense.
- As the pH increases from 1-6.9, the acidic character of the given substance decreases, i.e. the substance having low pH is more acidic than the substance having high pH, for example compound having pH=2 is more acidic than the compound having pH=3.
- The pH increase from 7.1 to 14.0 increases the strength of a base, i.e. a substance having pH = 8 is less basic than the substance having pH=10.

Exercise

Q1: Fill in the blanks.

i) Acids have............. taste.

ii) Bases turn red litmus ....

iii) Stomach has .... acid which helps in digesting the food.

iv) Salts are produced by the reaction of .... with a base.

v) The basic character of ammonia is well explained by .... concept.

vi) Arhenius described acids as .... donor.

vii) According to Lewis concept the .... tend to donate electron pair.

viii) The aluminium chloride falls under the type of .... salts.

ix) The citrus fruits contain .... acid.

x) The $-\log$ of $[H^{+}]$ is called the..............

Q2: Tick the correct answer from the given list.

i) A solution having pH of 7.5 mean that it is

(a) Acidic (b) Basic

(c) Neutral (d) Amphoteric

ii) A liquid has a pH of 7, what does this tell about the liquid?

(a) It is acid solution (b) It is neutral

(c) It is basic solution (d) It is a solution of a NaOH

iii) Which of the statements below is correct?

(a) All bases dissolve in water

(b) All acids are soluble in water

(c) Sodium chloride is a basic salt

(d) Alkalis are bases.

iv) Name the salt that forms when HCl is reacted with $Ca(OH)_2$

(a) Calcium carbonate (b) Calcium hydrate

(c) Calcium chloride (d) Calcium oxide

v) Which pair of substances will react together to form $CuSO_4$.

(a) Copper and Sulphuric acid.
(b) Copper oxide and Sulphuric acid
(c) Copper oxide and hydrochloric acid
(d) Copper and Sodium sulphate.

vi) The colour of potassium dichromate salt is:

(a) Yellow (b) Green
(c) Orange (d) Blue

vii) For a system where $[H^+]=10^5$, the $[HO^-]$=?

(a) 10^5 (b) 10^6
(c) 10^9 (d) 10^{10}

viii) Phenolphthalein indicator shows purple colour in basic media, while its colour in acidic media is:

(a) Red (b) Blue
(c) Yellow (d) Colourless

ix) Salts are produced when a base reacts with

(a) An Acid (b) Another base
(c) Another salt (d) Oxides

x) $CaCO_3$ is a salt which is:

(a) Soluble in water (b) Insoluble in water
(c) Sparingly soluble in water (d) Soluble in benzene

Q3: Answer the following questions briefly.

i) Write down the general properties of acids.
ii) What are the general characters of bases?
iii) Describe the general composition of a salt.
iv) What is a precipitate?
v) What is meant by neutralization reaction?
vi) What are the polyprotic acids?
vii) How you will explain the basic character of NH_3?
viii) What is an indicator?

ix) Write some uses of NaCl.

x) Name some salts that are important to medicinal use?

Q4: Answer the following questions with reasoning.

i) The Stomach contents of animals have very high acidic pH (about 1-2), explain why it does not damages the walls of stomach?

ii) Why the acidic character of a solution increases with the decrease in pH?

iii) Name 5 acids that are found in our food?

iv) How salts affect our health?

v) How molarity is related with the pH of a solution?

Q5: Write a note on strength of acids and bases?

Q6: Name a household consumer product that contains.

a) A strong acid b) A weak acid

c) A strong base d) A weak base

Q7: Describe the theory of Arhenius to explain the acids and bases.

Q8: How Bronsted-Lowry theory helps us to understand the Acids and Bases?

Q9: Comment that the Lewis theory can be best in order to understand the nature of acids and bases.

Q10: What do you understand by the chemical term "Indicator"? Name some of the natural substances that contain indicators?

Q11: Write down the colours of following indicators in both the acidic and basic medias?

Phenolphthalein, Litmus, methyl orange

Q12: Can you suggest two methods by which the sea water can be desalinated to make it drinkable?

Q13: What is a Salt? Describe the general characters of the Salts.

Q14: How Salts are prepared and purified?

Q15: What types of Salts are found in nature? Explain with examples.

Q 16: Arrange the following chemical species into Acids, Bases and Salts.

$NaHCO_3$, $Na_2CO_3.10H_2O$, $Al(OH)_3$,
$Ca(OH)_2$, CH_3COOH, CH_3COONa,
$HCOOH$, NH_3, NH_4OH,
HNO_3, $NaOH$, $Ca(OCl)Cl$,
Na_2SO_3, H_2CO_3, H_2SO_3.

Q17: Calculate the pH of a solution which contains 0.01 moles of HCl?

Q18: Calculate the molarity of H^+ for aqueous solutions for which the pH is:

a) 3.0 b) 10.0

Q19 : Calculate the pH of a solution that has the H^+ molarity,

a) 1×10^{-6} b) 1×10^{-11}

Chapter
11

ORGANIC CHEMISTRY

Conceptual Linkage

Before reading this chapter, the student must know the:

- Concept of valency
- Difference between ion, atom and radical
- Lewis structural formulae

Time Allocation

Teaching periods	=10
Assessment periods	=03
Weightage	=05%

LEARNING OUTCOMES

Students will be able to:

- Recognize structural, condensed and molecular formulas of the straight chain hydrocarbons up to ten carbon atoms. (Understanding)
- Identify some general characteristics of organic compounds. (Remembering)
- Explain the diversity and magnitude of organic compounds. (Understanding)
- List some sources of organic compound. (Applying)
- List the uses of organic compounds. (Remembering)
- Recognize and identify a molecule's functional groups. (Understanding)
- Distinguish between saturated and unsaturated hydrocarbons. (Understanding)
- Name the alkanes up to decane. (Remembering)
- Convert alkanes into alkyl radicals. (Applying)
- Differentiate between alkanes and alkyl radicals. (Analyzing)
- Define functional group. (Remembering)
- Differentiate between different organic compounds on the basis of their functional groups. (Analyzing)
- Classify organic compounds into straight chain, branched chain and cyclic compounds. (Understanding)

Introduction

The chemistry which is the science of matter deals with two basic types of materials, one type that has its origin from the non-livings like rocks and other earth material, and the other type of material that comes directly from the living organisms, like carbohydrates from the plants, this type of matter that originated from the living organisms has been classified as the organic matter and the study of such matter has named organic chemistry, while rest of the material has been classified as the inorganic matter and the study of this matter was carried out in the branch of chemistry named as inorganic chemistry.

Although organic chemistry deals with the study of the chemical compounds, which are of the origin of living organisms and for the production of such compounds a vital force had been considered as necessary. With the evolution of modern era of science and technology many of such organic compounds were prepared in artificially in laboratories. In this context Fredrick Wohler, a German scientist in 1828 prepared urea, a well known organic compound by heating an inorganic chemical compound ammonium cyanate, thus urea is regarded as the first synthetic organic compound.

$$NH_4CNO \xrightarrow[\Delta]{\sim} CO(NH_2)_2$$

(Where (~) is sign used to show intramolecular rearrangement)

After the synthesis of urea scientists prepared many of the organic compounds, and now a days millions of organic compounds have been prepared and more new being added in this list each year.

It has been observed that these organic compounds have their origin from the basic hydrocarbon series, the hydrocarbons are the compounds that contains only two elements the carbon and hydrogen.

In view of this the organic chemistry is now a days defined as the chemistry of the hydrocarbons and their derivatives.

This is to be remembered that some abundant and important chemical compounds which contain carbon and hydrogen too are not included in the list of organic compounds. e.g the ultimate oxides (CO_2, CO), carbonates, bicarbonates and cyanides are not included in the organic compounds.

The organic chemistry is an important branch of chemistry, this is because not only the organic compounds have interesting features but they are also very abundant. We deal with the organic compounds all times in our life, our food stuff, cloths, medicines, the hydrocarbon fuels. Almost everything which we use in our daily life mostly consists of the organic compounds.

There are many types of organic compounds which are not made naturally and they are in laboratories and factories prepared artificially, e.g the plastics, paints, detergents, cosmetics, artificial fibers (rayon and nylon). These artificially prepared organic compounds also play important role in our life.

11.1 The Organic compounds

The organic compounds, that contain the element carbon as the major element in their framework. The first member of the series of organic compounds is the famous methane which is gas at normal temperature and pressure, and is used as a fuel. In methane a carbon atom is surrounded by 4 hydrogen atoms and forms a regular tetrahedron structure. The structure of CH_4 is shown here. You can see that the CH_4 molecule can be represented by a number of ways. The common method is to represent the molecule by classical 2-D (dimension) manner, as shown in the figure-11.1.

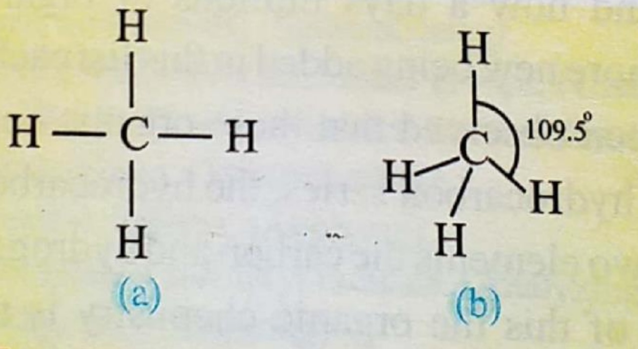


Fig. 11.1: Two dimensional representation of CH_4 molecule, (a) general representation, (b) Representation showing angles

The molecules are drawn mostly using some special signs, as shown in fig 11.2, this is because the three dimensional (3D) structure of these organic compound is of the interest of scientists and they use different signs to represent this actual 3-D structure. These signs are called Wedge and Dash, the wedge "◀" shows that the direction of the atom or the group that is represented by this is actually situated towards the viewer, and dash "ıııı" shows that the atom or groups present at its end is actually opposite to the direction of viewer.

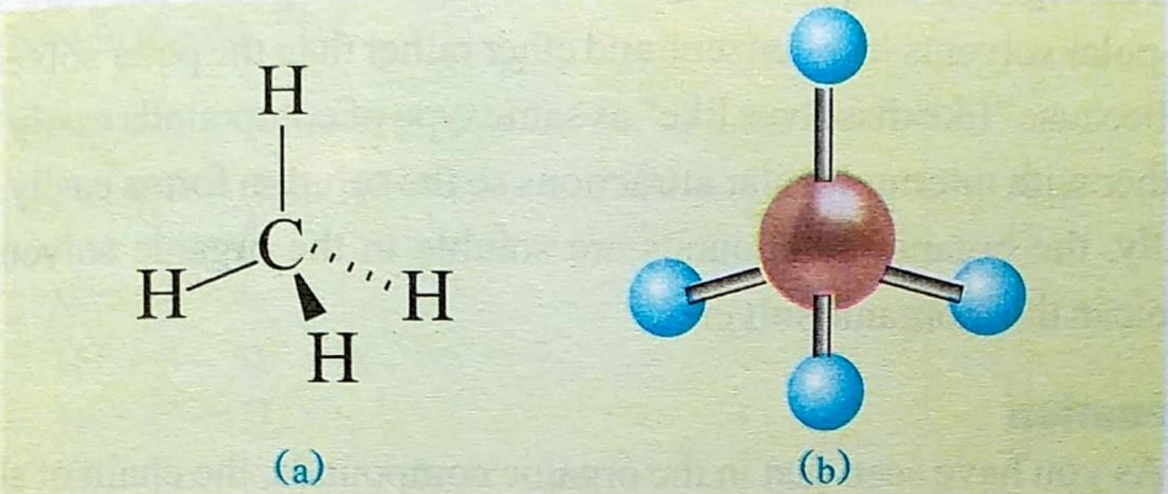


Fig. 11.2: (a) Wedge-dash representation of Methane molecule, (b) Ball and stick model of CH_4

As the number of carbon increase, the structure of organic compounds become more complex. So normally we use the simple 2-D structures of the molecules also we use the models and wedge-dash representation of the molecules in this book.

The second member of the series of the organic compounds is ethane, which contains 2 carbon atoms and 6 hydrogen atoms. This increases the complexity of the organic compound.

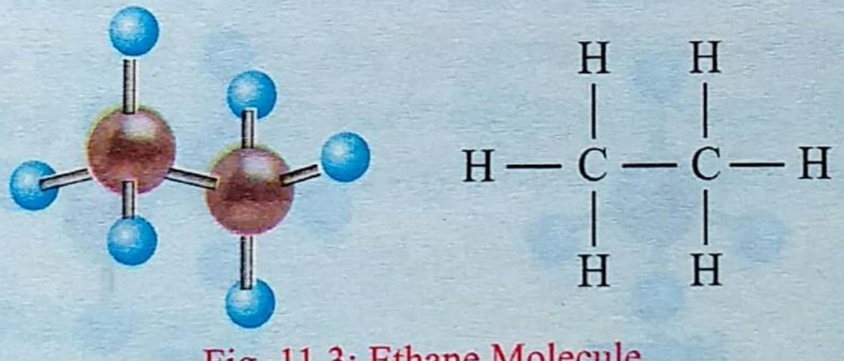


Fig. 11.3: Ethane Molecule

The organic compounds may have other elements of which O, N, S, P, Cl, and Br are important. Which make the nature of these organic compounds more complex. We will discuss such compounds later in this book.

11.1.1 General features of organic compounds

The organic compounds although show diverse characters and properties.

1. Solubility

The organic compounds are covalent and non-polar. They are soluble in non-polar solvents like benzene and ether rather than the polar solvents like water, because "like dissolves like" as same type of compounds easily bind to each other with intermolecular attractions so the solution forms easily. Hence generally, the organic compounds are soluble in the organic solvents, and inorganic in the inorganic solvents.

2. Catenation

As you have seen that in the organic compounds, the chain of skeleton increases with the increase in number of carbon atoms, the carbon has a great tendency of forming chain structures. This long chain formation ability of an element is called "catenation". As the organic compounds are primarily formed by the carbon element, which has ability of catenation. So the organic molecules may be very big and complex in which hundreds of atoms can be present, but we concentrate upon the simple ones to understand them satisfactorily. Some of the simple members of organic compounds are shown below.

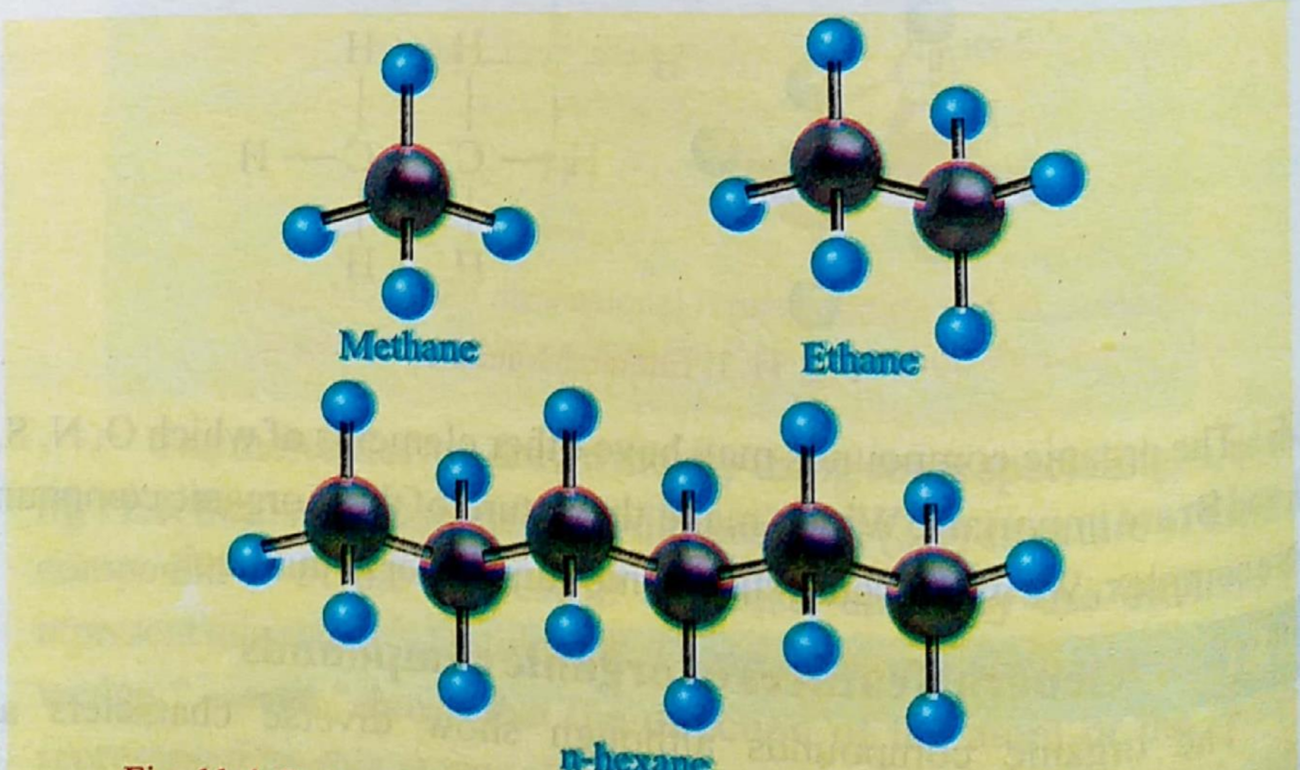
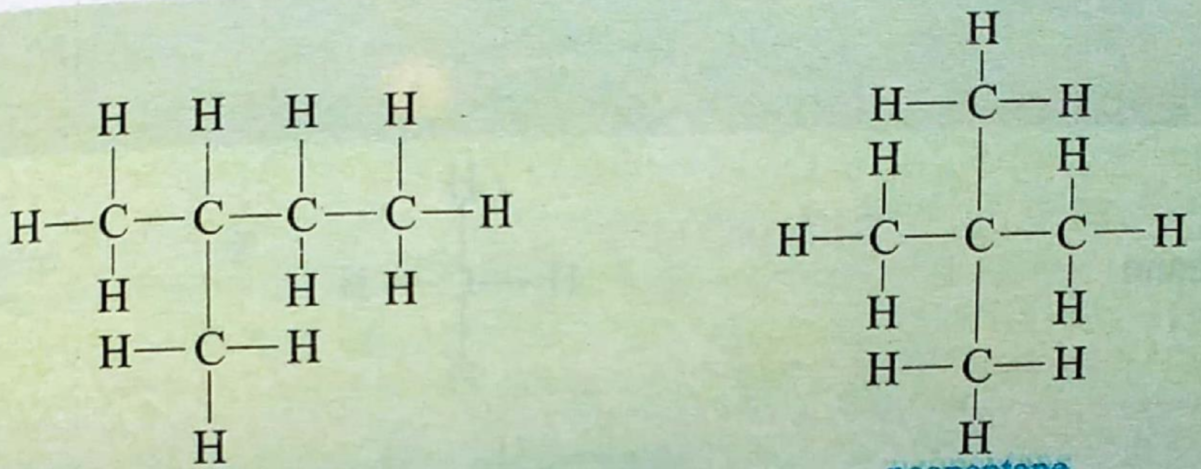


Fig. 11.4: Ball and Stick models of some simple organic molecules

The Carbon chain not only can increase in a single direction but to other directions too, e.g. in pentane, which has 5 carbon atoms, the linkage of atoms is shown here in the fig. 11.5.



isopentane

neopentane

Fig. 11.5: Isomers of Pentane

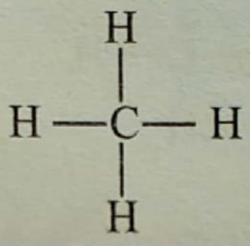
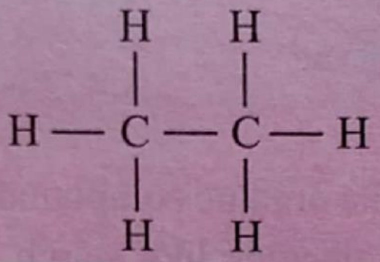
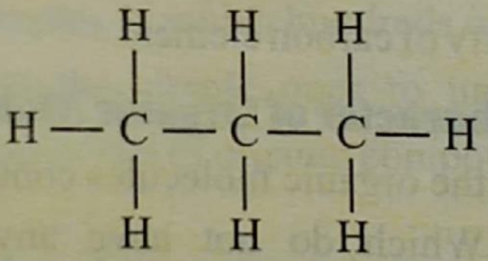
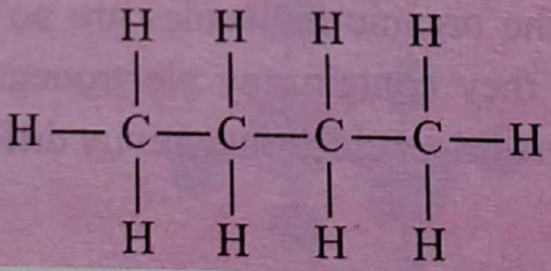
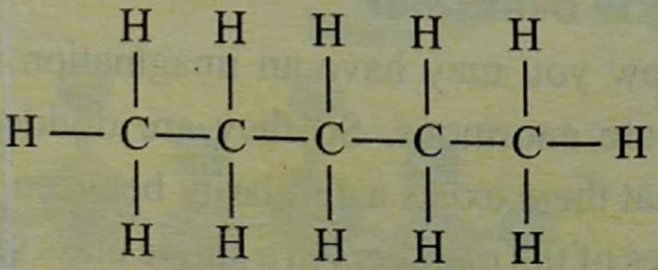
The chain in the organic compounds can increase enormously yielding complex organic molecules like starch and glycogen due to this distinct catenation property of carbon element.

3. Non Polar Character of Organic Molecules

In general the organic molecules contain carbon and hydrogen as the only elements. Which do not have any appreciable electronegativity difference, so the organic molecules are normally non-polar in character, however when they contain any electronegative element like halogen or oxygen then there arises electronegativity difference, which results in a polar molecule.

4. Simlarity in Behaviour

Till now you may have an imagination that the number of organic compounds are enormous. So they are divided into various classes, but remember that there exists a similarity between the members of same class. The properties of the members in a single class vary in a regular manner with the increase in the "•CH_2•" units of the members. Thus a series is obtained where in every next member a "•CH_2•" unit increases, this series is called "homologous series". In a homologous series all the members show much similarity in chemical behaviour, e.g. all the hydrocarbon behave same, and all alcohols behave same. Although they differ in physical characters in a regular manner. You can see this trend in the table below.

Name	No of C atoms in chain	Structural formula	Boiling point °C
Methane	1	 $\begin{array}{ccc} & H & \\ & \vert & \\ H- & C & -H \\ & \vert & \\ & H & \end{array}$	-162
Ethane	2	 $\begin{array}{ccccc} & H & & H & \\ & \vert & & \vert & \\ H- & C & - & C & -H \\ & \vert & & \vert & \\ & H & & H & \end{array}$	-89
Propane	3	 $\begin{array}{ccccccc} & H & & H & & H & \\ & \vert & & \vert & & \vert & \\ H- & C & - & C & - & C & -H \\ & \vert & & \vert & & \vert & \\ & H & & H & & H & \end{array}$	-42
Butane	4	 $\begin{array}{ccccccccc} & H & & H & & H & & H & \\ & \vert & & \vert & & \vert & & \vert & \\ H- & C & - & C & - & C & - & C & -H \\ & \vert & & \vert & & \vert & & \vert & \\ & H & & H & & H & & H & \end{array}$	0
Pentane	5	 $\begin{array}{ccccccccccc} & H & & H & & H & & H & & H & \\ & \vert & & \vert & & \vert & & \vert & & \vert & \\ H- & C & - & C & - & C & - & C & - & C & -H \\ & \vert & & \vert & & \vert & & \vert & & \vert & \\ & H & & H & & H & & H & & H & \end{array}$	36
n-hexane	6	$CH_3(CH_2)_4CH_3$	69

Name	No of C atoms in chain	Structural formula	Boiling point °C
Heptane	7	$CH_3(CH_2)_5CH_3$	98
Octane	8	$CH_3(CH_2)_6CH_3$	126

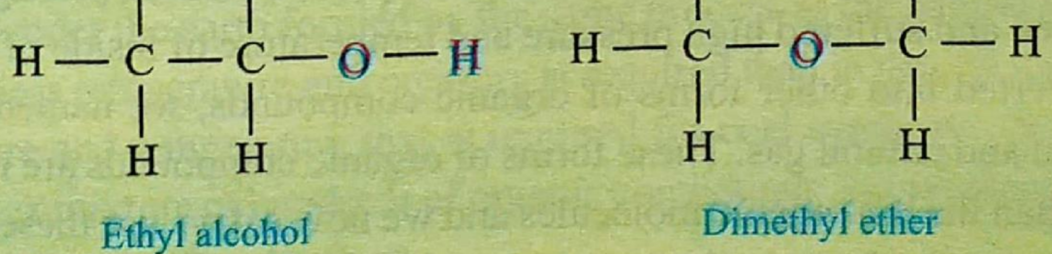
Table 11.1 Some important characters of simple hydrocarbons

5. Complexity in Organic Compounds

Because the organic molecules may comprise a large number of atoms, so the organic molecules like that of starch, protein and other bioorganic molecules are very complex in nature. The complexity increases as the chain increases, and even becomes so complex that even now a days with the usage of advanced technology we find it hard to understand completely the bioorganic compounds.

6. Isomerism in the Organic Compounds

One of the interesting features of the organic compounds is the sequence of atoms in a given molecule. The properties of organic molecule depends upon the sequence of the linkage between atoms rather than the type and number of atoms. So in many cases, two molecules although having same number and type of atoms, show different behaviours, e.g. ethyl alcohol and dimethyl ether both having same molecular formula C_2H_6O have totally



Ethyl alcohol

Dimethyl ether

Fig. 11.6: Isomerism in Organic Compounds

different physical and chemical properties, as the atoms are linked in both in different sequence.

This phenomenon in which more than one structures of a compound having same molecular formula are possible is called Isomerism, and the compounds formed thus are called Isomers.

7. Rates of Organic Reactions

The organic compounds are generally non-ionic and non-polar, so the speed or rate of their reactions is slower than the inorganic compounds.

11.2 Sources of Organic compounds

The major sources of organic compounds are the living organisms, both the animal and the plant kingdoms. The plant kingdom, which of course is the main source, provides the chief source of organic compounds from which other sources derive the main components and change the organic matter through bio-chemical processes. Thus the basic and chief sources of the organic compounds are the plants.

The plants absorb the inorganic compounds CO_2 and the H_2O from surroundings and by using the energy of sun convert these inorganic compounds into organic compounds of which the carbohydrates are the major ones. The animals that depend upon the plants for their food requirements convert the eaten carbohydrates into complex organic compounds, i.e. to Proteins, Fats and others through complex biochemical reactions.

We have yet described the process of formation of organic compounds which is in progress in nature all the times. But the history of life on the planet earth is ofcourse spreads over millions of years in past. The plants (and to some extent animals too) lived and died on the planet, with the passage of time they buried and suffered high pressure and temperature of inside of the earth and converted into other forms of organic compounds, we named as coal, petroleum and natural gas. These forms of organic compounds are relatively simpler than the bio organic molecules and we now a days use these not only for the use as fuel but we also make these into other organic materials, like plastics, synthetic rubber, artificial fibres and many others.

It is to be remembered that these different forms of organic compounds are produced due to the difference of pressure and temperature under the earth, more is the pressure and temperature, higher is the volatility of the fraction of organic compound.

Let's take a closer look on each of the fractions of these organic compound sources.

11.2.1 Coal

Coal is the readily combustible black or brownish-black solid form of the organic matter formed. Major use of coal is for fuel, and carbon is the chief element in coal which burns to yield energy.

The coal has been categorized according to the percentage of carbon content. Hence the top quality is the Anthracite which has more than 90% of carbon, then comes bituminous which has 80% carbon, this is used as domestic fuel in cold regions of Pakistan, lignite having 70% of carbon which is used in power stations for production of electricity. The most inferior type of coal is the Peat which is found near surface of earth and even above the surface, it has approximately 60% carbon content and high moisture content which makes less valuable for the use as good fuel. Peat is used as low cost furnace fuel, for example in brick making furnaces.

11.2.2 Petroleum

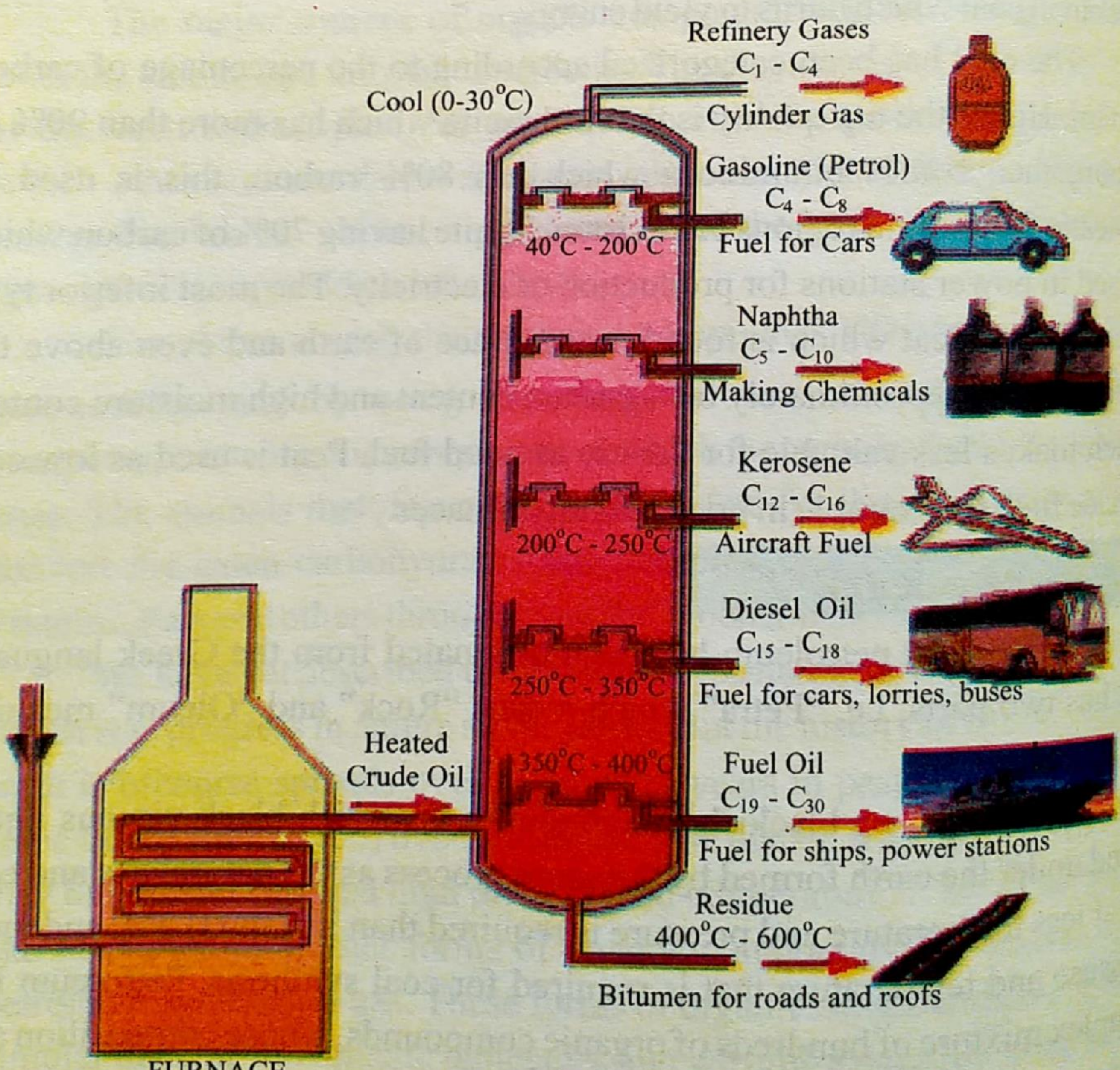
The word petroleum has been originated from the Greek language and has two parts, i.e. "Petra" which means "Rock" and "Oleum" meaning "Oil".

Petroleum is a blackish or sometimes brownish black viscous liquid found under the earth formed by the same process as the natural gas and coal but at less temperature and pressure is required than in natural gas, and more pressure and temperature that is required for coal synthesis. Petroleum is a complex mixture of hundreds of organic compounds, whose composition and colour changes place to place.

Crude petroleum is purified in oil refineries to obtain a various fractions, which are used for various purposes in the energy production.

Interesting Information

The crude petroleum is purified in the oil refineries, the different fractions in the crude oil are separated on the basis of the differences in the boiling points of different fraction. Not only the components present in crude oil can be separated but also these fraction can be interconverted, all this separation and interconversion is done on the basis of demand of required fractions.



11.2.3 Natural gas

The natural gas is also believed to be formed by the same process as the coal forms, but here the pressure and heat are applied more than the coal, so it is found in depths than the coal. Huge reserves of natural gas have been found in the area of Sui Balochistan in 1952, that is why it is also called “Sui gas” in Pakistan. The natural gas has generally following constitution, but the constitution varies from place to place.

Methane	70-90%
Ethane	5-15%
Propane	<5%
Butane	1-2%
N_2, CO_2, H_2S	Remaining

Table 11.2 General composition of natural gas

The natural gas is a cheap source of energy in Pakistan, and is used in almost all industries along with the domestic use. It is also used as CNG (compressed natural gas), LPG (liquefied petroleum gas), but in LPG the proportion of propane and butane is kept higher than methane and ethane, which eases the liquification process.

The natural gas is also used for the preparation of many compounds like urea fertilizer.(this process of making urea is well explained in section 16.3 later in this book)

11.2.4 Synthesis of organic compounds in laboratories/factories

Although the major source of the organic compounds is the plant kingdom, but now a days there are a number of organic compounds which are prepared in laboratories and later on in factories on industrial scale to meet their requirements. For example, the important organic compounds prepared on large scale are various plastic products, used in almost every field of life, The fertilizers like urea are also prepared in large scale to meet the increasing demands of food, many medicinal compounds are also required in large quantities e.g. the antibiotics, the antiulcerants, antipyretics etc, detergents, soaps and other cleansing agents, Paints and dyes, Artificial fibers and rubber, insecticides, pesticides and many other organic compounds are prepared in laboratories and in factories.

11.3 Uses of Organic compounds

Because of the catenation power of the carbon, the organic compounds comprise a tremendous list. There are so many types and varieties of organic compounds and each year more and more organic compounds are added in this list, so the use of these organic compounds is vast and in broad range. In fact they are used in almost every step of our daily life.

i) The organic compounds are the chief constituent of our food, and different food articles in the form of vegetables, fruits, meat, cereals etc are actually the organic compounds.

ii) The cloths we wear are also the organic compounds which are prepared from natural fibers i.e the cotton or wool, or from the artificial fibers i.e the rayon or other plastic threads are again actually the organic compounds.

iii) The medicines that comprise antipyretic, anti-inflammatory, antihistamines, antibiotics, anti ulcer, and others we take when we become sick are again mostly consists of organic compounds

iv) The fertilizers in the form of urea, and others we use to enhance the crops production are again the organic compounds.

v) The insecticide and fungicide preparations that are used to fight insect and fungus attack are again mostly organic in nature.

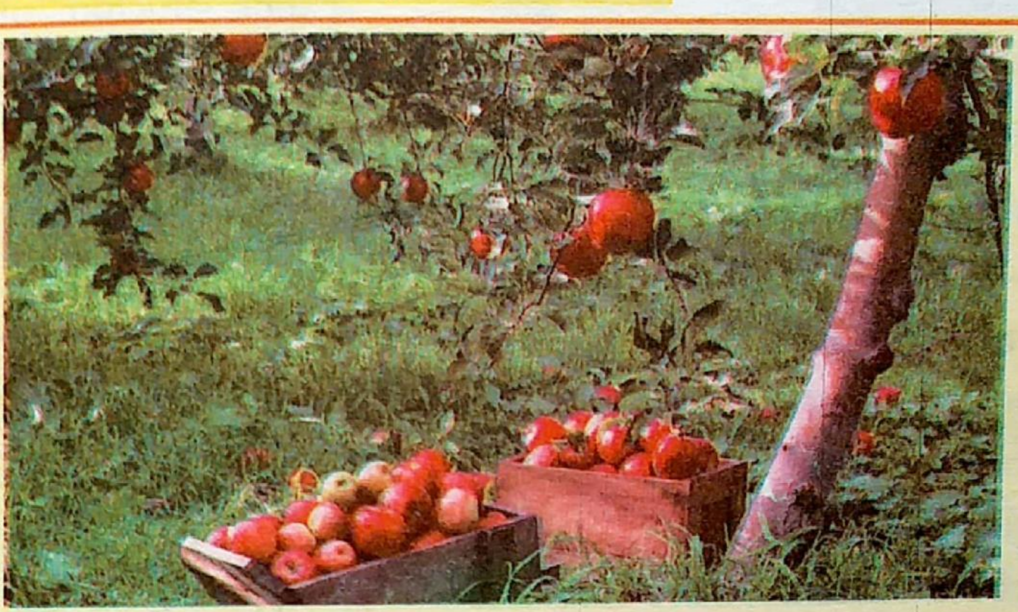
vi) The fuel as natural gas, petrol, kerosene oil. diesel, CNG, LPG, coal, wood (that we use to run our vehicles and in our home to cook the food that we eat) are all again organic in nature.

vii) The dyes that gives us a colourful life are again majorly comprise the organic compounds.

viii) Different types of plastics used in various fields of life are also the organic compounds.

These are just few categories of organic compounds and actually the organic compounds are very abundant and almost every place of our imagination involves the use of these organic compounds, so the impact of the organic chemistry is also very high and it affects our life too much.

11.4 Alkanes and Alkyl radicals



The paraffin wax coating that makes these apples so shiny is actually due to the mixture of alkanes

The Alkanes comprise the initial and simplest class of organic compounds, where the carbon is bonded with the other carbons by a single covalent bond, thus their general formula is C_nH_{2n+2} where n is the number of carbon atoms. The 1st member of the Alkane series is the methane, which has one carbon and all four bonds of carbon are with hydrogen, as shown figure-11.7.

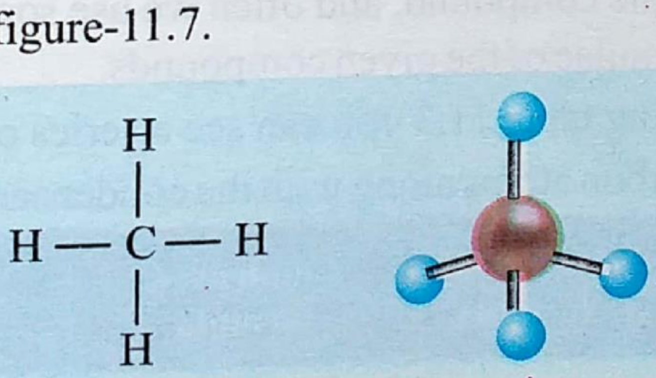


Fig. 11.7: Methane, the simplest organic compounds

The second member of this class of alkanes is the Ethane, which has two carbon atoms and '6' hydrogen atoms, its structure is shown in figure-11.8.

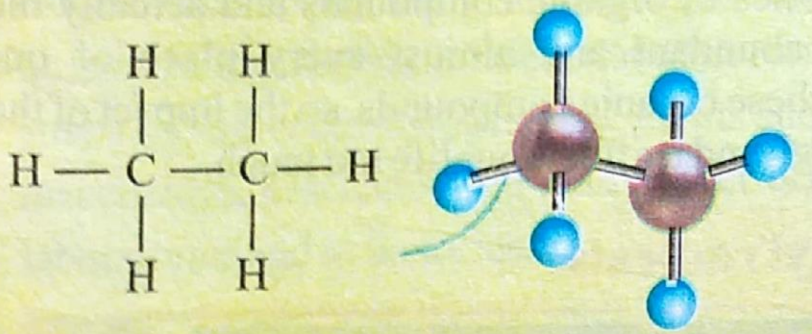


Fig. 11.8: Ethane, A two carbon containing organic compound

Activity 11.1

Draw "line structural formula" and "ball and stick structure" of Propane.

This series increases with the increase in the carbon atoms, and even the side branching can also appear, a branch is the area of chain where at least three other carbon atoms are attached with the carbon of chain, e.g. in figure-11.9.

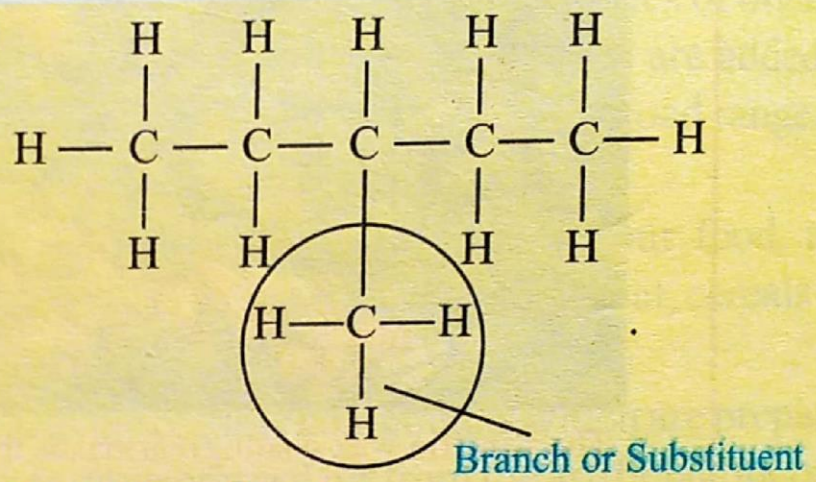
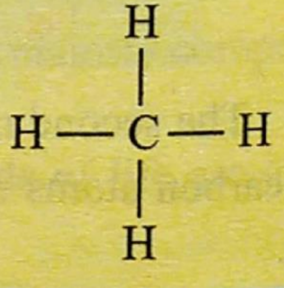


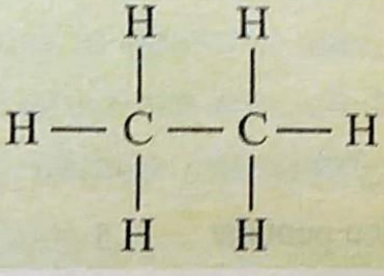
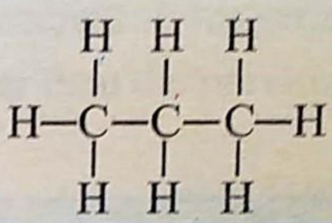
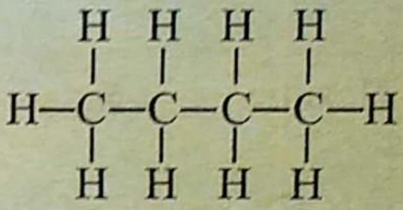
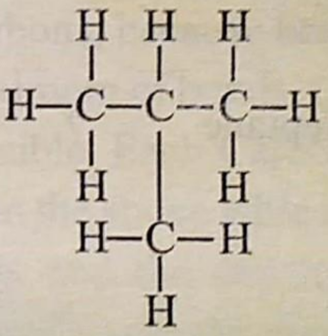
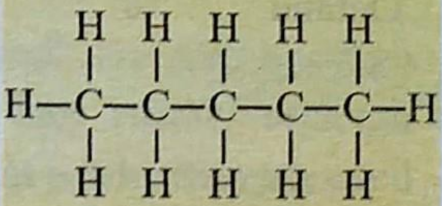
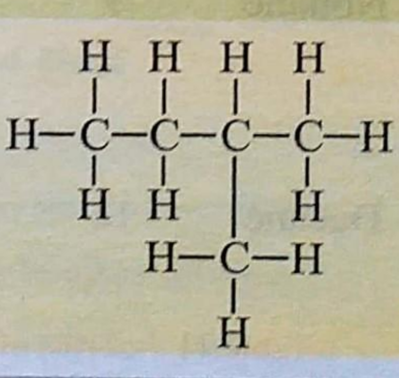
Fig 11.9 Branching in the organic compound

Note that in the fig11.9 the part of the chain having lesser number of carbon atoms is the branch or is also called a substituent.

As the number of carbon increases, the complexity in the organic compound also increases. It is not necessary that we always write full structure of the organic compound, and often we use some shortcuts like that of the condensed formulae of the given compounds.

In the following table 11.3 you can see a series of alkane class which comprise up to 10 carbon atoms along with the condensed formulae.

Name	No of C atoms in chain	Molecular formula	Condensed formula	Structural formula
Methane	1	CH_4	CH_4	

Name	No of C atoms in chain	Molecular formula	Condensed formula	Structural formula
Ethane	2	C_2H_6	CH_3CH_3	 $\begin{array}{ccccccc} & & H & & H & & \\ & & \vert & & \vert & & \\ H & - & C & - & C & - & H \\ & & \vert & & \vert & & \\ & & H & & H & & \end{array}$
Propane	3	C_3H_8	$CH_3CH_2CH_3$	 $\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & \vert & & \vert & & \vert & & \\ H & - & C & - & C & - & C & - & H \\ & & \vert & & \vert & & \vert & & \\ & & H & & H & & H & & \end{array}$
Butane	4	C_4H_{10}	$CH_3CH_2CH_2CH_3$ Or $CH_3(CH_2)_2CH_3$	 $\begin{array}{ccccccccccc} & & H & & H & & H & & H & & \\ & & \vert & & \vert & & \vert & & \vert & & \\ H & - & C & - & C & - & C & - & C & - & H \\ & & \vert & & \vert & & \vert & & \vert & & \\ & & H & & H & & H & & H & & \end{array}$
Isobutane	4	C_4H_{10}	$CH_3CH(CH_3)_2$	
Pentane	5	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$ or $H_3C(CH_2)_3CH_3$	 $\begin{array}{ccccccccccccc} & & H & & H & & H & & H & & H & & \\ & & \vert & & \vert & & \vert & & \vert & & \vert & & \\ H & - & C & - & C & - & C & - & C & - & C & - & H \\ & & \vert & & \vert & & \vert & & \vert & & \vert & & \\ & & H & & H & & H & & H & & H & & \end{array}$
Iso pentane	5	C_5H_{12}	$CH_3CH_2CH(CH_3)_2$	

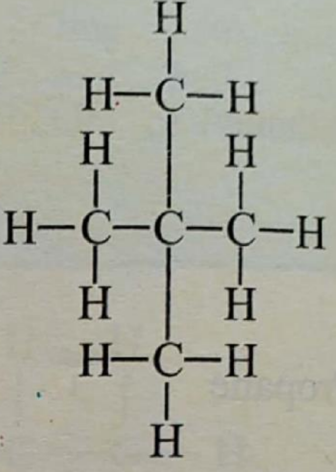
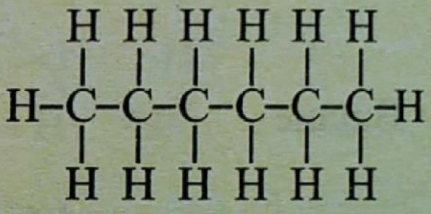
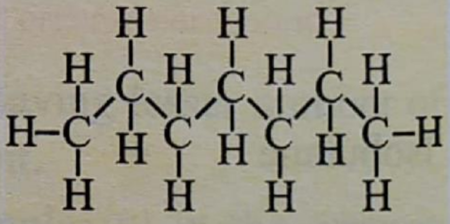
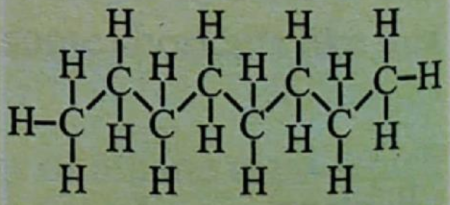
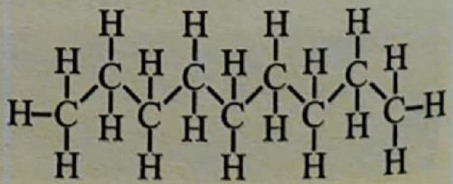
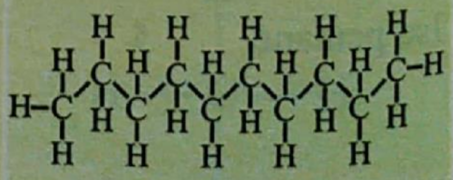
Name	No of C atoms in chain	Molecular formula	Condensed formula	Structural formula
Neo pentane	5	C_5H_{12}	$C(CH_3)_4$	
Hexane	6	C_6H_{14}	$CH_3(CH_2)_4CH_3$	 $\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H}$
Heptane	7	C_7H_{16}	$CH_3(CH_2)_5CH_3$	
Octane	8	C_8H_{18}	$CH_3(CH_2)_6CH_3$	
Nonane	9	C_9H_{20}	$CH_3(CH_2)_7CH_3$	
Decane	10	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$	

Table 11.3 Series of organic compounds composed of 1—10 carbon atoms.

This is notable that as the number of carbon atoms grows the complexity in the organic compound chain also increases, even the compounds having same number of carbon atoms can join in different ways yielding different type of compounds, e.g. in butane and in pentane, such compounds that have same number of atoms but different structures are called Isomers, this is clearly shown in case of '4' and '5' carbon containing compounds in table 11.3.

You can see in the above table that the individual members of this series of alkanes, each member contains one "•CH_2•" unit greater than the previous member, forming homologous series.

Activity 11.2

Write Condensed and structural formulae for the compounds

(a) n-Hexane (b) n-Octane

The Alkanes are also called the saturated hydrocarbons, because here the valency of "C" is fully satisfied, each 'C' forms its maximum of bonds, i.e '4' in number. and addition of any other atom is not possible. Each Carbon atom here is surrounded by 4 other atoms, as can be seen in the above table in their pictures. Alkanes are water insoluble compounds and the density, melting point and boiling point of these increases continuously with the chain length of carbon.

The Alkanes are relatively less reactive compounds, and they undergo reactions under extreme conditions only, although they readily undergo oxidation reactions yielding high amount of energy, that is why they are used as fuels.

$$C_nH_{2n+2} + xO_2 \longrightarrow yCO_2 + zH_2O + Heat$$

e.g Methane burns yielding following products.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)} + 891KJ/mol \text{ (at standard conditions)}$$

Higher alkanes which have more carbon atoms yield more energy, e.g.

$$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(g)} + 2220KJ/mol$$

This production of high energy is the reason the alkanes are used as fuel.

Alkanes having more than 20 atoms of carbon per mole are also used as low cost lubricants for engines and automobiles.

Paraffin wax which is a mixture of alkanes having generally 20—40 carbon atoms per molecule is usually used in candle making, in lubricants, water repellent and in skin cream preparations.

Activity 11.3

The Alkanes are used as low cost easy handling fuel, what products will you expect to form when kerosene oil (having 12 carbon atoms) is burnt.

11.4.1 Alkyl radical

As described earlier in this chapter that in a class of organic compounds different members that differ in ($\bullet CH_2\bullet$) unit comprise a homologous series, in such series the members differ in their properties in a gradual manner, e.g the boiling points in above series of alkanes increases in a rhythm. But the chemical properties in a class are almost same. So, in a class of an organic series the number of carbon atoms has not so value, as in the above alkanes, all the members in a class have almost similar chemical properties (although the physical properties differ in a regular rhythm), so, there is no need to write the number of carbon atoms, but instead, they are described by a general symbol "R". This “R” group is called Alkyl group. In alkanes the class is written as **"R-H"**, where "R" represents the alkyl chain of carbon atoms. So, removing a hydrogen atom from the parent hydrocarbon leaves behind the alkyl group (which also has an unpaired electron). Thus removing one hydrogen from methane, CH_4 gives a group of atoms $\bullet CH_3$, and is called methyl group or methyl radical. Similarly, from ethane (C_2H_6) the group $\bullet C_2H_5$ (called ethyl from ethane), is obtained.

$$CH_3—CH_3 \longrightarrow \bullet CH_2—CH_3 + \dot{H}$$

The dot written there represents unpaired electron which forms further bond with other species. In general, any alkane can be used to generate alkyl groups. The Alkyl groups are the key to naming organic molecules.

Here is chart that shows some common alkyl radicals with their names.

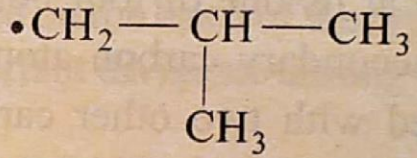
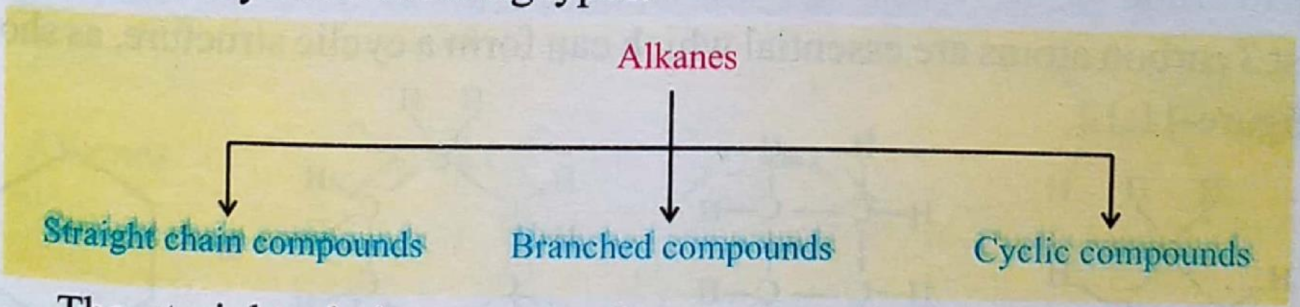
No of Carbon atom	Name	Structural representation
1	Methyl	$\bullet CH_3$
2	Ethyl	$\bullet CH_2CH_3$
3	n-propyl	$\bullet CH_2CH_2CH_3$
3	Isopropyl or sec.propyl	$H_3C - \overset{\bullet}{C}H - CH_3$
4	n-butyl	$\bullet CH_2 - CH_2 - CH_2 - CH_3$
4	isobutyl	 $\bullet CH_2 - \underset{\displaystyle CH_3}{\underset{\vert}{CH}} - CH_3$

Table 11.4 Some Alkyl radicals

It is to be noted that the line present above at starting of radical shows the point from where the bond forms with any other substrate species, and in naming a radical the suffix 'ane' from the parent chain is replaced by the 'yl' in the given radical.

Classification of Alkanes

The alkanes which are the simplest organic compounds can be classified broadly into following types.



The straight chain compounds are those in which each carbon is bonded to maximum of 2 other carbon atoms (such chain is called normal chain), as shown in the following.

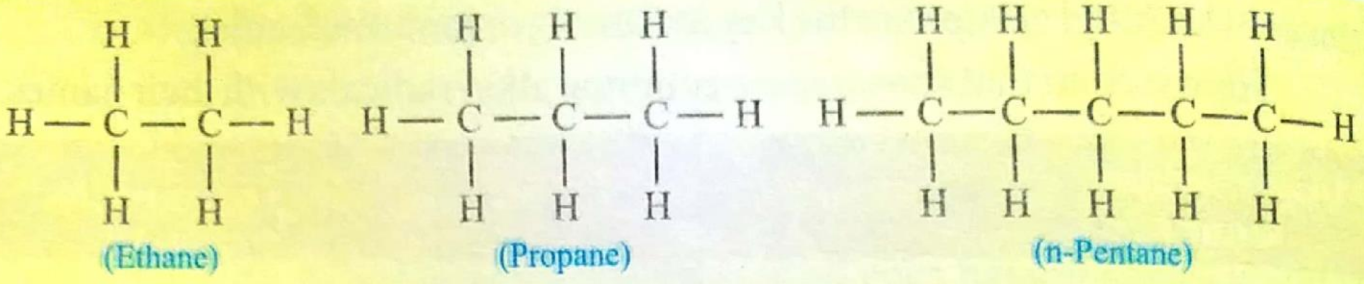


Fig. 11.10: Some straight chain Hydrocarbons

The branched organic compounds are those where at least one of the carbon atom present in the chain is bonded to 3 carbon atoms. There may be four different types of carbon atoms in the carbon chain. They are called primary, secondary, tertiary and quaternary carbon atoms. The primary carbon atom is that which is linked with only one carbon atom at its one of four bonds, the secondary carbon atom is linked with two other carbon atoms, the tertiary is linked with three carbon atoms and quaternary carbon atom is that which is linked with four other carbon atoms at its all four sides. This is further explained by the help of figure-11.11.

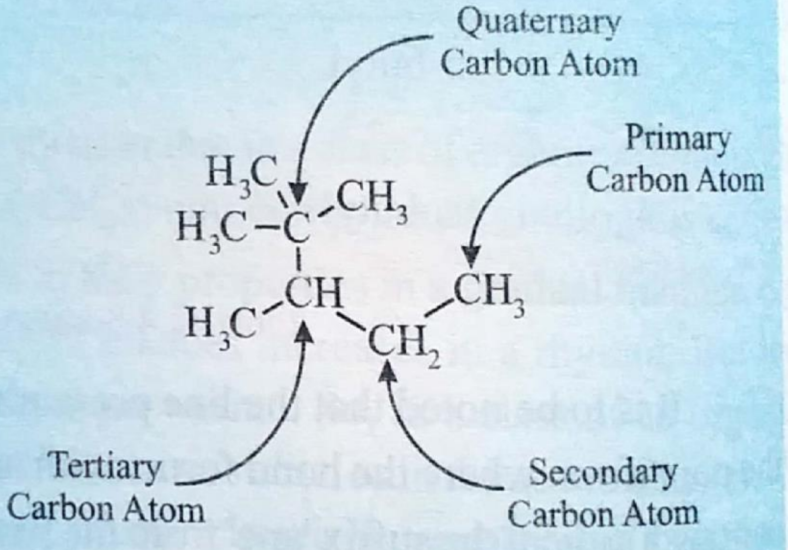


Fig. 11.11: A chain of hydrocarbon showing primary, secondary, tertiary and quaternary carbon atoms

In the cyclic compounds the carbon that forms the chain is bonded to other carbon atoms in a manner that a closed structure is resulted, for this at least 3 carbon atoms are essential which can form a cyclic structure, as shown in figure-11.12.

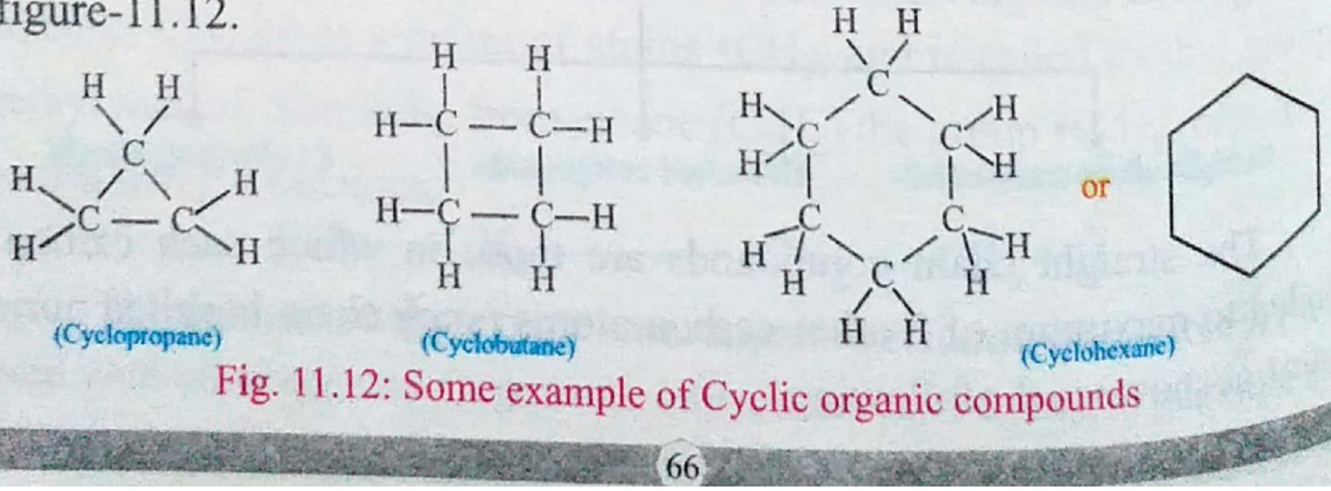


Fig. 11.12: Some example of Cyclic organic compounds

Notice that these cyclic compounds have been drawn here in different ways, this is how the organic compounds are written at different times and all these methods are correct, for ease we generally write the Carbon skeleton by lines and omit the 'C' symbol, as you can see in the case of Cyclohexane in above.

11.5 The Functional Groups

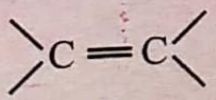
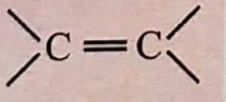
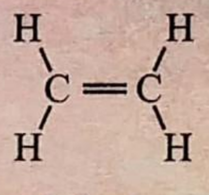
Although the organic compounds contain just a few elements, (carbon, hydrogen, oxygen, nitrogen, sulphur, and halogens), but they show vast diversity in their characters. This diversity is due to the difference in the linkages or sequence of atoms present in the molecule. This special linkages which constitute a class is called a functional group. The functional group can also be defined as the group of atom(s) upon which the functions or the properties of an organic compound depends.

The functional groups can further be divided on the basis of the types of atoms present in these compounds; thus the important divisions among these are:

- Functional groups having double and triple bonds
- Functional groups having C, H, and Halogens
- Functional groups having C, H, and N
- Functional groups having C, H and O

Following is table that shows these functional groups along with their sequence of atoms, an example of each is also given.

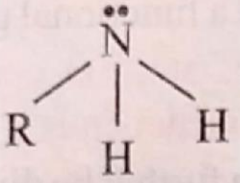
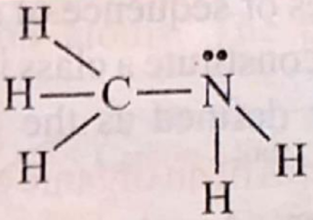
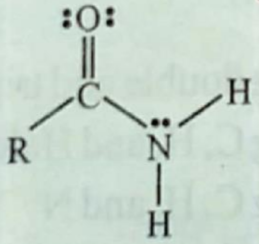
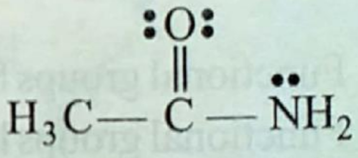
Functional groups having Double and triple bonds

Functional group	Formula	Structural formula	Example
Alkenes			 Ethene
Alkynes	$-C\equiv C-$	$-C\equiv C-$	$H-C\equiv C-H$ Ethyne

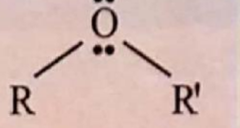
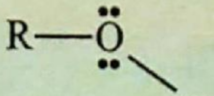
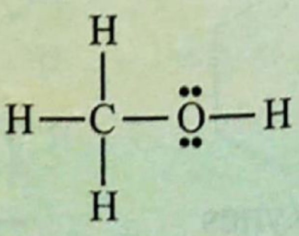
Functional groups having Carbon, Hydrogen and Halogens

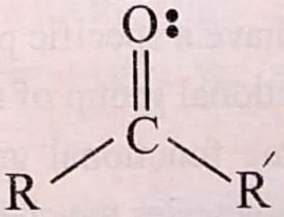
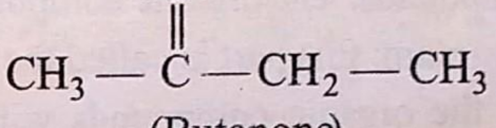
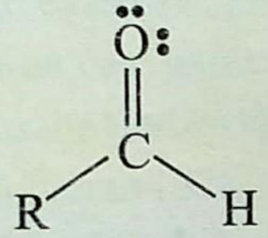
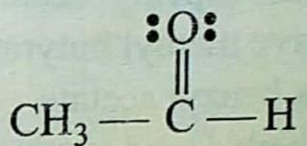
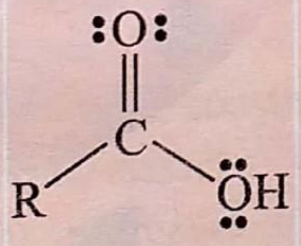
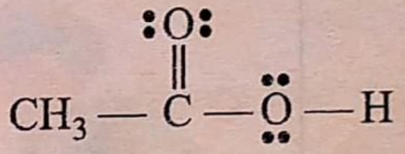
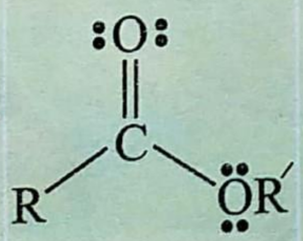
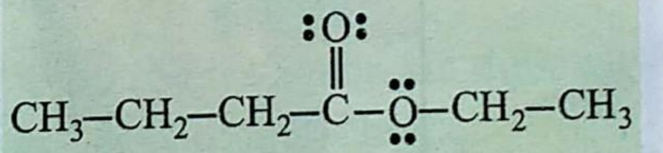
Functional group	Formula	Structural formula	Example
Alkyl Halides	RX	R — X	$H_3C — CH_2 — Cl$ (Chloroethane)

Functional groups having Carbon, Hydrogen and Nitrogen

Functional group	Formula	Structural formula	Example
Amines	$R\text{-}\ddot{N}H_2$		 (Methyl amine)
Amides	$RCONH_2$ or $RCONR_2$		 $H_3C-\overset{\overset{:O:}{\parallel}}{C}-\ddot{N}H_2$ (Ethanamide)

Functional groups having Carbon, Hydrogen and Oxygen

Functional group	Formula	Structural formula	Example
Ethers	$R\underset{\cdot\cdot}{\ddot{O}}R'$		$H_3C-CH_2-\underset{\cdot\cdot}{\ddot{O}}-CH_2-CH_3$ (Diethyl ether)
Alcohols	$R\underset{\cdot\cdot}{\ddot{O}}H$		 $H-\overset{\overset{H}{\vert}}{\underset{\underset{H}{\vert}}{C}}-\underset{\cdot\cdot}{\ddot{O}}-H$ (Methanol)

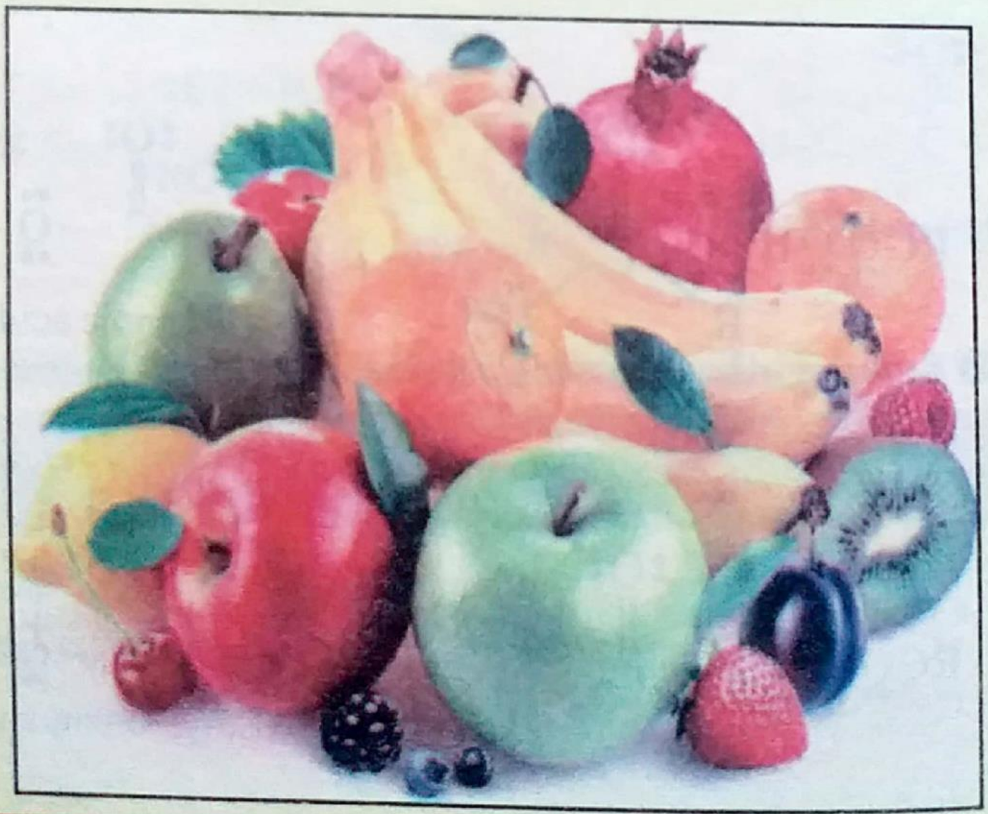
Functional group	Formula	Structural formula	Example
Ketone	$RC\ddot{\underset{\cdot\cdot}{O}}R'$		 $CH_3-\overset{\overset{:O:}{\|}}{C}-CH_2-CH_3$ (Butanone)
Aldehyde	$RCH\ddot{\underset{\cdot\cdot}{O}}$		 $CH_3-\overset{\overset{:O:}{\|}}{C}-H$ (Ethanal)
Carboxylic acid	$RC\ddot{\underset{\cdot\cdot}{O}}\,\ddot{\underset{\cdot\cdot}{O}}H$		 $CH_3-\overset{\overset{:O:}{\|}}{C}-\ddot{\underset{\cdot\cdot}{O}}-H$ (Ethanoic acid)
Esters	$RC\ddot{\underset{\cdot\cdot}{O}}\,\ddot{\underset{\cdot\cdot}{O}}R'$		 $CH_3-CH_2-CH_2-\overset{\overset{:O:}{\|}}{C}-\ddot{\underset{\cdot\cdot}{O}}-CH_2-CH_3$ (Ethyl butanoate)

You can see that in all these functional groups the atoms (mostly of same type) are linked in a special, characteristic and unique way that is why these organic compounds show so much diversity in their characters.

Interesting Information

One of the special features of the organic compounds is the property of having the homologous series; this property is not present in the inorganic compounds. The organic compounds have a specific part where the reactivity is maximum; this part is called the Functional group of that particular compound. All the organic compounds with same functional group fall under the same homologous series, and in a homologous series the chemical properties are same while physical properties vary in a regular manner; e.g. the distinct fragrance of most of the fruits is due to the presence of ester linkage in the homologous series.

Banana has Isopentyl acetate
Apples have methyl butyrate
Peach has benzyl acetate
Oranges have Octyl acetate
Pear has n-propyl acetate
Honey has Ethyl phenyl acetate



Summary of the Chapter

- Organic chemistry is one of the important branches of chemistry, this branch deals with the study of organic matter.
- In the organic chemistry we study the hydrocarbons and their derivatives.
- The hydrocarbons are the chemical compounds that have only carbon and hydrogen elements.
- In the organic compounds carbon is the chief element.
- The carbon has an extensive property of forming long chains; this property is termed as 'catenation'.
- Urea is regarded as the first synthetic organic compound, which was synthesized by Wohler in 1828.
- Methane is the first member of hydrocarbon series and simplest organic compound having molecular formula CH_4.
- The organic compounds are generally non-polar and water insoluble compounds.
- The organic compounds constitute a vast category and they are classified into several classes.
- In a class of organic compounds, the members differ by CH_2 units, the series formed by such is termed as the homologous series.
- As the number of carbon atoms increases, the organic compounds become more complex.
- The organic compounds can have same composition but different structures; such compounds are called isomers of each other.
- The major sources of organic compounds are the petroleum, natural gas and coal, and plant kingdom. Certain organic compounds are also synthesized artificially and these do not exist naturally, the important examples of such artificially synthesized compounds include different types of plastics.

- The petroleum, coal, and natural gas are also believed to be formed by decayed burried plants.
- The petroleum products play an important role in provision of energy rich compounds that run all the machineries of planet earth.
- The petroleum is refined in oil refineries on the basis that different fractions in petroleum have different boiling points; this technique of purification is called fractional distillation.
- Alkanes comprise saturated class of organic compounds having general formula C_nH_{2n+2}, where 'n' is the number of carbon atoms in the compound.
- Another important class of organic compounds constitutes the unsaturated hydrocarbon series, they are called 'alkenes' and 'alkynes'.
- Alkenes contain at least one double bond in their structure, while alkynes have one or more triple bond in their structure.
- The organic compounds also constitutes a cyclic structure where the carbon atoms are linked in a manner that a ring is formed, such compounds are classified as cyclic compounds.
- There exists a specific linkage of atoms in the organic compounds called 'functional group'; this functional group determines all the properties of organic compounds.

Exercise

Q1: Fill in the blanks with suitable words.

i) Organic chemistry deals with the study of ....

ii) Wohler was the first Scientist who prepared an organic compound named ....

iii) The long chain formation ability of carbon is termed as ....

iv) Alkanes are .... hydrocarbons.

v) A .... is the group of atoms, which determines the properties of organic compounds.

vi) General representation of the Alcohol is..............

vii) Ketone has the general formula..............

viii) The functional group present in Acetic acid is................

ix) The % of Carbon in ....coal is 80%.

x) The general formula of ether is ....

Q2: Choose the correct answer.

i) $NaHCO_3$ is categorized as:

(a) Organic compound

(b) Inorganic compound

(c) Some time organic, some time inorganic

(d) Bio-organic compound

ii) The Hydrocarbons are soluble in the:

(a) Organic solvents (b) Water

(c) Both of above (d) Non of above

iii) When two molecules have same molecular formula but different structures, the phenomenon is called:

(a) Catenation (b) Alkylation

(c) Isomerization (d) Sublimation

iv) Organic compounds undergo chemical reactions with the
(a) Very fast rate (b) Very slow rate
(c) Neither fast nor slow (d) They do not react

v) The important source of organic compounds is
(a) Coal (b) Petroleum
(c) Natural gas (d) All of these

vi) Major compound present in the natural gas is
(a) Methane (b) Ethane
(c) Propane (d) Butane

vii) When one 'H' atom is removed from an alkane, it forms:
(a) Saturated hydrocarbon (b) Unsaturated hydrocarbon
(c) Alkyl radical (d) Alkene

viii) The fraction of petroleum that contains Carbon atoms from 4—8 is called:
(a) Gasoline (b) Kerosene
(c) Diesel (d) Wax

ix) The fragrance of fruits is due to the presence of functional group called:
(a) Amines (b) Ethers
(c) Esters (d) Carboxyllic acid

x) On combustion the hydrocarbons produce
(a) CO_2 only (b) H_2O only
(c) Both CO_2 and H_2O (d) Oxygen

Q3: Answer the following questions briefly.

i) Define organic chemistry.
ii) What do you understand by the term "Catenation"?
iii) What is a homologous series?
iv) Write the names and uses of different types of coals.

v) Comment that the plants are main source of organic compounds.

vi) How organic chemistry is important to study?

vii) Define the functional group.

viii) Draw structures of the isomers of a hydrocarbon having 5 carbon atoms?

ix) What is an "alkyl group"?

x) Why peat is inferior quality coal?

Q4: Answer the following questions with reasoning.

i) What are the main differences between organic and Inorganic compounds?

ii) Why hydrocarbons do not dissolve in water?

iii) Why writing structural formulae of the organic compounds is important instead of the molecular formulae?

iv) Does catenation is shown by the carbon element only?

v) In the LPG, the fraction of propane and butane is more than the Methane gas.

Q5: Discuss the organic chemistry evolution. How Wohler broke the concept of vitalism?

Q6: How the organic chemistry helps the mankind?

Q7: What are the general characteristics of the organic compounds?

Q8: How crude oil is purified in the oil refineries?

Q9: Write a note on classification of alkane hydrocarbons?

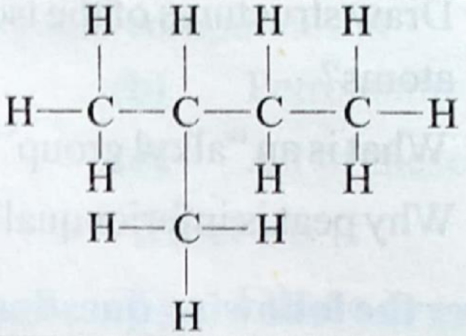
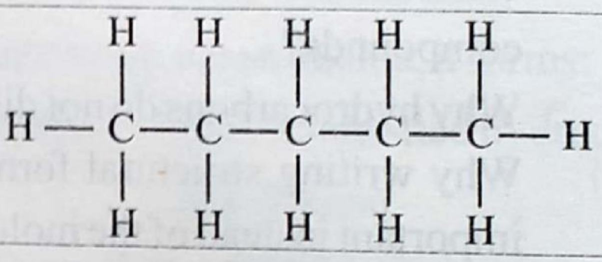
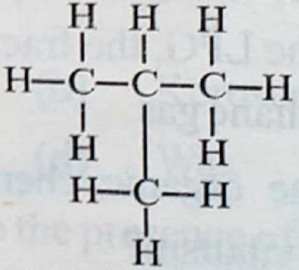
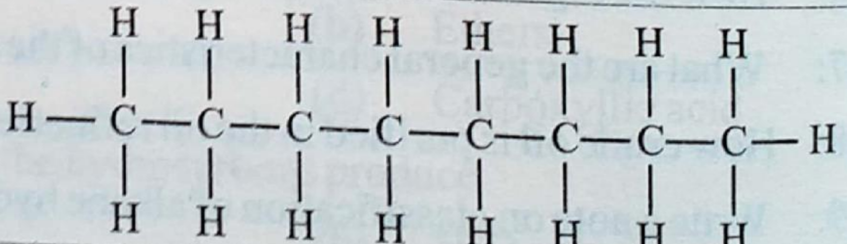
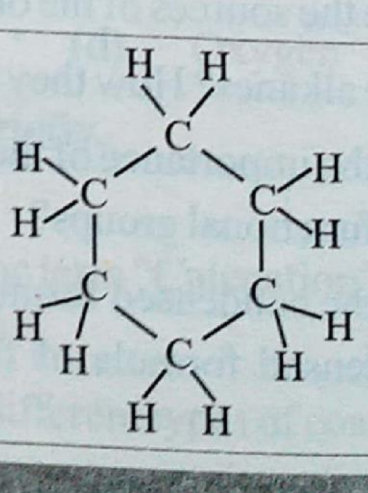
Q10: What are the sources of the organic compounds?

Q11: What are alkanes? How they are important to us?

Q12: Discuss the importance of the functional groups? What are the different types of functional groups?

Q13: What is the condensed formula used for the organic compound? Draw the condensed formula of first ten straight chain alkanes with their names.

Q14: Complete the table.

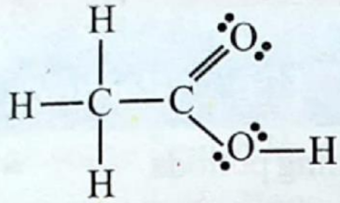
Name	Structure
Propane	
	
isohexane	
	
neohexane	
	
Cyclopentane	
	
neopentane	
	

Q15: What do you know about the Alkyl radicals? Explain with examples.

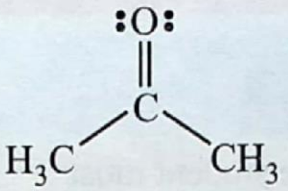
Q16: Identify the functional group in the given organic compound.

1. CH_3CHO
2. $CH_3—CO—CH_3$
3. CH_3COOH
4. $CH_3CO_2CH_3$
5. $CH_3—\ddot{N}H_2$
6. $CH_3CH=CH_2$

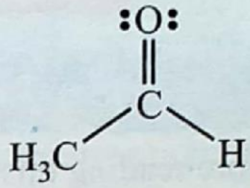
7.



8.



9.



10. $H_3C—CH_2—\underset{\cdot\cdot}{\ddot{O}}H$

Chapter

12

HYDROCARBONS

Conceptual Linkage

Before reading this chapter, the student must know the:

- Introduction of Organic Compounds
- Bounding in the Organic Compounds
- Difference in Saturated and Unsaturated
- Cyclic Structure of Organic Compounds

Time Allocation

Teaching periods =08
Assessment periods =02
Weightage =05%

LEARNING OUTCOMES

Students will be able to:

- Explain why a systematic method of naming chemical compounds is necessary. (Analyzing)
- Characterize a hydrocarbon. (Understanding)
- Draw electron cross and dot structures of simple alkanes. (Applying)
- Write a chemical equation to show the preparation of alkanes from hydrogenation of alkenes and alkynes and reduction of alkyl halides. (Remembering)
- Draw structural formulas of alkanes, alkenes and alkynes up to 5 carbon atoms. (Understanding)
- Write a chemical equation to show the preparation of alkenes from dehydration of alcohols and dehydrohalogenation of alkyl halides. (Remembering)
- Write a chemical equation to show the preparation of alkynes from Dehalogenation of 1, 2- dihalides and tetrahalides. (Remembering)
- Write chemical equations showing halogenation for alkanes, alkenes and alkynes. (Remembering)
- Write chemical equation showing reaction of $KMnO_4$ with, alkenes and alkynes. (Remembering)

Introduction

The Hydrocarbons are the simplest organic compounds which are made up of atoms of carbon and hydrogen only, (The hydro here stands for hydrogen and carbon for the carbon atoms).

The hydrocarbons are important to us in the sense that the fuels we use in our modern life is almost all composed of the hydrocarbons. The hydrocarbons are also helpful for us as they are used in the manufacture of most of the valuable substances of our daily usage.

Activity 12.1

Although the Hydrocarbons are widely used as energy resources but they produce some health hazard products on burning, pollute the environment and cause Green house effect, which is increasing the temperature of earth.

Can you suggest some sources of energy other than these hydrocarbons that can be used as alternate source of energy?

12.1 Classification of Hydrocarbons

The hydrocarbons are classified into two major groups, i.e the acyclic or open chain also called (aliphatic compounds) and the cyclic or closed chain compounds. They are described in detail separately in following section.

Open Chain or Acyclic hydrocarbons:

The acyclic hydrocarbons or the straight chain compounds are those in which the chain of carbon grows in two or more directions without cycle formation. All the "C" atoms in the chain are primary carbon atoms, (the primary carbon atom also called "1°" is that which is linked with the carbon atoms not more than 1 in number).

The branched aliphatic compounds are those which have at least one secondary or tertiary carbon atom in the chain, (The Secondary carbon or "2°" is that one which has two carbon atom directly attached with it, the tertiary carbon atom or "3°" is that

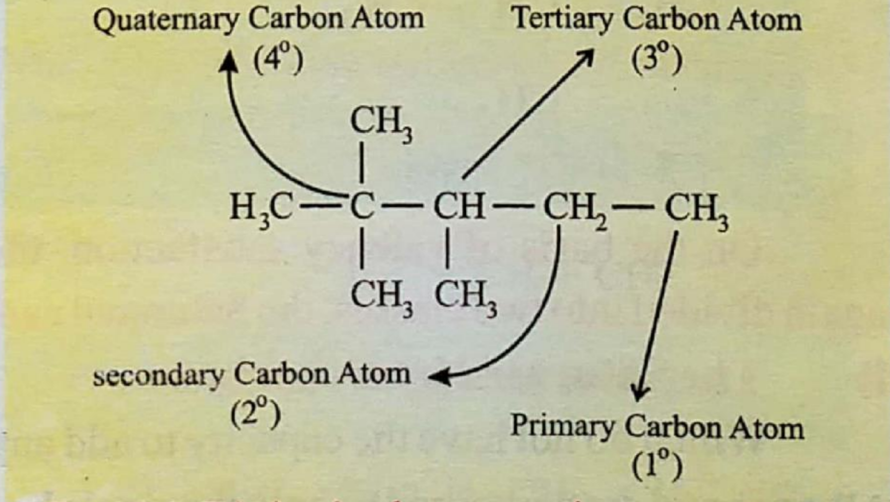


Fig. 12.1: Distinction between primary, secondary, tertiary and quaternary carbon atoms.

which is attached with three carbon atoms and the carbon atom which is linked at all four bonds with carbon is called quaternary carbon atom or “4^{o}”, see figure-12.1.

The acyclic hydrocarbons are further divided into two subtypes, which are explained here in following.

I) Straight Chained Hydrocarbons

In these hydrocarbons the chain of carbon atoms runs in two directions only and all carbon atoms present are either primary or secondary e.g.

$$CH_3-CH_2-CH_2-CH_3$$

n-Butane

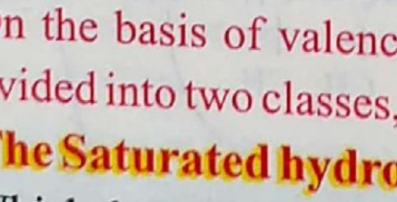
and

$$CH_3-CH_2-CH_2-CH_2-CH_3$$

n-pentane

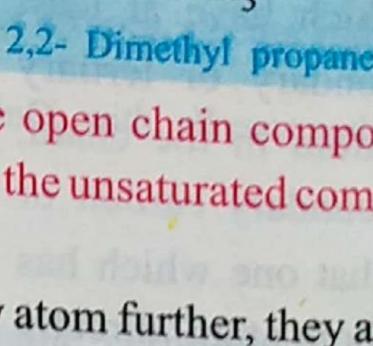
II) Branched Hydrocarbons

In this type certain branches appear upon the main carbon chain. Note that a branch is also a chain of carbon but it has lesser number of carbon atoms than the main chain, at branching a carbon atom is attached with '3' or '4' carbons and thus here tertiary (3^{o}) or quaternary (4^{o}) carbon atoms are seen e.g. 2-Methyl propane and 2,2-dimethyl propane.



$$CH_3-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_3$$

2- Methyl propane



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

2,2- Dimethyl propane

On the basis of valency satisfaction, the open chain compounds are again divided into two classes, the Saturated and the unsaturated compounds.

i) The Saturated hydrocarbons

Which do not have the capacity to add any atom further, they are called **Alkanes** and are composed of only the single bond between the carbon atoms. Examples of such compounds include.

Saturated Hydrocarbons	Line formula
Methane	CH_4
Ethane	$H_3C—CH_3$
Propane	$H_3C—CH_2—CH_3$
Butane	$H_3C—CH_2—CH_2—CH_3$

Table 12.1 Some Saturated Hydrocarbons

ii) The Unsaturated hydrocarbons

Those which can add atoms further, e.g. the alkenes and the alkynes are unsaturated hydrocarbons because the valency of carbon is not fully satisfied in these which contain double and triple bonds respectively.

$HC\equiv CH$ Ethyne	$H_2C=CH_2$ Ethene

Fig 12.2 Unsaturated hydrocarbons

The **Alkenes** contain at least one double bonds between the two Carbon atoms in the chain, while the **Alkynes** have at least one triple bond between the Carbon atoms of the chain, the addition of atoms during reactions takes place at this double or triple bonds of the compound.

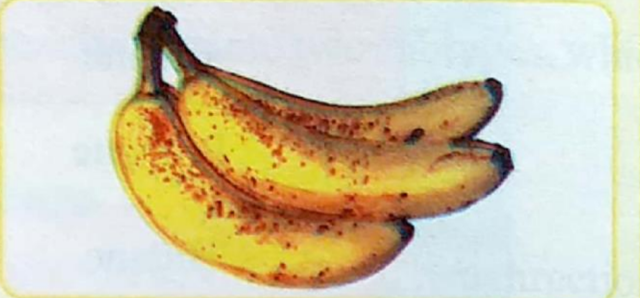
Some of the simplest alkenes are shown in the following table.

Alkene Hydrocarbons	Molecular Structural Formula
Ethene or Ethylene	$H_2C = CH_2$
Propene	$H_2C = CH— CH_3$
1-Butene	$H_2C = CH— CH_2— CH_3$
2-Hexene	$H_3C—CH=CH—CH_2—CH_2—CH_3$

Table 12.2 Some alkenes

Interesting Information

During ripening of bananas ethene gas is produced which makes fruits ripen faster and can lead to speed spoilage, that is the reason they enhance and accelerate the decaying process in the fruits at their neighbourhood. So, they should not be kept alongwith other fruits.



And the simple alkynes are written in the following table:

Alkyne Hydrocarbons	Molecular Structural Formula
Acetylene or Ethyne	$HC \equiv HC$
Propyne	$HC \equiv C - CH_3$
1-Butyne	$HC \equiv C - CH_2 - CH_3$
1-Pentyne	$HC \equiv C - CH_2 - CH_2 - CH_3$
2-Hexyne	$H_3C - C \equiv C - CH_2 - CH_2 - CH_3$

Table 12.3 Some alkynes

12.1.2 Cyclic hydrocarbons

Another class of the hydrocarbons is the cyclic or closed chained hydrocarbons which are the compounds having a closed structure where the carbon chain increases in a manner that a closed type ring is formed between the carbon atoms of chain. For such closed systems there must be at least 3 carbon atoms in the compound.

The cyclic compounds are divided into two further divisions, i.e. alicyclic compounds and the Aromatic compounds. The **aromatic compounds** are the organic compounds which contain at least one benzene ring in their structure, the benzene ring is shown here in figure-12.2.

Examples of such compounds include benzene itself, Naphthalene, Anthracene etc. Such compounds have special features e.g. they contain conjugate (alternate) double bonds, and although they are unsaturated but they do not react like aliphatic unsaturated compounds.

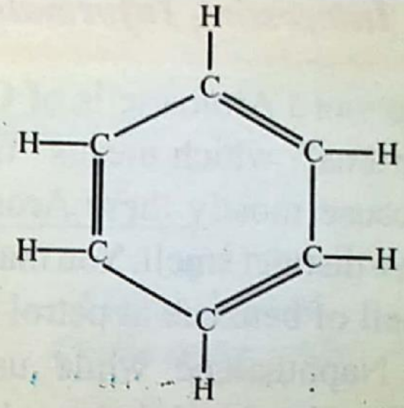


Fig 12.3 Benzene

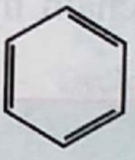
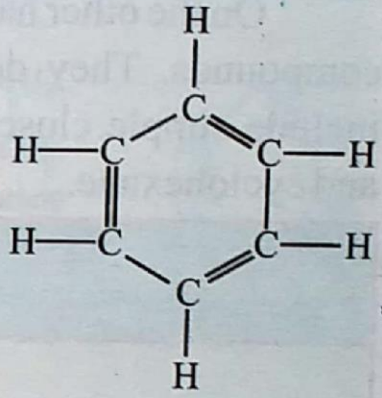
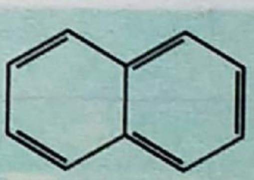
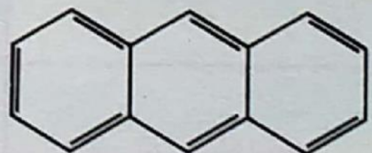
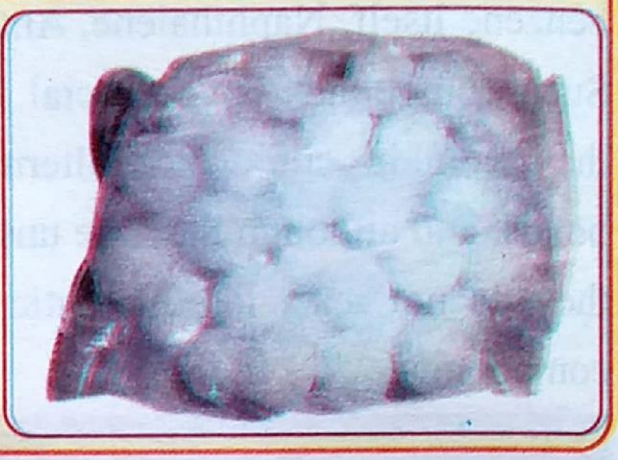
Aromatic Hydrocarbons	Molecular Formula
Benzene	C_6H_6  or 
Naphthalene	$C_{10}H_8$ 
Anthracene	$C_{14}H_{10}$ 

Table 12.4: Some Aromatic Hydrocarbon

Fig. 12. 4: In the cherries the odour is produced by an aromatic compound benzaldehyde.

Interesting Information

The word Aromatic is of Greek origin from "Aroma", which means "fragrance". This is because mostly these Aromatic compounds have distinct smell. You may have noticed the smell of benzene at petrol pumps, and smell of Naphthalene while using Naphthalene balls (the Naphthalene balls are kept in almirah and trunks to keep cloths moth free.)



On the other hand the **Alicyclic compounds** are other than the aromatic compounds. They do not have the Benzene ring in their skeleton, these include simple closed chain hydrocarbons like cyclopropane, cyclobutane and cyclohexane.

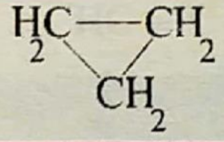
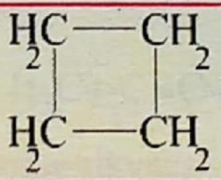
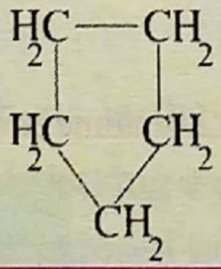
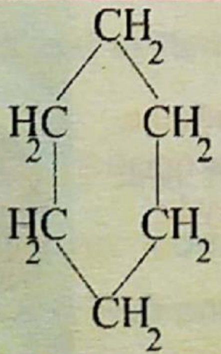
Number of Carbon atoms	Structure	Name
3		Cyclopropane
4		Cyclobutane
5		Cyclopentane
6		Cyclohexane

Table 12.5: Some Alicyclic Hydrocarbon

This whole classification of hydrocarbons is well explained in the flow sheet of figure-12.3.

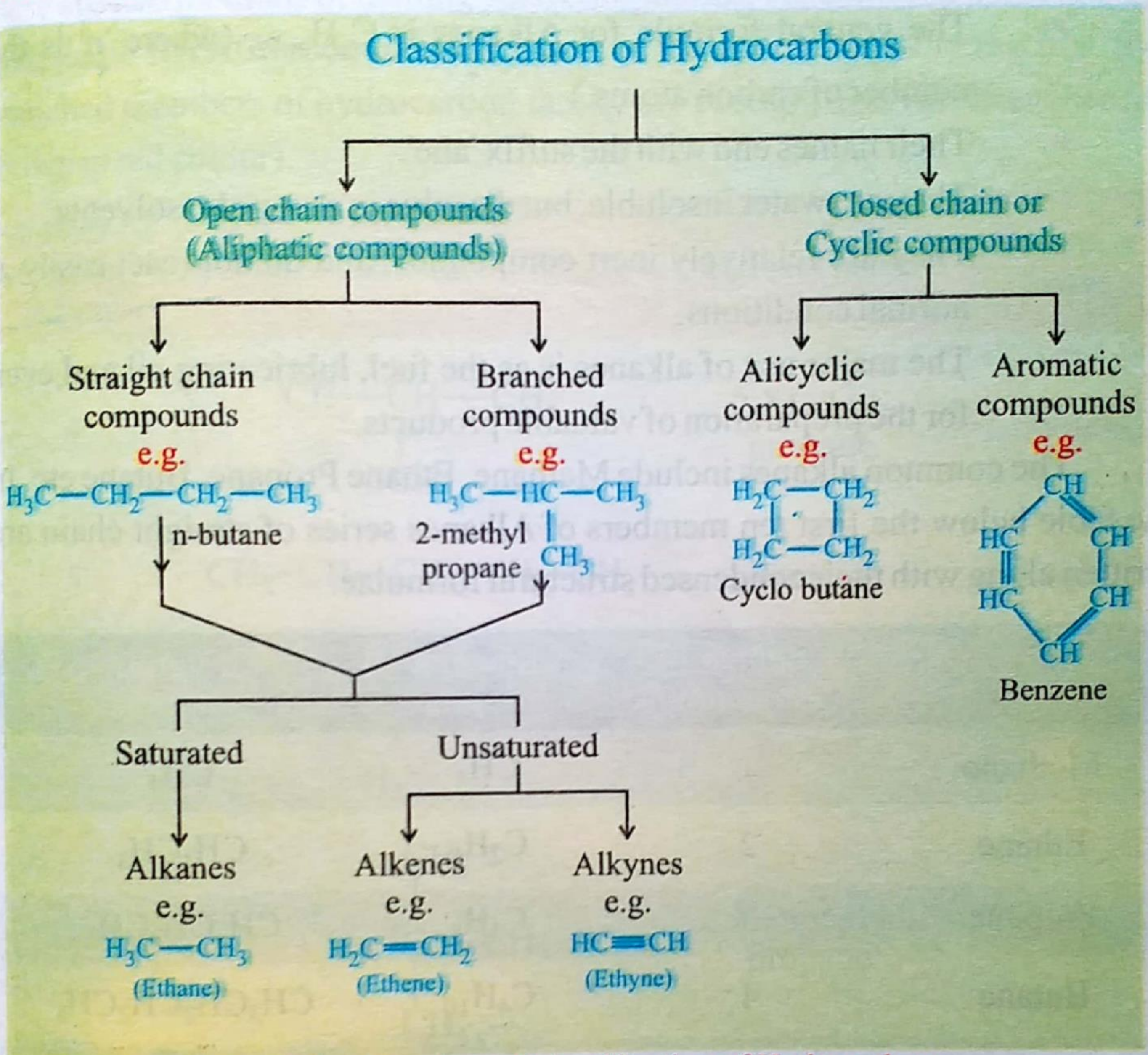


Fig. 12.5: Flow chart of classification of Hydrocarbons

In the subsequent sections we will discuss important and common members of these divisions.

12.2 The Alkanes

Alkanes comprise the class of organic compounds having only single bonds between the carbon atoms. The number of bonds that the carbon can form is '4', alkanes cannot add up any other atom in them so they are the saturated compounds.

The general characters that the alkanes posses are:

- They are called saturated compounds, and have only single bonds between the carbon atoms.
- The general formula for Alkanes is C_nH_{2n+2}, (where 'n' is the number of carbon atoms.)
- Their names end with the suffix 'ane'.
- They are water insoluble, but dissolve in non-polar solvents.
- They are relatively inert compounds, and do not react easily at normal conditions.
- The major use of alkanes is as the fuel, lubricating oil and even for the preparation of valuable products.

The common alkanes include Methane, Ethane Propane, Butane etc. In the table below the first ten members of Alkanes series of straight chain are written along with their condensed structural formulae.

Name	Number of Carbon atoms	Molecular Formula	Structural Formula
Methane	1	CH_4	CH_4
Ethane	2	C_2H_6	CH_3CH_3
Propane	3	C_3H_8	$CH_3CH_2CH_3$
Butane	4	C_4H_{10}	$CH_3CH_2CH_2CH_3$
Pentane	5	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$
Hexane	6	C_6H_{14}	$CH_3(CH_2)_4CH_3$
Heptane	7	C_7H_{16}	$CH_3(CH_2)_5CH_3$
Octane	8	C_8H_{18}	$CH_3(CH_2)_6CH_3$
Nonane	9	C_9H_{20}	$CH_3(CH_2)_7CH_3$
Decane	10	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$

Table 12.6 Straight chain alkanes having 1—10 carbon atoms

There can also arise branching in the chain of Alkanes, in such cases there are two methods of naming such compounds, the common name and the systematic IUPAC recommended name, in the following table the first five branched members of hydrocarbon family are exemplified, (the branches are shown in red colour).

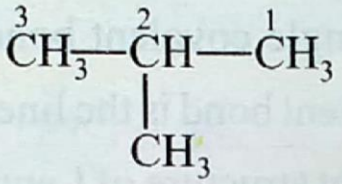
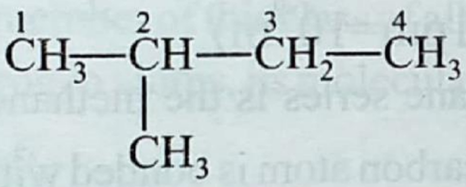
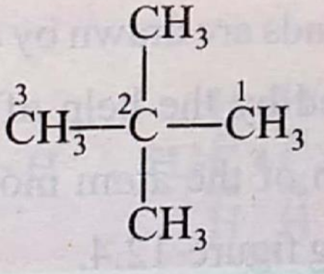
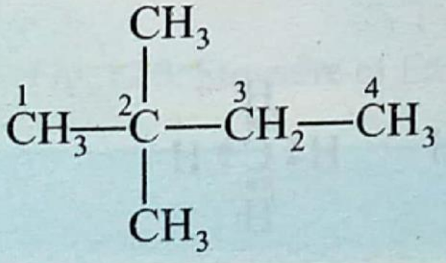
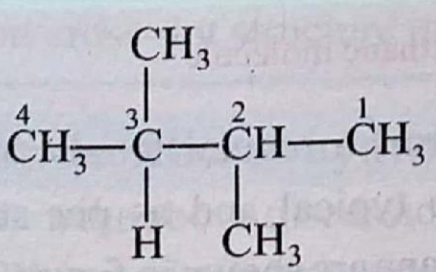
Number of Carbon Atom	Structure	IUPAC name	Common name
4	 $\overset{3}{C}H_3-\underset{\substack{\vert\\ CH_3}}{\overset{2}{C}H}-\overset{1}{C}H_3$	2-Methyl-propane	isobutene
5	$CH_3-CH_2-CH_2-CH_2-CH_3$	Pentane	n-Pentane
5	 $\overset{1}{C}H_3-\underset{\substack{\vert\\ CH_3}}{\overset{2}{C}H}-\overset{3}{C}H_2-\overset{4}{C}H_3$	2-Methyl-butane	isopentane
5	 $\overset{3}{C}H_3-\underset{\substack{\vert\\ CH_3}}{\overset{\substack{CH_3\\ \vert}}{{}^{2}C}}-\overset{1}{C}H_3$	2,2-Dimethyl-propane	neopentane
6	 $\overset{1}{C}H_3-\underset{\substack{\vert\\ CH_3}}{\overset{\substack{CH_3\\ \vert}}{{}^{2}C}}-\overset{3}{C}H_2-\overset{4}{C}H_3$	2,2-Dimethyl-butane	neohexane
6	 $\overset{4}{C}H_3-\underset{\substack{\vert\\ H}}{\overset{\substack{CH_3\\ \vert}}{{}^{3}C}}-\underset{\substack{\vert\\ CH_3}}{\overset{2}{C}H}-\overset{1}{C}H_3$	2,3-Dimethyl-butane	—

Table 12.7 Some branched alkanes

The Alkanes not only exist in straight chain linear form, as branched or unbranched hydrocarbon but cyclic alkanes also exist in nature, (remember in cyclic structures members do not follow the general formula C_nH_{2n+2} rule.). In the table 12.5 some important cyclo alkanes are shown.

Alkanes are obtained from natural sources of natural gas and petroleum crude oil, where they are present in the form of varying composition mixture. This mixture is distilled in oil refineries using the technique called "fractional distillation" and each fraction according to the market need is supplied.

Structurally the alkanes form single covalent bonds with carbon and hydrogen, the usual manner of the covalent bond is the line representation, but it can also be represented using cross-dot structure of Lewis form as well. The angles between H—C—H is 109.5° and the bond length between C—C is 1.54A° (154pm), while in C—H is the bond length is 1.10A° (110pm). (Remember that $1A^{\circ} = 10^{-10}$m and $1pm = 10^{-9}$m)

The first member of the Alkane series is the methane which has the molecular formula CH_4. Where the carbon atom is bonded with four hydrogen atoms through covalent bond. These bonds are drawn by a line representation normally. They can also be represented by the help of their cross and dot structures to show the electron of each of the atom more clearly. All these structure are shown here in the following figure-12.4.

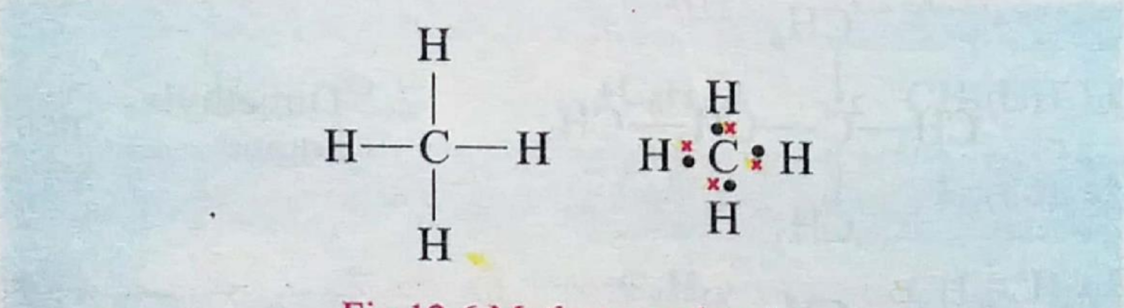


Fig 12.6 Methane molecule

The molecule of methane forms a regular tetrahedral structure, the bond angles and bond distance are typical and as per standard of other alkanes, these representation of methane are shown in figure-12.5.

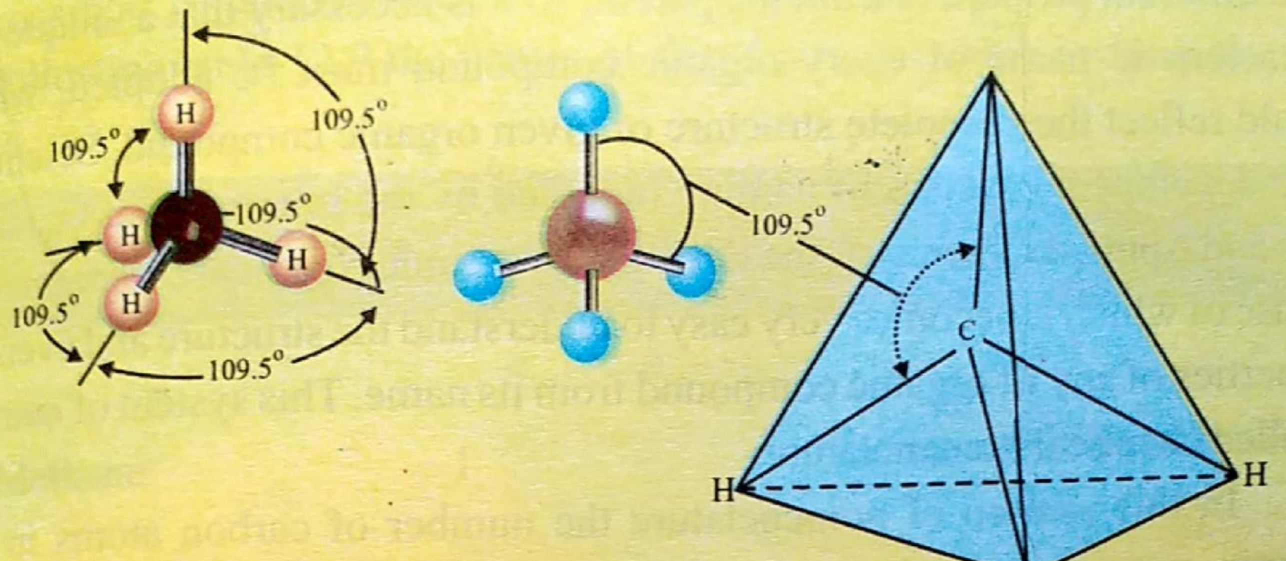


Fig. 12.7: The structure of Methane Molecule

Notice that angle between each of the H—C—H atoms is 109.5° and thus a regular tetrahedron structure is achieved.

The second member of this class of alkanes is the ethane, which has two carbon and six hydrogen atoms, its molecular formula is 'C_2H_6'. Its structure is shown in figure-12.6.

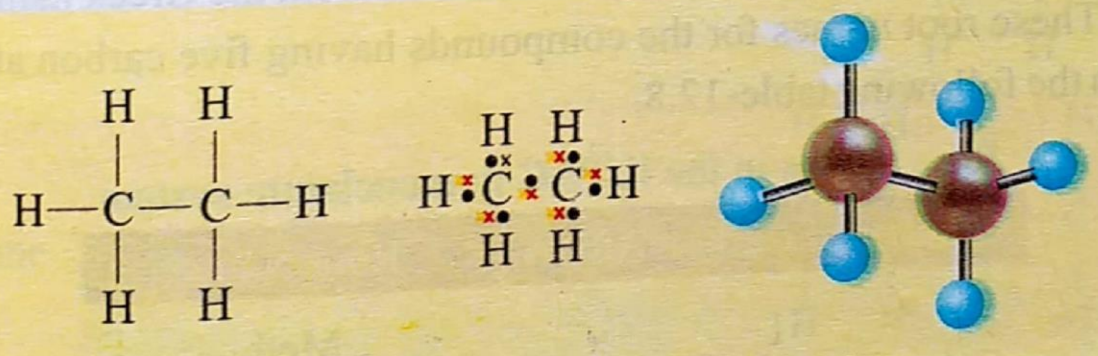


Fig. 12.8: Structure of Ethane Molecule

Activity 12.2

Write electron cross-dot structure of n-propane and n-butane.

12.2.1 Naming the Alkane hydrocarbons

This is clear from the above discussion that in the hydrocarbons chain a slight change i.e. (CH_2) results in the generation of new compounds which have different properties from the parent, so it is necessary that a unique and characteristic name of every organic compound must be adopted, which should reflect the complete structure of given organic compound. Scientists have developed a system of naming (adopted by the International Union of Pure and Applied Chemistry, the IUPAC) the organic chemical compounds by the use of which it becomes very easy to understand the structure and even the properties of any of organic compound from its name. This system of naming is called chemical nomenclature.

In this system of nomenclature the number of carbon atoms in the organic compound and the functional group which provides the basic classification of the organic compounds are used as the basis of the naming, and different prefixes or suffixes are used to distinguish between different compounds.

The root name for an organic compound indicates the number of carbon atoms in the longest continuous chain of carbon atoms containing the functional group. Thus the root name is a code which tells the number of carbons in a molecule. This root name is derived from the Greek name for the number. These root names for the compounds having five carbon atoms are written in the following table-12.8.

Root names in the IUPAC nomenclature system

Number of Carbon Atoms	Root Name
1	Meth
2	Eth
3	Prop
4	But
5	Pent

Table 12.8 Root names for 1—5 carbon

For example, the compound having one carbon atom from 'meth' will be methane where 'suffix 'ane' indicates saturated. It is the simple hydrocarbon. Similarly ethane is the hydrocarbon with two carbon atoms. In the following table-12.9 the names of first 5 straight chain hydrocarbons is given.

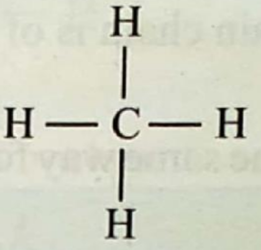
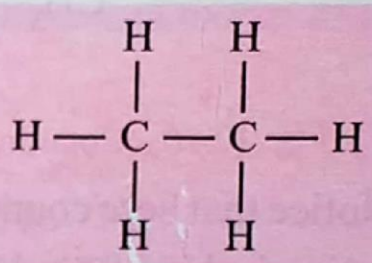
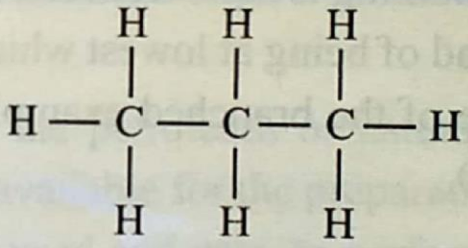
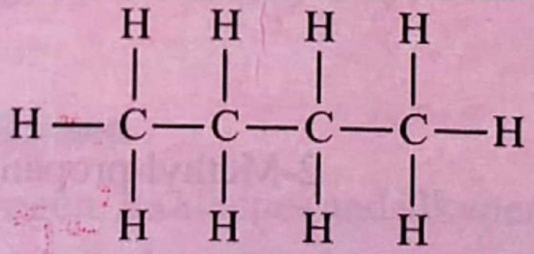
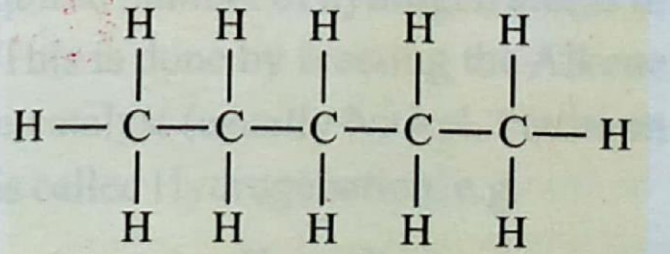
Name	No of carbon atoms in chain	Structural formula
Methane	1	
Ethane	2	
Propane	3	
Butane	4	
Pentane	5	

Table 12.9 Names of first five straight chained hydrocarbons

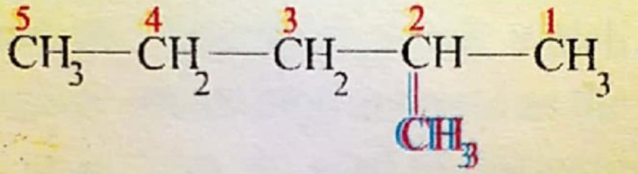
There is also the possibility that a branch arise from the hydrocarbon chain, in such case the whole chain is counted from the side at which the branch is at nearest position and the branch is named as radical.

$$\overset{1}{CH_3}-\underset{\displaystyle CH_3}{\overset{2}{CH}}-\overset{3}{CH_2}-\overset{4}{CH_3}$$

Fig. 12.9: Counting sequence of Carbon in chain

This compound is called 2-Methyl butane because the branch is of one carbon, and is situated at carbon number 2 of chain, so branch name is methyl, and the main chain is of four carbon so it is butane, hence name is 2-Methyl butane.

In the same way following compound is 2-Methyl pentane.

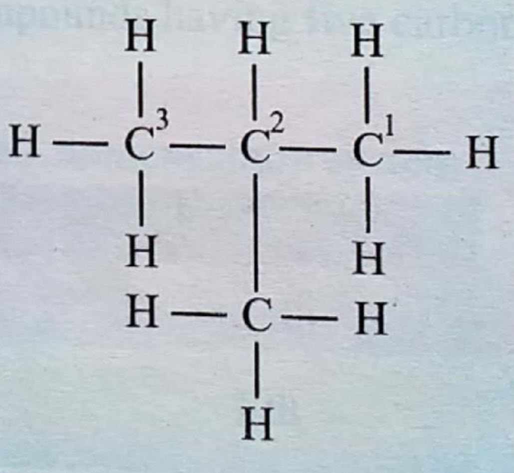


$$\overset{5}{CH_3}-\overset{4}{CH_2}-\overset{3}{CH_2}-\underset{\displaystyle CH_3}{\overset{2}{CH}}-\overset{1}{CH_3}$$

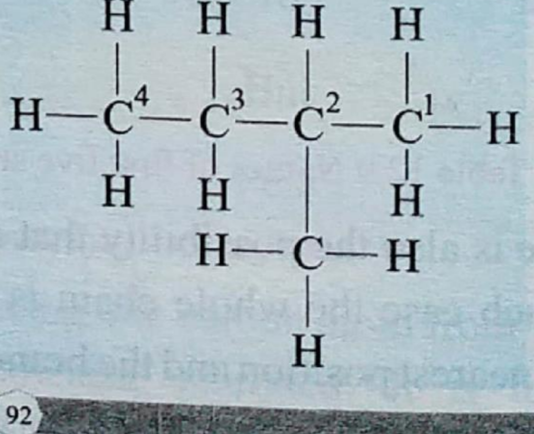
Fig. 12.10: Counting sequence of Carbon in 2-methyl pentane

Notice that here counting is done from right side of the chain because if the counting is done from left side, it will bring the position of chain farthest instead of being at lowest which is not according to rules framed by IUPAC. Some of the branched examples are described here in the following table-12.10.

2-Methyl-propane



2-Methyl-butane



2,2-Dimethyl-propane

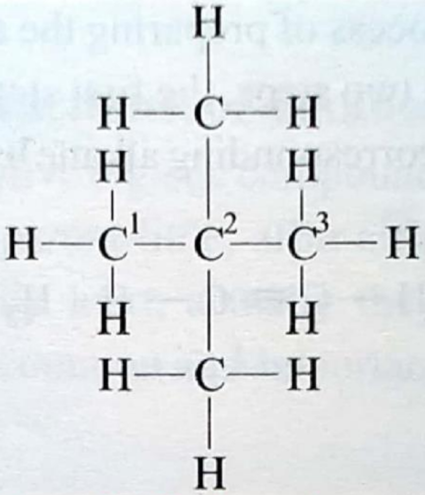


Table 12.10 Names of some branched hydrocarbons

Activity 12.3

Write structures of the following alkanes.

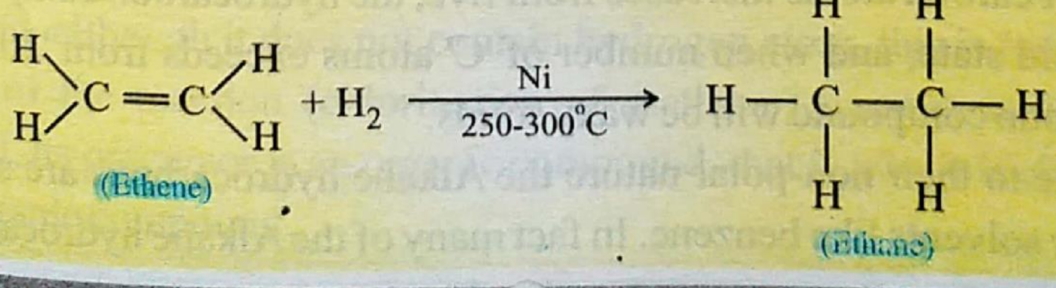
① 4-Methyl-pentane.
② 2,3-Dimethyl-hexane,
③ 2,2-Dimethyl-butane

12.2.2 Preparation of Alkanes

The alkanes are generally purified from the petroleum or natural gas sources. Although there are various methods available for the preparation of the alkanes. Two methods which are widely used and easy to perform are discussed here.

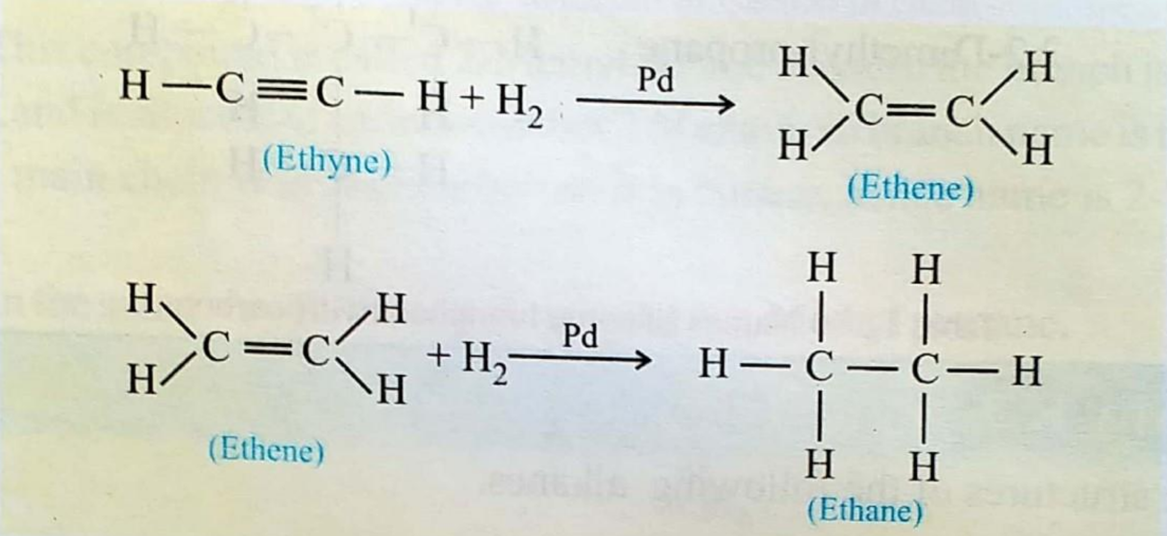
I. Hydrogenation of Alkenes and Alkynes

hydrogenation means addition of hydrogen. As alkenes and alkynes are deficient of hydrogen, so if we add the required number of hydrogen atoms to them, they form corresponding alkanes. This is done by reacting the Alkene and Alkyne by Hydrogen in presence of a catalyst (usually Nickel, Platinum or Palladium). This addition of hydrogen is called Hydrogenation. e.g.



$$H_2C=CH_2 + H_2 \xrightarrow[250\text{-}300^\circ C]{Ni} H_3C-CH_3$$

The process of preparing the alkanes from the alkynes is same but this takes place in two steps, the first step is the preparation of an alkene which is converted to corresponding alkane by the same process described earlier. i.e.



II. Reduction of Alkyl halides

Another method of preparing Alkanes is the reduction of Alkyl halides. The Alkyl halides are the compounds where the halogen atom is present in the alkyl chain. They are relatively more reactive compounds, so this reaction is easy to carry out without the need of any catalyst or much heat, just room temperature is enough. Only a suitable reducing agent like Zn metal is required. e.g.

$$H_3C—CH_2—Cl + 2[H] \xrightarrow{Zn/HCl} H_3C—CH_3 + HCl$$

Ethyl Chloride

Ethane

12.2.3 Physical properties of Alkanes

The Alkanes are covalent, non-polar compounds, their melting and boiling points increases with the increase of number of carbon atoms first four members of these are gaseous state at normal temperature and pressure, when number of carbon atoms increases from five, the hydrocarbon compound will be in liquid state, and when number of 'C' atoms exceeds from '20' then the hydrocarbon compound will be waxy solids.

Due to their non-polar nature the Alkane hydrocarbons are soluble in non-polar solvents like benzene. In fact many of the Alkane hydrocarbons are used as the good non-polar solvent.

12.2.4 Chemical properties (reactions) of Alkanes

The alkanes are relatively less reactive organic compounds. Due to less reactivity they are also called paraffin (parum-little, affin-affinity to react). But it doesn't mean that they are totally inert, actually they react under vigorous conditions. Some of the most common and important reactions of alkanes are following.

I. Halogenation

The reaction with the halogens is termed as the halogenation. The halogens are quite reactive elements, and the reactivity decreases down the group. Hence the fluorine is more reactive and reacts violently. The Alkanes react with the halogens in the presence of some energy source, generally the light provides the required energy sufficiently. e.g. the Cl_2 with methane reacts to give the chloro methane, that is called photo chemical reaction.

$$CH_{4(g)} + Cl_{2(g)} \xrightarrow[h\nu]{\text{Light}} CH_3Cl_{(g)} + HCl_{(g)}$$

The reaction proceeds further and more hydrogen atoms are replaced by the 'Cl' atoms (this depends upon the availability of 'Cl' atoms).

$$CH_4 + Cl-Cl \xrightarrow[h\nu]{\text{Light}} CH_3Cl + HCl$$

$$CH_3Cl + Cl-Cl \xrightarrow[h\nu]{\text{Light}} CH_2Cl_2 + HCl$$

$$CH_2Cl_2 + Cl-Cl \xrightarrow[h\nu]{\text{Light}} CHCl_3 + HCl$$

$$CHCl_3 + Cl-Cl \xrightarrow[h\nu]{\text{Light}} CCl_4 + HCl$$

Interesting Information

This is important to know that carbon tetrachloride (CCl_4) is an organic compound, although it does not contain hydrogen atom, this is because of the fact of the reaction (chlorination of methane) through which it is produced, its precursor is an organic compound, that is why it is classified as the organic compound.

II. Combustion

The combustion or complete oxidation of alkanes is vital for human beings as most of the fuel in petroleum products is in the form of alkane hydrocarbon and burning of this fuel is the chief source of energy for our requirements.

As the number of carbon atoms (and of course the hydrogen too) increases, the amount of energy released in the reaction also increases, e.g.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)} \quad \Delta H = -890KJ/Mole$$

The amount of energy released in this combustion of methane is 890KJ/mole.

$$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(g)} \quad \Delta H = 2219\ KJ/mole$$

The amount of energy released in combustion of propane is 2219KJ/mole feet.

12.3 The Alkenes

The alkenes are the unsaturated hydrocarbons having the general formula C_nH_{2n} (but remember that this general formula is true for the compounds when only one double bond is there in the carbon chain). The alkenes have at least one double bond in their structure, e.g. see table 12.11.

Ethene	$H_2C{=}CH_2$
Propene	$CH_2 = CH - CH_3$
1-Butene	$H_3C{-}CH_2{-}CH{=}CH_2$
2-Butene	$H_3C{-}CH{=}CH{-}CH_3$

Table 12.11 Some alkenes

Notice that the alkenes are also named likewise of their Alkane members, but the suffix 'ane' replaces with 'ene' where 'e' indicates the double bond.

The alkenes are important in the sense that they are more reactive compounds than the alkanes and are therefore used as the starting material for the preparation of many important organic compounds.

Activity 12.4

Draw electron dot structure of:

(a) Ethene, (b) Propene

12.3.1 Preparation of Alkenes

The Alkenes are prepared by a number of methods, some important of which are following.

I. Dehydration of alcohols

When an alcohol is dehydrated (dehydration-loss of water), an alkene is formed. The dehydration is brought by a strong dehydrating agent like H_2SO_4 at high temperature.

$$CH_3CH_2OH \xrightarrow[170^{\circ}]{H_2SO_4} CH_2 = CH_2 + H_2O$$

II. Dehydrohalogenation of Alkyl halides

When a hydrogen halide (HX) group is eliminated from alkyl halides, the alkene is formed, as shown in following example.

$$H_3C - CH_2 - Br + KOH \xrightarrow[100^{\circ}C]{\text{Alcoholic medium}} H_2C = CH_2 + KBr + H_2O$$

12.3.2 Reactions of Alkenes

The alkenes are highly reactive compounds. They are also called "Olefins" meaning oil forming compounds, because they form oily products with halogens. In addition they form many important products. Some of the typical reactions of alkenes are given here.

I. Addition of Halogens

The alkenes readily react with halogens to form the products.

$$CH_3 - CH = CH_2 + Cl_2 \xrightarrow{CCl_4} CH_3CHCl - CH_2Cl$$

The reaction takes place at room temperature.

II. Hydrohalogenation of alkenes

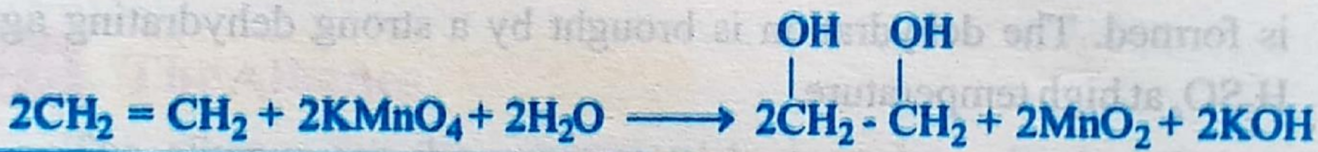
In hydrohalogenation alkenes are reacted with haloacids (HX) as a result of which both the hydrogen and halogen of haloacids bind at double bond of alkenes ycilding alkyl halides, e.g. Again the HBr add to alkene readily at room temperature to form ethyl bromide.

$$\underset{\textbf{Ethene}}{CH_2=CH_2} + HBr \longrightarrow \underset{\textbf{Ethyl Bromide}}{H_3C-CH_2Br}$$

This reaction is used to prepare alkyl halides.

III. Oxidation with $KMnO_4$

The water solution of $KMnO_4$ (1% alkaline $KMnO_4$ called Baeyer's reagent) forms glycols (compounds where the -OH substituent is at adjacent positions), at room temperature and the pink colour of $KMnO_4$ is discharged as a result. For example:



$$2CH_2=CH_2 + 2KMnO_4 + 2H_2O \longrightarrow 2\underset{}{\overset{OH}{\overset{|}{C}H_2}}-\overset{OH}{\overset{|}{C}H_2} + 2MnO_2 + 2KOH$$

12.2.3 Uses of Alkenes

The Alkenes are used as starting materials for many of the valuable organic compounds like Polythene, Glycols, Organic halogen derivatives, Alcohols etc.

The process of Ghee making is an example of hydrogenation of Alkenes. Ethene is used for the manufacture of plastic "Polythene", in ripening of fruits and as general anaesthetic agent.

Most of the organic compounds are prepared using alkenens as starting material.

Interesting Information

Reactions of alkenes with Cl_2, Br_2 and $KMnO_4$ results in the formation of colourless products from intensely coloured reactants, the colour change is thus used for the identification of doubles bond (and also triple bond) in the reacting substance.

12.4 The Alkynes

The Alkynes are also the unsaturated hydrocarbons having the general formula C_nH_{2n-2} which shows that they are more unsaturated, as compared to alkenes. The alkynes have at least one triple bond between two carbon atoms of the chain. In their structure, e.g.

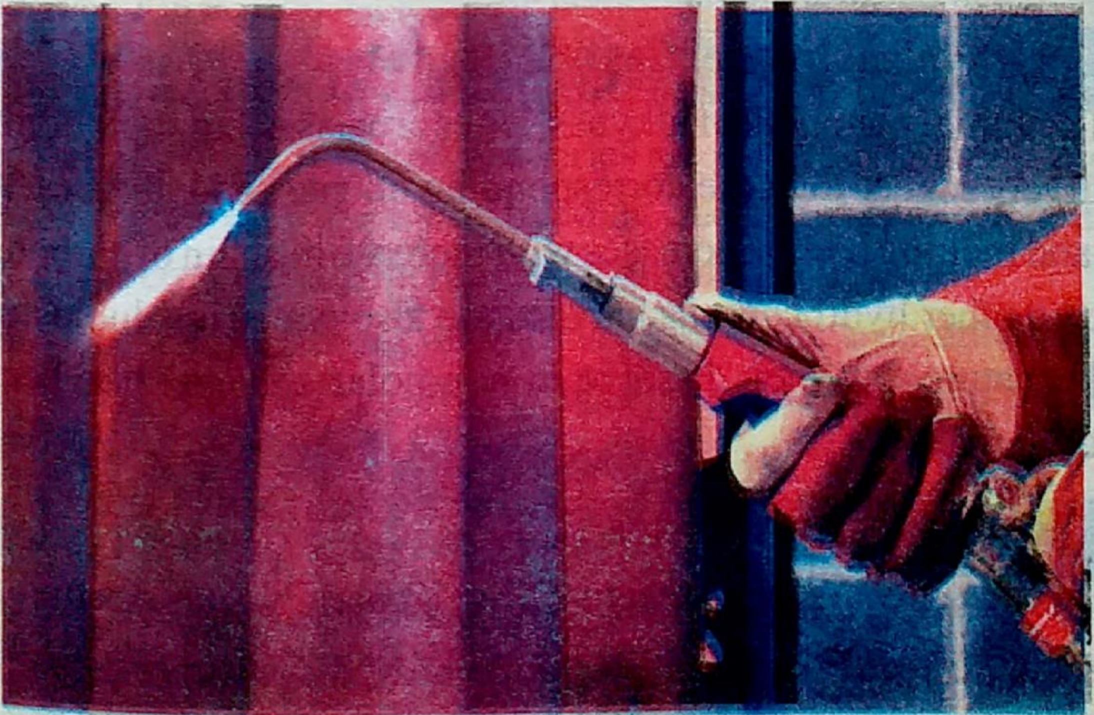
Ethyne or Acetylene	$HC \equiv CH$
Propyne	$HC \equiv C - CH_3$
1-Butyne	$HC \equiv C - CH_2 - CH_3$

Table 12.12 Some alkynes

The alkynes are also reactive compounds and are used as the starting material for the preparation of many organic compounds.

Interesting Information

The acetylene when reacts with oxygen produces high temperature, that is why it is used in oxy-acetylene torches for cutting and welding the metals, and you may have seen this during gas welding process.



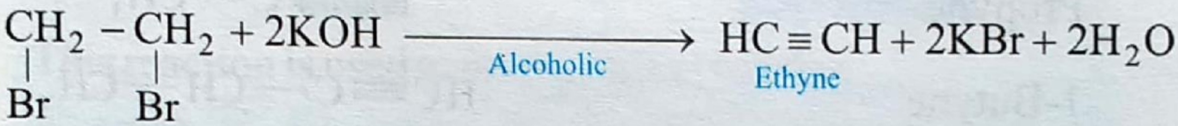
$$2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O + heat$$

12.4.1 Preparation of Alkynes

The Alkynes are prepared by a number of methods. Some important of which are following.

I. Dehydrohalogenation of adjacent alkyl dihalides

The dehalogenation of vicinal (Latin origin) dihalide (vicinal dihalides are the compounds where the halogens are present at adjacent carbons), yields the corresponding alkyne, e.g.

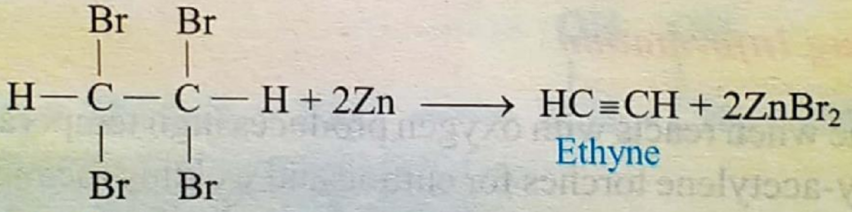


$$\underset{\text{Br}}{\underset{|}{CH_2}}-\underset{\text{Br}}{\underset{|}{CH_2}}+2KOH \xrightarrow[\text{Alcoholic}]{} \underset{\text{Ethyne}}{HC\equiv CH}+2KBr+2H_2O$$

Vicinal dibromide

II. Dehalogenation of tetrahalides

The tetrahalides on treatment with the Zn dust yield the corresponding alkyne, e.g.



$$H-\overset{\text{Br}}{\overset{|}{\underset{\text{Br}}{\underset{|}{C}}}}-\overset{\text{Br}}{\overset{|}{\underset{\text{Br}}{\underset{|}{C}}}}-H+2Zn \longrightarrow \underset{\text{Ethyne}}{HC\equiv CH}+2ZnBr_2$$

1,1-2,2 Tetrabromo ethane

12.4.2 Physical properties of Alkynes

The initial members of alkynes series are gases but their boiling points are relatively higher than the corresponding alkenes and alkynes. Again the boiling and melting points increases with increase in chain of carbon.

Like other hydrocarbons alkynes are also water insoluble due to their non-polar nature, but they dissolve in non-polar solvents like benzene and ether etc.

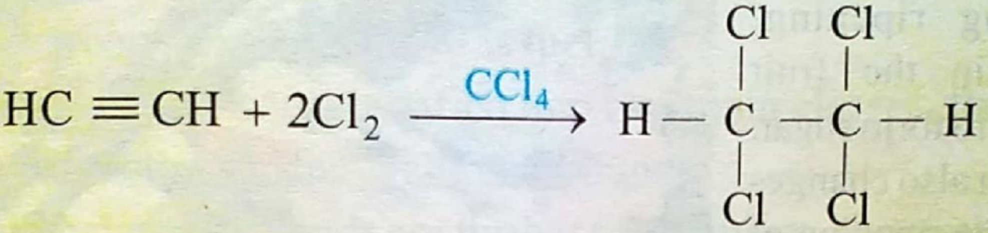
12.4.3 Reactions of Alkynes

The alkynes are also reactive (but generally less reactive than the Alkenes due to decreased bond distance of 'C≡C', as a result of which pi electrons of the multiple bonds lie close to carbon nucleus and relatively held there with more strength.) and they are used for many of the organic synthesis reactions.

Some of the important reactions of alkynes are given here,

I. Addition of Halogens

The alkynes readily react with halogens to form the corresponding halogen derivatives.



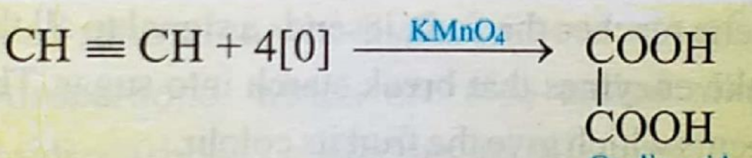
$$HC \equiv CH + 2Cl_2 \xrightarrow{CCl_4} H-\underset{Cl}{\overset{Cl}{C}}-\underset{Cl}{\overset{Cl}{C}}-H$$

1,1,2,2-Tetrachloro ethane

The reaction takes place at room temperature.

II. Oxidation with $KMnO_4$

The $KMnO_4$ in presence of an acid breaks the molecule of alkyne at the triple bond, e.g.



$$CH \equiv CH + 4[0] \xrightarrow{KMnO_4} \begin{array}{c} COOH \\ | \\ COOH \end{array}$$

Oxalic acid

This reaction is used for locating position of triple bond in the chain.

12.4.4 Physical properties of Alkynes

The initial members of alkynes series are gases but their boiling points are relatively higher than the corresponding alkenes. Again the boiling and melting points increases with increase in chain of carbon.

Like other hydrocarbons alkynes are also water insoluble due to their non-polar nature, but they dissolve in non-polar solvents like benzene and ether etc.

Uses of Alkynes:

The Alkynes are also used as the starting material for organic synthesis, like in the manufacture of PVC (Poly Vinyl Chloride), synthetic rubber, alcohols, alkyl halides etc. Acetylene which is the first and important member of alkynes class is the cheap and readily available member of the class is used for cutting, welding of metals in gas welding process. It is also used for artificial ripening of citrus and other fruits like mangoes and for the preparation of many important organic compounds.

Interesting Information

During ripening, the starch in the fruit breaks down to form sugar. The fruit skin also changes its colour. The ripening of a fruit depends on the season. For example, we get mangoes only in summer and apples only in start of winter. In ripening the plant produces Acetylene (or also called ethyne) which spreads across the plant. When ethylene reaches the fruit, it sends a signal to all the cells in the fruit. The cells then make enzymes that break starch into sugar. The cells in the skin start making pigments which give the fruit its colour.

Sometimes the fruits are not yet ripe when they are to be sold. Hence they have to be artificially ripened. Fruits are kept in hay-lined wooden boxes called crates. These crates are stacked on shelves and a wood fire is lit below them. The smoke contains ethylene and acetylenes gases, which induce ripening.
Sometimes, fruits are placed in a room in which ethylene gas or acetylene gas is introduced.

In another method, calcium carbide (CaC_2) is applied over fruits. It reacts with moisture to form acetylene.

$$CaC_{2(s)} + 2H_2O_{(l)} \longrightarrow C_2H_{2(g)} + Ca(OH)_{2(aq)}$$

This acetylene produced in the crates containing Calcium carbide enhances ripening process artificially.

While artificial ripening is fast, it doesn't give the fruit the flavour it gets when naturally ripened, and most important the direct contact of fruits with calcium carbide makes it health hazard, and upon handling such polluted fruit humans can also suffer the bad effect on their health.

Summary of the Chapter

- Hydrocarbons are the chemical compounds that contain only two type of elements, i.e. C and H.
- Hydrocarbons are obtained from their natural sources of Petroleum, coal and natural gas.
- Hydrocarbons are mostly used as fuel.
- The hydrocarbons are classified into two main classes, the straight chain (aliphatic) and the cyclic compounds.
- The aliphatic compounds are further of two types, the straight chain and the branched compounds.
- The carbon of the chain where the branch arises is either secondary carbon, or tertiary carbon or quaternary carbon.
- The cyclic compounds are again divided into two types, the aromatic and the alicyclic (non-aromatic) compounds.
- On the basis of saturation, the hydrocarbons are of two types the saturated hydrocarbons, which are also called alkanes, and the unsaturated hydrocarbons i.e. alkenes and alkynes.
- The unsaturated hydrocarbons can be divided into two major classes, one that posses double bond is called alkenes, and second which posses triple bond are called alkynes.
- Alkanes have the general formula C_nH_{2n+2}. Their name ends with suffix "ane".
- Alkenes have the general formula C_nH_{2n}. Their name ends with suffix "ene".
- Alkynes have the general formula C_nH_{2n-2}. Their name ends with suffix "yne".
- The alkanes which are saturated hydrocarbons are used mostly as fuel, they are relatively inert compounds.
- The unsaturated hydrocarbons are reactive compounds and are used as starting material for organic synthesis.

Exercise

Q1: Fill in the blanks with suitable words.

i) The hydrocarbons are the compound containing ………… and ………… elements only.

ii) Saturated hydrocarbons are relatively ………… in reactivity.

iii) Unsaturated hydrocarbons are ………… reactive.

iv) Alkenes react with halogens at ………… temperature.

v) The water solution of $KMnO_4$ forms ………… with alkenes.

vi) Alkenes are ………… reactive than Alkynes.

vii) Benzene is an ………… hydrocarbon.

viii) Acetylene gas is used in …………

ix) Alkanes are also known as …………

x) Hydrogenation process results in formation of ………… from oils.

Q2: Choose the correct answer.

i) The simplest member of hydrocarbon family is the

(a) C_4H_{10} (b) C_3H_8 (c) C_2H_6 (d) CH_4

ii) The Alkynes have the general formula

(a) C_nH_{2n+2} (b) C_nH_{2n+0}

(c) C_nH_{2n-2} (d) C_nH_{2n+4}

iii) Dehydration of alcohols with sulphuric acid yields:

(a) Alkene (b) Alkyne

(c) Alkane (d) Benzene

iv) Glycols are the compounds having:

(a) adjacent halogens

(b) adjacent hydroxyl groups

(c) alternate hydroxyl groups

(d) alternate halogens

v) To prepare ghee the vegetable oil is reacted with:

(a) hydrogen
(b) halogen
(c) oxygen
(d) nitrogen

vi) The secondary carbon atoms is linked with the number of carbon atoms

(a) 1 (b) 2 (c) 3 (d) 4

vii) Hydrogenation reaction utilizes catalyst:

(a) Ni or Pd (b) Zn
(c) H_2 (d) do not requires any catalyst

viii) General formula of Alkanes is

(a) C_nH_{2n-2} (b) C_nH_{2n+2} (c) C_nH_{2n} (d) C_nH_{2n-1}

ix) Halogenation means introduction of

(a) Cl (b) Br
(c) I (d) All of these

x) Olefin is another name for

(a) Alkanes (b) Alkenes
(c) Alkynes (d) Aromatic compounds.

Q3: Answer the following questions in short.

i) Define hydrocarbons.

ii) What is the difference between alicyclic and aromatic hydrocarbons?

iii) Explain what is the difference between saturated and unsaturated compounds?

iv) Why chlorine and methane react in light?

v) Describe the chemistry of combustion.

vi) What do you understand by the term "homologous series"?

vii) Describe the difference between dehydrogenation and dehydrohalogenation?

viii) What is meant by dehydration? What products are formed by dehydration of alcohols?

ix) What is the role of acetylene gas in fruit ripening?

x) Write chemical test to distinguish between saturated and unsaturated organic compounds?

Q4: Answer the following questions with reasoning.

i) Why alkenes are more reactive than alkanes?

ii) Why hydrocarbons do not dissolve in water?

iii) In your opinion, which is more reactive, Acetylene or Ethene? And why?

iv) n-pentane boils at higher temperature than n-propane?

v) Alkenes form addition products where as alkane form substituted products?

Q5: What do you understand by the term 'hydrocarbon'? how they have been produced in nature?

Q6: How the hydrocarbons are classified? Explain with examples.

Q7: Write a comprehensive note on chemistry of alkanes.

Q8: How you can prepare the alkenes? Describe the reactivity of alkenes too.

Q9: Explain various methods for the preparation of alkynes?

Q10: Explain the chemical properties of alkynes?

Q11: State the general rules for naming of alkanes by giving examples.

Q12: Draw the structure of following hydrocarbons?

i) 3,3-Dimethyl pentane ii) 2-Methyl hexane

iii) n-Hexane iv) 3,4-Dimethyl heptane

v) Isopentane. vi) Cyclo hexane

Chapter 13

BIOCHEMISTRY

Conceptual Linkage

Before reading this chapter, the student must know the:

- Basic properties of Organic Compounds
- Structure of Organic Compounds
- Isomerism concept

Time Allocation

Teaching periods =15
Assessment periods =03
Weightage =06%

LEARNING OUTCOMES

Students will be able to:

- Distinguish between mono-,di- and trisaccharides. (Understanding)
- Describe the bonding in a protein molecule. (Understanding)
- Explain the sources and uses of carbohydrates, proteins, and lipids. (Understanding)
- Differentiate between fats and oil. (Applying)
- Describe the importance of nucleic acids. (Understanding)
- Define and explain vitamins and their importance. (Understanding)

Introduction

Chemistry is the science of matter and we discuss and try to understand the matter while studying chemistry. A great part of our world is consisting of the matter we call living organism. *The matter that the living bodies are made up of is studied in the branch of chemistry called the biochemistry or in simple words.* Biochemistry is the branch of chemistry which deals with the composition, structure and properties of matter present in the living organisms.

Biochemistry is actually a branch of organic chemistry as all the bio material is organic in nature. But in addition the organic compounds also include the compounds of carbon and hydrogen which are artificially synthesized and show properties like that of other hydrocarbons. Such artificially prepared chemical compounds include different types of plastics and synthetic rubber which have same properties like natural organic compounds. But in the biochemistry such chemical compounds are not studied. Only those material are under consideration which is present in the living organisms. Even the hydrocarbon fuel matter is not studied in this field.

The biochemistry also deals with the study of the chemical processes and transformations taking place in the living organisms. The structure and function of cellular components, such as proteins, carbohydrates, lipids, nucleic acids, and other biomolecules. These biomolecules are indeed very complex in nature and giant in structure.

Although the living organisms show too much diversity in their behaviour, structure and form. But they are composed of generally same type of elements. Such types helps greatly in understanding the life.

The most common types of compounds that the livings organism contain are:

- The carbohydrates
- The proteins
- The lipids
- Nucleic acids
- The vitamins

In the subsequent sections we will study each of these type of compounds in detail.

The principles set up by the biochemistry helps us to increase the standard of our life, to fight against the diseases by developing and understanding the systems in living organisms. Generation of new and better types of crops using genetic engineering procedures and many more applications.

13.1 The Carbohydrates

The term carbohydrate is very common word in our daily life especially when we talk about the food we eat. It is the class of bio organic compounds having general formula normally '$C_x(H_2O)_y$', that is why the term carbohydrate was originally used to describe compounds that were literally "hydrates of carbon" .e.g. the most common simple carbohydrate for us is the glucose, having molecular formula $C_6H_{12}O_6$, and the formula shows that it has the empirical formula as CH_2O. Although in many cases this relation does not exists, e.g. in the table sugar, the sucrose, which has the molecular formula $C_{12}H_{22}O_{11}$.

Carbohydrates are the most abundant bio compounds, and they are used mostly as a source of energy for the living systems. In nature the carbohydrates are formed by the plants using the process of photosynthesis, which is performed by using the energy of sun and plant pigment 'Chlorophyll'.

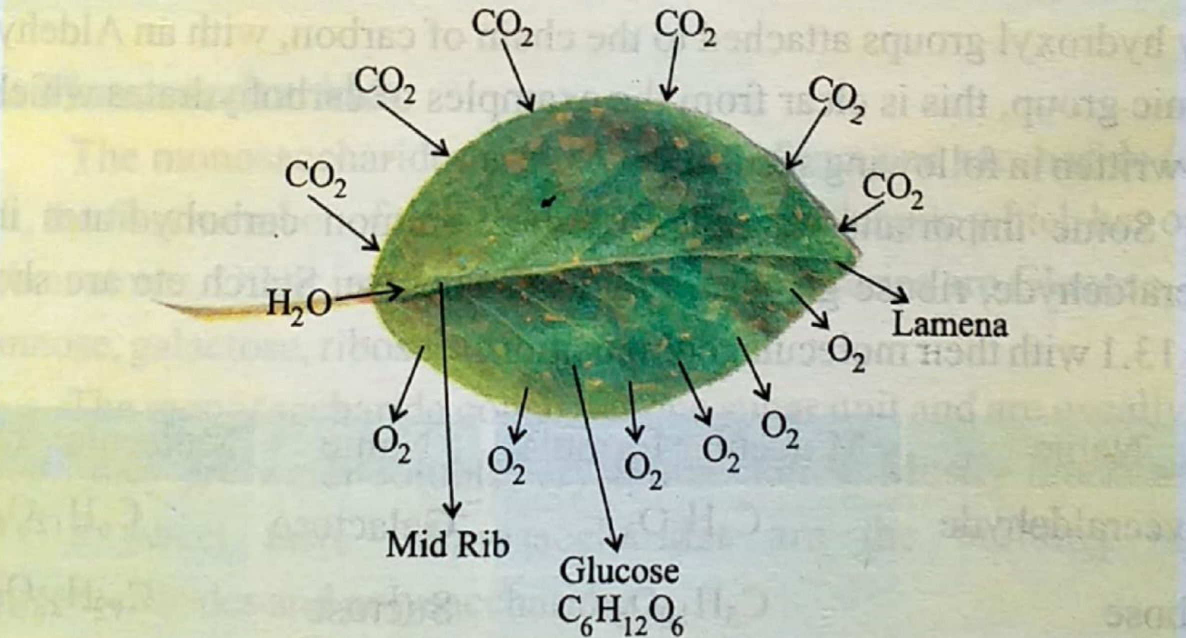
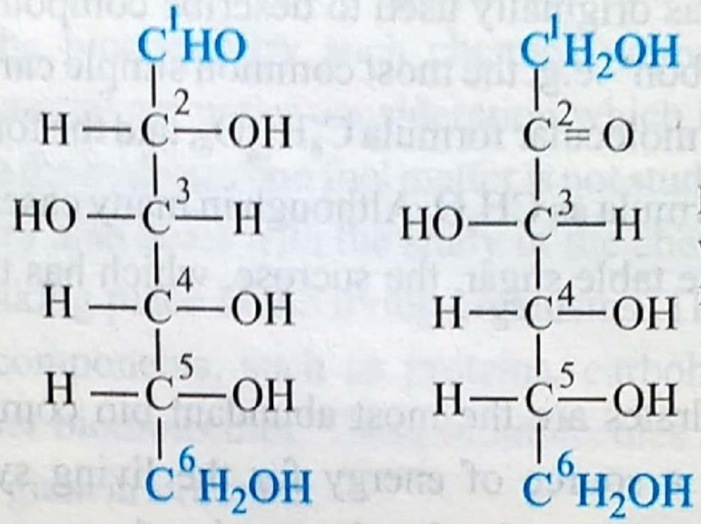


Figure-13.1: The plant leaf is a factory which uses CO_2 and H_2O as raw materials and produces Glucose and Oxygen

$$6CO_{2(g)} + 6H_2O_{(l)} \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} \underset{\text{Glucose}}{C_6H_{12}O_{6(aq)}} + 6O_{2(g)}$$

As by the sense of chemistry, the carbohydrates are the polyhydroxy aldehydes or ketones. Recall your knowledge that Aldehydes are the compounds that have –CHO linkage and the ketones are the organic compounds that have the linkage of R—CO—R, while the hydroxyl group is the –OH group.



Glucose sugar which contains addhydic functional group

Fructose Sugar which has ketonic functional group

Figure-13.2: Basic carbohydrate units showing aldehydic / ketonic groups

This means that the carbohydrates are the compounds which have many hydroxyl groups attached to the chain of carbon, with an Aldehydic or Ketonic group, this is clear from the examples of carbohydrates which have been written in following section.

Some important examples of the common carbohydrates include glyceraldehyde, ribose glucose, Fructose, Sucrose, Starch etc are shown in table 13.1 with their molecular composition.

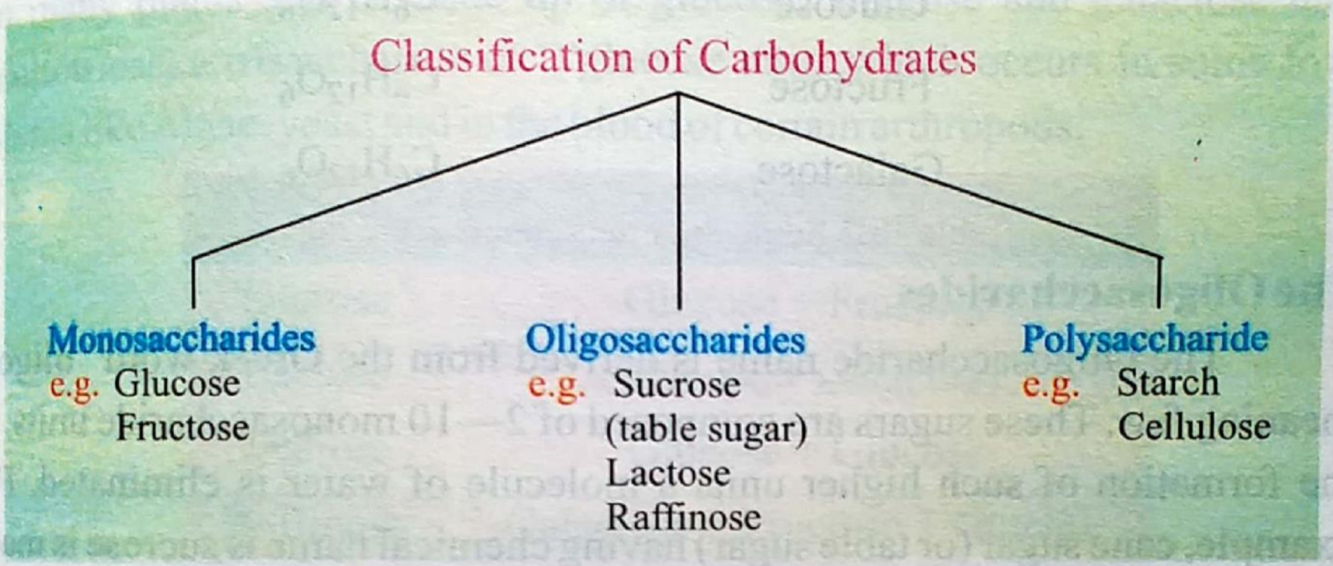
Name	Molecular formula	Name	Molecular formula
Glyceraldehyde	$C_3H_6O_3$	Galactose	$C_6H_{12}O_6$
Ribose	$C_5H_{10}O_5$	Sucrose	$C_{12}H_{22}O_{11}$
Glucose	$C_6H_{12}O_6$	Starch	$(C_6H_{10}O_5)_n$
Fructose	$C_6H_{12}O_6$	Cellulose	$(C_6H_{10}O_5)_n$

Table 13.1 Some important carbohydrates

13.1.1 Classification of Carbohydrates

The carbohydrates are classified according to the number of sugar units presents in them, thus the carbohydrates containing only one sugar unit are called **monosacharides**, (saccharides-Greek-sakcharon meaning "sugar"). Thus they are classified into 3 main groups, i.e.

- **Monosaccharides**
- **Oligosaccharides**
- **Polysaccharides**



The Monosaccharides

The monosaccharides are composed of just one saccharide (or sugar) unit, the first member of this class is the Glyceraldehyde which has only three carbon atoms. Other important members of this series are Glucose, fructose, mannose, galactose, ribose etc.

The monosaccharide consist of one sugar unit and are usually white in colour, they are water-soluble, crystalline solids. Mostly monosaccharides have a sweet taste. Monosaccharides are the building blocks of Oligosaccharides and polysaccharides.

The monosaccharides are the simplest but important type of carbohydrate which among other properties contains carbon, hydrogen, and oxygen in the same ratio (1:2:1) as described by the general formula of carbohydrate class, $(C_n(H_2O)_n)$. Glucose, one of the most important and well known monosaccharide carbohydrate is very common in nature. The fructose, also called the fruit sugar, as it is the sugar that gives fruits their sweet taste in most is also a monosaccharide. Some important monosaccharides are shown in table 13.2.

Name	Molecular formula
Glyceraldehyde	$C_3H_6O_3$
Ribose	$C_5H_{10}O_5$
Glucose	$C_6H_{12}O_6$
Fructose	$C_6H_{12}O_6$
Galactose	$C_6H_{12}O_6$

Table 13.2 Some important monosaccharides

The Oligosaccharides

The Oligosaccharide name is derived from the Greek word "oligos" meaning few. These sugars are composed of 2—10 monosaccharide units. In the formation of such higher units a molecule of water is eliminated. For example, cane sugar (or table sugar) having chemical name is sucrose is made from glucose and fructose, similarly milk sugar (lactose) is made from glucose and galactose.

$$\text{Glucose} + \text{Fructose} \longrightarrow \text{Sucrose} + \text{Water}$$

Similarly the milk sugar "Lactose" is the disaccharide of Glucose and Galactose.

$$\text{Galactose} + \text{Glucose} \longrightarrow \text{Lactose} + \text{Water}$$

The disaccharides are important to us in the sense that most of the energy drinks we take contains these carbohydrates, and so they serve for us as a source of quick energy, their cheap sources are available in nature in abundance, and they also take less time to digest in our body due to having lesser monosaccharide units.

Interesting Information

The disaccharides provide us a quick energy as they are digested easily in no time. That is why a sugar patient when suffers hypoglycemia, a condition resulting from low blood sugar, is advised to take sucrose (a disaccharide sugar) in a little quantity, or a candy containing sugar. The sugar is readily digested even in the mouth by the action of saliva, increasing blood sugar of the patient.

The oligosaccharides are further divided into several types depending upon the number of units present in. The oligosaccharides consisting of '2' units are called disaccharides, (sucrose, maltose, lactose are disaccharides), The oligosaccharides that consists of three sugar units are called trisaccharides, the examples of these include raffinose, a trisaccharide found in many plants and is made up of glucose, fructose and galactose units, maltotriose, a trisaccharide of '3'glucose units which occurs in some lower plants like Algae, yeast and in the blood of certain arthropods.

Name	Monosaccharide Units
Sucrose	Glucose + Fructose
Lactose	Glucose + Galactose
Maltose	Glucose + Glucose
Raffinose	Galactose + Fructose + Glucose
Maltotriose	Glucose + Glucose + Glucose

Table 13.3 Some important oligosaccharides

The Polysaccharides

The polysaccharides, as the name indicates contain a large number of saccharide units, (more than '10' to several hundreds.) The important examples of polysaccharides are, starch, glycogen, cellulose. All these three polysaccharides are made up of glucose units but differ in the sequence of units.

13.1.3 Sources and uses of Carbohydrates

Carbohydrates are the most abundant organic compounds in nature. They are synthesized and consumed by nearly all plants and animals. They are essential constituents of all living things. Carbohydrates are formed by green plants from carbon dioxide and water during the process of photosynthesis.

$$nCO_2 + nH_2O + \text{energy} \longrightarrow C_nH_{2n}O_n + nO_2$$

In the animals, glucose is oxidized to carbon dioxide and water to provide metabolic energy. Which is used in life processes. Plants and animals store energy in the carbohydrate form as starch and glycogen respectively. Cellulose constructs the cell walls and provides the structural framework of plants. In addition to the use of carbohydrates as a source of energy in foods. Thus the plant products are good source of carbohydrates and cereals, wheat, maize, rice, potatoes, banana and other fruit are good source of carbohydrates. In table 13.4 some of important carbohydrates and their derivatives are written.

Carbohydrate	Sources
Glucose	Grapes
Fructose	Fruits, honey
Sucrose	Sugar cane, beet root
Lactose	Milk and dairy products
Starch	Potato, cereals like wheat, rice, maize etc.
Glycogen	Animal liver

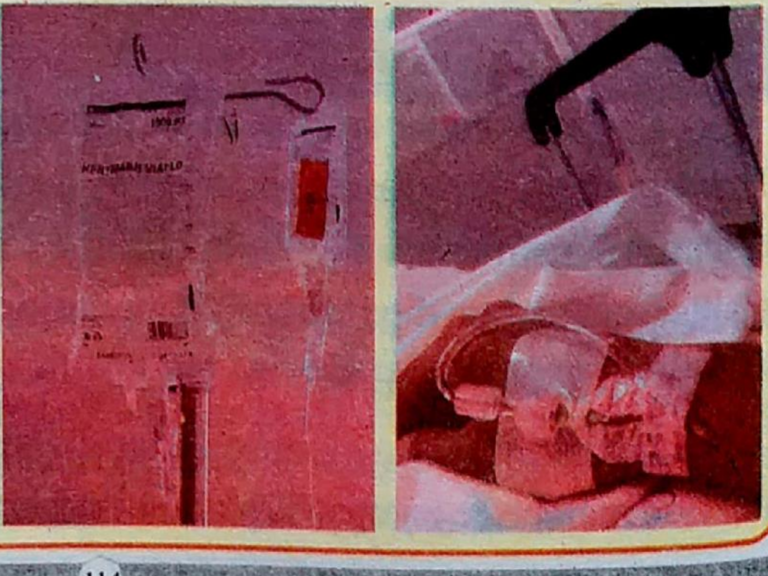
Table-13.4: Some important carbohydrates and their sources

The carbohydrates are also used in many other fields of life, e.g. as building materials (wood and glues) in construction, in paper and paper products, in clothing (cotton) and many more.

Interesting Information

The carbohydrates are the instant source of energy: In hospitals 5% glucose solution marketed as 5% dextrose is used frequently in the form of drips for parenteral nutrition to treat the patients who can not take food or have some problems in eating food.

This saves lives of thousands of humans:



13.2 The Proteins

Proteins are the giant bio-organic compounds, which are composed of by joining of the amino acids.(remember that the amino acids are the organic molecules containing both the amino group “• $\ddot{N}H_2$” and the carboxyl group “•COOH").

The word protein has its origin from the Greek **proteios**, meaning first. So this class of organic compounds which are present in living organisms and vital to every living cell. In the form of skin, hair, cartilage, muscles, tendons and ligaments, proteins hold together, protect, and provide structure to the body of a multi cellular organism. In the form of enzymes, hormones, antibodies, and globulins. They catalyze, regulate, and protect the body chemistry. In the form of hemoglobin, myoglobin and various lipoproteins, they effect the transport of oxygen and other substances within an organism. In human body the proteins are formed by joining '20' different amino acids, of which '10' amino acids are synthesized by our body, and remaining '10' must be taken through food sources. The amino acids that are needed in food are called essential amino acids.

13.2.1 Amino acids as building blocks of Proteins

As already discussed that proteins are formed by joining amino acids. Amino acids are actually such organic compounds in which two types of functional groups, the amino group and the carboxyl group are present simultaneously in a single compound.

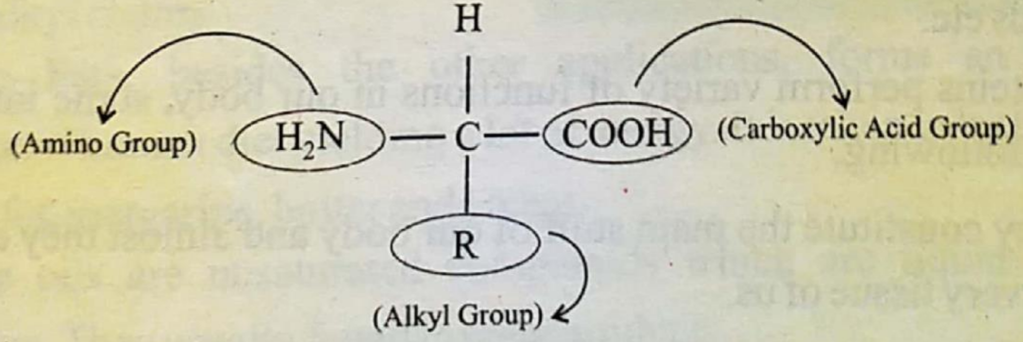
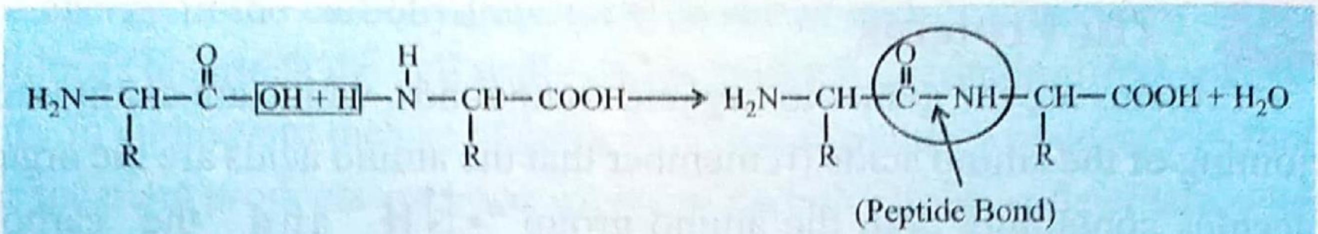


Fig 13.3 General representation of an amino acid.

The 'R' here represents chain of carbon.



$$H_2N-\underset{R}{\underset{|}{CH}}-\overset{O}{\overset{\|}{C}}-\boxed{OH + H}-\overset{H}{\overset{|}{N}}-\underset{R}{\underset{|}{CH}}-COOH \longrightarrow H_2N-\underset{R}{\underset{|}{CH}}-\overset{O}{\overset{\|}{C}}-NH-\underset{R}{\underset{|}{CH}}-COOH + H_2O$$

(Peptide Bond)

Fig 13.4: Formation of peptide bond

These amino acids when combine to form a bigger molecule, a water molecule is eliminated in this reaction.

The bond that joins two amino acids is called peptide bond. A protein is formed when thousands of such amino acids are linked with each other through peptide bonds. This is to be remembered that when hydrolysis of a protein is carried out, the amino acids that form that protein are regained.

Proteins are giant molecules so to reduce the occupied space they form a folded structure.

13.2.2 Sources and uses of Proteins

Protein make the basic body stuff of not only the humans but also of other animals and to some extent of plants too. The dry mass of animals constitute about 50% of the proteins. The plants are able to prepare their own protein using simple elements, but the animals mostly form their proteins by eating amino acids in their food. Although they can form some of the amino acids by themselves.

We can obtain required proteins or the amino acids through different sources for example by eating meat, eggs, beans, fruits, lentils, pulses, dry fruits, seeds etc.

Proteins perform variety of functions in our body, some important of which are following,

- They constitute the main stuff of our body and almost they are present in every tissue of us.
- Proteins serve as the carrier to carry many substances from one place to another in our body.
- As a catalyst these protein catalyze reactions in our body, without

which all functions in our body stop.

- They also serve as hormone, and thus run the tissue systems well in our body.
- The protein are also used in many field other than food, for example leather which is also a protein is used in making shoes, cloths, and sports articles.

So in view of all these we can say that protein are an essential part of our life.

13.3 The Lipids

The lipids are long chained esters of fatty acids and glycerol (Glycerine). They form an important class of organic compounds. These are widely distributed among the living organisms. One of a member of which you are well familiar is the Fat. The other members of the lipids include steroids, terpenes and waxes. The Fats are triesters of glycerol and long-chained carboxylic acids, they are generally represented by the general formula shown in figure-13.5, where R_1, R_2 and R_3 represents three different alkyl chains.

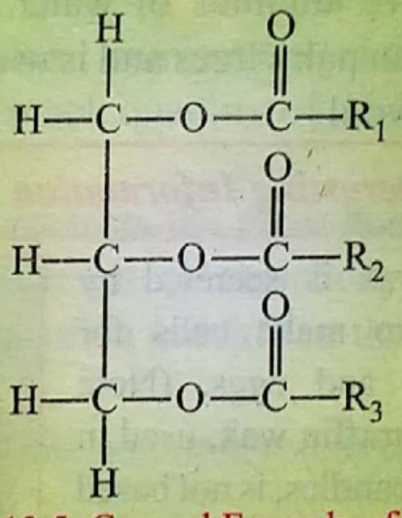


Fig. 13.5: General Formula of Fats

The Fats, besides the other applications, forms an important constituent of human diet yielding a lot of energy. It is taken in by the humans as animal fat, margarine, butter and cream.

The oils are unsaturated compounds which are liquid at normal temperature. They usually found in plant products.

The Steroids are the lipids that have a characteristic four condensed rings structure as shown in figure-13.6.

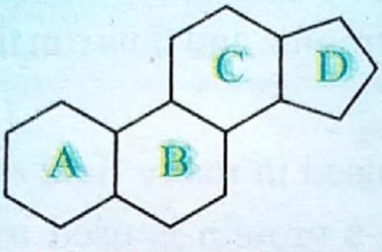
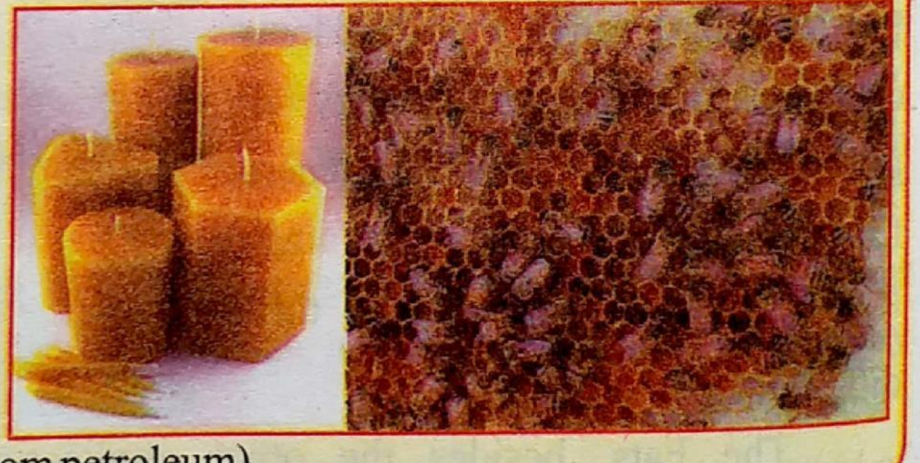


Fig-13.6: Four condensed ring nucleus of steroids

The steroids also play an important role in our life especially as hormones, e.g the male and female sex hormones, the Testosterone and progesterone are steroids in nature, moreover the bile juices also contain some steroidal compounds which are important in digestion process.

Another form of lipids are the waxes, which are found in nature as coatings on leaves and stems, and serves to prevents the plant from losing excessive amounts of water. e.g Corunda wax is found on the leaves of Brazilian palm trees and is used in floor and automobile waxes, lanolin coats lambs wool.

Interesting Information



Beeswax is secreted by bees to make cells for honey and eggs. (Note that paraffin wax, used in some candles, is not based upon the ester functional group, but is a mixture of high molecular weight alkanes which is obtained from petroleum).

Waxes have a variety of functions including lubrication, protection, structure, and energy storage. Many of the waxes are used in ointments, hand creams, and cosmetics

13.3.1 The Fatty acids

Fatty acids are the bio-organic compounds that form lipids. They consist of a carboxylic acids that contain a carboxyl group and a long chain of unbranched carbons as a tail. For example palmitic acid ($C_{15}H_{31}COOH$), stearic acid ($C_{17}H_{35}COOH$) etc.

13.3.2 Sources and uses of lipids:

The lipids are obtained through both of plant and animal kingdom. In animals these are found as fats and in the milk, while in plants they are found as oils, and we purify them from these sources mostly by using specialized chemical techniques.

The lipids act as the source of large energy in our food, they are also used in many other fields too, some important of which are in the following,

- The lipids are used to increase the taste of food, for this purpose use of butter, ghee, different oils is very common.
- The animals that undergo hibernation use the stored fats of their body.
- The fatty tissues keep safe the humans and the animals from severe cold.
- In plants the oily lipids serves to protect them from severe cold strokes, that is why the cold region plants have much quantity of oils in their structure.
- The desert area plants these oily layer protects the plant body from excessive transpiration and helps to store the water in their body.
- In order to protect from cold, the humans often use fats on their open skin areas.
- Many of the oils and fats are used as drugs, for example cod liver oil, oil from seeds, steroids etc.

Interesting Information

The athletes often use steroid based drugs to increase the muscular activity, and to reduce the effect of wounds. The use of such steroids increases the anabolic activity of their body and thus the performance of the athlete also increases, that is why the used of such therapy has been declared illegal.

13.4 The Nucleic Acids

You may have heard the phenomenon of heredity many times in your life. This heredity character is due to some special type of biopolymers in our body these biopolymers are called DNA (Deoxyribose nucleic acid) and RNA (Ribose nucleic acid), which form the unit of heredity and also determines who we are among the other living organisms.

The DNA and RNA carry the genetic information in the sequence of their subunits, which is called the Nucleotide. This nucleotide is responsible for the production of a specific type of protein and these proteins actually run the cells of our body, and hence our body acts under the command of these DNA and RNA built Genes.

Not only the running of our body is under the command of these DNA and RNA but also the diversity of life we see is actually due to small differences in sequences of subunits that make up a part of each DNA molecule. Relatively small structural differences determine whether an organism is a flower, an ant, or a human being, can you imagine that the genetic material of humans and of Chimpanzees differ only just 3%. Now we take a look separately the two basic units of these genetic material building units, called DNA and RNA.

13.4.1 The DNA or Deoxyribose nucleic acid

DNA or Deoxyribose nucleic acid is the basic unit that give us only the identity but they also control the cell functioning. It is the DNA under whose command cell produces certain proteins and these proteins run cell and are responsible for each activity of the cell. It is the instruction of these DNA that each tissue of our body behaves separately, although they are produced from the same single cell.

DNA bears a complicated structure which was discovered by two scientists J-Watson and F-crick in 1953. The unit of their structure is called 'nucleotide'. Every nucleotide is made up of a phosphate group, a pentose sugar and a nitrogenous base. All these groups are linked with each other in a special manner, and they form a big chain. This chain consists of 4 types of nitrogenous bases, the Adenine, Cytocine, Thiamine and Guanine. These bases are well known by the abbreviations of first alphabet of their name, i.e A,T,C and G. The sequence of these 4 bases forms the code of DNA, each gene has its distinct code. The giant structural chain formed by linking of these is called DNA strand. In DNA two strands run parallel so DNA forms a double stranded giant structure. This is shown if fig-13.6.

13.4.2 The RNA or Ribose nucleic acid:

This is second type of nucleic acid . It has the structure like DNA but only consists of single strand. The nucleotide structure contains 3 basic groups like of DNA but there are few differences as compared to DNA.

The pentose sugar of RNA is ribose instead of Deoxyribose and the nitrogenous base uracil replaces thiamine. The pentose sugar of RNA is ribose instead of Deoxyribose and the nitrogenous base uracil replaces thiamine.

The functions of RNA are also different from that of DNA. The RNA performs a variety of functions among which include the massaging from DNA, it forms different protein in the command of DNA and these protein catalyze and control the reactions and processes of cells.

The structure of both DNA and RNA has been shown and compared in fig-13.6.

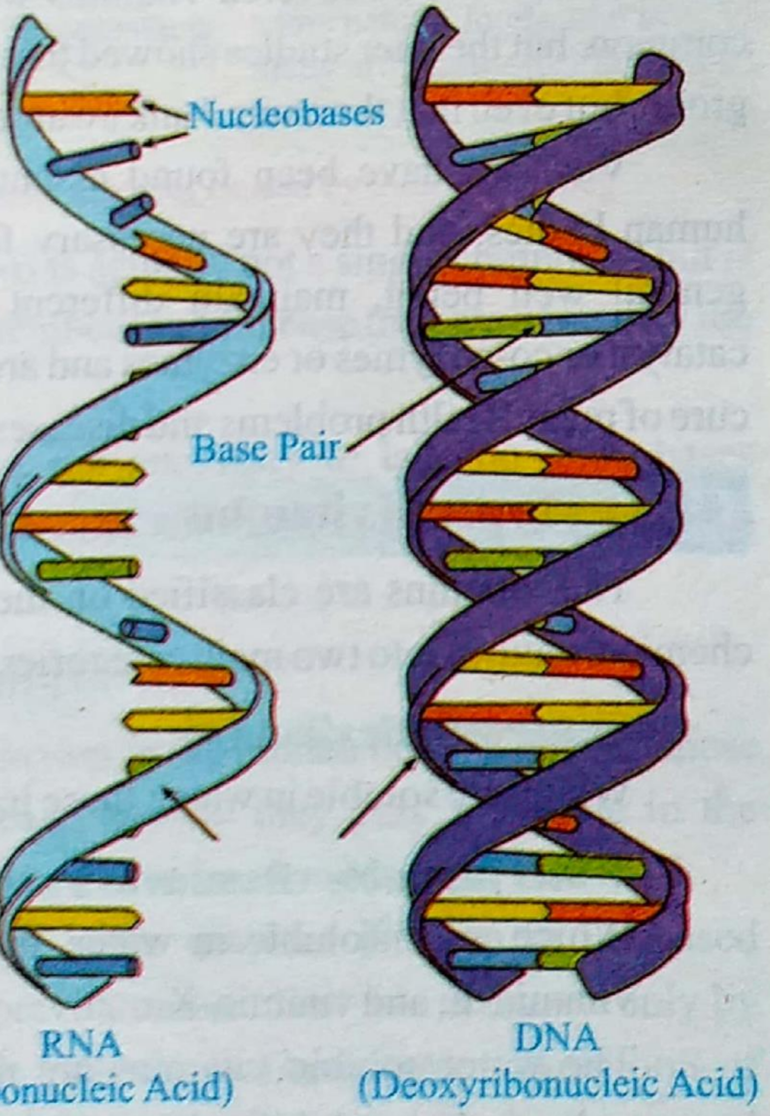


Fig 13.6 Structure of DNA and RNA

Interesting Information

You may have heard about DNA test actually coding in DNA is not only different in various organisms but each human being has its own characteristic sequence inherited from his parents. In DNA test this characteristic sequence is matched and hence many problems can be resolved.

13.5 Vitamins

Vitamins are the certain organic compounds which are needed in our diet for normal body health. The word "vitamin" has its origin from "vita" a Latin word meaning "life", and "amin" from "amine" as the initially studied of the members of this class were known to contain the amino group. This name was given by the Polish biochemist Kazimierz Funk in 1912, who observed that the discovered vitamins were containing the amino group in common, but the later studies showed that not all the vitamins have this amino group, but even that the name Funk awarded stuck and is still used.

Vitamins have been found essential for the normal functioning of human bodies, and they are necessary for normal growth, vitality, health, general well being, maintain different biochemical processes acting as catalyst or co-enzymes or enzymes and are responsible for the prevention and cure of many health problems and diseases.

13.5.1 Types of vitamins

The vitamins are classified on the basis of their solubility (i.e. their chemical nature) into two main categories,

- **Water soluble vitamins**

  Which are soluble in water, these include vitamin-B and vitamin-C.

- **Water insoluble vitamins or Fat soluble vitamins**

  Which are insoluble in water, these include vitamin-A, vitamin-D, vitamin-E, and vitamin-K.

The water soluble vitamins are necessary to take in on daily basis because due to their solubility in water they are excreted through urine even if

Vitamin name	Solubility	Daily requirement	Deficiency disease	Sources
Vitamin-A	Fat	900 µg	Night-blindness	Present in many animal tissues, especially fish and liver.
Vitamin-B	Water	1.2-1.5 mg	Beriberi, anemia	meats, leafy green vegetables, grains and legumes.
Vitamin-C	Water	90.0 mg	Scurvy	fruits and vegetables. Rich sources include citrus fruits, strawberries, tomatoes and leafy green vegetables.
Vitamin-D	Fat	5.0 µg-10 µg	Rickets and Osteomalacia	Synthesized in the skin when exposed to sunlight. Also present at low concentration in some natural foods, and in many artificially-fortified food products.

Table 13.5: Source of vitamins and diseases caused by their deficiency

extra amount is taken. The vitamin-B is actually not a single compound but is a group consisting of a number of members and for ease they are named by the numbers, such as B_1, B_2 etc.

The fat soluble vitamins are not necessary to take on daily bases because they are stored in the body tissues and can be used from there when required by the body.

13.5.2 Importance of Vitamins

The requirement dose and function in the human body of each of these vitamins may vary from case to case; mostly they play their role in the metabolic pathways.

The vitamins can also induce some diseases if taken in increased amount, this condition is called hypervitaminosis but this is caused only by the fat soluble vitamins for example vitamin-A. The common symptoms of such hypervitaminosis is the nausea and vomiting.

Interesting Information

In addition to the essential nutrients present in our food, there is also the need of some material that is non-ingestible and should be used to carry out the undigested products. This material is called dietary fibre. Its recommended quantity is 20-30 grams per day for a normal human. Fibre is an important part of a healthy diet. A diet high in fibre has many health benefits. The dietary fibre not only acts as the laxative but it also helps to prevent heart disease by lowering blood cholesterol, diabetes, weight gain, some cancers, and it improves digestive health.

Constipation is the most common disease caused in absence of dietary fibre.

Summary of the Chapter

- The branch of chemistry that deals with the study of matter found in living organisms is called biochemistry.
- In biochemistry we study specially carbohydrates, proteins, lipids, nucleic acids and vitamins.
- .Carbohydrates are the chemical compounds that give instant energy to living organisms upon eating.
- The carbohydrates are actually such ketones or aldehydes that have many hydroxyl groups too.
- Carbohydrates are of three types, monosaccharides, oligosaccharides and polysaccharides.
- A monosaccharide consists of one sugar unit, the oligosaccharide has 2-10 saccharide or sugar units and polysaccharide has more than 10 to several thousand saccharide units.
- The basic source of carbohydrates is the plant kingdom that make these by the process of photosynthesis.
- Proteins are the bio-organic compounds that form the body stuff of animals. These are formed by the union of amino acids.
- Important sources of proteins are meat, egg, milk, lentils etc.

- The lipids are the bio-molecules that are formed by union of fatty acids, we use these as food.
- The lipids are found in both animals and plants.
- The animals have the lipids called fats.
- In plants the lipids are found in the form of oils which is in liquid state at normal temperature.
- Lipids not only give body structure to animals but performs as blanket to save animals from severe cold, various lipids also acts as hormones in the form of steroids.
- Nucleic acids are of two types DNA and RNA.
- DNA are double stranded and give instructions to run the cell.
- RNA are single stranded and perform various functions among which important are, conveying commands from DNA to a specific site, preparation of certain protein.
- For normal body growth certain compounds are needed in small amounts, these are called vitamins.
- Vitamins are of two types, water soluble and fat soluble.
- Vitamin-B and vitamin-C are water soluble vitamins and we have to take them on daily basis to meet our requirements.
- Vitamin-A, D, E and K are fat soluble. They are stored up in the body.

Exercise

Q1: Fill in the blanks with suitable words.

i) Biochemistry deals with the study of matter derived from ....

ii) Vitamin-D is the .... soluble vitamin.

iii) Carbohydrates are classified according to .... units.

iv) Lactose is a .... carbohydrate.

v) There are .... essential amino acids in number.

vi) Glyceraldehyde is the first member of carbohydrates containing .... carbon atoms.

vii) Sucrose is common name of ....

viii) Proteins are the polymers of ....

ix) There are .... types of nucleic acids.

x) Deficiency of Vitamin-C causes ....

Q2. Encircle the correct answer.

i) Plants mainly composed of:

(a) Carbohydrates (b) Proteins

(c) Lipids (d) All of these

ii) The general formula of monosaccharide is:

(a) C_nH_{2n+2} (b) C_nH_{2n+0}

(c) C_nH_{2n-2} (d) $C_n(H_2O)_n$.

iii) Monosaccharides are the carbohydrates that are composed of:

(a) 1 glucose unit (b) 2 glucose units

(c) 3 glucose units (d) Many glucose units

iv) Amino acids contain the functional group.

(a) Carboxyl (b) Amino

(c) Aldehydic group (d) Both amino and carboxyl groups

v) Lipids are:
- (a) Long chained fatty acids
- (b) Long chained esters of fatty acids
- (c) Polymer of amino acids
- (d) Monomer of PVC.

vi) The number of essential amino acids are:
(a) 10 (b) 20 (c) 30 (d) 40

vii) DNA is the nucleic acid responsible for:
- (a) Metabolism functions of Glucose
- (b) Heredity characters
- (c) Controlling diseases in body
- (d) All these functions

viii) Fats perform the function of:
- (a) A source of dietary energy
- (b) As energy reservoir
- (c) Protects vital organs
- (d) Perform all these functions

ix) Deficiency of Vitamin-A causes
- (a) Night blindness
- (b) Scurvy
- (c) Bone diseases
- (d) Anemia

x) Vitamin-D is found in:
- (a) Tomatoes
- (b) Potatoes
- (c) Synthesized when body is exposed to sun light
- (d) Citrus fruits

Q3: Write short answers of the following.

i) Comment that carbohydrates are hydrates of carbon.
ii) What functional groups are found in carbohydrates?
iii) Does the nucleic acids contain any sugar unit?
iv) What are functions of Oligosaccharides?
v) What are the functional group in amino acids?

vi) Write a note on Essential amino acids?
vii) What is meant by Fatty acids?
viii) Describe biological roles of Steroids.
ix) What are vitamins? How they are classified?
x) How Vitamin-D is produced in body?

Q4: Explain following with reasoning.
i) Lipids provide more energy than carbohydrates.
ii) Carbohydrates constitute the plant body and proteins constitute animal's body?
iii) Cellulose is not digested by Humans but easily digested by Cows?
iv) Beef provides more proteins than the Beans?
v) The water soluble vitamins are required to take daily but fat soluble are not?

Q5. What are the carbohydrates? Write a brief note on their classification and importance?

Q6. Write a note on chemistry of proteins.

Q7. What are the Lipids? How they are important to us?

Q8. What are vitamins? How vitamins affect our life?.

Q9: Describe the nature of Nucleic acids, describe their role in living organisms.

Q10: What are the diseases caused by deficiency of vitamins?

Q11: Name the important sources of the Vitamins.

Chapter
14

ENVIRONMENTAL CHEMISTRY-I ATMOSPHERE

Conceptual Linkage

Before reading this chapter, the student must know the:

- Definitions and differences among ion radical, atom and molecules
- Common elements their symbols and basic characters
- Introduction of acidic matter

Time Allocation

Teaching periods =10
Assessment periods =02
Weightage =07%

LEARNING OUTCOMES

Students will be able to:

- Define atmosphere. (Remembering)
- Explain composition of atmosphere. (Understanding)
- Differentiate between stratosphere and troposphere. (Analyzing)
- Summarize the components of stratosphere and troposphere. (Understanding)
- Describe major air pollutants. (Understanding)
- Describe sources and effects of air pollutants. (Understanding)
- Explain ozone formation. (Understanding)
- Describe acid rain and its effects. (Understanding)
- Describe ozone depletion and its effects. (Understanding)
- Describe global warming. (Understanding)

Introduction

Atmosphere is the layer of gases that covers our planet earth. The atmosphere contains almost 78% nitrogen, 20.95% oxygen, 0.93% argon, 0.04% carbon dioxide, and trace amounts of other gases. In addition to these gases about 1% water vapours also constitute an important part of this atmosphere. This mixture of gases is commonly known as air and the area where this air and some other species lie is called Atmosphere.

compared with the diameter of the earth, the atmosphere is very thin, and almost lasts for up to about 500Km. But remember that there is no definite boundary of this atmosphere and it slowly thins and finally fades into outer space.

The atmosphere is very important for maintaining life on this planet earth, as all the livings of this planet rely upon the air for their normal life processes e.g the respiration, It also serves as the thermo blanket which maintains a specific temperature for these organisms. It is the coating of the gases of atmosphere that protects the earth and life on earth from the hazardous radiation of space.

14.1 Composition of the Atmosphere

Although we live and see a little part of the earth atmosphere but in real the atmosphere of the earth is not just composed of few gases, but some other constituents are also present here. These constituents are present in the form of different layers, each having a distinct character. There is a delicate relation and effect of these layers upon the life forms of the earth. Any change in the composition of atmosphere could be fatal not only to us but also on all life forms. So we must have to maintain the composition of the earth's atmosphere as it is.

14.2 The Layers of Atmosphere

The atmosphere of earth is made up of several layers which are composed of different constituents and each layer serves in different way, which the nature has given to it.

In the subsequent section we will see the composition and functions of each of these layers separately.

14.2.1 Troposphere

The troposphere is the lowest layer of the atmosphere which begins at the surface of earth and extends to between 7 km to 14 km, with some variation due to weather factors. Most of the mass of earth atmosphere (about 75%) is present here in this layer.

The troposphere is the only atmospheric layer that can support life. where large amount of water vapour are present. The clouds develop here, and the birds fly here.

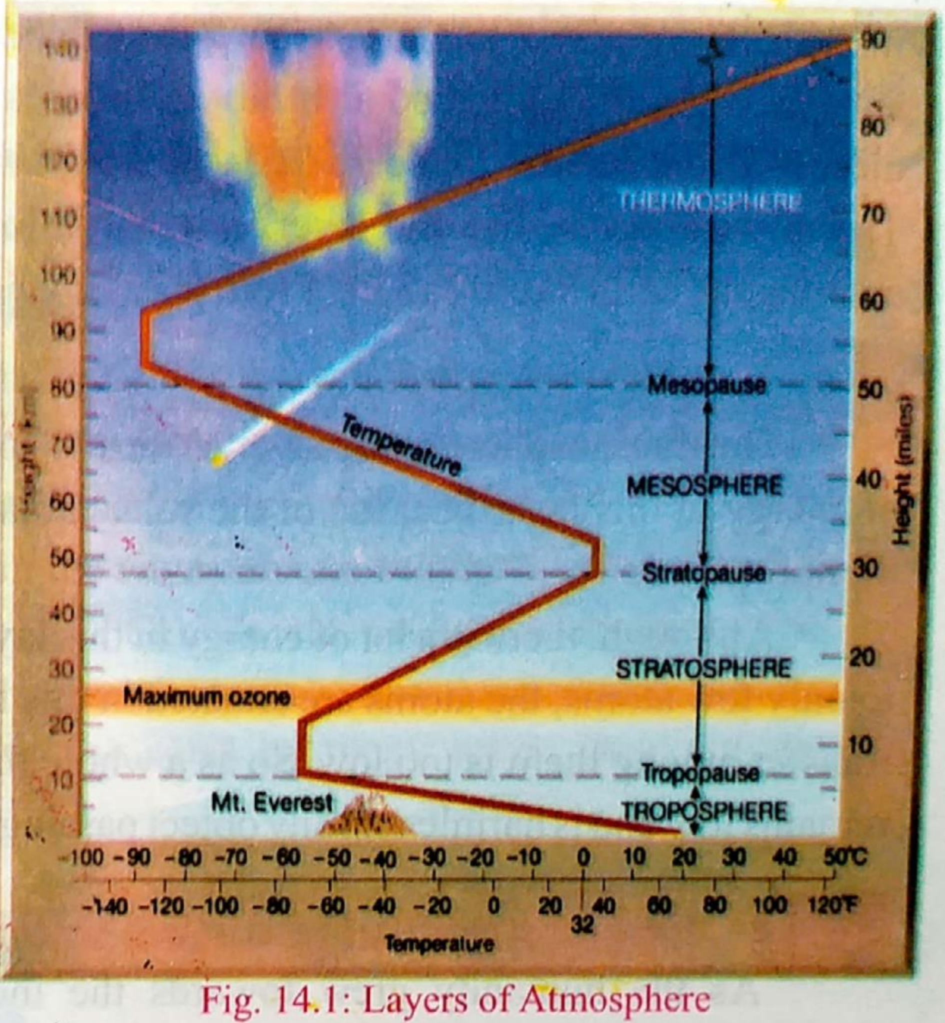


Fig. 14.1: Layers of Atmosphere

14.2.2 Stratosphere

The troposphere extends from the earth's surface up to the tropopause where the stratosphere begins. The stratosphere lasts up to the distance of almost 50Km from the surface of earth. The real importance of the stratosphere is the ozone layer (Some scientists classify this layer as ozonosphere). Where ozone (O_3) molecules (an allotropic form of the oxygen) absorb large amount of UV (ultra-violet) radiation of the sun. A chemical reaction takes place when an ozone molecule absorbs the UV radiation. The energy is then radiated as IR (infra-red) radiation, and that is what heats up the layer, and so this layer has relatively higher temperature than the other layers. Without the ozone, UV radiations would flood the surface of the earth causing destruction to the life.

14.2.3 Mesosphere

The mesosphere is the coldest region of atmosphere where the temperature ranges from 20°C to -80°C. The temperature falls as we move from the earth to the upper atmosphere. The mesosphere starts above from the stratosphere at about 50Km and lasts up to about 90Km. The amount of oxygen, nitrogen, and carbon dioxide in the mesosphere is almost same as that in the levels of the earth's atmosphere immediately above the earth's surface. But the water vapour concentration here is very low, moreover the mesosphere contains higher percentages of ozone than the lower levels. The mesosphere is also the layer in which a lot of meteors burn up while entering the earth's atmosphere. From the earth they are seen as shooting stars.

14.2.4 Thermosphere

The thermosphere is the layer closest to space. There is a huge amount of energy in this layer because of the solar radiations from space hitting the thermosphere.

Although, there is a lot of energy in this layer, but this energy is limited to only few atoms, the atoms are situated in this layer at far distance and heat transfer among them is too low. So as a whole the overall heat of the system remains low and is harmless to any object passing there.

14..3 Environmental pollution and Pollutants

As the humanity grew towards the industrialization and humans discovered and made new inventions to ensure a high standard of life, they introduced into the environment such compounds which were not the part of natural environment ever before or they were present in smaller quantities. Among these additions there were also such compounds that caused a direct or indirect threat to living organisms and life forms of the planet earth. Such compounds were named **pollutants** that were affecting the natural functioning of our ecosystems and this phenomenon through which these pollutants are coming in our environment is called **environmental pollution.**

Thus a pollutant is a substance that causes contamination to the earth's environment affecting the quality of life, or the natural functioning of ecosystems.

Although some environmental pollution is a result of natural causes such as volcanic eruptions, most is caused by human activities. There are two main categories of polluting materials, or pollutants.

- **Biodegradable pollutants:**
  These are materials, such as sewage, that rapidly decompose by natural

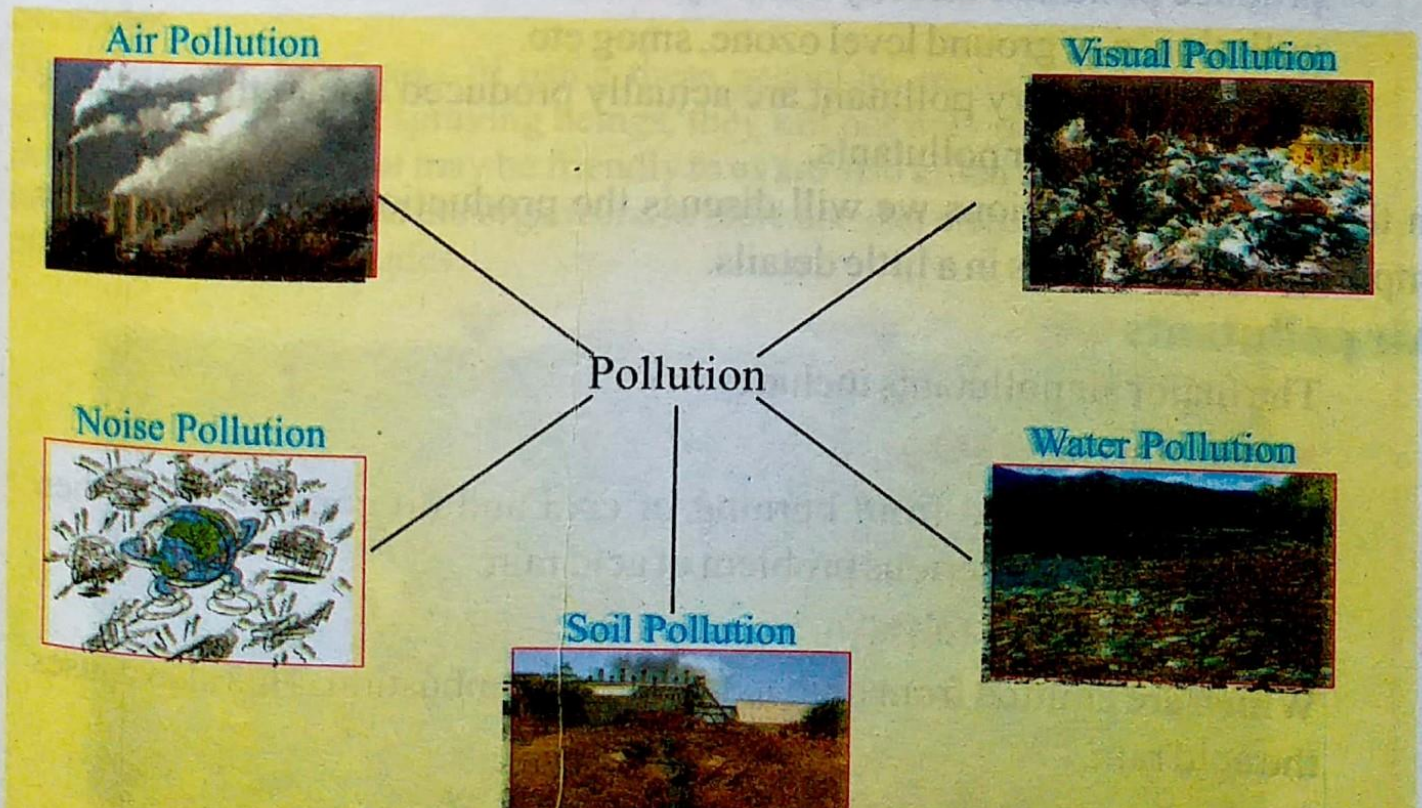
processes. These pollutants become a problem when added to the environment faster than they can decompose. Other examples of biodegradable pollutants include some gaseous substances, e.g CO , CO_2, SO_2 NO, NO_2, hydrocarbon fuel vapours etc.

- **Non-degradable pollutants**

These are materials that either do not decompose or decompose slowly in the natural environment, so they cause a real danger to the livings and to the planet earth. Once such contamination occurs, it is difficult or impossible to remove these pollutants from the environment. Examples of such pollutants include chlorofluorocarbons (CFCs), dioxin pesticides, various types of plastic products, radioactive materials etc.

The pollutants pollute the earth by many ways, their pollution is classified further as:

- Air pollution
- Soil contamination
- Visual pollution
- **Water pollution**
- **Noise pollution**



Here we will discuss only the air pollution due to its greater importance, whereas the topic of water pollution has been discussed in next chapter in detail.

14.3.1 Air pollution

The air pollution is mainly caused by the release of chemicals and particulates into the atmosphere, for example by the carbon monoxide, carbon dioxide, sulfur dioxide, chlorofluorocarbons (CFCs), and nitrogen oxides produced by industry and motor vehicles, and also by some natural processes too, e.g. by the volcanic activities, which are rather uncontrollable, We are more concerned here with the man made sources of air pollution, which has grown up during industrialization.

On the basis of their role in the environment, the air pollutants have been divided into two major classes, discussed as follows,

A. **Primary air pollutants:** Which include SO_2, NO_x, CO_x, hydrocarbons and particulate material like dust, ash, smoke etc.

B. **Secondary air pollutants:** These are the pollutants which do not produce pollution directly but they have indirect effect and thus cause pollution. e.g, ground level ozone, smog etc.

The secondary pollutant are actually produced due to the activities of primary air pollutants.

In the subsequent sections we will discuss the production and role of some important air pollutants in a little details.

Air pollutants

The major air pollutants include

- **Sulfur dioxide: (SO_2)**

  Which are emitted from burning of coal and oil containing sulpher. This gas causes a serious problem of acid rain.

- **Nitrogen dioxide (NO_2)**

  Which are emitted from high temperature combustion. This also causes the acid rain.

- **Carbon monoxide: (CO)**

  Which is produced by incomplete combustion of fuel such as natural gas, coal or wood. Vehicular exhaust is a major source of carbon monoxide.

- **Carbon dioxide: (CO_2)**

  Which is emitted in combustion processes and has caused the green house effect (increase in the temperature of earth atmosphere).

- **Particulate materials:**

  These include smoke and dust, and even more poisonous Lead. They are the suspended particles 2.5-10 micrometers in diameter. that enter the nasal cavity, and even the bronchia and lungs.

- **Chlorofluorocarbons (CFCs):**

  These are the organic compounds containing 'Cl' and 'F' elements. They emit from the spray paints, Freon refrigerant, DDT insecticide etc. These are harmful to the ozone layer. The ozone layer protects the earth from the hazardous ultraviolet radiations that come from the sun and other stars.

Interesting Information

Although the pesticides and herbicides are frequently used to and herbs produce the agriculture products in large quantities by controlling the pests of crops, but on the other hand there are a number of health hazard effects of using these pesticides.

The important drawbacks of using these pesticides include their direct effect upon the dwelling and spraying beings, they kill not only the disease producing pests but other pests that may be friendly to us are also killed by these. They enter into aquatic systems and the organisms in there are also affected by the poisonous effects of these insecticides.

- **Radioactive pollutants:**

  They come out from the nuclear explosions and from the hospital usages which are disinfected by radioactive radiations.

- **Ground level ozone:**

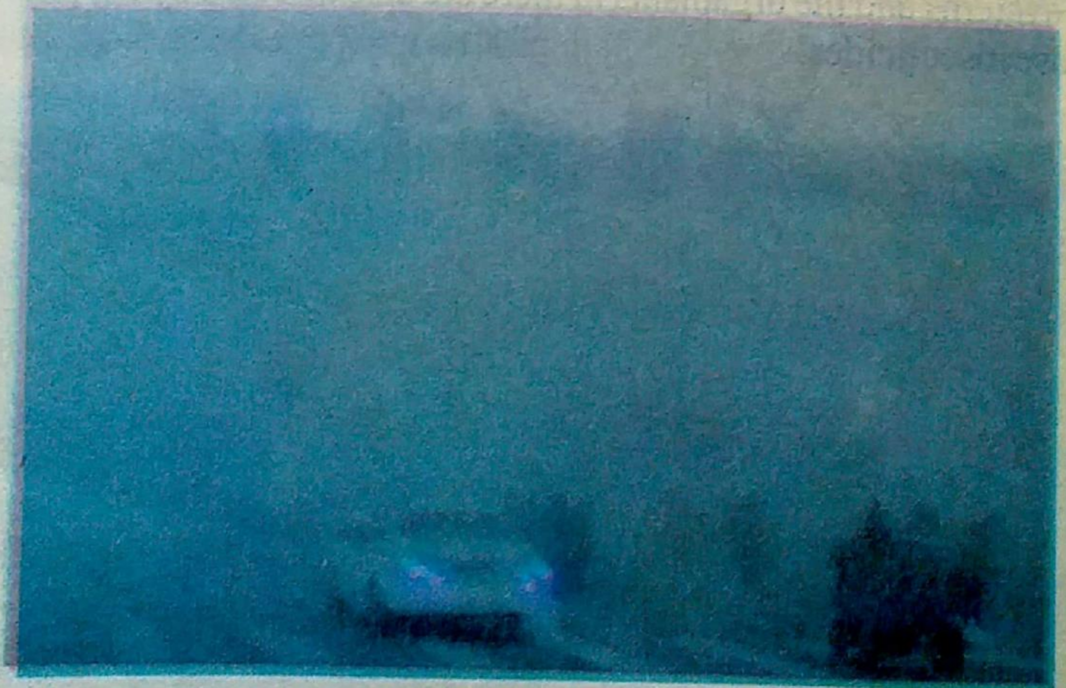
  Although the upper atmosphere ozone layer is beneficial to us, but at ground it is poisonous for living beings, this is produced by the equipments that utilizes high voltages, e.g the photo state machines, where the pungent smell of ozone is often detectable.

- **Odours:**

  The odour or the smell comes from garbage, sewage, and industrial processes. The bad odour also indicates that there are germs which could cause diseases.

Interesting Information

A great problem that is arising in the highly populated cities of our country is the "Smog". The word Smog is the combination of smoke and fog. You may have noticed the problem of smog in many regions of the country, which usually becomes severe during winter season. The smog not only effects the health of the people of the areas but also causes the difficulties (and even accidents) in the flow of traffic.



14.4 The acid rain and its effects

As already indicated that the acid rain is caused chiefly by two types of oxides, i.e sulphur oxides and nitrogen oxides. The term "Acid rain" is used to describe rain fall that has a pH level of less than 5.6. Acid rain is formed when oxides of sulphur or nitrogen combine with moisture in the atmosphere to make sulphuric acid and nitric acid. The sulphur dioxide reacts with the oxygen of air to give SO_3 which on combining with water forms sulphuric acid. This acid makes the water in rain acidic.

$$2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$$

$$SO_{3(g)} + H_2O_{(l)} \longrightarrow H_2SO_{4(aq)}$$

Similarly, the oxides of nitrogen, combines with water of atmosphere to form acidic products, e.g NO_2 and water.

$$2NO_{2(g)} + H_2O_{(l)} \longrightarrow HNO_{3(aq)} + HNO_{2(aq)}$$

These acids can be carried away far from their origin in clouds and then come down as rain fall. This acid rain has caused great environmental damages, and directly destroys the life forms where this acid rain falls. It has adverse impacts on forests, freshwaters and soils, killing off insect and aquatic life forms as well as causing damage to buildings and having possible impacts on human health.

In order to prevent the acid rains a number of international treaties (e.g. montreal and Kyoto treaties) on the long range transport of atmospheric pollutants have been agreed, and this has significantly reduced the emission of hazardous gases into atmosphere, and thus has short down the acid rains.

14.5 Ozone depletion and its effects

As described earlier that a protective layer of ozone gas is present at the upper atmosphere (Stratosphere), which protects the earth from the highly energetic and dangerous ultraviolet radiations. This process can be described by the following chemical reactions.

$$O_{3(g)} + uv \longrightarrow \dot{O}_{(g)} + O_{2(g)}$$

The O_2 produced again combines with the atomic oxygen to yield the ozone back.

$$O_{2(g)} + \dot{O}_{(g)} \longrightarrow O_{3(g)}$$

In the late 1970s, scientists found that some chemicals called chlorofluorocarbons (CFCs) damage this protective layer. When chlorine of these CFCs react with the ozone there.

$$\dot{Cl}_{(g)} + O_{3(g)} \longrightarrow \dot{Cl}O_{(g)} + O_{2(g)}$$

$$O_{3(g)} \xrightarrow{\text{UVlight}} \dot{O}_{(g)} + O_{2(g)}$$

$$Cl\dot{O}_{(g)} + \dot{O}_{(g)} \longrightarrow \dot{Cl}_{(g)} + O_{2(g)}$$

Fig. 14.2: Ozone hole (inside blue area) upon arctic region in Sep-1980

As it is seen above that this is a chain reaction and a single chlorine atom depletes thousands of ozone molecules, and thus the ozone is constantly depleting.

The ozone depletion is considered to have the following important effects upon the earth systems. As ozone stops the UV rays to penetrate into the earth, its depletion will allow this radiation into earth surface, which is expected to increase the skin cancer to humans. The increased UV radiations destroys the micro organisms and thus misbalancing the entire ecosystem.

The increase in UV also causes global warming directly and indirectly. Fortunately, the ozone hole yet discovered is at the antarctic region, where the

Interesting Information

Although the ozone gas is helping us to keep the planet earth safe from the destructive effects of solar and stars radiation and thus is playing a valuable role to fit the environment of earth for life, but itself the ozone is poisonous and causes undesirable effects when comes in contact. Many urban activities now a days cause the production of ground level ozone e.g sparks in electric equipments, and you may have observed this by the distinct smell of ozone near photo state machines. Thus ground level ozone is a form of air pollution.

life is not so abundant, and yet the damage to life has not been caused by this hole, but the measures are required to be taken to stop this damage.

In this consequence several steps have been taken, important of which is the ban on the usage of CFCs.

Summary of the Chapter

- Atmosphere is the layer of different gases that has covered our planet earth.
- Air is also a part or layer of the atmosphere which consists of 78% N_2, 20.95% O_2, 0.93%Ar, 0.04% CO_2 and some other gases in smaller amounts.
- The atmosphere is extended up to about 500km above the earth, but its concentration decreases slowly and it has no strict boundary.
- The atmosphere plays very important role in sustaining life at earth.
- The atmosphere consists of various layers of which the important are troposphere, stratosphere, mesosphere and thermosphere.
- Ozonosphere which is actually a part of stratosphere filters off the hazardous ultraviolet radiations that come from sun and stars.
- The substances that contaminate the earth environment in a manner that quality of life is disturbed are called 'pollutant', and the process of spreading such contamination is called 'pollution'.
- The pollutants are of two types, one that decomposes natural way is called bio-degradable, and the second which does not degrades by nature which is called non-biodegradable.
- The branch of chemistry which deals with the study of elements found in our environment is called environmental chemistry.
- The pollution could be of types, for example air pollution, water pollution, soil pollution, noise pollution and visual pollution etc.
- The air pollution is the contamination of injurious substances into

atmosphere which are causing danger to living organisms on planet earth.

- The air pollutants are basically of two types, primary and the secondary.
- The primary pollutants are those who themselves produce pollution and so are dangerous for living organisms.
- The secondary air pollutants are those that do not produce pollution directly themselves but they indirectly are dangerous and create situation or are responsible for the creation of some hazardous substance that pollute air.
- Chlorofluoro carbons destroy the ozone layer of atmosphere, these compounds are present in spray paints, Freon refrigerant and insecticide spray like DDT.
- The oxides of sulphur and nitrogen produce acid rains.

Exercise

Q1: Fill in the blanks with suitable words.

i) The mesosphere contains the same .... of gases as in near the earth crust.

ii) Thermosphere is the layer having .... temperature.

iii) Biodegradable pollutants decompose by ....

iv) The ozone layer protects the earth from ....

v) The ozone depletion is caused primarily by ....

vi) The acid rain has a pH ....

vii) Smog is the combination word of ....and ....

viii) Different oxides of .... and......... are the major primary pollutants.

ix) The temperature of mesosphere ranges..........

x) Percentage of O_2 in atmosphere is..............

Q2: Choose the correct answer.

i) The atmosphere contains almost the oxygen:

(a) 20% (b) 21% (c) 78% (d) 0.04%

ii) The troposphere is the layer of atmosphere that exists at:

(a) Uppermost level (b) Lowermost level

(c) In middle (d) Non of above

iii) Among following the primary air pollutant is the:

(a) SO_2 (b) CFCs (c) CO (d) All of the above

iv) The main cause of acid rain is:

(a) SO_2 (b) NO_2

(c) Both SO_2 and NO_2 (d) Ozone and smog

v) Green house effect is causing the temperature change and results in:

(a) Increase in temperature

(b) Decrease in temperature

(c) Retains temperature constant

(d) Does not has any effect up on temperature

vi) Plastic is the pollutant which is:

(a) Biodegradable (b) Non-biodegradable

(c) Primary pollutant (d) Secondary pollutant

vii) Thermosphere layer lasts up to the altitude of

(a) 100-350 km (b) 100-150 km

(c) 50-100 km (d) 5-100 km

viii) The ozone layer prevents:

(a) The light that comes from sun

(b) The heat energy that comes from sun

(c) The ultra violet rays that come from sun and stars

(d) The heat energy that escapes from earth

ix) The percentage of CO_2 in the atmosphere is:

(a) 0.04% (b) 25% (c) 78% (d) 21%

x) Percentage of O_2 in Thermosphere is:

(a) 78% (b) 21% (c) 0% (d) 4%

Q3: Explain with reasoning.

i) Smog is produced mostly in winter season.

ii) Although ozone is a pollutant but it is also necessary for livings too.

iii) CO_2 gas is a pollutant but its presence is essential for living organisms.

iv) What measures should be taken to fill the hole in ozone layer?

v) How global warming is being caused?

Q4 Discuss how the atmosphere plays the role in sustaining life on the earth?

Q5: What is the composition of earth atmosphere?

Q6: What do you understand by the term pollution? How the pollution creates?

Q7: What are pollutants? Describe the difference between primary and secondary pollutants?

Q8: How the ozone layer affects the earth life? Discuss main causes of ozone depletion?

Q9: Explain how ozone is produced in atmosphere?

Chapter

15

ENVIRONMENTAL CHEMISTRY-II
WATER

Conceptual Linkage

Before reading this chapter, the student must know the:

- Basics of pollution and its importance in our life
- Sources of pollution
- Basic characteristics of water

Time Allocation

Teaching periods	= 10
Assessment periods	= 02
Weightage	= 08%

LEARNING OUTCOMES

Students will be able to:

- Describe the occurrence of water and its importance in the environment including industry. (Analyzing)
- Review our dependence on water and the importance of maintaining its quality. (Analyzing)
- Describe the composition and properties of water. (Understanding)
- Differentiate among soft, temporary and permanent hard water. (Analyzing)
- Describe methods for eliminating temporary and permanent hardness of water. (Applying)
- Identify water pollutants. (Analyzing)
- Describe industrial wastes and household wastes as water pollutants. (Understanding)
- Describe the effects of these pollutants on life. (Understanding)
- Describe the various types of water borne diseases. (Understanding)

Introduction

Water is an essential part of all living forms on this planet, and without water no life is even thought to have the existence. Water which is very important reffered as "Hydrosphere" of the earth atmosphere. Although, the water is abundant in earth but the water actually available for the use of human beings is limited. Water scarcity is very common at majority of areas in earth. This scarcity is because of the distribution and usage of water. Water is an important essential for us and we use water in our daily life on a large scale, especially for drinking, washing cultivation and other purposes.

15.1 Water

Water constitutes an important part of our environment and covers 71% the Earth's surface, of this saltwater of oceans and ground saline water holds 97.5%, The 2.5% is the fresh water. This fresh water glaciers and polar ice caps hold 68.7%, 30.1% of this fresh water is the ground water, available for our use. It means that only a small fraction of the total water content of the earth is available for us, which is about 0.7%.

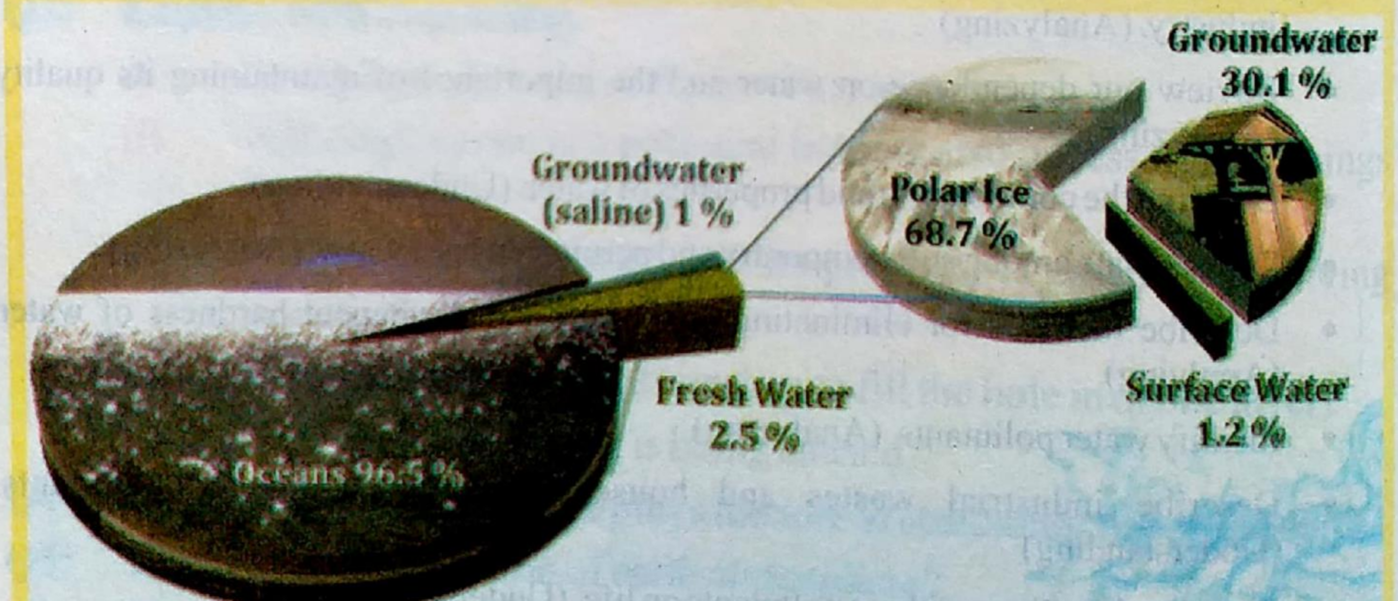


Fig. 15.1: Water resources on earth

Water captured in all of the above stated forms moves perpetually through the water cycle of evaporation, transpiration, precipitation, and runs off usually reaching the sea.

The water cycle is well explained by the following figure-15.2.

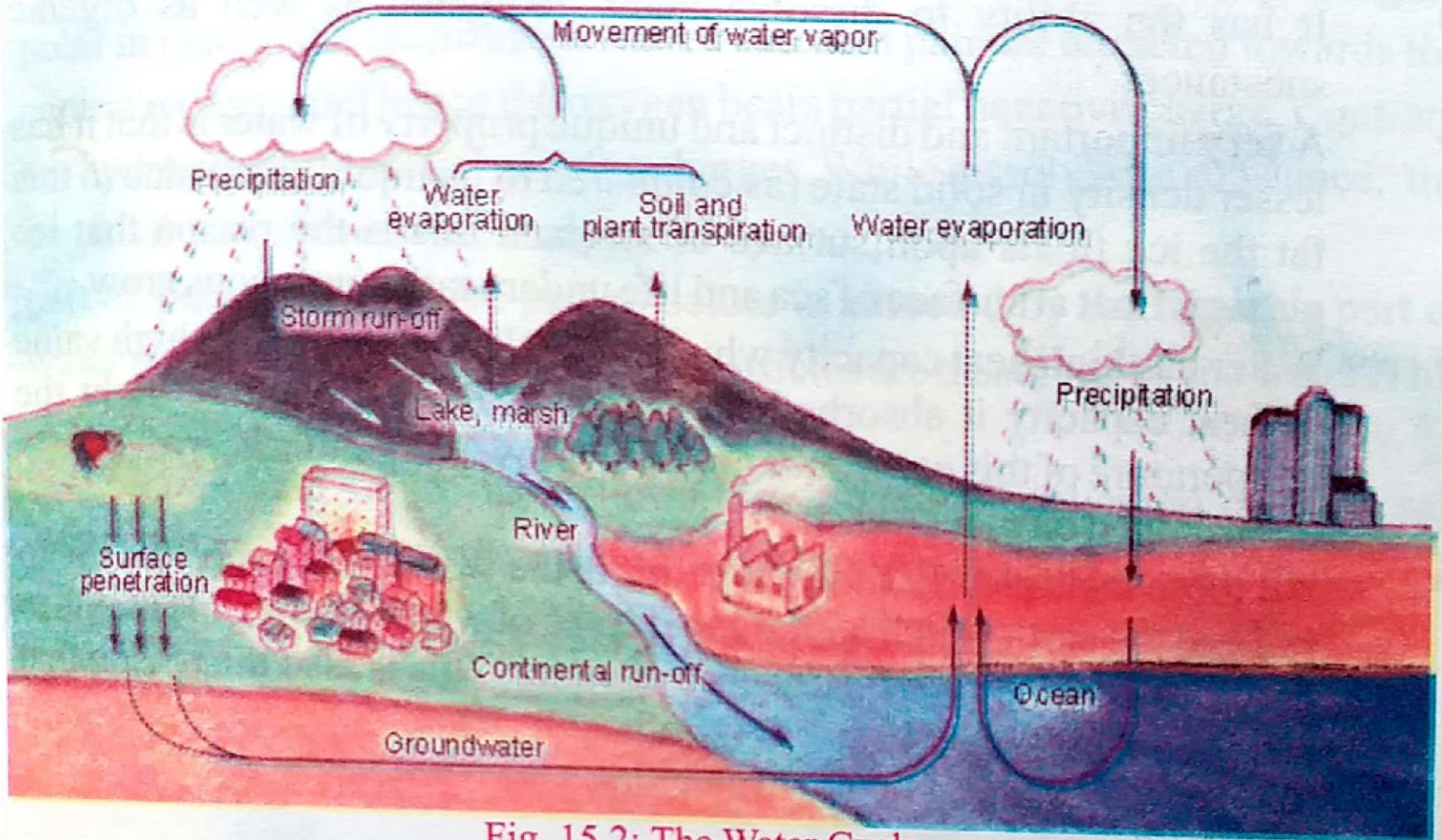


Fig. 15.2: The Water Cycle

The humans have been disturbing the water cycle from centuries and this disturbance has been accelerated with the beginning of industrialization. Mostly the sewage of industries is excreted through the same passage that the water uses for its flow in nature and hence the problem of polluting the water arises in major.

The use of polluted water causes many diseases to living organisms and thus endangers the life of the planet. This is also a duty of environmental chemists and scientists to overcome such situations. In this chapter we will discuss the water, its basic properties and the problem of water pollution and its prevention measures in detail.

15.1.1 Properties of Water

Pure water shows some very interesting features, it is colourless, and tasteless compound having molecular formula H_2O having following important characters:

- At normal temperature and pressure it occurs in liquid state.
- It is neutral compound and does not shows any acidic or basic properties.

- It has the ability to dissolve many inorganic as well as organic substances.
- A very important and distinct and unique property of water is that it has lesser density in solid state (as compared to its liquid state), due to this fat the ice floats upon surface of sea, and this is the reason that ice glaciers float at surface of sea and life underneath continuous grow.
- Water has high heat capacity which is $4.18Jg^{-1}C^{-1}$, due to this high value of heat capacity it absorbs heat energy at day time and at night the temperature of this earth does not falls to low values this keep the life to be sustained on planet earth.
- All these facts clearly shows that this is the water, that keeps the life to run and the earth which has large reserves of water (about 3/4) is able to carry life due to this high quantity of water. This is also the reason that scientist while exploring life on other planets see the presence of water first on prior basis.

15.2 Water as a solvent

Water is an excellent solvent, and it dissolves most of inorganic and many organic compounds.

The chemical formula of water shows that it is composed of two types of atoms i.e. the oxygen and the hydrogen atoms these atoms are linked with each other with an angle of 104.45° between the 'H–$\ddot{O}$ – H' atoms, and the distance between the 'O–H' is 0.9584A°.

Pure water boils at 100°C and freezes at 0°C.

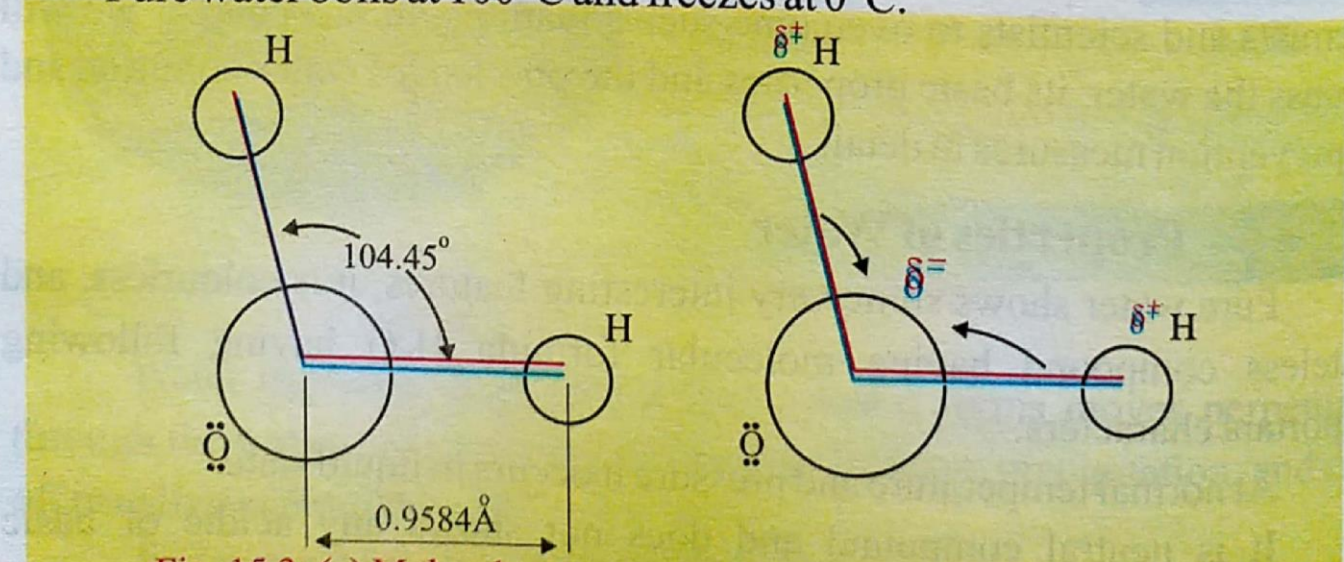


Fig. 15.3: (a) Molecular structure of water showing angles between H–O–H (b) Polarity in Water Molecule

This high solubility is due to the polar nature of water. Water is highly polar in nature, the electrons of shared electron pair are attracted towards the central oxygen, and hence the oxygen bears partial negative charge, Contrary the hydrogen bears partial positive charges. While dissolving a substance, the negative part of the solute is captured by the positive part of water, and positive part of solute is attracted by the negative part of water molecule, and hence the solute particles are dissolved by the water. This process is termed as solvation.

Following figure-15.5 shows this process of solvation of table salt (NaCl), enabling you to understand the phenomenon easily.

Fig. 15.4: Solvation process of water and NaCl

So this is clear that upon solvation the polar substances breakup into ions and these ions are masked by the water molecule (through their poles), and thus some new forces develop in this solute—solvent interaction.

15.3 Soft and hard water

The term hard water is used for the water which is rich in mineral contents, especially calcium or magnesium ions and their bicarbonates and sulphates.

When rain water passes through the locations where the source of these ions are located, usually these ions enter a water supply by leaching from minerals within an aquifer. Common calcium-containing minerals are calcite and gypsum. A common magnesium mineral is dolomite (which also contains calcium). This dissolution makes the water hard.

$$CaCO_{3(s)} + CO_{2(g)} + H_2O_{(l)} \rightleftharpoons Ca^{2+}_{(aq)} + 2HCO^-_{3(aq)}$$

$$MgCO_{3(s)} + CO_{2(g)} + H_2O_{(l)} \rightleftharpoons Mg^{2+}_{(aq)} + 2HCO^-_{3(aq)}$$

The CO_2 in the process can be absorbed from the atmosphere.

A very simple test for the hardness is to treat the water with soap, if the water is hard it will not lather up, but the soft easily lathers.

15.4 Types of hardness of water

The hardness of water is classified on the basis of types of mineral content. Thus if the mineral is easily removable then it is classified as the **temporary hardness** and if the mineral is not easily removable then it is termed as the **permanent hardness**, and the water containing such contamination is termed as the temporary hard water and permanent hard water respectively. The example of temporary hard water is the water containing the Ca^{2+} and HCO_3^- ions. This type of hard water is when warmed, the hardness is removed, (As when the calcium bicarbonate is heated, it converts into insoluble carbonate).

$$Ca(HCO_3)_{2(s)} + heat \rightleftharpoons CaCO_{3(s)} + CO_{2(g)} + H_2O_{(g)}$$

The insoluble carbonate settles down and simple decantation gives water free of this.

The permanent hardness is that which cannot be removed by simple methods. In such hardness the sulphates of Ca^{2+} or Mg^{2+} or both are present as mineral contents, which become more soluble by heating so they can't be removed by heating. Although some complex methods are available for softening of this type, e.g. ion exchange method.

15.5 Methods of removing hardness

Several methods are available for water softening, these methods largely depends upon the type of ions that have made the water hard. Thus there are two categories of removing hardness of water.

I) Removal of temporary hardness:

This type of hardness is relatively easy to remove,

i) **Removing hardness by boiling:** When the water is boiled the bicarbonate changes to insoluble carbonates, these solid precipitates can be easily removed just by decantation or filtration. e.g.

$$Ca(HCO_3)_{2(s)} \xrightarrow{\Delta} CaCO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$$

ii) **The Clark's method:** This method involves the addition of slaked lime, this converts dissolved bicarbonates into insoluble carbonates. e.g.

$$Ca(HCO_3)_{2(aq)} + Ca(OH)_{2(aq)} \longrightarrow 2CaCO_{3(s)} + 2H_2O_{(l)}$$

II) Removal of permanent hardness:

The permanent hard water that contains sulphates or chlorides of calcium or magnesium is relatively difficult to remove, they are removed by using special type of ion exchangers like sodium or potassium zeolites or soluble sodium/potassium carbonates (or washing soda) which serve also as ion exchangers.

$$Na_2CO_{3(aq)} + CaSO_{4(aq)} \longrightarrow CaCO_{3(s)} + Na_2SO_{4(aq)}$$

$$Na_2\text{-zeolite} + CaSO_{4(aq)} \longrightarrow Ca\text{-zeolite} + Na_2SO_{4(aq)}$$

15.6 Disadvantages of using hard water

The hard water usage has many disadvantages; some of these disadvantages are discussed following.

In the hard water the soap or shampoo does not lathers up and so cleaning the skin, scalp or the cloths is not achieved in a good manner. Similarly, the insoluble salts that get left behind from using regular shampoo in hard water tend to leave hair rougher and harder to detangle.

A very serious problem is that the salts in hard water deposits in boilers and pipes, these deposits can even block the passage of steam flow and the system can blow up. Such accidents have caused loss of lives many times.

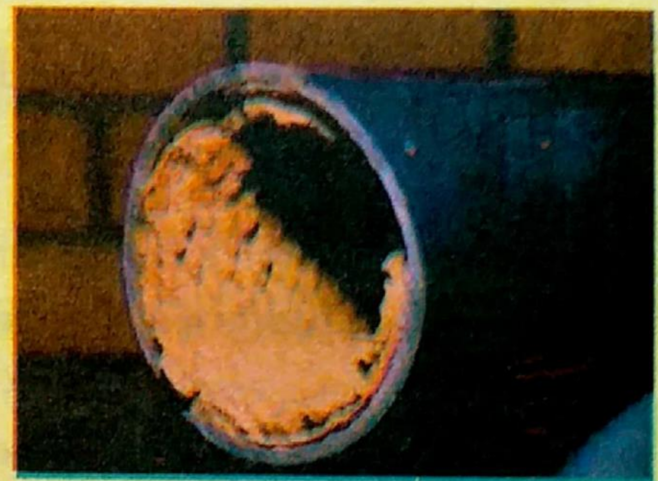


Fig. 15.5: Salts deposition inside of boiler pipes

15.7 The Water pollution

The term "water pollution" is described to represent the adverse effect upon the water contents, like lakes, rivers, oceans, or ground water by contaminations made by humans. The water pollution has many causes, but the important one is the wastes discharged by the industries that contain heavy metals like lead, arsenic and mercury, and other pollutants including organic toxins, insecticides, oils, and other materials. The Water pollution is a great problem faced by the human beings, and is the direct result of industrialization. It has not only endangered the water life and ecosystem but also to the human beings directly and indirectly. Following are the important types of wastes responsible for the water pollution.

15.7.1 Industrial wastes

The industrial wastes are the sewage released by industries or mines. These wastes are released in large amounts and have caused a great damage to living beings at many areas of the world due to having toxic substances dissolved in it.

Fig. 15.6: Contaminated water from industries

Such releases include heavy metals, organic wastes and many other toxic substances endangers the aquatic life and when such contaminated species are taken as a food by humans or used for cultivation or drinking purposes, also has a fatal effect to them.

15.7.2 Household wastes

The household wastes that pollute the water resources mainly consists of organic debris, which on mixing with ground water resources makes it unfavorable for drinking. These debris may also contain germs of various diseases, such as hepatitis, cholera, GIT (Gastro Intestinal Tract), typhoid and many others. Beside organic debris, there are many other pollutants on household level that pollute the water, these include insecticides or pesticides, lye preparations, food wastes, and very important the polyethylene products.

15.7.3 Agriculture wastes

The agriculture wastes mainly consists of pesticides preparations, which when sprayed are then washed away to near water reservoirs and thus pollute them on large scale, killing the life forms there and thus causing a great ecological problem. The other agriculture wastes are different types of fertilizers (both organic and inorganic). These fertilizers contaminate the drinking water on a large scale and also make it difficult for the aquatic life to survive.

15.8 Water borne diseases

The water borne diseases are those which are caused by drinking or handling contaminated water. There are many cases where the contaminated water has caused death to living organisms directly, especially when contaminated by the pesticide preparations and mercury compounds. Some contaminations like high fluoride content can cause abnormalities to bone formations. The acid rain also has an adverse effect upon the living organisms.

The sewage of industries is excreted in water channels which contains harmful poisoning compounds, the fish and other life forms dwelling in the water channels are then become affected by this polluted water, thus the contaminations in the sewage enters into food chain, such contaminated fishes when eaten by the birds and animals (including humans) show an adverse effect on their life.

Not only the chemically polluted water is injurious to the ecosystem but biological contaminations that include the micro organisms are evenly polluting the water sources and affecting the living organisms directly.

There is also a large list of diseases caused by the germs that nourish in contaminated water. Some most common in our country are following.

Gastro or Gastric intestinal diseases:

Intestinal diseases usually called Gastro are the most common in our country which is caused by the usage of contaminated water. This kills thousands of humans each year. The main diseases of this series include Cholera and diarrhea.

Hepatitis

The hepatitis is the disease that damages liver and is caused by a virus which is mainly present in the contaminated water.

GIT worms

There are many worms that live in the gastro intestinal tract (GIT) of humans, especially in the small intestine. These worms include Round worms, Hook worms, Tap worms, Pin worms and Whip worms etc. Again the main reason of their introduction and transmission is the contaminated water. These worms cause diarrhea, Anemia, Itching, Irritation of GIT and rectum.

Jaundice

Jaundice is a yellow discoloration of the skin, mucous membranes, and the whites of the eyes caused by increased amounts of bilirubin in the blood. GIT is a sign of an underlying disease process. The jaundice is often seen in liver disease such as hepatitis or liver cancer. It may also indicate obstruction of the biliary tract, for example by gallstones or pancreatic cancer.

Typhoid fever:

Typhoid fever is a bacterial disease which is caused and spreads by the use of contaminated water. This is a fatal disease if not treated well.

Beside these diseases stated above there is a number of diseases which are linked indirectly with the contaminated water e.g. the Malaria. In fact most of the bacteria and virus have their life cycle in water hence contaminated water is the main cause of the diseases they cause.

Interesting Information

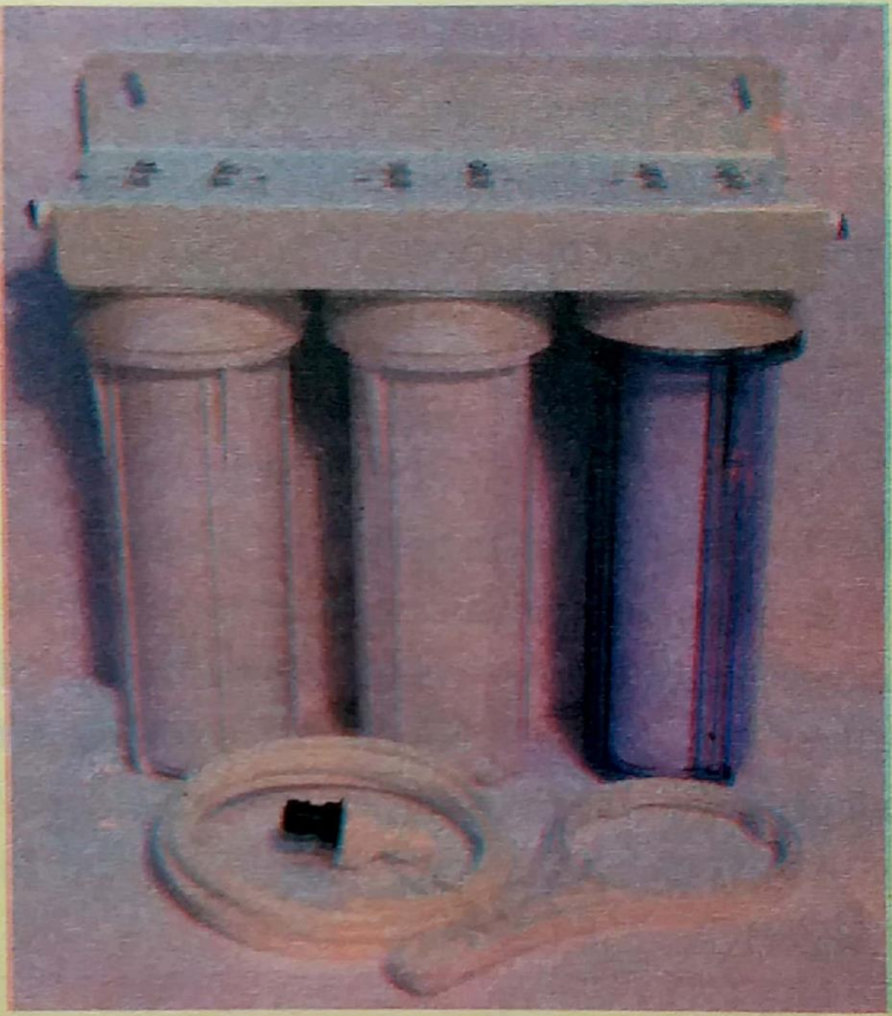
A quick and easy way to obtain good quality drinkable water is the use of 3 stage advanced filtration processed water filters. This uses a combination of Sediment Filter, Activated Carbon Filter and UV Disinfection to give safe drinking water.

The Sediment filtration unit acts as a sieve to remove the particulate matter of specific size present in the water.

The second unit which is usually consisting of activated charcoal carbon filter which is actually a porous substance and is used to absorb both organic and inorganic odourous and coloured substances from water.

The third and final unit is an Ultraviolet light energy producing unit and it acts to kill the germs and microorganisms present in the water. Hence after passing from three units the water obtained is of good quality for drinking purpose.

But remember the units especially the charcoal one has to be replaced when the pores are filled up with particles.



Summary of the Chapter

- Water forms an essential part of earth, and forms Hydrosphere of the planet.
- About 97.5% of the total water content is saline and unusable for general use.
- Only 0.7% of the total water can be used for drinking and other usage by humans.
- Water captured in different forms moves perpetually through the water cycle of evaporation, transpiration, precipitation, and runs off reaching the sea.
- Pure water is a colourless, odourless, and tasteless but the water we use has taste due to different dissolved salts, as water is an excellent solvent.
- If water has dissolved bicarbonates or sulphates of calcium or magnesium, it is said to be hard water.
- Hard water causes diarrhea on drinking, and does not produces lather with soap, and upon boiling salts are deposited on inner walls of pipes and boilers.
- When water is contaminated with chemicals and microorganisms that make it disease causing, it is called polluted water.
- There are many sources that contaminate water; these sources could be from industries, house hold wastages, from microorganisms, or other human activities.
- The polluted water causes many diseases.

Exercise

Q1: Fill in the blanks with suitable words.

i) Water covers .... % of the earth.

ii) Fresh water reserves are ....% of total water content of earth.

iii) Pure water has .... smell.

iv) The water can dissolve most of the .... and some .... compounds.

v) The water in the Antarctic ice sheet constitute ....% of fresh reservoir.

vi) The percentage of water out of total water content that we can drink is ....

vii) Water pollution is caused due to dissolved .... and ....

viii) Gastro is caused by ....

ix) Jaundice is recognized by .... pigmentation of body parts.

x) High Fluoride content causes .... disease.

Q2: Choose the correct answer.

i) Pure water has the taste:

(a) Salty (b) Sweet

(c) sour (d) tasteless

ii) The hard water contains the bicarbonates and sulphates of:

(a) Ca (b) Mg

(c) both of these (d) none of these

iii) The major responsibility for polluting the water goes to:

(a) humans (b) Animals

(c) natural disasters (d) died fishes

iv) The hard water can be drunk safely:

(a) true (b) false

(c) depends upon the type of impurity
(d) none of above

v) The hard water can be used for washing:
(a) quite easily (b) with difficulty
(c) can not be used (d) hard water does not exists

vi) The percentage of water locked in polar ice sheet is:
(a) 68.7% (b) 2% (c) 1% (d) 30%

vii) The largest fresh water source of earth is:
(a) Oceans (b) Rivers
(c) Ground water resources (d) Polar ice caps

viii) Solvation is the process that makes:
(a) Solution (b) Pure water
(c) Desalinated water (d) Mineral water

ix) The hard water is the water that contains ions of metal bicarbonate, sulphate or chloride ionis of:
(a) Mg only (b) Sulphates
(c) Phosphates (d) Calcium or Magnesium

x) The major cause of water pollution is:
(a) Sewage of Industries (b) Acid rains
(c) Chlorofluoro carbons (d) improper water channels

Q3: Explain with reasoning.

i) The rain water is always soft in nature.
ii) How UV energy can be used to make water drinkable?
iii) Although the pure water is tasteless, but when we buy bottled water it shows marked taste.
iv) Use of Pesticides should not be encouraged.
v) How Malaria fever is associated with water?

Q4: How the water effects our environment?

Q5: What is the difference between the hard and soft water? Can the hardness be removed?

Q6: Why water dissolves the most of common compounds?

Q7: Write a note on water pollution.

Q8: How can the untreated water can be made fit for drinking?

Chapter 16

THE INDUSTRIAL CHEMISTRY

Conceptual Linkage

Before reading this chapter, the student must know the:

- Importance of chemistry.
- Different uses of chemical compounds.
- Basic characteristics of metals.
- Basic organic chemistry.

Time Allocation

Teaching periods = 13
Assessment periods = 03
Weightage = 09%

LEARNING OUTCOMES

Students will be able to:

- Describe some metallurgical operations. (Applying)
- Make a list of raw materials for Solvay process. (Applying)
- Outline the basic reactions of Solvay process. (Analyzing)
- Develop a flow sheet diagram of Solvay process. (Creating)
- Describe the composition of urea. (Understanding)
- Develop a flow sheet diagram for the manufacture of urea. (Creating)
- List of uses of urea. (Remembering)
- Define petroleum. (Remembering)
- Describe the formation of petroleum and natural gas. (Understanding)
- Describe he composition of petroleum. (Remembering)
- Describe briefly the fractional distillation of petroleum. (Applying)

Introduction

The Subject of chemistry (and also the others) would have no importance if it remains only in texts or in laboratories. It must be utilized in our daily life and should have a place in more than the labs and texts. This is done by the industries, which put a project to be used at home and in our daily life. For example, the researchers study a reaction, say the anti-inflammatory

Aspirin, prepared in factories in some specialized manner. These processes through which the chemical compounds are prepared in bulk in factories are discussed in the head of Industrial chemistry.

The industrial chemistry, as it seems is of great value, because all actions of science knowledge come true for a user by such operations in industries.

Following are some examples to show how the industry uses the chemical processes.

16.1 Basic Metallurgical Operations:

Metallurgy is the study of the structure and properties of metals, with special reference to their extraction from the ground. The procedures for refining, alloying, and making things from the metals.

An Ore is the raw mineral which is found in earth crust and from which some specific metal is extracted.

There is no common process available for the extraction of all the metals because different metals differ in their chemical and physical properties and also the impurities associated with them is different. So each metal requires characteristic techniques for separation and purification from its ore. However, there are certain operations or procedures common in the metallurgy of all metals. These operations or procedures are called Metallurgical Operations. The various steps involved in metallurgical operations are;

1. Crushing and Grinding of Ore (Pulverisation)

Most of the metals found in nature in the ores which are present in hard lumps. So in order to separate the metal, it has to be vulnerable for chemical procedures. The first step involved in the metallurgy is grinding and crushing of the ore into small pieces by using proper mill.

2. Concentration of Ore

The grinded ores are then concentrated by removing the major impurities present in the ore, this step is called concentration. This step is different for different types of metals which are to be purified.

3. Extraction of Metal from Oxide Ore.

In this step the ores which are usually in the form of metal oxides are extracted using specific technique for different types of metals chemically.

4. Refining of Crude Metal.

The process of purifying the crude metal is called as refining. There are various methods for the refining process which depends upon the physical as well as chemical properties of metal. For example; distillation, electrolytic refining, zone refining, vapour-phase refining and chromatography are the common methods used for the refining.

16.1.1 Metallurgy of Copper

Copper is an important element and finds many uses in our daily life. The value of electricity is well known by every one. Due to the excellent electric conduction properties and high resistive power to corrode almost every electrical instrument uses copper in some ways. Copper is also used in utensils and in alloys (e.g brass and bronze) formation.

The earth crust contains 0.007% copper, but remember that the concentration is not uniform every where. Copper is found in many mineral ores e.g chalcopyrite ($CuFeS_2$), bornite (Cu_5FeS_4), covellite (CuS), chalcocite (Cu_2S) azurite ($Cu_3(CO_3)_2(OH)_2$), malachite ($Cu_2CO_3(OH)_2$), cuprite (Cu_2O) and some others. The first step is to mine the copper from the area that contains rich copper source. The process for the separation of Cu varies for different types of ores. Generally the sulphides which are more abundant pass from the following procedure to get pure Cu.

The First step is to **Concentrate** the ore in Cu content. This is done by crushing the ore to increase the surface area of the ore for subsequent processing. The powdered ore is mixed with some chemicals and introduced to a water bath (aeration tank) containing surfactant. Air is constantly forced through the slurry and the hydrophobic copper sulfides particles catches onto and rides the air bubbles to the surface, where it forms froth and is skimmed off. These skimmings are generally re-processed to reach a high purity copper concentrate. The remainder is discarded as tailings. After concentration process CuS is obtained free from other impurities and this contains about 40% Cu. The next step is the **Extraction** of pure Cu from the concentrate. In this process the other impurities e.g the FeS are separated by treating the concentrate with SiO_2 and lime, at 1200°C.

$$2FeS_{(s)} + 3O_{2(g)} + 2SiO_{2(s)} \longrightarrow 2FeO.SiO_{2(s)} + 2SO_{2(g)}$$

The $FeO.SiO_2$ or slag is discarded, and the remainings that contain almost 70% Cu is called copper matte. Air is blown through this copper matte at high temperature. As a result of which pure copper up to 98% purity (called blister) is separated.

$$2Cu_2S_{(s)} + 3O_{2(g)} \xrightarrow{\Delta} 2Cu_2O_{(s)} + 2SO_{2(g)}$$

$$Cu_2S_{(s)} + 2Cu_2O_{(s)} \longrightarrow \underset{\text{Blister}}{6Cu_{(s)}} + SO_{2(g)}$$

For further purity, the **electro refining** of the blister is carried out. For this purpose the blister is placed into an aqueous solution of 3-4% copper sulfate and 10-16% sulphuric acid in an electrolytic cell. The Cathodes are made up of highly pure copper. A potential of only 0.2-0.4 volts is required for the process to start. At the anode, copper and less noble metals dissolve. The impurities like silver, gold, selenium and tellurium settle at the bottom of the cell as anode mud, which forms a valueable byproduct.

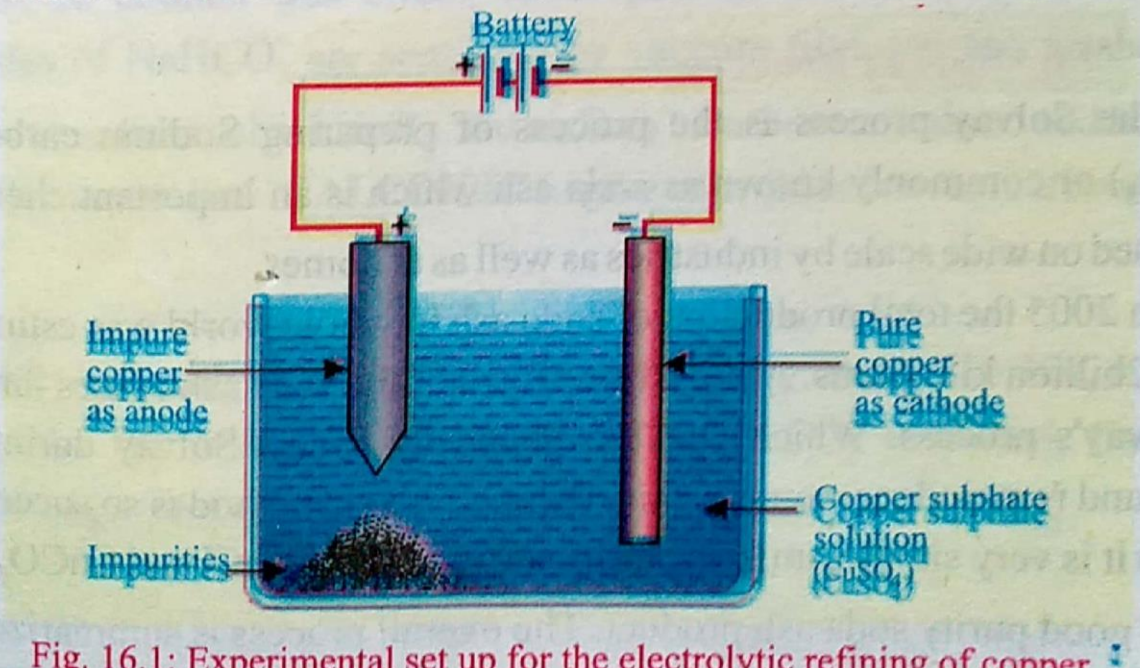


Fig. 16.1: Experimental set up for the electrolytic refining of copper

Copper ions migrate through the electrolyte to the cathode. At the cathode, copper metal plates out and can be collected easily. Some constituents such as arsenic and zinc remain in solution. The reactions are:

At the anode: $Cu_{(s)} \longrightarrow Cu^{2+}_{(aq)} + 2e^-$

At the cathode: $Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$

After electro refining, the Cu produced is 99.9% pure and can be used in any installation comfortably.

This whole process is summarized in following flow chart diagram.

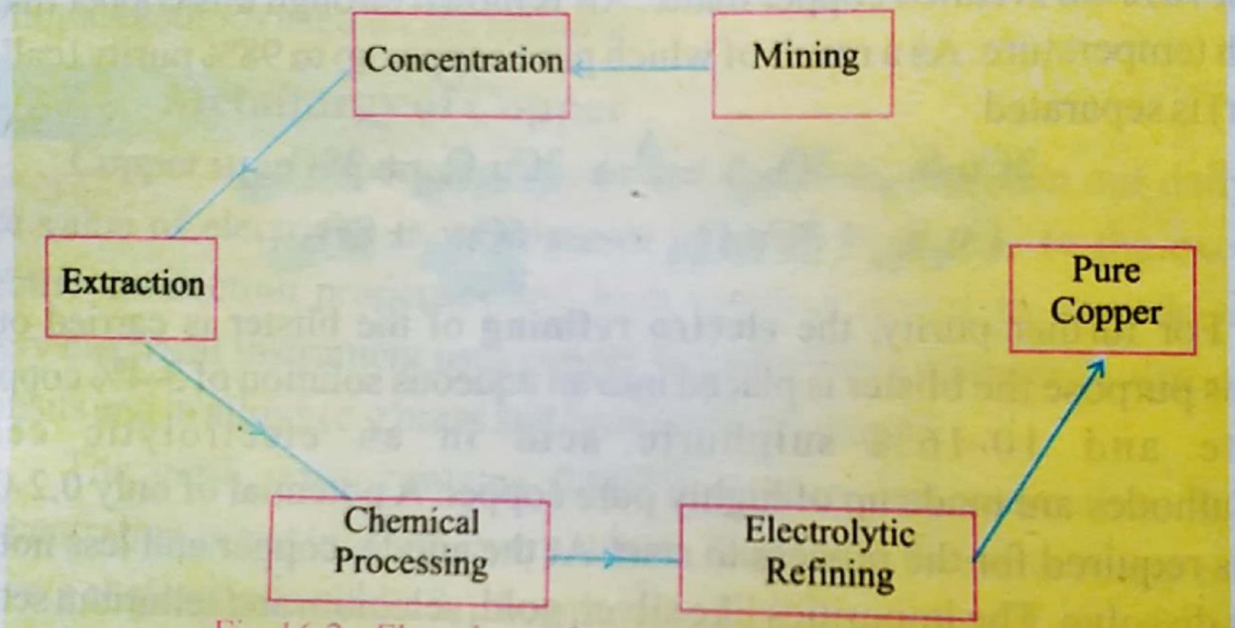


Fig-16.2: Flowchart of copper metallurgy process

16.2 The Solvay Process

The Solvay process is the process of preparing Sodium carbonate (Na_2CO_3) or commonly known as soda ash which is an important chemical and is used on wide scale by industries as well as at homes.

In 2005 the total production of soda ash in whole world was estimated about 42billion kilograms. Almost three forth of the soda ash comes through the Solvay's process. Which was developed by Ernest Solvay during the 1860's, and remainder amount is mined directly. The method is so successful because it is very simple, utilizes cheap raw materials, NaCl and $CaCO_3$, and yields a good purity soda ash product. The overall process is summarized by the reaction.

$$2\,NaCl_{(aq)} + CaCO_{3(aq)} \longrightarrow Na_2CO_{3(aq)} + CaCl_{2(aq)}$$

But in practice, the process is carried out by the following manner. In the first step, a saturated solution of NaCl (brine) is allowed to flow down an ammoniating tower. Here NH_3 gas is mixed with brine. In the second step, ammoniated brine is allowed to trickle down a carbonating tower known as solvay tower. Here brine is mixed with carbon dioxide gas, which is produced by heating lime stone in a separate chamber called "kiln".

$$CaCO_{3(s)} \longrightarrow CaO_{(s)} + CO_{2(g)}$$

In the Solvay tower, the CO_2 reacts with ammonia to form ammonium carbonate.

$$2NH_{3(g)} + CO_{2(g)} + H_2O_{(l)} \longrightarrow (NH_4)HCO_3$$

Ammonium carbonate further reacts with CO_2 to form ammonium bicarbonate.

$$(NH_4)_2CO_{3(aq)} + CO_{2(g)} + H_2O_{(l)} \longrightarrow 2NH_4HCO_{3(aq)}$$

Ammonium bicarbonate then react with NaCl to form sodium bicarbonate.

$$NH_4HCO_{3(aq)} + NaCl_{(aq)} \longrightarrow NaHCO_{3(aq)} + NH_4Cl_{(aq)}$$

Due to exothermic nature of above reactions, solubility of $NaHCO_3$ increases. To counter this effect, lower part of solvay tower is cooled; precipitates of $NaHCO_3$ are separated by vacuum filtration and washed to remove ammonium salts. Finally, the sodium bicarbonate is dried and heated in rotary furnace called "CALCINER" to give anhydrous sodium carbonate or soda ash.

$$2NaHCO_{3(aq)} \xrightarrow{\Delta} Na_2CO_{3(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Carbon dioxide is re circulated to carbonating tower. The NH_3 is also recovered by the following procedure. When $CaCO_3$ is heated, CaO is obtained along with CO_2. CaO is treated with water to form $Ca(OH)_2$.

$$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)}$$

$Ca(OH)_2$ is heated with NH_4Cl to form NH_3 and calcium chloride.

$$2NH_4Cl_{(aq)} + Ca(OH)_{2(aq)} \longrightarrow CaCl_{2(aq)} + 2NH_{3(g)} + 2H_2O_{(l)}$$

The overall procedure is summarized in following schematic diagram in figure-16.3.

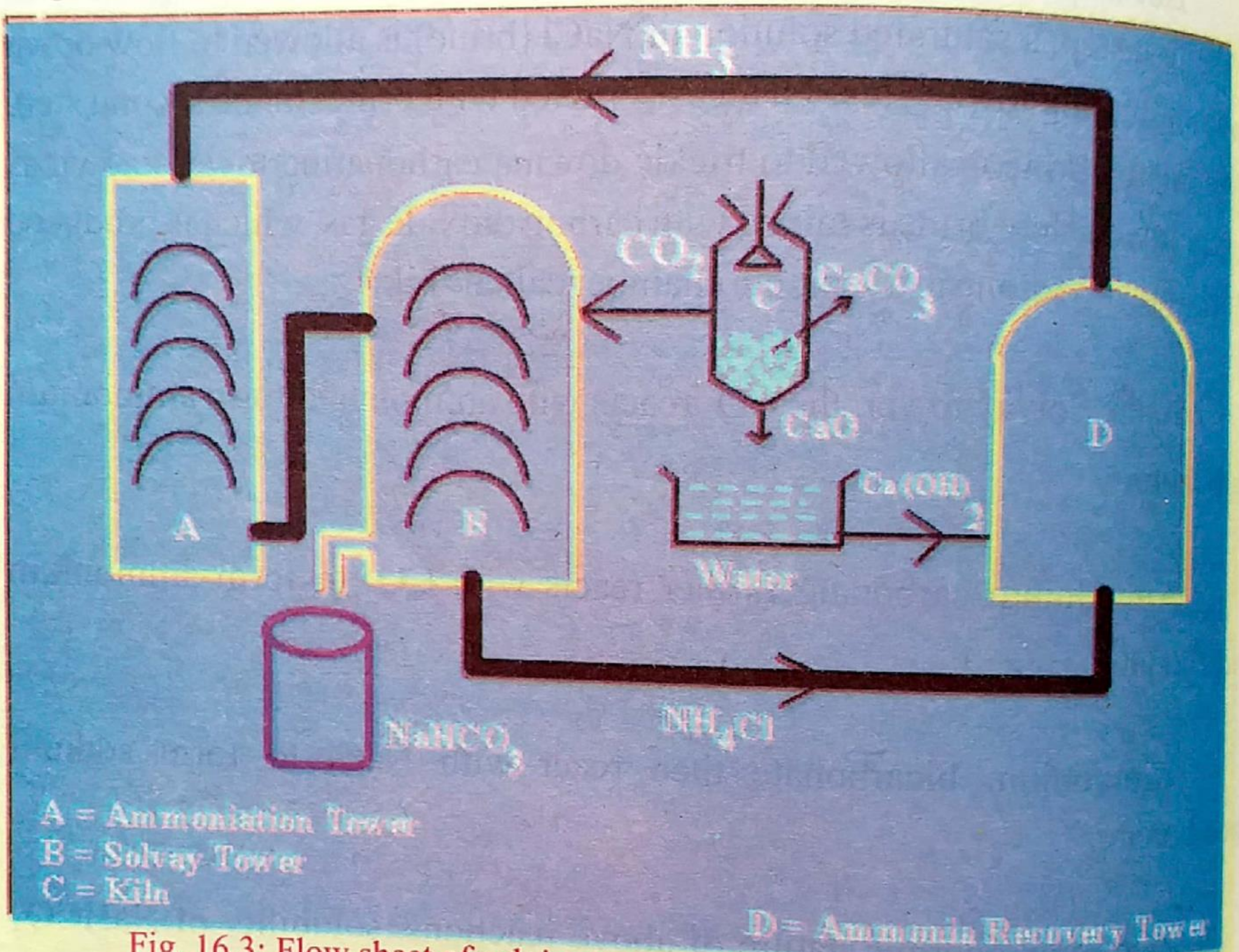


Fig. 16.3: Flow sheet of solving process for preparation of soda ash.

16.3 Urea

Urea or Carbamide is a well known fertilizer and is widely used throughout the world and as well in Pakistan. It has the molecular formula $CO(NH_2)_2$. It is regarded as the first organic compound to be synthesized in 1828 by Wohler. But its importance is due to the use as fertilizer for the nitrogen source for the plant, moreover due to its slight basic nature it also reduces the acidity of the soil produced by the decaying action of organic matter.

On commercial scale urea is prepared using CO_2 and NH_3. Which react to give urea.

$$2NH_{3(g)} + CO_{2(g)} \longrightarrow CO(NH_2)_{2(s)} + H_2O_{(l)}$$

The procedure in an industry is carried out through a series of steps. These steps are discussed here in the following.

First of all CO_2 and H_2 are prepared by the action of steam and natural gas over Ni catalyst.

$$CH_{4(g)} + 2H_2O_{(g)} \xrightarrow[heat]{Ni} CO_{2(g)} + 4H_{2(g)}$$

The H_2 produced is treated with N_2 at 500°C over Fe_2O_3 to obtain the NH_3.

$$N_{2(g)} + 3H_{2(g)} \xrightarrow{Fe_2O_3} 2NH_{3(g)}$$

Both CO_2 and NH_3 are combined to get the ammonium carbamate.

$$2NH_{3(g)} + CO_{2(g)} \longrightarrow NH_2COONH_{4(s)}$$

The ammonium carbamate is dehydrated by heating to obtain the Urea.

$$NH_2COONH_{4(s)} + heat \longrightarrow CO(NH_2)_{2(s)} + H_2O_{(l)}$$

The water present here along with the urea is evaporated by heat. The molten urea obtained by heating is sprayed in a cooled tower. Hence, the urea drops solidify as small prills, which are then filled in bags and send to market.

The whole operation is described by the following flow sheet diagram in figure-16.4.

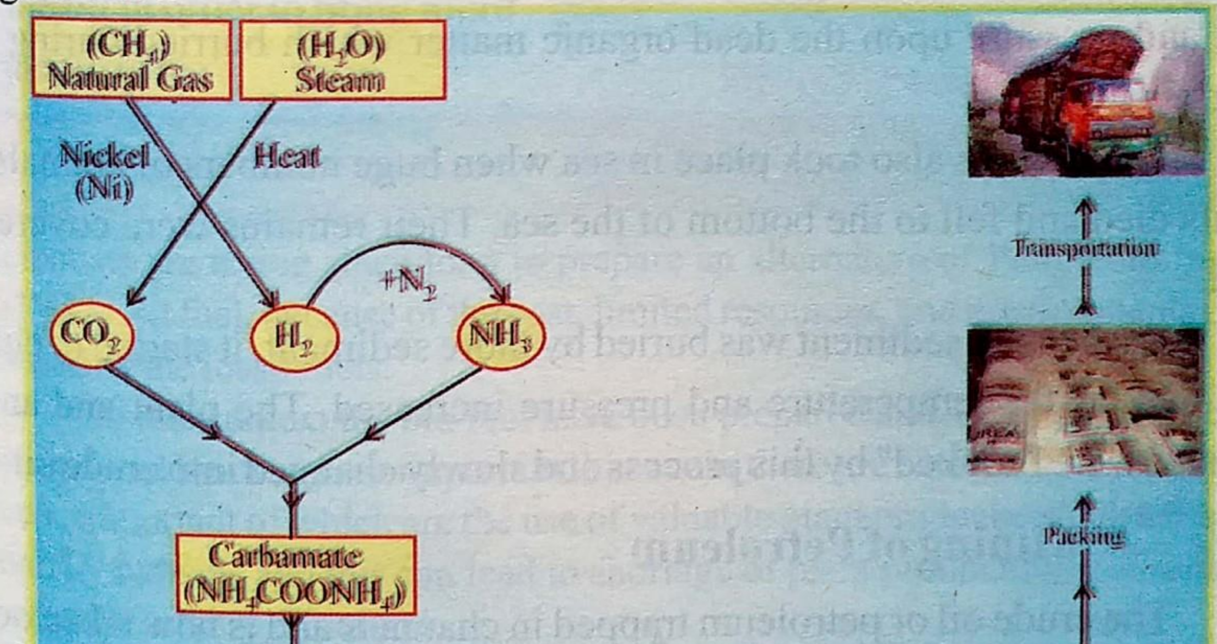


Fig. 16.4: Flow chart of Industrial preparation of Urea

16.4 Petroleum Industry

The word petroleum has been originated from two Greek words, i.e: "Petra" which means "Rock" and "Oleum" meaning "Oil".

Petroleum is a blackish or sometimes brownish black, viscous liquid found under the earth, from where it is drilled out. The Petroleum is a complex mixture of thousands of organic compounds. For different uses these compounds are separated in fractions at oil refineries. The petroleum is very important and vital for today's world, as it fulfills almost all energy requirements of the human beings today directly, moreover there are many industries that depend upon the petroleum industry directly for their raw material, e.g the plastic industry is all based upon the material which is obtained through petroleum. You can imagine the types and quantity of plastic products around yourself.

16.4.1 Origin of Petroleum

The Petroleum is believed to be originated by the action of Bacteria, heat and pressure upon the dead organic matter which burried during time course.

The process also took place in sea when huge numbers of animals and plants died and fell to the bottom of the sea. Their remains were covered by mud.

As the mud sediment was buried by more sediment, it started to change into rock as the temperature and pressure increased. The plant and animal remains were "cooked" by this process and slowly changed into crude oil.

16.4.2 Mining of Petroleum

The crude oil or petroleum trapped in channels and is now taken out by tubes same as the trapped water in a tube well. But unlike water the petroleum is not so abundant, and is found in some special areas at more depths than water. The most common method of obtaining petroleum is extracting it from oil wells found in oil fields. After the well has been located, various methods are used to recover the petroleum. Primary recovery methods are used to extract oil that is brought to the surface by underground pressure. This generally recovers about 20% of the oil present. After the oil pressure has depleted to the point that the oil is no longer brought to the surface, secondary recovery methods draw another 5 to 10% of the oil in the well to the surface. Finally, when secondary oil recovery methods are no longer viable, tertiary recovery methods reduce the viscosity of the oil in order to bring more to the surface.

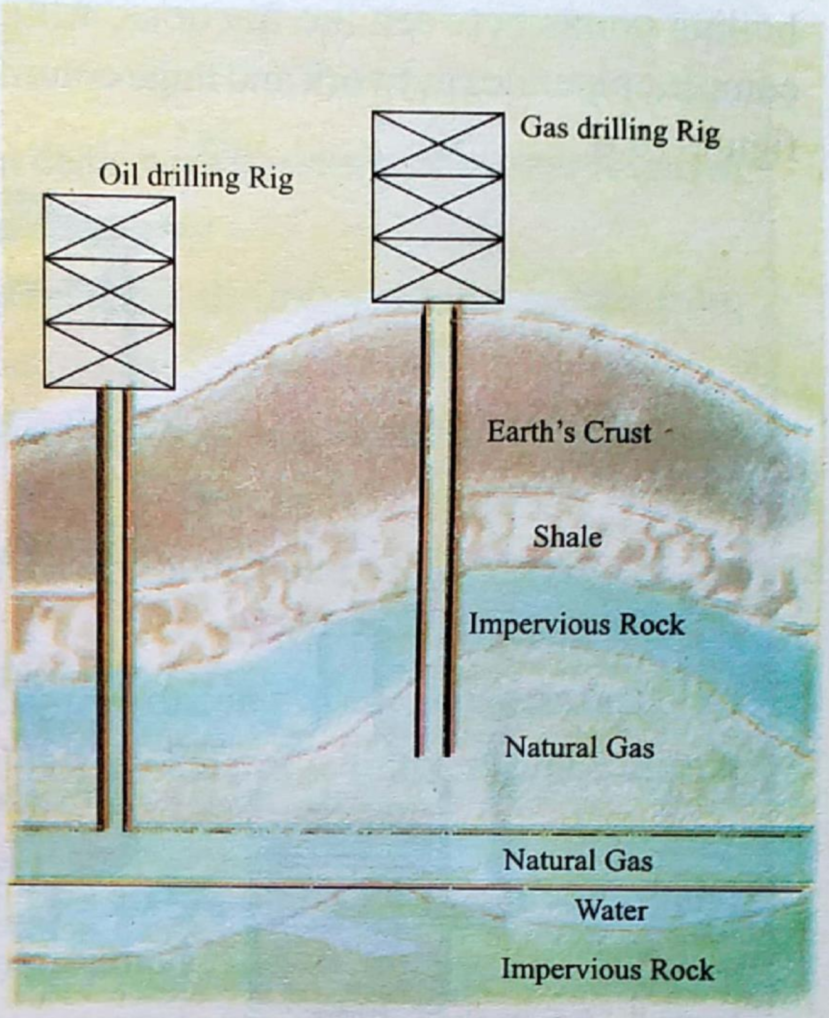


Fig. 16.5: Petroleum Mining

Interesting Information

Scientists are trying since long to prepare an alternative of Petroleum fuel also called fossil fuel, because of the cost, limited resources, and environmental issues caused by the fossil fuels.

In this context the bio fuel have been prepared and are in use, of these the ethanol and biodiesel are important, but again there are reservations for these bio fuels, important of which are the use of valuable plant products which are used as food by humans and this can lead to shortage of plant product food of which the vegetable oils are important.

16.4.3 Important fractions of Petroleum

After the crude oil is extracted in an oil field. It is brought in an oil refinery in order to separate different fractions which can be used in different ways. The refinery process utilizes the **distillation technique** which separates the different fractions of the crude oil due to the difference of boiling points between the fractions. Although, an oil refinery consists of a complex pipelines network and huge columns, but simply it is described in the figure-16.6.

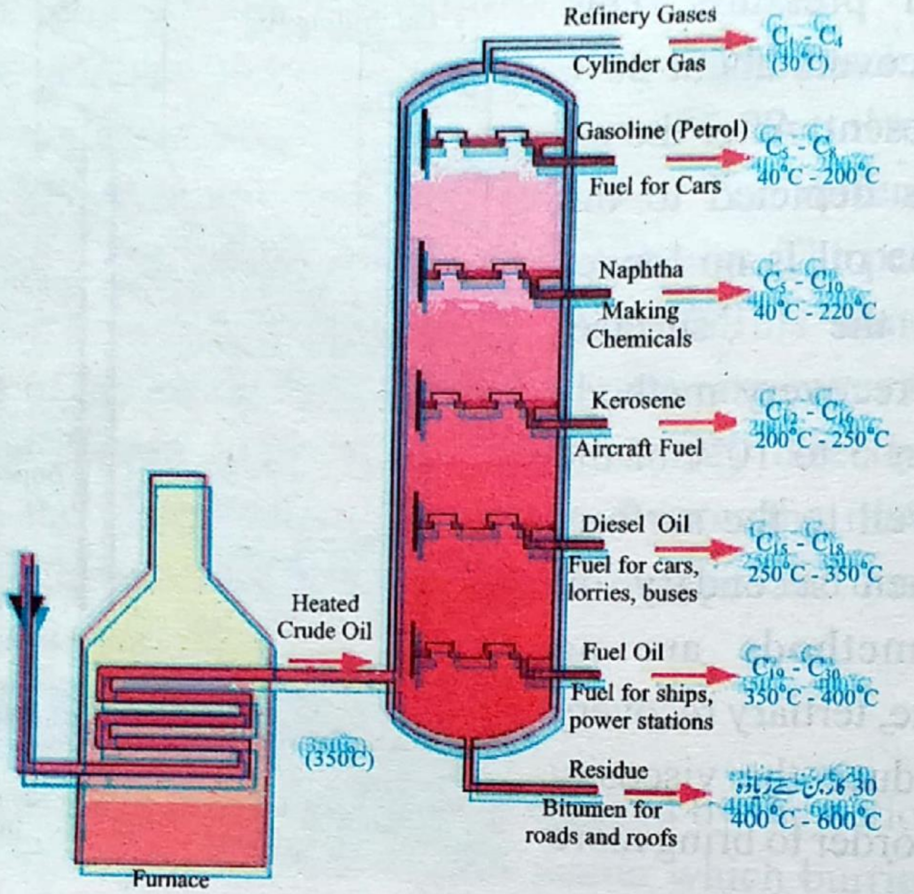


Fig. 16.6: Fractions obtained by refining of petroleum and their uses

Notice that the different fractions collected are used in different types of engines. Actually these fractions differ in the number of carbon atoms per molecule, as the number of carbon atoms in a molecule increase, the boiling point and density both increase and even the fractions that contain more than 40 atoms may be solid or semi solids.

Interesting Information

The quality and rating of petroleum fuels are measured by a number called **"Octane number"**. Higher the octane number higher will be the performance of the fuel. The standard octane number is the "100", but in Pakistan the petrol pumps sell the gasoline of "80" octane number. The octane number of fuel is increased by adding TEL (tetra ethyl lead), but this also causes environmental problems. Another substance that is used to increase octane number is BTX, which is actually a mixture of three compounds, the Benzene, Toluene and xylene. The BTX is also environmental pollutant increasing substance but relatively less than the TEL.

Summary of the Chapter

- The branch of chemistry that deals with the study of matter found in industries is called Industrial chemistry.
- The branch of science that deals with the extraction of metals from its ores is called chemical metallurgy.
- Mineral is a natural inorganic chemical compound which is found in earth crust.
- An ore is the substance that is unrefined, impure source of metal and is obtained by mining process.
- The general metallurgy involves crushing of ore, concentration of ore, extraction of metal from its oxides or sulphides, and refining processes.
- Sodium carbonate (soda ash) is an important chemical compound and is prepared using solvay's method.
- The important fertilizer urea is prepared by using the natural gas and steam as starting raw materials.
- Petroleum is the back bone of economy of any country. The use of petroleum also determines the prosperity of a country.
- Petroleum is mined from earth and is purified in oil refineries.
- The fractions of petroleum are separated using the fact that different chemical compounds have different boiling points. This technique is called fractional distillation.

Exercise

Q1: Fill in the blanks with suitable words.

i) Metallurgy deals with .... of pure metals from its ores.

ii) Solvay process is used for the preparation of ....

iii) Wohler prepared .... in 1828.

iv) Petroleum is believed to be prepared by the action of bacteria upon ....

v) Petroleum is found in the earth in more .... than the water.

vi) Quality of petroleum fuel is determined using a number called..........

vii) Chemical formula of Soda ash is ....

viii) Ammonium carbamate is the hydrated form of...........

ix) The first step in metallurgy of a metal is the..........of metal ore.

x) Petra is a Greek word meaning.............

Q2: Choose the correct answer.

i) The soda ash is prepared commercially by using:

(a) $NaNO_3$ and KCO_3 (b) $NaNO_3$ and NH_3

(c) NaCl and $MgCO_3$ (d) NaCl and $CaCO_3$

ii) The first step in metallurgical operations is to:

(a) Concentrate the ore

(b) Crushing the ore

(c) Extraction of metal from ore

(d) Refining the ore

iii) Commercially urea is prepared by:

(a) Carbamide (b) Ammonia and carbon dioxide

(c) Cyanogens (d) All of these

iv) Petroleum is refined by the technique of:

(a) Distillation (b) Crystallization

(c) Condensation (d) All of above

v) As the number of carbon atoms increase in petroleum fractions, it also increases the:

(a) Boiling point (b) Density

(c) Both of these (d) None of these

vi) Solvay process is used to prepare:

(a) Urea (b) Soda Ash

(c) Gasoline (d) Iron

vii) Methane gas is used in preparation of:

(a) Urea (b) Ammonia gas

(c) Petrol (d) Copper ore

viii) LPG contains the mixture of :

(a) Methane and pentane (b) Methane and ethane

(c) Ethane and Pentane (d) Propane and butane

ix) The Major fraction in the CNG is:

(a) Methane (b) Ethane

(c) Propane (d) Butane

x) Octane number is used to measure:

(a) Number of 'C' atoms in a molecule of a fuel

(b) Number of 'H' atoms in the fuel molecules

(c) Efficiency of fuel

(d) Percentage of Methane in any fuel

Q3: Explain with reasoning.

i) Why the Petroleum fuels are called Fossil fuels?

ii) Diesel provides more energy per mole than petrol.

iii) Extraction of metals from their ore is different for different metals.

iv) Why Soda ash is essential to prepare on large scale?

v) Urea is more used in Pakistan rather than ammonia fertilizer.

Q4: How the industries help in the progress of mankind?

Q5: Write a brief note on the metallurgical operations? How the copper can be extracted from the earth?

Q6: Discuss the importance of soda ash. Also explain the solvay process for its preparation.

Q7: Why the fertilizers are needed for more production of crops? Explain the preparation method for the urea.

Q8: How the petroleum originated in the earth crust? What are the different fractions obtained from the petroleum, and also describe the utilization of these fractions.

Glossary

acetylene A colourless, highly flammable gas that is explosive when compressed; the simplest compound containing a triple bond; Also known as ethyne. Its formula is C_2H_2.

acid **1.** Any of a class of chemical compounds whose aqueous solutions turn blue litmus paper red, react with and dissolve certain metals to form salts, and react with bases forming salts. **2.** A compound capable of transferring a hydrogen ion in solution. **3.** A molecule or ion that combines with another molecule or ion by forming a covalent bond with two electrons from the other species.

adsorption The surface retention of solid, liquid, or gas molecules, atoms, or ions by a solid or liquid.

aerosol A suspension of small particles in a gas; the particles may be solid or liquid or a mixture of both; aerosols are formed by the conversion of gases to particles, the disintegration of liquids or solids, or the suspension of powdered material.

air The mixture of a variety of individual gases formingthe earth's enveloping atmosphere.

alcohol Any member of a class of organic compounds in which a hydrogen atom of a hydrocarbon has been replaced by a hydroxy (OH) group.

aldehyde One of a class of organic compounds containing the CHO radical.

aldohexose A hexose, such as glucose or mannose, containing the aldehyde group.

alicyclic A cyclic hydrocarbon which is non aromatic

aliphatic organic compound characterized by a straight chain of the carbon atoms;

alkali Any compound having highly basic qualities.

Alkaline earth metals The members of group 2 in the periodic table; (calcium, strontium, magnesium, and barium.)

alkane A member of a series of saturated aliphatic hydrocarbons having the empirical formula C_nH_{2n+2}. Also known as paraffin; paraffinic hydrocarbon.

alkene One of a class of unsaturated aliphatic hydrocarbons containing one or more carbon-to-carbon double bonds.

alkyl An organic group that results from removal of a hydrogen atom from alkane ; It is represented by symbol 'R'.

alkyl halide A compound consisting of an alkyl group and a halogen;

alkyne One of a group of organic compounds containing a carbon to carbon triple bond.

amide One of a class of organic compounds containing the $CONH_2$ radical.

amine One of a class of organic compounds which can be considered to be derived from ammonia by replacement of one or more hydrogen.

amino-, amin- Having the property of a compound in which the group NH_2 is attached to a radical other than an acid radical.

amphoteric Having both acidic and basic characteristics.

anion An ion that is negatively charged.

anti on the opposite side of a reference plane;

antifreeze A substance added to a liquid to lower its freezing point; the principal automotive antifreeze component is ethylene glycol.

antioxidant A substance that, when present at a lower concentration than that of the oxidizable substrate, significantly inhibits or delays oxidative processes.

aqua Latin for water.

aqua regia A fuming, highly corrosive, volatile liquid with a suffocating odour made by mixing 1 part concentrated nitric acid and 3 parts concentrated hydrochloric acid; It reacts with all metals, including silver and gold.

aromatic A compound characterized by the presence of at least one benzene ring.

atom The basic unit of any chemical element which enters into chemical reactions.

base A substance having the property of turning litmus from red to blue, it donates OH^-, electron pair and accepts H^+ ion during chemical reactions.

biochemistry The study of chemical substances occurring in living organisms.

bond The strong attractive force that holds together atoms or ions in molecules and crystalline salts.

Bronsted acid A chemical species which can act as a source of protons. Also known as proton acid; protonic acid.

Bronsted-Lowry theory A theory that all acid-base reactions consist simply of the transfer of a proton from one base to another. Also known as Bronsted theory.

catalyst Substance that speeds up the velocity of a chemical reaction but is not consumed in the reaction.

cation A positively charged atom or group of atoms

caustic soda The sodium hydroxide.

chemical equilibrium A condition in which a chemical reaction is occurring at equal rates in its forward and reverse directions, so that the concentrations of the reacting substances do not change with time.

chemical kinetics The branch of physical chemistry concerned with the mechanisms and rates of chemical reactions.

chemical reaction A change in which a substance (or substances) is changed into one or more new substances;

concentration In solutions, the mass, volume, or number of moles of solute present in proportion to the amount of solvent or total solution.

condensation Transformation from a gas to a liquid.

covalent bond A bond in which each atom of a bound pair contributes one electron to form a pair of electrons.

cyclic compound A compound that contains a ring of atoms.

dehydration Removal of water from any substance.

derivative A substance that is made from another substance or it is the product formed from parent compound.

dilute To make less concentrated

distillation The process of producing a gas or vapour from a liquid by heating the liquid in a vessel and collecting and condensing the vapours back into liquids.

distilled water Water that has been freed of dissolved or suspended solids and organisms by distillation.

double bond A type of linkage between atoms in which two pair of electrons are shared equally.

double salt 1. A salt that upon hydrolysis forms two different anions and cations. 2. A salt that is a molecular combination of two other salts.

dry ice Carbon dioxide in the solid form,

empirical formula A chemical formula that indicates the composition of a compound in terms of the relative numbers and kinds of atoms in the simplest ratio.

fractional distillation A method to separate a mixture of several volatile components of different boiling points; the mixture is distilled at the lowest boiling point, and the distillate is collected as one fraction until the temperature of the vapour rises, showing that the next higher boiling component of the mixture is beginning to distill; this component is then collected as a separate fraction.

free radical An atom or a diatomic or polyatomic molecule which possesses one unpaired electron. Also known as radical.

freezing point The temperature at which a liquid and a solid may be in equilibrium.

green chemistry The use of chemical products and processes that reduce or eliminate substances hazardous to human health or the environment.

halogen 1. A family of elements (in the periodic table) of Group-18. 2. Any of the elements of the halogen family (Group-17), consisting of fluorine, chlorine, bromine, iodine, and astatine.

halogenation A chemical process or reaction in which a halogen element is introduced into a substance, generally by the use of the element itself.

hard water Water that contains certain salts, such as phosphates or sulphates of calcium or magnesium, which form insoluble deposits in boilers and form precipitates with soap.

heat of combustion The amount of heat released in the oxidation of 1 mole of a substance at constant pressure, or constant volume.

heat of decomposition The change in enthalpy accompanying the decomposition of 1 mole of a compound into its elements at constant pressure.

heat of dissociation The change in enthalpy at constant pressure, when molecules break apart.

heat of formation The increase in enthalpy resulting from the formation of 1 mole of a substance from its elements at constant pressure.

heat of hydration The increase in enthalpy accompanying the formation of 1 mole of a hydrate from the anhydrous form of the compound and from water at constant pressure.

heat of reaction Change in enthalpy accompanying a chemical reaction at constant pressure.

heavy water A compound of hydrogen and oxygen containing a higher proportion of the hydrogen isotope. Also known as deuterium oxide.

hydrate A form of a solid compound which has water in the form of H_2O molecules associated with it; for example, hydrated copper sulfate having formula $CuSO_4.5H_2O$.

hydration The incorporation of molecular water into a complex molecule with the molecules or units of another species; the complex may be held together by relatively weak forces or may exist as a definite compound.

hydrocarbon One of a very large group of chemical compounds composed only of carbon and hydrogen; the largest source of hydrocarbons is from petroleum crude oil.

hydrogen bond A type of intermolecular force where a linkage is formed between 'H' and strongly electronegative element like 'O' or 'F'.

hydrolysis Decomposition or alteration of a chemical substance by water.

hydronium ion H_3O^+ An oxonium ion consisting of a proton combined with a molecule of water; found in pure water and in all aqueous solutions.

Hydrosphere The water layer of the earth surface is called hydrosphere e.g. ocean.

Amino acid Organic acid in which the NH_2 group is attached to carbon; for example, NH_2CH_2COOH.

ion An isolated electron or positron or an atom or molecule which by loss or gain of one or more electrons has acquired a net electric charge.

ionization A process by which a neutral atom or molecule loses or gains electrons, thereby acquiring a net charge and becoming an ion; occurs as the result of the dissociation of the atoms of a molecule in solution ($NaCl \longrightarrow Na^+ + Cl$)

iso- A prefix indicating a single branching at the end of the carbon chain.

isomer One of two or more chemical substances having the same elementary percentage composition and molecular weight but differing in structure, and therefore in properties; there are many ways in which such structural differences occur; for example *n*-butane, $CH_3(CH_2)_2CH_3$, and isobutane, $CH_3CH(CH_3)_2$ are the isomers of butane (C_4H_{10}).

isomerism The phenomenon whereby certain chemical compounds have structures that are different although the compounds possess the same elemental composition.

IUPAC Abbreviation for International Union of Pure and Applied Chemistry.

ketone One of a class of chemical compounds of the general formula RCOR', where R and R' are alkyl or aryl radicals; the groups R and R' may be the same or different.

law of mass action The law stating that the rate at which a chemical reaction proceeds is directly proportional to the molecular concentrations of the reacting compounds.

Lewis acid A substance that can accept an electron pair from a base; e.g. $AlCl_3$, BF_3 and SO_3 are Lewis acids.

Lewis base A substance that can donate an electron pair; examples are the hydroxide ion, OH, and ammonia, NH_3.

Lewis structure A structural formula in which electrons are represented by dots; two dots between atoms represent a covalent bond. Also known as electron- dot formula; Lewis formula.

ligand The molecule, ion, or group bound to the central atom in a chelate or a coordination compound; an example is the NH_3 in $[Co(NH_3)_6]^{3+}$.

line-formula method A system of notation for hydrocarbons showing the chemical elements, functional groups, and ring systems in linear form; an example is acetone, CH_3COCH_3.

lipophilic **1.** Having a strong affinity for fats. **2.** Promoting the solubilization of lipids

lipophobic Lacking an affinity for, repelling, or failing to absorb or adsorb fats.

macromolecule A large molecule in which there is a large number of one or several relatively simple structural units, each consisting of several atoms bonded together.

methyl red $(Ch_3)_2NC_6H_4NNC_6H_4COOH$. A dark red powder or violet crystals; soluble in alcohol, ether, and glacial acetic acid; used as an acid-base indicator.

molality Concentration given as moles per 1000 grams of solvent.

monomer A molecule which is capable of combining with like or unlike molecules to form a polymer; it is a repeating structure unit within a polymer.

neutralization The process of making a solution neutral (pH 7) by adding a base to an acid solution, or adding an acid to an alkaline (basic) solution. Also known as neutralization reaction.

orbital overlap The overlapping of two electron orbitals, one from each of two different atoms, such that each orbital obtains a share in the electron of the other atom, forming a chemical bond.

organic Of chemical compounds, based on carbon chains or rings and also containing hydrogen with or without oxygen, nitrogen, or other elements.

organic chemistry The study of the structure, preparation, properties, and reactions of carbon compounds, or the ***hydrocarbons*** and their derivatives.

organic salt The reaction product of an organic acid and an inorganic base, for example, sodium acetate (CH_3COONa) from the reaction of acetic acid (CH_3COOH) and sodium hydroxide (NaOH).

phase Portion of a physical system (liquid, gas, solid) that is homogeneous throughout, has definable boundaries, and can be separated physically from other phases.

pH A term used to describe the hydrogen-ion activity of a system;

precipitate A substance separating, in solid particles, from a liquid as the result of a chemical or physical change;

rate of reaction A measurement based on the mass of reactant consumed in a chemical reaction during a given period of time.

reactivity The relative capacity of an atom, molecule, or radical to combine chemically with another atom, molecule, or radical

Single bond: a covalent bond in which one pair of electrons is shared between two atoms.

Solubility: the amount of solute that dissolves in a given quantity of solvent (normally 100ml) at a specific temperature.

Standard pressure: A pressure of 1 atmosphere which is equal to 760mmHg.

Standard temperature: A temperature of 0.0 °C, or 273.16 K.

S.T.P. S.T.P. is the abbreviation of standard temperature pressure.(273.16 K and a pressure of 1 atmosphere).

Structural formula: A formula which defines the bonding and arrangement of the atoms present in a compound.

Temperature: The temperature of a sample of matter is a measure of the average *kinetic energy* of the molecules in that sample.

Unsaturated compound: A compound in which double or triple bonds are present.

Valence electrons: Electrons in the outer electronic shell of an atom, and which are involved in chemical reactions.

Vapour pressure: The pressure exerted by a vapour. At the boiling point, the vapour pressure of a liquid is equal to the pressure exerted on the liquid by the atmosphere.

Water of crystallization: Water molecules which form an integral part of the lattice of ionic crystals. The water of crystallization is normally included in the formula for the substance, i.e., $CuSO_4.5H_2O$.

Index

TABLE OF ELEMENTS

Element	Symbol	At.No	At.mass	Element	Symbol	At.No	At.mass
Hydrogen	H	1	1.0079	Selenium	Se	34	78.96
Helium	He	2	4.0026	Bromine	Br	35	79.904
Lithium	Li	3	6.941	Krypton	Kr	36	83.798
Beryllium	Be	4	9.0122	Rubidium	Rb	37	85.4678
Boron	B	5	10.811	Strontium	Sr	38	87.62
Carbon	C	6	12.01	Yttrium	Y	39	88.9058
Nitrogen	N	7	14.0067	Zirconium	Zr	40	91.224
Oxygen	O	8	15.9994	Niobium	Nb	41	92.906
Fluorine	Fr	9	18.9984	Molybdenum	Mo	42	95.94
Neon	Ne	10	20.1797	Technetium	Tc	43	98.9063
Sodium	Na	11	22.9898	Ruthenium	Ru	44	101.07
Magnesium	Mg	12	24.305	Rhodium	Rh	45	102.9055
Aluminium	Al	13	26.9815	Palladium	Pd	46	106.42
Silicon	Si	14	28.0855	Silver	Ag	47	107.8682
Phosphorus	P	15	30.9738	Cadmium	Cd	48	112.411
Sulphur	S	16	32.065	Indium	In	49	114.818
Chlorine	Cl	17	35.453	Tin	Sn	50	118.71
Argon	Ar	18	39.948	Antimony	Sb	51	121.76
Potassium	K	19	39.0983	Tellurium	Te	52	127.6
Calcium	Ca	20	40.078	Iodine	In	53	126.9045
Scandium	Sc	21	44.9559	Xenon	Xe	54	131.293
Titanium	Ti	22	47.867	Caesium	Cs	55	132.9054
Vanadium	V	23	50.9415	Barium	Ba	56	137.327
Chromium	Cr	24	51.9961	Lanthanum	La	57	138.9055
Manganese	Mn	25	54.938	Cerium	Ce	58	140.116
Iron	Fe	26	55.845	Praseodymium	Pr	59	140.9076
Cobalt	Co	27	58.933	Neodymium	Nd	60	144.242
Nickel	Ni	28	58.6934	Promethium	Pm	61	146.9151
Copper	Cu	29	63.546	Samarium	Sm	62	150.36
Zinc	Zn	30	65.409	Europium	Eu	63	151.964
Gallium	Ga	31	69.723	Gadolinium	Gd	64	157.25
Germanium	Ge	32	72.64	Terbium	Tb	65	158.925
Arsenic	As	33	74.9216	Dysprosium	Dy	66	162.5

Element	Symbol	At.No	At.mass
Holmium	Ho	67	164.93
Erbium	Er	68	167.259
Thulium	Tm	69	168.93
Ytterbium	Yb	70	173.04
Lutetium	Lu	71	174.967
Hafnium	Hf	72	178.49
Tantalum	Ta	73	180.9479
Tungsten	W	74	183.84
Rhenium	Re	75	186.207
Osmium	Os	76	190.23
Iridium	Ir	77	192.217
Platinum	Pt	78	195.084
Gold	Au	79	196.9665
Mercury	Hg	80	200.59
Thallium	Tl	81	204.283
Lead	Pb	82	207.2
Bismuth	Bi	83	208.98
Polonium	Po	84	208.98
Astatine	At	85	209.98
Radon	Rn	86	222.176
Francium	Fr	87	223.0197
Radium	Ra	88	226.0254
Actinium	Ac	89	227.278
Thorium	Th	90	232.0381
Protactinium	Pa	91	231.0359
Uranium	U	92	238.0289

Element	Symbol	At.No	At.mass
Neptunium	Np	93	237.0482
Plutonium	Pu	94	244.0642
Americium	Am	95	243.0614
Curium	Cm	96	247.0703
Berkelium	Bk	97	247.0703
Californium	Cf	98	251.0796
Einsteinium	Es	99	252.0829
Fermium	Fm	100	257.0951
Mendelevium	Md	101	258.0986
Nobelium	No	102	259.1009
Lawrencium	Lr	103	260.1053
Rutherfordium	Rf	104	261.1087
Dubnium	Db	105	262.1138
Seaborgium	Sg	106	263.1182
Bohrium	Bh	107	262.1229
Hassium	Hs	108	265
Meitnerium	Mt	109	266
Darmstadtium	Ds	110	269
Roentgenium	Rg	111	272
Copernicium	Cn	112	285
Ununtrium	Uut	113	284
Ununquadium	Uuq	114	289
Ununpentium	Uup	115	288
Ununhexium	Uuh	116	292
Ununseptium	Uus	117	unknown
Ununoctium	Uuo	118	294

IUPAC Periodic Table of the Elements

Key:

atomic number
Symbol
name
standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** hydrogen [1.007, 1.009]																	2 **He** helium 4.003
3 **Li** lithium [6.938, 6.997]	4 **Be** beryllium 9.012											5 **B** boron [10.80, 10.83]	6 **C** carbon [12.00, 12.02]	7 **N** nitrogen [14.00, 14.01]	8 **O** oxygen [15.99, 16.00]	9 **F** fluorine 19.00	10 **Ne** neon 20.18
11 **Na** sodium 22.99	12 **Mg** magnesium [24.30, 24.31]											13 **Al** aluminium 26.98	14 **Si** silicon [28.08, 28.09]	15 **P** phosphorus 30.97	16 **S** sulfur [32.05, 32.08]	17 **Cl** chlorine [35.44, 35.46]	18 **Ar** argon 39.95
19 **K** potassium 39.10	20 **Ca** calcium 40.08	21 **Sc** scandium 44.96	22 **Ti** titanium 47.87	23 **V** vanadium 50.94	24 **Cr** chromium 52.00	25 **Mn** manganese 54.94	26 **Fe** iron 55.85	27 **Co** cobalt 58.93	28 **Ni** nickel 58.69	29 **Cu** copper 63.55	30 **Zn** zinc 65.38(2)	31 **Ga** gallium 69.72	32 **Ge** germanium 72.63	33 **As** arsenic 74.92	34 **Se** selenium 78.96(3)	35 **Br** bromine [79.90, 79.91]	36 **Kr** krypton 83.80
37 **Rb** rubidium 85.47	38 **Sr** strontium 87.62	39 **Y** yttrium 88.91	40 **Zr** zirconium 91.22	41 **Nb** niobium 92.91	42 **Mo** molybdenum 95.96(2)	43 **Tc** technetium	44 **Ru** ruthenium 101.1	45 **Rh** rhodium 102.9	46 **Pd** palladium 106.4	47 **Ag** silver 107.9	48 **Cd** cadmium 112.4	49 **In** indium 114.8	50 **Sn** tin 118.7	51 **Sb** antimony 121.8	52 **Te** tellurium 127.6	53 **I** iodine 126.9	54 **Xe** xenon 131.3
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57-71 lanthanoids	72 **Hf** hafnium 178.5	73 **Ta** tantalum 180.9	74 **W** tungsten 183.8	75 **Re** rhenium 186.2	76 **Os** osmium 190.2	77 **Ir** iridium 192.2	78 **Pt** platinum 195.1	79 **Au** gold 197.0	80 **Hg** mercury 200.6	81 **Tl** thallium [204.3, 204.4]	82 **Pb** lead 207.2	83 **Bi** bismuth 209.0	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89-103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium		114 **Fl** flerovium		116 **Lv** livermorium		

57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	59 **Pr** praseodymium 140.9	60 **Nd** neodymium 144.2	61 **Pm** promethium	62 **Sm** samarium 150.4	63 **Eu** europium 152.0	64 **Gd** gadolinium 157.3	65 **Tb** terbium 158.9	66 **Dy** dysprosium 162.5	67 **Ho** holmium 164.9	68 **Er** erbium 167.3	69 **Tm** thulium 168.9	70 **Yb** ytterbium 173.1	71 **Lu** lutetium 175.0
89 **Ac** actinium	90 **Th** thorium 232.0	91 **Pa** protactinium 231.0	92 **U** uranium 238.0	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium

Chapter No.9

Activity: 9.1

i) $N_{2(g)} + 2O_{2(g)} \rightleftharpoons 2NO_{2(g)}$

ii) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

iii) $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

iv) $2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_2$

v) $CO_{2(g)} + 4H_{2(g)} \rightleftharpoons CH_{4(g)} + 2H_2O_{(g)}$

Activity: 9.2

i) $K_c = \frac{[NaNO_3][AgCl]}{[NaCl][AgNO_3]}$

ii) $K_c = \frac{[Na_2SO_4][H_2O]^2}{[NaOH]^2 [H_2SO_4]}$

iii) $K_c = \frac{[NH_4Cl]^2 [CaCO_3]}{(NH_4)_2O_3[CaCl_2]}$

Q3. ii) $Kc = \frac{[NH_4Cl]}{[NH_3][HCl]}$

Chapter No.10

Activity: 10.1

i) $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons N^+H_{4(aq)} + O^-H_{(aq)}$

NH_3 is a base here

H_2O is acting as an acid here.

N^+H_4 is a conjugate acid of reaction

O^-H is a conjugate base of reaction

ii) $\underset{\text{Acid}}{HNO_{3(aq)}} + \underset{\text{Base}}{H_2O_{(l)}} \rightleftharpoons \underset{\text{Conjugate Acid}}{H_3O^+_{(aq)}} + \underset{\text{Conjugate Base}}{NO^-_{3(aq)}}$

iii) $\underset{\text{Acid}}{CH_3COOH_{(aq)}} + \underset{\text{Base}}{H_2O_{(l)}} \rightleftharpoons \underset{\text{Conjugate Base}}{CH_3COO^-_{(aq)}} + \underset{\text{Conjugate Acid}}{H_3O^+_{(aq)}}$

Activity: 10.2

Ans. = $[H^+] = 0.001$ mols/lit

Activity: 10.4

i) $HCl_{(aq)} + KOH_{(aq)} \rightleftharpoons KCl_{(aq)} + H_2O_{(l)}$

ii) $CH_3COOH_{(aq)}\ NaOH_{(aq)} \rightleftharpoons CH_3COONa_{(aq)} + H_2O_{(l)}$

iii) $2HNO_{3(aq)} + Ca(OH)_{2(aq)} \rightleftharpoons Ca(NO_3)_{2(aq)} + 2H_2O_{(l)}$

Q17. Ans. is = pH = '2'

Q18. (a) 0.00001M

$1 \times 10^{-5}M$

(b) $1 \times 10^{-10}M$

Q19. (a) 6
(b) 11

Chapter No.11

Activity: 11.3

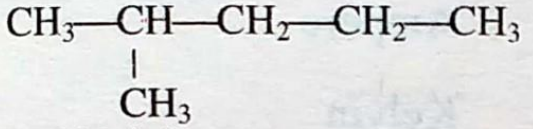
The products of combustion reaction of hydrocarbons are always CO_2 and water.

$$\underset{\text{Kerosine Oil}}{C_{12}H_{26}} + \frac{37}{2}O_2 \longrightarrow 12CO_2 + 13H_2O$$

Chapter No.12

Activity: 12.3

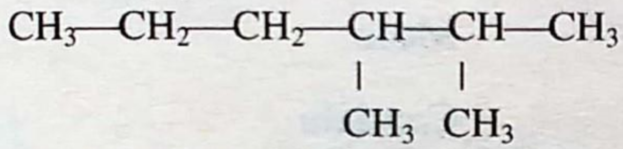
1.



$$CH_3-\underset{\underset{CH_3}{|}}{CH}-CH_2-CH_2-CH_3$$

2-Methyl pentane

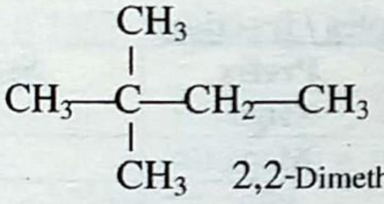
2.



$$CH_3-CH_2-CH_2-\underset{\underset{CH_3}{|}}{CH}-\underset{\underset{CH_3}{|}}{CH}-CH_3$$

2,3-Dimethyl hexane

3.

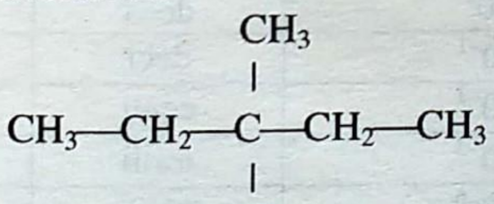


$$CH_3-\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}}-CH_2-CH_3$$

2,2-Dimethyl butane

Q12. Draw structures:

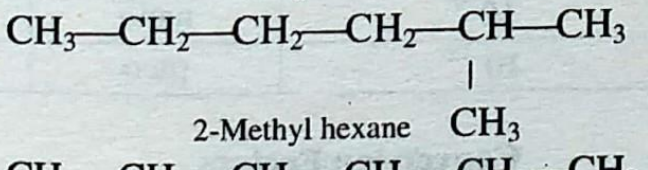
i)



$$CH_3-CH_2-\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}}-CH_2-CH_3$$

3,3-Dimethyl pentane

ii)



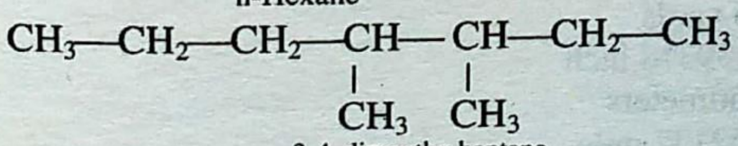
$$CH_3-CH_2-CH_2-CH_2-\underset{\underset{CH_3}{|}}{CH}-CH_3$$

2-Methyl hexane

iii) $CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$

n-Hexane

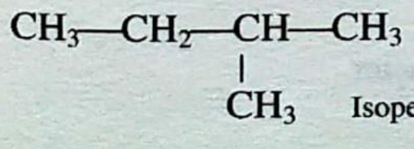
iv)



$$CH_3-CH_2-CH_2-\underset{\underset{CH_3}{|}}{CH}-\underset{\underset{CH_3}{|}}{CH}-CH_2-CH_3$$

3-4-dimenthy haptane

v)



$$CH_3-CH_2-\underset{\underset{CH_3}{|}}{CH}-CH_3$$

Isopentane

Table of Basic S.I units

S/No	Measurement	Unit	Symbol
1	Length	Metre or Meter	m
2	Mass	Kilogram	Kg
3	Time	Second	s
4	Electric current	Ampere	A
5	Temperature	Kelvin	K
6	Amount of substance	Mole	mol
7	Luminous intensity	Candela	cd

Some Prefixes for Multiples / fraction

Factor	Scientific Notation	Prefix	Symbol
1000,000,000	10^9	Giga	G
1000,000	10^6	Mega	M
1000	10^3	kilo	k
100	10^2	hecto	h
10	10^1	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000,001	10^{-6}	micro	μ
0.000.000.001	10^{-9}	nano	n
0.000,000,000,001	10^{-12}	pico	p

Conversion Factors

Length

1 metre = 1.0936 yards
1 centimeter = 0.39370 inch
1 inch = 2.54 centimeters
1 kilometer = 0.62137 mile
1 mile = 1.6093 kilometers
1 angstrom = 10^{-10}meter = 100 pico meter

Mass

1 kilogram = 1000gm = 2.2046 Pounds

1 Pound = 453.5gms = 0.454 kilograms

1 ton = 2000 pounds = 907.185 kilograms

1 metric ton = 1000 kilograms = 2204.6 pounds

1a.m.u = 1.66054×10^{-27} kilograms = 1.66054×10^{-24}gms

Temperature

$0K = -273.15^{\circ}C = -459.67^{\circ}F$

$K = {}^{\circ}C + 273.15$

$${}^{\circ}C = \frac{5}{9}\,({}^{\circ}F - 32)$$

$${}^{\circ}F = \frac{9}{5}\,({}^{\circ}C) + 32$$

Energy

1 Calorie = 4.184 Joules = 3.965×10^{-3}btu

1 btu = 1055.06 Joules = 252 Calories

Pressure

1 atmosphere = 101325 Pascals = 760 torr

= 760mmHg = 14.70 Pounds per squre inch

1 bar = 10^5 Pascals

1 pascal = 1 N/m^2 = $1Kgm^{-1}s^{-2}$