CHEMISTRY

Class

10

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Chapter

9

Chemical Equilibrium

In this chapter you will be able to:

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

Introduction

Consider a closed container partially filled with a liquid at a given temperature. Molecules escape from the liquid into the vapour phase and are collected in the free space above the liquid. Some of the vapour molecules start to condense back into the liquid state. Initially the rate of condensation is slower than that of evaporation. But as more and more vapours are formed the rate of condensation increases and utlimately becomes equal to the rate of evaporation. At this stage both evaporation and condensation continue to take place without any net change. This system is said to be in a state of dynamic equilibrium.

$$\underset{\text{(Water)}}{\text{liquid}} \underset{\text{condensation}}{\overset{\text{evaporation}}{\rightleftharpoons}} \underset{\text{(vapours)}}{\text{gas}}$$

9.1 Reversible Reactions and Dynamic Equilibrium

Consider the following reaction,

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

This reaction proceeds in the forward direction but as soon as some amount of ammonia is formed the ammonía molecules dissociate into nitrogen and hydrogen and the reaction is reversed.

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

Such reactions which proceed in the forward as well as in the reverse direction are called *reversible reactions*. Most of the reactions are reversible. A reversible reaction can be represented by two arrows ($\rightleftharpoons$) between the reactants and products. For example, the above reaction can be written as follows.

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

Other examples are given below.

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

$$H_{2\,(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

Let us consider a general reaction in which A reacts with B in the gaseous state in a closed vessel forming products C & D.

$$A_{(g)} + B_{(g)} \rightleftharpoons C_{(g)} + D_{(g)}$$

The initial concentration of A and B is taken the same, while that of the products C and D is zero. As the forward reaction proceeds, the concentrations of the reactants (A,B) decrease and the concentration of the products (C,D) increase continuously. Therefore, the rate of forward reaction decreases and that of backward reaction increases. Ultimately, a stage reaches when the rate of forward reaction becomes equal to the rate of backward reaction. At this stage the concentrations of the reactants and products become constant. Reaction at this stage is said to be at the state of equilibrium.

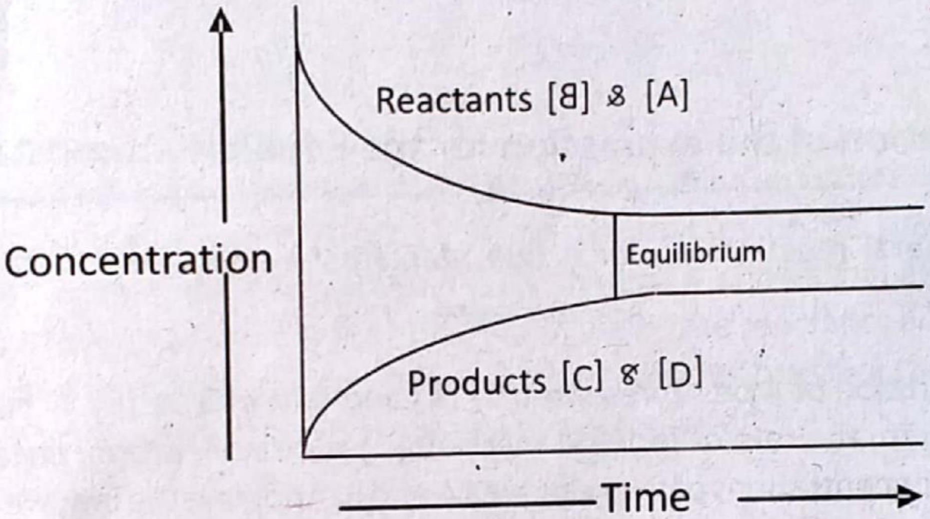


Fig. 9.1 Reversible Reaction and equilibrium state

At the equilibrium state, it seems that the reaction has stopped since no more product is formed. Actually the reaction continues and the amount of the products formed is transformed back into the reactants. Such an equilibrium in the reversible reactions is called the dynamic equilibrium.

Society, Technology and Science

Nitrogen and oxygen are important components of the atmosphere. These are used successfully in the industrial preparation of nitric acid (Birkland-Eyde process), which is a very important chemical.

In this process air is passed through electric arc to obtain nitric oxide.

$$N_2 + O_2 \rightleftharpoons 2NO$$

The nitric oxide is further oxidized to NO_2 in the presence of oxygen.

$$2NO + O_2 \longrightarrow 2NO_2$$

The NO_2 gas is dissolved in water in the absorption tower and nitric acid is formed

$$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$$

9.2 Law of mass action

This law was suggested by two chemists, Guldberg and Waage in 1864. It gives a relation between the concentrations of reactants and products at equilibrium in a chemical reaction. This law states that "the rate or speed of a chemical reaction is proportional to the product of the active masses of the reacting substances". By the term active mass we mean the molar concentration, or number of moles per dm^3 in a dilute solution.

9.2.1 Derivation of the expression for the Equilibrium constant

Consider a general reaction in which two reactants A and B react to form the products C and D.

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

Let the concentration of A be represented by [A] and that of B by [B]. According to law of mass action, the rate of forward reaction (r_1) is directly proportional to the product of the concentrations of the reactants A and B. Applying the law, we get.

$$\text{Rate of forward reaction} = r_1 \propto [A][B]$$

Replacing the sign of proportionality by equality sign we introduce a proportionality constant, k_1 and the above equation becomes,

$$r_1 = k_1 [A][B]$$

Here k_1 is the rate constant for the forward reaction.

The reaction under study is a reversible reaction. As the products C and D are formed they react back and are converted into the reactants, A and B. For the reverse reaction.

$$\text{Rate of reverse reaction} = r_2 \propto [C][D]$$

$$r_2 = k_2 [C][D]$$

Where, k_2 is the rate constant for the reverse reaction.

At equilibrium,

the rate of forward reaction = the rate of reverse reaction

$$r_1 = r_2$$

Therefore,

$$k_1 [A] [B] = k_2 [C] [D]$$

$$\frac{k_1}{k_2} = \frac{[C] [D]}{[A] [B]}$$

Therefore $K_c = \frac{[C] [D]}{[A] [B]}$ $K_c' = \frac{k_1}{k_2}$

Where, K_c is called the equilibrium constant. The equilibrium constant, K_c may be defined as the ratio of the product of the active masses of the products to the product of active masses of reactants. A large value of K_c shows that at equilibrium, the product concentrations are greater than those of the reactants and vice versa. The equilibrium constant of a reaction is independent of pressure, concentration and catalyst and its value is constant for a particular reaction.

Example 9.1

We have the values of K_c as:

i) 10^2 ii) 10^{30} iii) 10^{-30} and iv) 1

Which value of Kc for the following reaction, predicts that the reaction goes to completion in the forward direction:

Solution: $CaCO_3 \rightleftharpoons CaO + CO_2$

$$K_c = \frac{[CaO] [CO_2]}{[CaCO_3]}$$

Since the reaction goes to completion in the forward direction, the concentration of the products is much more as compared to the reactants and the value of K_c would be very large. Hence, the answer is ii) 10^{30}.

Activity

Write equilibrium constant expression for the following reversible reactions.

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

$$PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)}$$

9.3 Equilibrium constant and its Units

Equilibrium constant is a ratio of the product of the concentrations of the products to the product of the concentrations of the reactants. Hence the unit of K_c depends on the equilibrium constant expression for the given reaction. For example if number of moles of reactants and products are equal, the equilibrium constant has no units as concentration units cancel out.

Example 9.2

What is the unit of K_c if one mole of each reactant and product is present in the equilibrium mixture of the following reaction?

$$2NO_{(g)} \rightleftharpoons N_{2(g)} + O_{2(g)}$$

Solution

Writing equilibrium constant expression, we get no units for K_c for the above reaction.

$$K_c = \frac{[N_2][O_2]}{[NO]^2} = \frac{[1\ \cancel{mole\ dm^{-3}}] \times [1\ \cancel{mole\ dm^{-3}}]}{[1\ \cancel{mole\ dm^{-3}}]^2}$$

9.4 Equilibrium calculations

The value of equilibrium constant can be calculated if we know the concentrations of the reactants and products in the equilibrium mixture.

Example 9.3

In the equilibrium mixture, the concentration of hydrogen and iodine is 0.04 moles per dm^3 each while that of hydrogen iodide is0.08 mole per dm^3. Find K_c of the following reaction.

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

Solution

Writing the equilibrium constant expression for the above reaction.

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

$$K_c = \frac{[0.08]^2}{[0.04][0.04]} = 4$$

9.5 Importance (applications) of equilibrium constant

The value of equilibrium constant is specific and remains constant at a particular temperature. The value of K_c helps us to predict:

(i) Direction of reaction

We know that, $K_c = \frac{[products]}{[reactants]}$ for any reaction

The direction of a chemical reaction at any particular time can be predicted by means of [products]/[reactants] ratio. The value of [products]/[reactants] ratio leads to one of the following three possibilities.

(a) The ratio is less than K_c. This implies that more of the product is required to attain the equilibrium, therefore, the reaction will proceed in the forward direction.

(b) The ratio is greater than K_c. It means that the reverse reaction will occur to attain the equilibrium.

(c) When the ratio is equal to K_c, then the reaction is at equilibrium.

(ii) Extent of Reaction

(a) If the equilibrium constant is very large, this indicates that the reaction is almost complete.

(b) If the value of Kc is very small, it reflects that the reaction does not proceed appreciably in the forward direction.

(c) If the value of Kc is moderate this shows a very little forward reaction.

(iii) The effect of external conditions on the position of equilibrium

When a system reaches equilibrium it will remain in same state indefinitely if the conditions do not change. However, the equilibrium state of a system is disturbed if external conditions are changed, e.g, change of pressure, temperature and concentrations of reactants and products alter the position of the equilibrium. Whenever, the equilibrium is disturbed by changes in the external conditions, the system always tends to restore equilibrium.

9.6 *Conditions for equilibrium*

The following are the conditions of chemical equilibrium.

(I) When a chemical equilibrium is established in closed vessel at constant temperature concentration of various species in the reaction become constant. The concentrations are called equilibrium concentration.

(ii) Equilibrium cannot be attained in open vessel. In an open vessel the gaseous reactants and products may escape into atmosphere leaving behind no possibility of attaining equilibrium.

(iii) A catalyst cannot change the equilibrium point, it only speeds up the rate of both the forward and the reverse reaction.

The experimental methods used for the determination of the equilibrium constant, depend on the nature of reactants and temperature. Two types of procedures have been used.

In the first of these the reacting substances are sealed into glass bulbs and allowed to attain equilibrium and contents are analyzed. The second procedure is the "flow method", in which the gases are passed through a tube and equilibrium mixture is analyzed. When concentration of equilibrium mixture becomes constant, the equilibrium is established. This is the principal criterion of chemical equilibrium.

KEY POINTS

- The reaction that does not go to completion and the products formed react to form the reactants back is called a reversible reaction.
- A state of dynamic equilibrium is established when the rate of forward reaction becomes equal to the rate of reverse reaction.
- The reversible reaction when reaches the equilibruim stage, no more changes in concentrations of reactants and products take place.
- The rate at which a substance reacts, is directly proportional to its active mass and the rate of reaction is directly proportional to the product of active masses of the reacting substances. Active mass or activity "a" is directly proportional to the molar concentration "c".
- *Equilibrium Constant of the reaction,* K_c is defined as the ratio of the product of the molar concentration of the products to that of the reactants. A very large value of equilibrium constant, K_c indicates that the reaction is almost complete. If the value of K_c is very small, then the reaction proceeds a little in the forward direction.
- The equilibrium constant can be used to predict the direction in which a chemical system would proceed to acquire the equilibrium state.

EXERCISE

1. Choose the correct answers from the given options

i. Consider the system :

Water(l) $\rightleftharpoons$ Water(g)

At dynamic equilibrium:

A) reversible reaction stops
B) amount of liquid water and water vapour is the same
C) amount of liquid water and water vapour is constant
D) Amount of liquid is minimum

ii. A reversible reaction proceeds in the:

A) reverse direction
B) forward direction
C) forward and reverse direction
D) more backward less forward

iii. The equilibrium constant (K_c) is:

A) The sum of the two rate constants
B) The difference of the two rate constants
C) The ratio of the two rate constants
D) The product of the two rate constants

iv. For the reaction A + B $\rightleftharpoons$ C + D

K_c is equal to:

A) $\frac{[A]+[B]}{[C]+[D]}$ B) $\frac{[A]+[D]}{[B]+[C]}$

C) $\frac{[A][B]}{[C][D]}$ D) $\frac{[C][D]}{[A][B]}$

v. For a reaction $N_{2(g)} + O_{2\,(g)} \rightleftharpoons 2NO_{(g)}$

if $K_C = 10^{-30}$ at 25°C. One can predict:

A) More NO is formed
B) The forward reaction goes to completion

C) The backward reaction goes to completion
D) More reactants are consumed

vi. The unit of Kc for the following system is:

$PCl_5 \rightleftharpoons PCl_3 + Cl_2$,

A) mol^2/L^2 B) L/mol
C) mol/L^2 D) mol/dm^3

vii. Molecules of chlorine do not decompose into atomic chlorine i.e:

$Cl_2 \rightleftharpoons 2\dot{Cl}$

This is because K_c of this reaction is:

A) Very large B) Very small
C) Zero D) 1

viii. How much reaction is complete when $K_c = 1$:

A) 10% B) 25%
C) 50% D) 100%

2. *Write Short answers to the following questions*

i. Give an expression for K_c for the following reversible reactions.

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

B) $H_{2(g)} + CO_{2(g)} \rightleftharpoons CO_{(g)} + H_2O_{(g)}$

C) $4NH_{3(g)} + 5O_{2(g)} \rightleftharpoons 4NO_{(g)} + 6H_2O_{(g)}$

ii. Define law of mass action
iii. Write down the units of K_c.
iv. What are reversible and irreversible reactions?
v. What is dynamic equilibrium?

3. *Write long answers to the following questions?*

I. What is the importance of equilibrium constant?
ii. Write down the conditions necessary for equilibrium.
iii. What is equilibrium constant? Explain its units.

Chapter

10

Acids Bases and Salts

In this chapter you will be able to:

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

Introduction

The term acid is derived from Latin word acidus, which means sour. Lemon, and oranges are sour in taste because each of them contain an acid known as citric acid. Hydrochloric acid is present in our stomach which helps to digest food. Similarly we use bases and salts in our daily life e.g. washing soda ($Na_2CO_3.10H_2O$) and baking soda ($NaHCO_3$) are used for washing and in bakery respectively.

Similarly Sodium chloride (NaCl) is a salt that we use in our daily diet to taste our food.

10.1 Various Concepts of acids and bases

The Arhenius Concept (1884)

According to this concept all those substances which can give H^+ ion when dissolved in water are called acids e.g.

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

$HC\ell$ is an acid which dissolve in water and give H^+ ion and forms H_3O^+.

Base is a substance which can give hydroxyl ion OH^- when dissolved in water. e.g.

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

10.1.2 Bronsted and Lowry Concept

According to Bronsted and Lowry concept.

All those substances which donate or tend to donate proton (H^+ ion) are called acids. Whereas those substances which accept or tend to accept proton are known as bases.

$$\underset{acid}{HCl_{(aq)}} + \underset{base}{NH_{3(aq)}} \longrightarrow NH^+_{4(aq)} + Cl^-_{(aq)}$$

In this example HCl donates proton and acts as an acid, while NH_3 accepts proton and serves as base.

Conjugate Acid and Conjugate Base:

When an acid gives proton (H^+) it forms negatively charged species which can accept proton and act as a base and is called conjugate base of the corresponding acid e.g.

$$\underset{\text{acid}}{CH_3COOH} + \underset{\text{base}}{H_2O} \rightleftharpoons \underset{\text{Conjugate base}}{CH_3COO^-} + \underset{\text{Conjugate acid}}{H_3O^+}$$

When acetic acid (CH_3COOH) loses a proton it forms CH_3COO^- ion which can take proton and acts as a base and thus CH_3COO^- is called conjugate base of the acid (CH_3COOH).

When a base takes proton then it forms positively charge species which can act as an acid and is called conjugate acid of the corresponding base. e.g.

$$\underset{\text{base}}{NH_3} + \underset{\text{acid}}{H_2O} \longrightarrow \underset{\text{Conjugate acid}}{NH_4^+} + \underset{\text{Conjugate base}}{OH^-}$$

NH_4^+ is called conjugate acid of NH_3.

Monoprotic Acids

Those acids which can donate only one proton are called mono protic acids e.g.

HCl, HBr, HNO_3 and HCN etc.

Polyprotic Acids

Those acids which can donate two or more than two protons are called polyprotic acids e.g.

H_2SO_4 and H_3PO_4

Amphoteric Substances:

Those substances which can act both as an acid and a base are called amphoteric substances e.g. water.

When water is treated with an acid it acts as a base but when it is treated with a base, it acts as an acid. e.g.

$$\underset{\text{acid}}{HCl} + \underset{\text{base}}{H_2O} \longrightarrow \underset{\text{conj base}}{Cl^-} + \underset{\text{conj acid}}{H_3O^+}$$

$$\underset{\text{base}}{NH_3} + \underset{\text{acid}}{H_2O} \longrightarrow \underset{\text{conj acid}}{NH_4^+} + \underset{\text{conj base}}{OH^-}$$

$$\underset{\text{acid}}{H_2O} + \underset{\text{base}}{H_2O} \longrightarrow \underset{\text{conj base}}{OH^-} + \underset{\text{conj acid}}{H_3O^+}$$

10.1.3 The Lewis Concept

According to Lewis.

Those species (Molecules or ions) which can accept a pair of electrons are called acids.

While those species which can donate a pair of electrons are called bases.

An acid base reaction involves the donation of electrons pair from base to an acid and forming coordinate covalent bond.

Compounds having less than eight electrons in velance shell of central atom and positive ions act as lewis acids.

While compounds having lone pair of electrons in the valance shell or negatively charged ions can donate electron pair and behave as Lewis bases.

For Example:

$$\underset{\text{base}}{\ddot{N}H_3} + \underset{\text{acid}}{BF_3} \longrightarrow \underset{\text{Complex}}{[H_3N \longrightarrow BF_3]}$$

$$\underset{\text{acid}}{H^+} + \underset{\text{base}}{\ddot{N}H_3} \longrightarrow \underset{\text{Ammonium ion}}{[H_3N \longrightarrow H]^+}$$

$$\underset{\text{acid}}{H^+} + \underset{\text{base}}{H_2\ddot{O}:} \longrightarrow \underset{\text{Hydronium ion}}{[H_2\ddot{O} \longrightarrow H]^+}$$

I. STRONG ACIDS:

Acids, which are ionized almost completely in aqueous solution and give higher concentration of H^+ ions, are called strong acids. OR

Acids, which are completely dissociated in aqueous solutions, are called strong acids. HCl, HNO_3, and H_2SO_4 are examples of strong acids.

HCl is a strong acid and when it is dissolved in water, it dissociates completely to give hydrogen ions (H^+) $HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

It has been proved that solution of HCl does not have any un-dissociated HCl molecules in it. All the molecules of HCl have been completely dissociated to give H^+ and Cl^- ions.

ii. WEAK ACIDS:

The acids, which partially ionize in aqueous solution and give lower concentration of H^+ ion, are called weak acid. OR

The acids, which do not dissociate completely when added to water, are called weak acids. For example, acetic acid is a weak acid. When it is dissolved in water, only few molecules of it dissociate to give hydrogen ions (H^+) and acetate ions.

$$CH_3COOH_{(aq)} \rightleftharpoons H^+_{(aq)} + CH_3COO^-_{(aq)}$$

Acetic acid dissociates only slightly. Therefore, in the solution apart from H^+ and $CH_3COO^-_{(aq)}$ ion, un-dissociated acetic acid, molecules are also present.

Other examples of weak acids are H_2CO_3 and H_3PO_4.

iii. STRONG BASES:

The bases, which are almost completely ionized in aqueous solution and give higher concentration of OH^- ion, are called strong bases.

For example NaOH is a strong base, which dissociates completely in water as follow.

$$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$$

All the NaOH molecules dissolved in water break up to give Na^+ and OH^- ions. KOH is also an example of a strong base.

iv. WEAK BASES:

The bases, which are partially ionized in aqueous solution and give lower concentration of OH^- ion, are called weak bases OR

The bases, which do not dissociate completely in water, are called weak bases.

For Example NH_4OH is a weak base. It partially dessociate into its ions.

$$NH_4OH_{(aq)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

Society, Technology and Science

Acids and bases are very important in our daily life. Sulfuric acid and hydrochloric acid as well as other acids have many industrial applications. HCl is present in our stomach, which helps in digestion of food. Carbonic acid (H_2CO_3) is a weak acid that is present in a soda water.

Bases also have important role in our daily life. For example NaOH is used to make soaps and as drain opener. Sometime we take bases as antacid such as $Mg(OH)_2$ to neutralize excess of stomach acid which causes heart burn. Slaked lime $Ca(OH)_2$ is used for white washing purposes.

10.2 pH Scale (Hydrogen ion Concentration):

The acidity or basicity of an aqueous solution depends upon the relative numbers of hydronium ions (H_3O^+) and hydroxide ions (OH^-) present in it. Pure water contains equal number of hydronium and hydroxide ions. In water the product of hydronium ions concentration and hydroxide ions concentration is always 1×10^{-14} at 25°C and is called water dissociation constant "k_w".

$$2H_2O \rightleftharpoons H_3O^+ + OH^-$$

$$K_w = [H_3O]^+ [OH]^-$$

$$K_w = 10^{-14}$$

It has been so obtained because at room temp (25°C) water molecules are much stable and only one molecule of H_2O out of 10^7 molecules dissociates into H^+ and OH^- ions i.e

$$H_2O \rightleftharpoons H^+ + OH^- \text{ .... } 1$$

So, Concentration of H^+ ions $= \frac{1}{10^7} = 10^{-7}$ mol.dm^{-3}

Concentration of OH^- ions $= \frac{1}{10^7} = 10^{-7}$ mol.dm^{-3}

k_c for equation 1 is

$$k_c = \frac{[H^+][OH^-]}{[H_2O]}$$

Concentration of water is constant, so

$$k_c\,[H_2O] = [H^+][OH^-]$$

$$k_c\,[H_2O] = k_w$$

$$K_w = 10^{-7} \times 10^{-7} = 10^{-14}$$

Society, Technology and Science

Gastric juice is a digestive fluid, formed in the stomach. It has a pH of 1 to 2 and is composed of hydrochloric acid (HCl) (around 0.5%, or 5000 parts per million), and large quantities of potassium chloride (KCl) and sodium chloride (NaCl). The acid plays a key role in digestion of proteins, by activating digestive enzymes, and making ingested proteins unravel so that digestive enzymes can breakdown the long chains of amino acids.

Gastric juice is produced by cells lining the stomach, which are coupled to systems to increase acid production when needed.

pH and pOH Scales:

Sorenson in 1909 proposed a scale for the measurement of strength of acids and bases called P^{H} and P^{OH} scale. Here P stands for "potenz" (The potential to be) and H^{+} stands for Hydrogen and OH^{-} stands for hydroxyl ion. The P^{H} Scale measures how acidic or basic a solution is? It ranges from 0 to 14.

pH	
The logarithm of the reciprocal of moler hydrogen ions concentration is known the P^{H}	The logarithm of the reciprocal of moler OH^{-} ions concentration is known the P^{OH}.
$P^{H} = \log\frac{1}{[H^{+}]}$ $P^{H} = \log 1 - \log[H^{+}]$ As $\log 1 = 0$ $P^{H} = -\log[H^{+}]$	$P^{OH} = \log\frac{1}{[OH^{-}]}$ $P^{OH} = \log 1 - \log[OH^{-}]$ As $\log 1 = 0$ $P^{OH} = -\log[OH^{-}]$
The negative logarithm of moler hydrogen ions concentration is called P^{H}.	The negative logarithm of moler OH^{-} ions concentration is called P^{OH}.
P denotes negative log. $-\log = P$	

As we have

$$Kw = [H^{+}][OH^{-}] = 10^{-14}$$

Take negative logarithm of above equation.

$$-\log kw = -\log[H^{+}][OH^{-}] = -\log 10^{-14}$$

$$[-\log[H^{+}]] + [-\log[OH^{-}]] = -(-14)\log 10$$

As $\log 10 = 1$

$$P^{H} + P^{OH} = 14.$$

The sum of pH and pOH for a neutral substance is 14. i.e. pH $=7$ and pOH $=7$.

For a neutral solution pH is equal to 7 and pOH is equal to 7. Each pH whole number value below 7 is ten times more acidic than the next higher value. For example a pH of 3 is ten times more acidic than pH of 4 and 100 times more acidic than pH of 5. The same holds true for pH values above 7 each of which is ten times more alkaline (basic) than the next lower whole number value i.e. a pH of 9 is ten times more alkaline than pH of 8.

Example: Calculate the pH and pOH of 0.001M solution of nitric acid=?

Solution:

$$\underset{0.001}{HNO_3} \longrightarrow \underset{0.001}{H^+} + \underset{0.001}{NO^{-3}}$$

Hydrogen ions concentration $=\left[H^+\right]=0.001=\dfrac{1}{1000}=10^{-3}$

pH $=-\log\left[H^+\right]$

$$-\log 10^{-3} = -(-3)\log 10$$

$$pH = 3$$

As

$$pH + pOH = 14$$

So

$$pOH = 14 - pH$$

$$pOH = 14-3=11$$

Example: Calculate the P^H and P^{OH} of 0.01 M Solution of HCl.

Solution:

$$\underset{0.01}{HCl} \longrightarrow \underset{0.01}{H^+} + \underset{0.01}{Cl^-}$$

Hydrogen ions concentration = $\left[H^+\right]=0.01=\dfrac{1}{100}=10^{-2}$.

NOT FOR SALE

$$pH = -\log\left[H^+\right]$$

$$= -\log\left(10^{-2}\right)$$

$$-(-2)\log 10 = 2$$

$$pH + pOH = 14.$$

$$pOH = 14 - pH$$

$$pOH = 14 - 2 = 12$$

A scale known as the $_pH$ scale has been devised to express the acidic and basic strength of solution in terms of the $_pH$ value.

Concentration of H^+ ions	pH	pOH	
1	0	14	Strong acids
$\frac{1}{10}=10^{-1}$	1	13	
$\frac{1}{100}=10^{-2}$	2	12	
$\frac{1}{1000}=10^{-3}$	3	11	
10^{-4}	4	10	Weak acids
10^{-5}	5	9	
10^{-6}	6	8	
10^{-7}	7	$7 \rightarrow$ Neutral	
10^{-8}	8	6	Weak Bases
10^{-9}	9	5	
10^{-10}	10	4	
10^{-11}	11	3	
10^{-12}	12	2	– Strong bases
10^{-13}	13	1	
10^{-14}	14	0	

10.3 Salts

A Compound formed due to neutralization reactions of an acid and base is called salt. A salt consists of positive ion from the base and negative ion from the acid. For example sodium chloride $(NaCI)$ is composed of sodium(metal)positive ion (Na^{+}) and chloride (non–metal) ion CI^{-}.

Some metal positive ions $(Na^{+}, K^{+}, Ag^{+}, Mg^{++}, Ca^{++})$

some negative ions $(C\ell^{-}, Br^{-}, SO_4^{-2}, PO_4^{-3})$.

Sodium chloride $NaC\ell$, silver bromide $(AgBr)$, potassium sulphate (K_2SO_4) and ferric phosphate $(FePO_4)$ etc. are examples of salts.

10.3.1 Preparation of Salts

Salts can be formed in different ways. It can be formed by the neutralization of acids with bases e.g.

$$\underset{acid}{HCI} + \underset{base}{NaOH} \longrightarrow \underset{salt}{NaCI} + \underset{water}{H_2O}$$

In certain salts there are poly atomic positive ions and poly atomic negative ions e.g. Ammonium sulphate $(NH_4)_2SO_4$ and Ammonium nitrate (NH_4NO_3).

Generally salts are ionic compounds. Soluble salts are called electrolytes. In molten state or in solution state, electrolytes are good conductors of electricity.

10.3.2 Types of Salts

i. **Neutral Salts:**

The salts formed when the hydrogen ion of an acid are completely replaced by metal ions or a group of atom, behaving like metal ions. Sodium chloride is formed from sodium hydroxide and hydrochloric acid,

$$\underset{\text{Strong acid}}{HCl} + \underset{\text{Strong base}}{NaOH} \rightarrow \underset{\text{salt}}{NaCl} + \underset{\text{water}}{H_2O}$$

For example NaCl is the neutralization product of HCl and NaOH.

Similarly,potassium sulphate, sodium sulphate, sodium carbonate, ammonium sulphate, sodium phosphate etc. are other examples of normal salts.

ii. **Acidic Salts:**

Salts formed when hydrogen ions of an acid are partially replaced by metal ions or group of atoms behaving like metal ions are called acidic salts.

For example $KHSO_4$, $NaHCO_3$, $(NH_4)H_2PO_4$, etc are acidic salts. These salts can further react with bases forming neutral salts.

$$H_2SO_4 + KOH \longrightarrow KHSO_4 + H_2O$$

Acidic salts are formed by Polybasic acid only.

iii. **Basic Salts:**

Salts formed when OH^- ion of a base are partially neutralized by an acids are called basic salts.

For example,

$$Pb(OH)Cl, Cu(OH)Cl$$

$$Pb(OH)_2 + HCl \longrightarrow Pb(OH)Cl + H_2O$$

Basic salts are produced by Poly acid bases.

10.3.3 Uses of Salts

Salts have many different uses, ranging from household to big industries. Many salts, like sodium chloride, are necessary for life itself. Calcium phosphate is the main ingredient of our bones. Some salts, like calcium sulphate dihydrates ($CaSO_4 . 2H_2O$) are used in building materials. Some of the most common salts and their uses are given below.

1. **Sodium carbonate (Na_2CO_3):** It is also called as soda ash or washing soda. It is used as a cleaning agent in laundries and as water softner. It is also used as raw material in glass manufacturing. It also finds applications in paper industry, petroleum refining industry and leather industry.

2. **Sodium hydrogen Carbonate (sodium bicarbonate) $NaHCO_3$:** It is also called baking soda because it is used for baking cake and other confectionaries. It is used in medicine as antacid and also in tooth paste etc.

3. **Copper sulphate ($Cu\ SO_4 .\ 5H_2O$) (blue vitriol):** It is used for copper plating in electroplating process. It is also used to kill algae in water reservoirs and in agriculture spray.

4. **Magnesium sulphate ($Mg\ SO_4 .7H_2O$) Epsom salt:** It is used as antacid and laxative in medicine. It is also used in dye industries.

5. **Alum or potash alum $K_2SO_4\ Al_2\ (SO_4)_3 .24H_2O$:** It is used for water purification to remove suspended impurities from water by a process called as flocculation. It is widely used in textile industry since it causes dyes to adhere to the fabric. In the field of medicine, it is used as blood coagulant in small injuries.

10.4 Neutralization

When acids react with bases, salt and water is formed, the process is called neutralization reaction.

For example, when HCl reacts with NaOH, NaCl and water are formed.

$$\underset{\text{Acid}}{HCl_{(aq)}} + \underset{\text{Base}}{NaOH_{(aq)}} \rightarrow \underset{\text{salt}}{NaCl_{(aq)}} + \underset{\text{water}}{H_2O_{(l)}}$$

To understand the process of neutralization the acid, base and salt should be written in their ionic form.

$$H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$$

In solution, HCl exists as H^+(or H_3O^+) and Cl^-, and NaOH exists as Na^+ and OH^-. In neutralization H^+ reacts with OH^- to form water, leaving Na^+ and Cl^- ions which are present on both sides as they have not reacted. They are called spectator ions. Only H^+ and OH^- combine to form H_2O.

Thus the net reaction is the chemical combination of OH^- ion and H^+ ion to form water molecule. The net reaction of neutralization is as under.

$$H^+ + OH^- \rightarrow H_2O$$

10.5 Common ion Effect:

The process in which the solubility of already present electrolyte in solution is decreased by adding another electrolyte having the common ion is called common ion effect.

In this process the solubility of less soluble electrolyte is decreased by adding more soluble electrolyte in the solution where both gives common ion for example:

When we add $KC\ell$ into solution of less soluble salt $KC\ell O_3$, then due to common ion effect. The solubility of $KC\ell O_3$ decreases. So $KC\ell O_3$ separates out of solution as crystals.

$$KClO_3 \rightleftharpoons K^+ + ClO_3^-$$

$$KCl \longrightarrow K^+ + Cl^-$$

2. When $HC\ell$ is added to solution of H_2S, they produce H^+ as common ion.

$$H_2S \rightleftharpoons 2H^+ + S^{-2}$$

$$HCl \longrightarrow H^+ + Cl^-$$

Because H_2S is a weak acid and HCl is a stronger acid, therefore ionization of H_2S is suppressed. Thus less S^{-2} ions are produced.

3. When we add $NH_4C\ell$ to solution of NH_4OH, the $\overset{+}{N}H_4$ ion is common.

$$NH_4Cl \rightleftharpoons NH_4^+ + Cl^-$$

$$NH_4OH \rightleftharpoons NH_4^+ + OH^-$$

Due to common ion effect the ionization of NH_4OH is suppressed and less OH^- ions are produced.

KEY POINTS

- According to Arhenius those substances which can give H^+ ion in water are called acids, while those which can give OH^- ion in water are called bases.
- According to Lowry and Bronted those substances which donate or tend to donate proton are called acids, while those which accept or tend to accept proton are called bases.
- According to Lewis those species which can accept a pair of electron are called acids, while those which can donate a pair of electron are called bases.
- A specie and which can act as a base as well as acid is called amphoteric substance
- P^H and P^{OH} scales are used for the measurement of strength of acid and bases.
- P^H of neutral solution is 7
- P^H of acidic solution is less than 7
- P^H of basic solution is more than 7
- When an acid neutralizes a base salt is formed
- Salts are of three types i.e neutral, acidic and basic.

EXERCISE

Q.1 Select the suitable option.

i. According to Bronsted, Acids are:
   a. Proton donor b. Proton accepter
   c. Electron donor d. Electron accepter

ii. NH_3 is ____________.
   a. Acid b. Base
   c. Salt d. Buffer Solution

iii. Neutral solution has a P^H value :
   a. 3 b. 5
   c. 7 d. 14

iv. Lower the PH value ________ will be an acid.
   a. Weaker b. Stronger
   c. Neutral d. Alkaline

v. Salts are ____________ compounds.
   a. Acidic b. Basic
   c. Neutral d. Neutral

vi. Those bases which give hydroxyl ion in water are called.
   a. Acids b. Alkalies
   c. Salts d. Neutral substances

vii. $KHSO_4$ is a ________ salt.
   a. Basic b. Acidic
   c. Neutral d. Neutral

Q.2 Write short answers to the following questions:

i. What are double salts?
ii. What are amphoteric substances
iii. Differentiate between lone pair and bond pair of electrons
iv. What will be the pH and POH of 0.001M NaOH solution?
v. Calculate the pH and POH of 0.05M HCl Solution?

Q.3 Write long answers to the following questions:

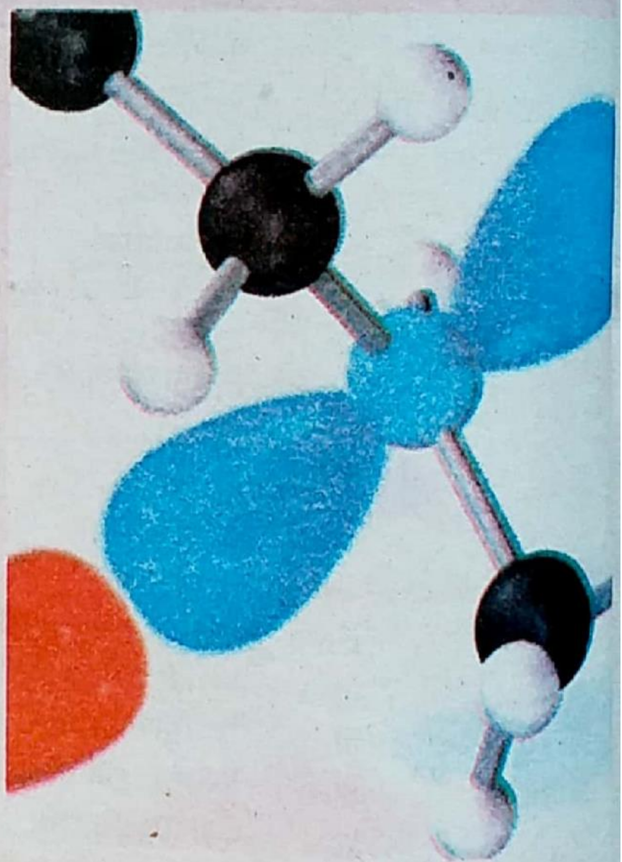
i. What are salts and explain their different types.
ii. Write a detailed note on P^H.
iii. Define common ion effect. Explain with example how it effects the chemical reactions.
iv. Write different concepts of acids.
v. Define Lewis acids and bases, giving examples.

Chapter

11

Organic Chemistry

After careful study and working on the exercise of this chapter the students will be able to:



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

Introduction

Nearly two centuries ago all substances then known were classified on the basis of source from which they were derived into two main classes, inorganic and organic. The compounds derived from earth crust were named as inorganic and those obtained from vegetable and animals or in other words from living organisms as organic. For example, table salt (NaCl), marble ($CaCO_3$) and carbon dioxide (CO_2) were inorganic, whereas, urea (from urine), tartaric acid (from grapes), Citric acid (from lemons) and sucrose (from cane sugar) were organic.

Since Organic compounds have common features and exist in large number, they are studied in separate branch of chemistry called organic chemistry. *"The branch of chemistry which deals with the study of organic compounds is called organic chemistry"*.

11.1 Organic Compounds

It has become evident that all organic compounds whether natural or synthetic, essentially contain carbon and hydrogen and occasionally a few other elements such as oxygen, nitrogen, sulphur, phosphorus and halogens.

Organic compounds can now be defined as the compounds of carbon except the oxides of carbon, carbonates, bicarbonates and some metal carbides. Further, organic compounds made up of only carbon and hydrogen are called hydrocarbons. All other organic compounds may be regarded to have been derived from them. Therefore, organic chemistry may be defined as *the chemistry of hydrocarbons and their derivatives*.

Characteristics of Organic Compounds

Organic compounds have many common characteristics which are entirely different from inorganic compounds. Some of their general characteristics are described below.

1. **Composition:**
Carbon is the essential constituent of all organic compounds.

2. **Low melting and boiling points:**
Organic compounds have generally low melting and boiling points and are volatile in nature.

3. **Thermal Instability:**
Many organic compounds are thermally unstable. Since organic compounds have low melting and boiling points, they generally decompose at high temperature into simple substances.

4. **Inflammability:**
Most of the organic compounds are inflammable and burn in air to give carbon dioxide water and heat energy. Thus most fuels such as natural gas, petrol and coal are organic and their combustion or burning is our main source of heat energy.

5. **Bonding:**
Organic compounds are generally covalent in nature.

6. **Solubility:**
Most of the organic compounds are non-polar in nature so they are soluble in non-polar solvents such as acetone, ether and benzene etc. They are less or insoluble in water, which is polar.

7. **Electrical conductivity:**
Because of non-polar covalent bonds present in most of the organic compounds, they are poor conductor of electricity both in fused state and in solution form.

8. **Reactivity:**
Reactions involving organic compounds are much slower than the reactions which involve inorganic substances.

Society, Technology and Science

It was assumed that the organic compounds could only be produced by living organisms under the influence of a super natural force called *Vital Force*. In 1828, Friedrich Wohler, a German chemist, synthesized the organic substance urea in the laboratory from inorganic substance ammonium cyanate. Ammonium cyanate is obtained by heating solid ammonium chloride with solid potassium cyanate.

$$NH_4Cl_{(s)} + KCNO_{(s)} \xrightarrow{\text{heat}} NH_4CNO_{(s)} + KCl_{(s)}$$

$$\underset{\text{Ammonium Cyanate}}{NH_4CNO_{(s)}} \xrightarrow{\text{heat}} \underset{\text{Urea}}{NH_2CONH_{2\,(s)}}$$

The synthesis of urea proved that the formation of organic compound is no more dependent on the vital force and that the influence of living organism was not necessary for the production of the organic compounds.

11.2 Sources of Organic Compounds

All organic compounds, long before, were obtained from plants and animals. Many of the organic compounds are still derived directly or indirectly from these sources. Coal, petroleum and natural gas are the major sources of a large variety of organic compounds. They are called fossil fuels and are formed over a long period of time, from the decay of plants and animals.

Coal

Coal is a major source of organic compounds. It is used as a solid fuel. It yields coke and coal tar on heating at a high temperature in the absence of air. More than two hundred important organic compounds have been isolated from coal tar.

Petroleum

It is an important source of organic compounds. It is generally dark brown coloured and unpleasant smelling liquid containing a mixture of hydrocarbons. Majority of these are open chain and cyclic alkanes. After refining, it is used as a fuel. It is also used for the production of useful products such as synthetic rubber, explosives and plastics etc.

Natural gas

Natural gas is a mixture of the gaseous hydrocarbons. It consists of 85% methane and 15% ethane, propane butane. It is used as a fuel for domestic as well as for industrial purposes. It is also used for the production of many organic compounds. It is a chief source of power generation in Pakistan.

Plants

Plants are the main source of organic compounds. Most of the organic compounds are obtained directly from plants e.g Sugar, while some other are obtained indirectly from their decay and death, e.g Coal.

Synthesis in Laboratory

The synthesis of organic compound in Laboratory started a new era of organic compound. The synthesis of NH_4CNO (Ammonium Cyanate), caused the end of vital force theory.

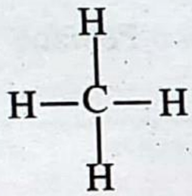
11.3 Uses of organic compounds

Organic compounds are very important. They are extensively used in our daily life e.g the food that we eat, the clothes that we wear, the natural gas that we burn for cooking and in industry are all organic compounds. Similarly the petroleum we use in our vehicle, the ink and paper that we use for writing and the drugs and medicines that we use are also organic compounds.

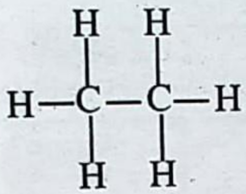
11.4 Alkanes and Alkyl Radicals

11.4.1 Alkanes:

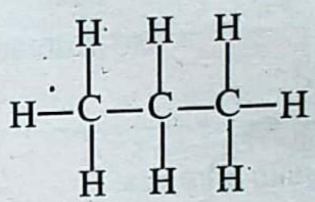
Alkanes are saturated hydrocarbons in which all carbon-carbon bonds are single covalent bonds. They have the general formula C_nH_{2n+2}, where n represents the number of carbon atoms. The first three members of this class can be represented as CH_4, C_2H_6 and C_3H_8. Their structural formulae are given below.



Methane



Ethane



Propane

11.4.1.1 Classification of Alkanes

On the basis of the structure of chain, alkanes are classified into two types.

1) Open chain alkanes
2) Cyclic alkanes

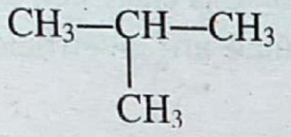
1) **Open chain alkanes:**
Compounds which consist of open chain of carbon atoms are called aliphatic compounds. They are further classified into

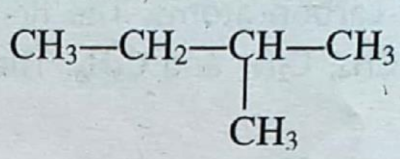
i) *Straight chain alkanes*: These alkanes contain straight chain of carbon atoms in their molecules. A carbon atom in straight chain alkanes is not linked to more than two other carbon atoms. They are commonly named as n-alkanes. For example n-Butane and n-pentane are given below.

$CH_3—CH_2—CH_2—CH_3$
n-Butane

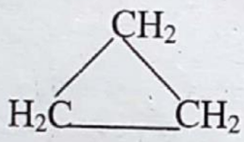
$CH_3—CH_2—CH_2—CH_2—CH_3$
n-Pentane

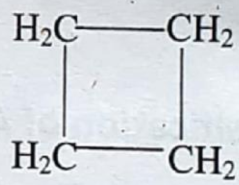
ii) *Branched chain alkanes*: As the name suggests, all the carbon atoms are not present in a linear sequence in branched chain alkanes. At least one carbon atom is linked to more than two other carbon atoms in their molecules. Their common names have a prefix iso– with the corresponding alkanes. For example iso-Butane and iso-pentane are given below.


iso-Butane


iso-Pentane

2) Cyclic alkanes:
When carbon atoms are linked in cyclic form they are called cyclic compounds. Examples are as follows.


Cyclopropane


Cyclobutane

11.4.1.2 Naming of Alkanes

Simple straight chain alkanes can be named by the following rules.

1. Count the number of carbon atoms in a formula of an alkane.
2. The first four alkanes are named methane, ethane, propane and butane. For higher alkanes write the prefixes of Greek numerals, pent, hex, hept etc for 5, 6, 7 and so on.
3. End the name by writing –ane to the Greek numerals.

The names of first ten alkanes are as follows; Methane, (CH_4), Ethane, (C_2H_6), Propane, (C_3H_8), Butane, (C_4H_{10}), Pentane, (C_5H_{12}), Hexane (C_6H_{14}), Heptane (C_7H_{16}), Octane (C_8H_{18}), Nonane (C_9H_{20}), Decane ($C_{10}H_{22}$).

11.4.2 Alkyl Radicals

The radicals or groups derived from alkanes by removal of one H-atom are called alkyl radicals or alkyl groups. They are denoted by a general symbol –R. Hence, the formula of alkyl group is C_nH_{2n+1}, where n is the number of carbon atoms = 1,2,3....The name of an alkyl group is derived from the name of corresponding alkane by replacing the –ane by –yl

Table 11.1 shows first ten members of alkanes and their corresponding alkyl radicals.

Table 11.1

C-atoms	Name of Alkane	Formula C_nH_{2n+2}	Name of Alkyl Radicals	Formula C_nH_{2n+1}
1	Methane	CH_4	Methyl	$-CH_3$
2	Ethane	C_2H_6	Ethyl	$-C_2H_5$
3	Propane	C_3H_8	Propyl	$-C_3H_7$
4	Butane	C_4H_{10}	Butyl	$-C_4H_9$
5	Pentane	C_5H_{12}	Pentyl	$-C_5H_{11}$
6	Hexane	C_6H_{14}	Hexyl	$-C_6H_{13}$
7	Heptane	C_7H_{16}	Heptyl	$-C_7H_{15}$
8	Octane	C_8H_{18}	Octyl	$-C_8H_{17}$
9	Nonane	C_9H_{20}	Nonyl	$-C_9H_{19}$
10	Decane	$C_{10}H_{22}$	Decyl	$-C_{10}H_{21}$

Activity 11.1: Name the following alkyl groups.

Activity 1

Name the following alkyl groups.

i) $CH_3CH_2CH_2-$ ii) CH_3CH_2- iii) CH_3-
iv) $CH_3(CH_2)_2CH_2-$ v) $CH_3(CH_2)_4CH_2-$

11.5 Functional Groups

An atom or group of atoms which replaces the hydrogen atom in alkane and gives the molecule its characteristic chemical properties is called functional group. The most common functional groups are –OH, –CHO, –COOH, $-NH_2$ and –X (halogens) etc. Organic compounds are composed of two parts

(i) The hydrocarbon part which is alkyl group i.e. –R.(ii) Functional group part
For example in methanol, CH_3OH, $-CH_3$ is R and –OH is the functional group.

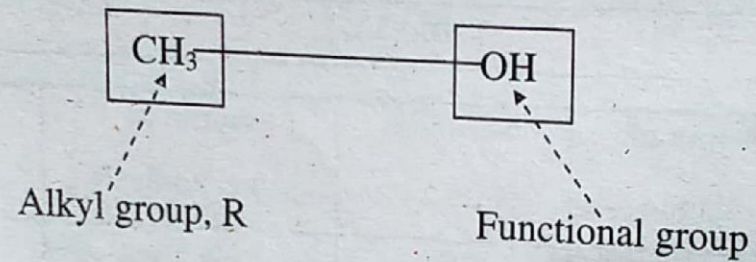


Table 11.2 represents the organic compounds containing methyl radical attached to different functional groups.

Table 11.2

Functional Group	Name of the class	Example	Name of the Compound
–OH	Alcohols	CH_3-OH	Methanol
–CHO	Aldehydes	CH_3-CHO	Ethanal
–CO–	Ketones	$CH_3-CO-CH_3$	Propanone
–COOH	Carboxylic acids	CH_3-COOH	Ethanoic acid
$-NH_2$	Amines	CH_3-NH_2	Methyl amine
–X	Alkyl halides	CH_3-Cl	Methyl chloride

11.5.1

Functional groups containing carbon, hydrogen and oxygen. Alcohols, Aldehydes, Ketones and Carboxylic acids are its examples.

11.5.2

Functional groups containing carbon, hydrogen and nitrogen. Amines come in this category, e.g., Methyl amine, CH_3-NH_2.

11.5.3

Functional groups containing carbon, hydrogen and halogen. Alkyl halides are the examples , e.g. $CH_3 - Cl$ (methyl chloride)

Activity 2

Name the class of the compounds to which each of the following belongs.

i) $CH_3CH_2CH_3$ ii) CH_3CH_2Br iii) CH_3COOH

iv) C_2H_5CHO v) CH_3CH_2OH

11.6 Homologous Series

There are millions of organic compounds and several thousand new compounds are synthesized each year. In order to study such a large number of organic compounds they are classified into various groups or series. The classification is based on the fact that all the members in a particular series possess the same functional group and have the same chemical properties. There are seven homologous series of the organic compounds. They are hydrocarbons, alcohols, carboxylic acids, carbonyl compounds, alkyl halides, amines and ethers. Table 11.1 shows a homologous series of alkanes which is the simplest of organic compounds. It is clear from table-11.1 that each member differs from its adjacent member by one CH_2 (Methylene) group. A homologous series may be defined as *a series of compounds in which adjacent members differ by a CH_2 unit.* The individual member is called *homologue*.

Activity 3

What is the next homologue of each of the following compound?

i) C_3H_8 ii) CH_3OH iii) CH_3COOH

iv) CH_4 v) C_2H_5Br vi) $C_3H_7NH_2$

KEY POINTS

- The branch of chemistry which deals with the study of hydrocarbons and their derivatives is called organic chemistry.
- The compounds which contain carbon and hydrogen as essential elements and occasionally a few other elements such as oxygen, nitrogen, sulphur, phosphorus and the halogens are called organic compounds.
- Hydrocarbons are the simplest organic compounds which contain carbon and hydrogen only, for example, methane (CH_4), ethane (C_2H_6) etc.
- A hydrocarbon is said to be saturated if it contains only single covalent bonds.
- Alkanes are saturated hydrocarbons for example, methane (CH_4), ethane (C_2H_6) etc. Their general formula is C_nH_{2n+2}.
- Alkyl Radicals are groups derived from alkanes by removing one H-atom. Their general formula is C_nH_{2n+1}.
- Functional Group is an atom or group of atoms which replaces the hydrogen atom in alkanes and gives its characteristic properties to the molecule. For example, when a hydrogen atom from methane (CH_4) is replaced by -OH, methyl alcohol (CH_3OH) is formed, which has its own characteristic properties. So –OH is a functional group which gives characteristic properties to the molecule.
- Homologous Series is a set of organic compounds containing the same elements with the same general formula and have the same chemical properties.
- Each member of the homologous series is termed as homologue.

EXERCISE

Q.1 Choose the correct answer.

i. Which of the following is organic compound.

A) CO B) CO_2
C) $NaHCO_3$ D) C_2H_2

ii. Which one of the following is the general formula of alkanes.

A) C_nH_{2n+2} B) C_nH_{2n+1}
C) C_nH_{2n-1} D) C_nH_{2n-2}

iii. The homologues have the same:

A) State B) Colour
C) Density D) Chemical properties

iv. Carbon atom usually:

A) Forms four covalent bonds B) Gains four electrons
C) Loses four electrons D) Ionizes

v. Organic radical with general formula C_nH_{2n+1} is:

A) Phenyl B) Benzyl
C) Alkyl D) Allyl

vi. The next homologue of C_8H_{18} is:

A) C_8H_{16} B) C_9H_{20}
C) C_9H_{18} D) C_7H_{14}

vii. Methane is the first member of:

A) Alkane series B) Alkene series
C) Alcohol series D) Carboxylic acids series

viii. The compound C_3H_8 must have :

A) All single bonds B) At least one double bond
C) At least one triple bond D) An ionic bond

ix. Organic compounds are originated from.

A) Air B) Rock
C) Sun D) Living organisms

x. The name of C_6H_{14} is:

A) Propane B) Heptane
C) Hexane D) Decane

xi. Which one of the following organic compounds has different chemical properties:

A) CH_3OH B) C_2H_5COOH

C) C_2H_5OH D) $C_5H_{11}OH$

xii. Which of the following is inorganic:

A) CH_4 B) CH_3OH

C) NaCN D) CH_3Cl

Q. 2 Write answers for the given questions.

i. Why organic compounds are volatile in nature?

ii. Organic compounds are insoluble in water but soluble in organic solvents?

iii. Functional group is a group of atoms but not a molecule explain.

iv. Organic substances can be made from inorganic substances.

v. Why the vital force theory was discarded?

vi. Why are hydrocarbons combustible?

vii. The chemical properties of a homologous series are always the same?

Q.3 Write long answers of the given questions.

i What is a homologous series? Give the names of alkane homologous series up to ten C-atoms.

ii. What are alkyl groups? Name and derive the alkyl groups from the first five members of alkane series.

iii. Give characteristic properties of organic compounds. Why organic compounds are placed in a separate branch of chemistry?

iv. What is organic chemistry? Briefly discuss how organic and inorganic compound differ.

Chapter

12

Hydrocarbons

In this chapter you will be able to:

- Explain why a systematic method of naming chemical compounds is necessary.
- Characterize a hydrocarbon.
- Draw electron cross and dot structures of simple alkanes.
- Write a chemical equation to show the preparation of alkanes from hydrogenation of alkenes and alkynes and reduction of alkyl halides.
- Draw structural formulae of alkanes, alkenes and alkynes up to 5 carbon atoms.
- Write a chemical equation to show the preparation of alkenes from dehydration of alcohols and dehydrohalogenation of alkyl halides.
- Write a chemical equation to show the preparation of alkynes from Dehalogenation of 1,2-dihalides and tetrahalides.
- Write chemical equations showing halogenations of alkanes, alkenes and alkynes.
- Write chemical equations showing reaction of KMnO4, with, alkenes and alkynes.

Introduction to Hydrocarbons

Hydrocarbons are considered as parent organic compounds. Hydrocarbons are the organic compounds which contain only carbon and hydrogen. They are classified as saturated hydrocarbons and unsaturated hydrocarbons.

Saturated Hydrocarbons are called alkanes and unsaturated as alkenes and alkynes.

12.1 Alkanes

Alkanes are saturated hydrocarbons. Alkane series has the general formula C_nH_{2n+2}, Where "n" is the number of carbon atoms. The carbon atom in the molecules of alkanes is bonded by single covalent bonds. Each carbon atom of an alkane is linked to four other atoms to use its four valence electrons. Hence, alkanes are saturated hydrocarbons.

Alkanes contain single covalent bonds between C-C and C-H atoms. Therefore, this class of hydrocarbons are chemically inert. They are sometimes referred to *paraffins* which is a Latin word meaning "little affinity".

The names of first ten alkanes along with their physical states, melting and boiling points are given in Table –12.1.

Table 12.1

C-atoms	Name	Formula C_nH_{2n+2}	Physical State	Melting Point (°C)	Boiling Point (°C)
1	Methane	CH_4	Gas	−183	−162
2	Ethane	C_2H_6	Gas	−172	-89
3	Propane	C_3H_8	Gas	−188	-42
4	Butane	C_4H_{10}	Gas	−138	-0.5
5	Pentane	C_5H_{12}	Liquid	−130	36
6	Hexane	C_6H_{14}	Liquid	-95	69
7	Heptane	C_7H_{16}	Liquid	-91	98
8	Octane	C_8H_{18}	Liquid	-57	126
9	Nonane	C_9H_{20}	Liquid	-51	151
10	Decane	$C_{10}H_{22}$	Liquid	-30	174

12.1.1 Preparation of Alkanes.

Alkanes are prepared by the following methods.

12.1.1.1 Hydrogenation of alkenes and alkynes:

Unsaturated hydrocarbons, like alkenes and alkynes react with hydrogen in the presence of nickel as catalyst at 200-300°C to form alkanes.
For example ethene and ethyne on reaction with hydrogen at 200-300°C in the presence of nickel form ethane.

i) $$CH_2{=}CH_2 + H_2 \xrightarrow[200\text{–}300\ ^\circ C]{Ni} CH_3{-}CH_3$$

ii) $$CH{\equiv}CH + 2H_2 \xrightarrow[200\text{–}300\ ^\circ C]{Ni} CH_3{-}CH_3$$

12.1.1.2 Reduction of alkyl halides:

Alkyl halides on reduction with nascent hydrogen (hydrogen at the time of its generation is called nascent hydrogen) form corresponding alkanes.

$$R{-}X + 2[H] \xrightarrow{Zn + HCl} RH + HX$$

For example methyl iodide gives methane on reduction.

$$CH_3{-}I + 2[H] \xrightarrow{Zn + HCl} CH_4 + HI$$

12.1.2 Properties and Important Reactions of Alkanes.

12.1.2.1 Physical properties

i) First four alkanes methane, ethane, propane and butane are gases. Next thirteen members are colourless liquids while the higher alkanes are solids.

ii) Alkanes are insoluble in water but soluble in organic solvents such as ether and acetone etc.

iii) The melting and boiling points generally increase with increase in molecular masses.

12.1.2.2 Chemical properties

Alkanes, due to their saturated nature are chemically inert at room temperature. However, at high temperatures or on absorption of light the following reactions take place. The important reactions of alkanes are as follows.

1. Halogenation

The substitution of hydrogen by halogen in alkanes is called Halogenation.
For example methane reacts with chlorine in diffused sun light to produce chloromethane.

$$CH_4 + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{Chloromethane}}{CH_3Cl} + HCl$$

The reaction does not stop at this stage. The remaining three hydrogen atoms are successively replaced by chlorine atoms to give di, tri and tetra chloromethane respectively.

$$CH_3Cl + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{Dichloromethane}}{CH_2Cl_2} + HCl$$

$$CH_2Cl_2 + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{Trichloromethane (chloroform)}}{CHCl_3} + HCl$$

$$CHCl_3 + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{Tetrachloromethane (carbon Tetrachloride)}}{CCl_4} + HCl$$

2. Combustion

Alkanes in the presence of oxygen at high temperature burn to form CO_2 and H_2O with evolution of heat

$$CH_{4\,(g)} + 2\,O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)} + \text{heat}$$

12.2 Alkenes

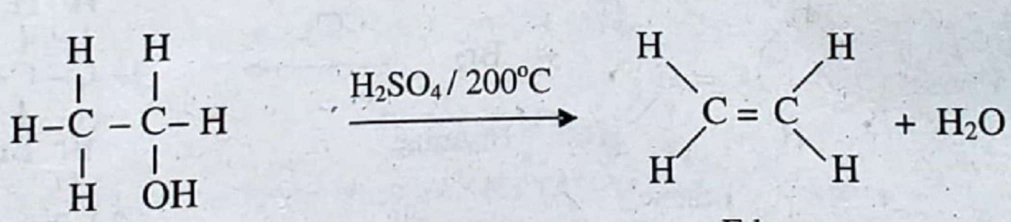
Alkenes are unsaturated hydrocarbons containing at least one double bond between two carbon atoms. The general molecular formula of alkenes is C_nH_{2n}. It is obvious from the formula that alkenes have two hydrogen atoms less than the corresponding alkanes. Alkenes also make a homologous series and each member of the series is less by a CH_2 group than its next higher member.

12.2.1 Preparation

Most of the methods of preparation of alkenes involve elimination of two atoms or groups from the two adjacent carbon atoms.

12.2.1.1 Dehydration of alcohols

When an alcohol is heated at 200°C in the presence of sulphuric acid, a molecule of water is eliminated and an alkene is formed. For example, ethyl alcohol on dehydration yields ethene.

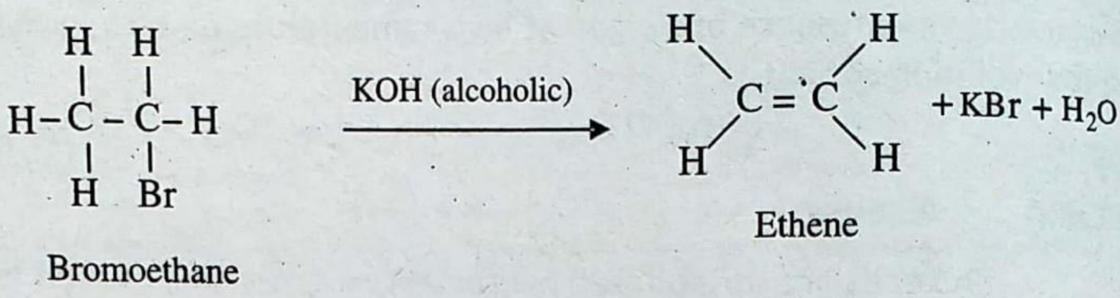


Ethene

Ethyl alcohol

12.2.1.2 Dehydrohalgenation of alkyl halides

When an alkyl halide is heated with an alcoholic solution of potassium hydroxide, a molecule of hydrogen halide is removed and an alkene is formed. In this elimination halogen is removed from one carbon and hydrogen from the other adjacent carbon atom. For example, ethyl bromide on de-hydrohalogenation, gives ethene and hydrogen bromide.

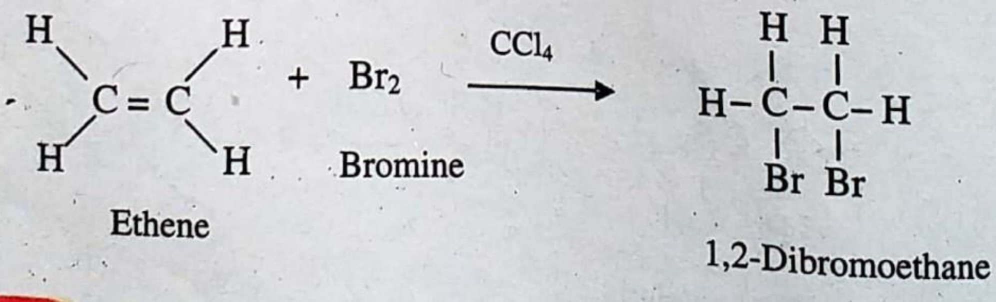


12.2.2 Important Reactions

Because of the unsaturated nature of alkenes, they easily undergo addition reactions and in this way, they are converted into saturated compounds.

1. Addition of halogens

Chlorine and bromine readily add to a double bond of alkenes, in the presence of an inert solvent like carbon tetrachloride to form dihalo compounds. It does not need any high temperature or sun light.
For example, addition of bromine to ethene decolourizes the red colour of bromine and produces 1,2-dibromoethane.



Activity 1

You have bromine solution and two gases ethane and ethene. Distinguish between these hydrocarbons.

2. **Addition of hydrogen halides**

A molecule of hydrogen halide adds to alkene giving the corresponding alkylhalide.

$$CH_2=CH_2 + HBr \longrightarrow \underset{\text{Bromoethane}}{CH_3-CH_2-Br}$$

3. **Oxidation by $KMnO_4$**

Alkenes react with cold dilute potassium permanganate solution to form glycols. Glycols are alcohols which contain two hydroxyl groups (–OH) on two adjacent carbons.

$$3CH_2=CH_2 + 2KMnO_4 + 4H_2O \longrightarrow \underset{\text{Ethylene glycol}}{3\begin{array}{cc} CH_2- & CH_2 \\ | & | \\ OH & OH \end{array}} + 2MnO_2 + 2KOH$$

Potassium permanganate is changed to manganese dioxide and potassium hydroxide so its purple colour disappears. This is a very useful test for the detection of double bond and is called *Baeyer's test.*

4. **Hydrogenation**

Alkenes readily react with hydrogen in the presences of nickel as a catalyst at 240ºC forming the corresponding alkanes. Hydrogenation is an exothermic process.

$$CH_2=CH_2 + H_2 \xrightarrow[240^\circ C]{Ni} \begin{array}{ccccc} & H & & H & \\ & | & & | & \\ H- & C & - & C & -H \\ & | & & | & \\ & H & & H & \end{array} + \text{Heat}$$

Hydrogenation of alkenes is industrially used for the conversion of vegetable oils into ghee.

Activity 2 Distinguish between propane and propene using Baeyer's test.

11.3 Alkynes

Unsaturated hydrocarbons which contain at least a triple bond are called alkynes. They have two hydrogen atoms less than the corresponding alkenes. Their general formula is C_nH_{2n-2}. Example of alkyne are Ethyne, Propyne and butyne etc.

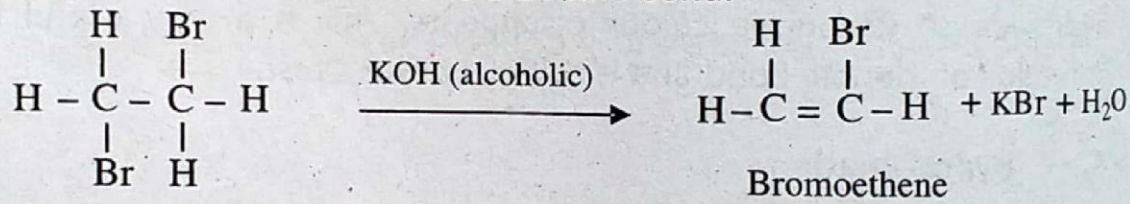
11.3.1 Preparation

Alkynes are prepared by the following methods.

11.3.1.1 Dehydrohalogenation of 1,2-dihalides

Compounds that contain two halogen atoms at the first two adjacent carbon atoms are called 1,2-dihalides. Alkynes are obtained by reacting 1,2-dihalides with alcoholic potassium hydroxide, two molecules of hydrogen halide are eliminated.

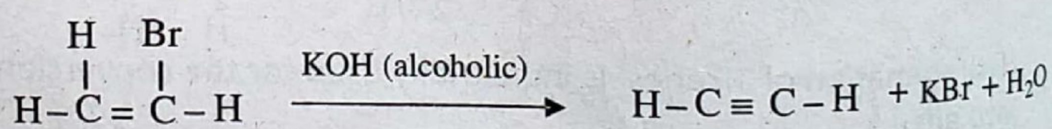
Acetylene can be prepared by this method by the reaction of 1,2-dibromo ethane with alcoholic potassium hydroxide. This reaction is completed in two steps. In the first step, one molecule of hydrogen bromide is eliminated and single bond between C-C atoms is converted to a double bond.



1,2- Dibromoethane

Bromoethene

In the second step, another molecule of hydrogen bromide is eliminated and the double bond is converted into a triple bond.



Acetylene or ethyne

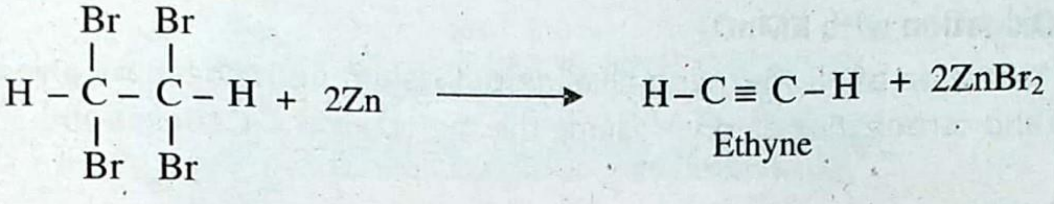
Activity 3

Synthesize acetylene from ethane.

11.3.1.2 Dehalogenation of tetrahalides

Compounds that contain four halogen atoms at the two adjacent carbon atoms are called tetrahalides.

Tetrahaloalkanes are heated with active metal like zinc dust to produce alkynes.



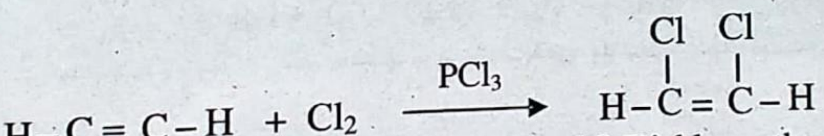
1,1,2,2–Tetrabromo ethane

11.3.2 Important Reactions

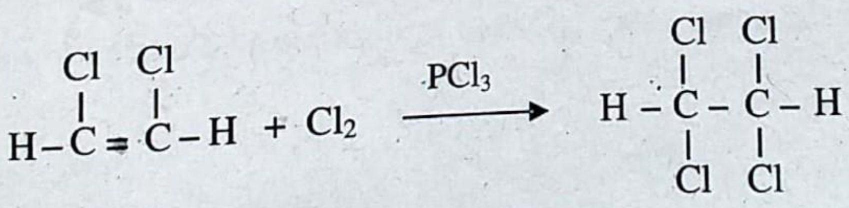
Because of the unsaturated nature of alkynes, they easily undergo addition reactions and in this way, they are converted into saturated hydrocarbons.

1. Halogenation

Addition of halogen at the double and triple bonds is called halogenation. Two molecules of halogen add to the triple bond in two steps forming a di and a tetrahalide. Chlorine and bromine react readily while iodine reacts slowly. PCl_3 is used as a catalyst.



1,2-Dichloro ethene



1,1,2,2 -Tetrachloro ethane

2. Oxidation with $KMnO_4$

The oxidation of alkynes with alkaline potassium permanganate gives carboxylic acid and carbon dioxide on breaking the molecule at C-C triple bond.

$$R-C\equiv C-H + 4[O] \xrightarrow{KMnO_4} R-COOH + CO_2$$

Society, Technoloy and Science

Hydrocarbons are currently the main source of the world's electric energy and heat sources (such as home heating) because of the energy produced when burnt. Often this energy is used directly as heat such as in home heaters, which use either oil or natural gas. The hydrocarbon is burnt and the heat is used to heat water, which is then circulated. A similar principle is used to create electric energy in power plants.

Common properties of hydrocarbons are the facts that they produce steam, carbon dioxide and heat during combustion and that oxygen is required for combustion. The simplest hydrocarbon, methane, burns as follows:

$$CH_4 + 2\,O_2 \rightarrow 2\,H_2O + CO_2 + \text{Energy}$$

KEY POINTS

- Alkanes are saturated hydrocarbons having general formula C_nH_{2n+2}
- First four alkanes are gases, next thirteen liquids while higher alkanes are solids.
- In alkanes substitution reactions take place.
- Alkenes are unsaturated hydrocarbons with two hydrogen atoms less than the corresponding alkanes.
- Alkenes are very reactive compounds. They readily undergo addition reactions and become saturated.
- Alkenes are easily oxidized by the cold and dilute solution of $KMnO_4$. It decolourizes its purple colour. This test is called the Baeyer'test, which distinguishes alkenes from alkanes
- Hydrocarbons containing a triple bond are called alkynes.
- Alkynes have a triple bond between two carbon atoms. The electron density between the two carbon atoms is very high which draws the two atoms close to each other. So the reactivity of alkynes is less than alkenes but greater than alkanes.
- Addition of halogens at the double or triple bonds is called halogenation.
- Alkynes undergo addition reactions, due to their unsaturated nature.
- Alkynes are oxidized by a solution of $KMnO_4$ to give carboxylic acids.

EXERCISE

Q.1. Choose the correct option from the given choices.

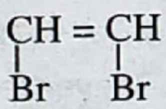
i. Dehydration of ethyl alcohol with conc. H_2SO_4 results in the formation of:

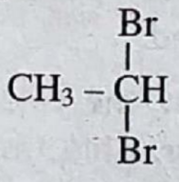
A) Ethane
B) Methane
C) Acetylene
D) Ethene

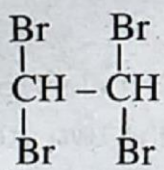
ii. Which one of the following reagents distinguishe ethene from acetylene:

A) Alkaline solution of $KMnO_4$
B) Bromine solution
C) Carbon tetrachloride solution
D) Alcoholic KOH

iii. The final product X in the following reaction is: $HC\equiv CH + 2HBr \rightarrow X$

A) 

B) 

C) 

D) $CHBr_3$

iv. Which one of the following decolourises Br_2 water:

A) Propane
B) Ethene
C) Ethane
D) Methane

v. Ethene reacts with HBr, the compound formed is:

A) CH_3-CH_2-Br
B) $Br-CH_2-CH_2-Br$
C) $CH_3-CH_2-CH_3$
D) Acetylene

vi. Which of the following statements is not true for alkynes:

A) They contain a triple bond

B) They burn to form CO_2

C) They perform Baeyer's test

D) They undergo addition reaction

vii. General formula for alkenes is:

a) $C_nH_{2n}O_n$ B) C_nH_{2n-1}

C) C_nH_{2n-2} D) C_nH_{2n}

viii. All the members of alkane series have:

A) All single bonds

B) At least one double bond

C) At least one triple bond

D) All types of bonds

ix. Baeyer's reagent is:

A) Conc. $KMnO_4$ B) Alkaline $KMnO_4$

C) Acidic $KMnO_4$ D) Hot $KMnO_4$

x. Which one gives carboxylic acid with alkaline $KMnO_4$:

A) Ethane B) Ethene

C) Acetylene D) Methane

xi. Which one gives a mixture of hydrocarbons on halogenation:

A) Ethyne B) Ethene

C) Ethane D) Ethyl alcohol

xii. Baeyer's test shows the presence of:

A) A single bond B) A double bond

C) A triple bond D) No bond

xiii. Which one is the least reactive :

A) Ethyne B) Propene

C) Ethene D) Ethane

xiv. Ethane reacts with chlorine in the presence of:

A) Carbon tetra chloride

B) Ether

C) Sunlight

D) water

Q. 2. Write short answers for the given questions.

i. Why alkane is inert in nature.
ii. What is Baeyer's test?
iii. What do you mean by saturated hydrocarbons?
iv. What are addition reactions?
v. What is alkene? Give examples.
vi. Why alkenes are more reactive than the corresponding alkane.
vii. How Ethane can be produced from ethene?
viii. Why addition reactions take place in ethene and ethyne but not in ethane.
ix. Write down two methods of preparation of alkyne?

Q.3. Write long answers of the following questions.

i. Differentiate between alkanes and alkenes. Give methods of preparation for alkanes.
ii. Give important reactions of alkenes.
iii. Give oxidation reactions of ethene and ethyne.
iv. Give important reactions of ethyne.

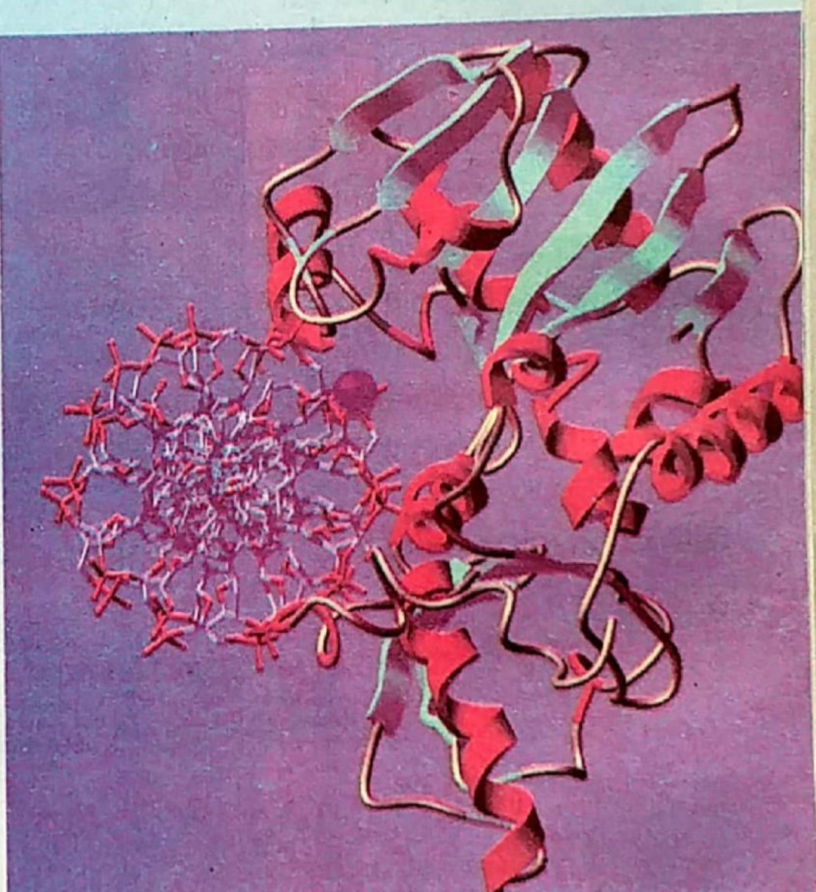
Chapter

13

Biochemistry

In this chapter you will be able to:

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



Introduction

The bodies of living organism are made up of chemical elements. The most common elements in the bodies of living organisms are carbon, hydrogen, nitrogen, oxygen, phosphorous and sulphur. The chemical analysis of protoplasm shows that it is composed of two types of compounds, i.e. organic compounds and inorganic compounds. These compounds are present in somewhat different proportions in different organisms and even in different types of cells of the same organism. Organic compounds consists of carbohydrates, proteins, lipids or fats, and nucleic acids. These are also called biological molecules.

13.1 Carbohydrates

The name carbohydrate (hydrates of carbon) is derived from the fact that the first compound of this group which was studied had a general formula of $C_n(H_2O)_n$,here "n" will take a value of either 3 or greater than 3.

They are commonly known as "Sugars" and can be defined as polyhydroxy derivatives of "aldehydes and ketones".

Thus these are poly functional (Alcohol + Aldehyde or ketone) organic compounds containing mainly carbon, hydrogen and oxygen, some times along with nitrogen (chitin) and sulphur (keratin sulfates).

Main function of carbohydrates is to support plant structure (cellulose) and to store chemical energy in the form of glycogen and starch.

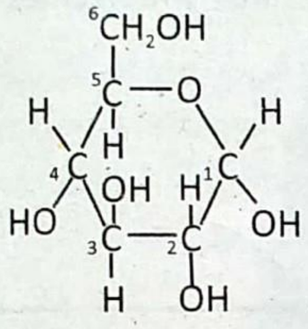
13.1.1 Classification of Carbohydrates:

Carbohydrates are classified into the following three categories.

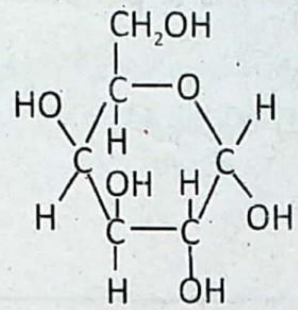
13.1.1.1 Monosaccharides:

These are simplest sugars /carbohydrates which can not be hydrolysed further. They are colourless, water soluble organic compounds, having sweet taste and general formula $C_n(H_2O)_n$ where $n = 3$, 4, 5 and so on.

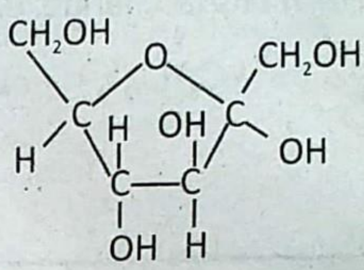
Monosaccharide are either aldoses e.g glucose having aldehydic functional group or ketoses (having ketonic functional group) e.g fructose. These may be trioses $(C_3H_6O_3)$, tetroses $(C_4H_8O_4)$, pentoses $(C_5H_{10}O_5)$, Hexoses $(C_6H_{12}O_6)\cdot$ etc



Glucose



Galactose



Fructose

13.1.1.2 Oligosaccharides:

Oligosaccharides are formed when two to nine monosaccharide units combine with each other by the loss of water molecules, resulting in the formation of glycosidic linkage.
Conversely hydrolysis of an oligosaccharide in water in the presence of an acid or enzyme yields two to nine monosaccharide units.
Those oligosaccharides which consist of two monosaccharide units are called as disaccharides e.g.

Disaccharides	**Monosaccharides**
Maltose $\longrightarrow$	Glucose + Glucose
Lactose $\longrightarrow$	Glucose + Galactose.
Sucrose $\longrightarrow$	Glucose + Fructose

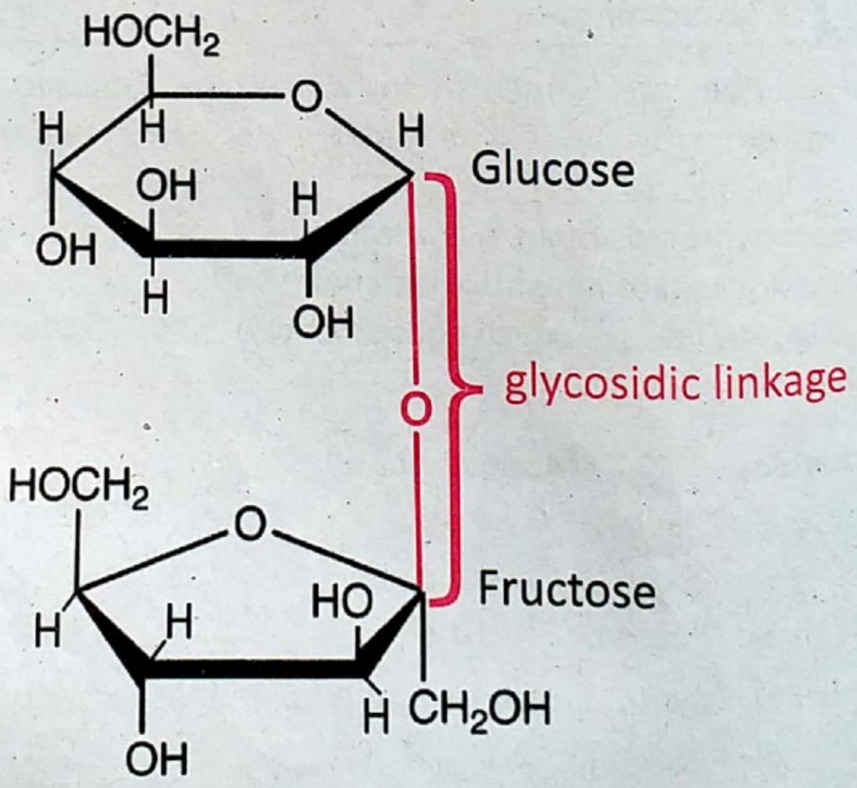
Those oligosaccharides containing three monosaccharide units are known as trisaccharides e.g. Raffinose $(C_{18}H_{32}O_{16})$ etc.
In general monosaccharides and disaccharides are crystalline solids, soluble in water, sweet in taste and are collectively known as "Sugars".

13.1.1.3 Polysaccharides:

Polysaccharides are biopolymers of monosaccharides. They have high molecular mass and consists of 100 or more monosaccharide units joined together, through glycosidic linkages. Hydrolysis of polysaccharides gives many molecules of monosaccharide. e.g.

$$\underset{\text{Starch}}{(C_6H_{10}O_5)_n} + nH_2O \xrightarrow{H^+} \left(\underset{\text{Glucose}}{nC_6H_{12}O_6}\right)$$

A glycosidic linkage or glycosidic bond, is the two-bond link between the rings in an oligosaccharide or polysaccharide.



Examples:
Starch, dextrine, Glycogen and cellulose etc.
Polysaccharides are amorphous solids, insoluble in water, tastless and are called **"non sugars".**

Polysaccharides perform two main functions in animals and plants i.e. They are used as a energy storage and structural Units of cell e.g. glycogen (animal) and starch (plant).

Society, Technology and Science

Dextrose drips are administered to the dehydrated and weak patients in clinics and hospitals. In this process oxidation of dextrose takes place in the blood and are converted into water and carbon dioxide with release of energy. That is why, it is not only the instant source of energy but also compensate the loss of water during dehydration.

13.1.2 Sources and uses of Carbohydrates:

Sources: Main sources of carbohydrates are:

- Sugarcane
- Sugarbeet
- Pineapple
- Apricot
- Mango
- Honey
- Wheat
- Rice
- Maize
- Potatoes etc.

Uses of Carbohydrates:
The following are various uses of carbohydrates.

1) **Textile Industry:** Carbohydrates like cotton are used in Manufacturing of cloths.

2) **Paper Industry:** Cellulose is the basic component of paper.

3) **Medical Uses:** Cardiac glycosides are used to normalize heartbeat. Constipation and diarrhea are mainly controlled by the use of carbohydrate fibres. Carbohydrates also act as a chief source of energy and structural components in living organisms.

Do you know!

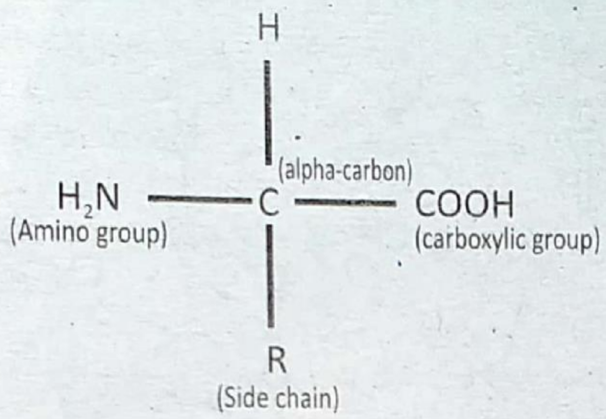
All the carbohydrates are of plant origin except lactose which is of animal origin. Sugars (mono and oligosaccharides) are soluble in water at normal conditions and give a solution but polysaccharides e.g starch are not soluble at normal conditions. Their solubility increases with heating but yet they do not give true solutions.

13.2 Proteins

The name protein is derived from Greek word "Proteios" meaning "of prime importance". Proteins are biopolymers of amino acids.

They are complex nitrogenous compounds present in living cells of plants and animals which are essential for growth and maintenance of life. Elements like carbon, nitrogen, oxygen, hydrogen and sulphur are present in proteins. Amino acids are the building blocks of proteins. All of amino acids are joined together by "peptide –linkage" in protein polymers.
Thus proteins are polyamides formed by condensation of Alpha –amino acids with a molecular weight greater than 10,000 .

Examples: Globulin , Keratin , Albumin etc.



Proteins, carbohydrates and lipids are the three important components of food stuff collectively called "Triumvirates".

13.2.1 Bonding in Protein Molecules (Amino acid as building block of protein):

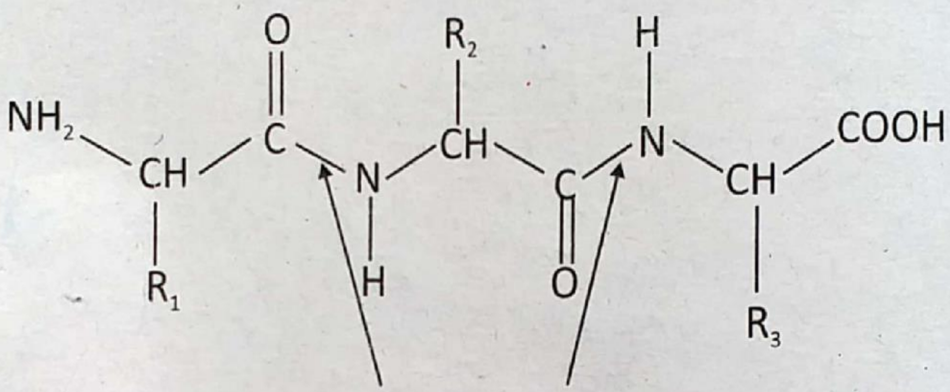
In protein molecules three types of bondings may occur i.e.

i. Peptide Bondings ii. Hydrogen Bondings

iii. Disulfide Bridges.

Protein molecules are formed due to amino acid condensation (with the removal of water molecule) giving a linear sequence of a protein polymer.

Proteins are fundamental in both the structure and function of living materials. All proteins contain four essential elements: carbon, hydrogen, oxygen and nitrogen. Most proteins also contain some sulphur. These elements are bonded together to form compounds called amino acids, which contain the COOH (carboxyl) group and amino group (NH_2). Both the COOH and the NH_2 groups are attached to the same carbon atom (alpha) carbon. Finally, each amino acid has a side chain designated as R (alkyl group). The various alpha amino acids differ in their side chains or R groups. R may be very simple, as in glycine, where it is only a hydrogen atom, or it may be very complex, as in tryptophan, where it includes two ring structures. Twenty different amino acids are commonly found in proteins.



Disulfide bridges are found only in sulfur containing protein molecules.
Due to the presence of Hydrogen bonding and sulphide bridges protein molecules get folded and refolded to give secondary, tertiary and quarternary structures.
Protein molecules may be fibrous e.g. keratin in skin & nails and globular e.g. haemoglobin and antibodies etc.

13.2.2 Sources of Proteins:

Plants and animals are the major sources of proteins e.g.
Eggs, pulses, meat, beans are the chief sources of proteins like albumins, Globulins, legumine and collagens etc.

13.2.3 Uses / Functions of Proteins:

The following are various uses of proteins e.g.

1) **Body Structures** like skin, nail, hair, hoofs, horns and feathers are composed of proteins.

2) **As oxygen Carrier:** Haemoglobin which is a blood protein is a main carrier of oxygen to all parts of the body.

3) **As Body Regulators:** Hormones and enzymes are protienaceous in nature which are chemical regulators in the body.

4) **Commercial uses of Enzymes:** Enzymes are proteins with catalytic function. It turns the starch into sugar which is less expensive than cane sugar . It also helps in improving the quality of products such as textile, detergents, foods, and beverages. Vinegar, cheese is also produced due to utilization of enzymes in bacteria and yeast.

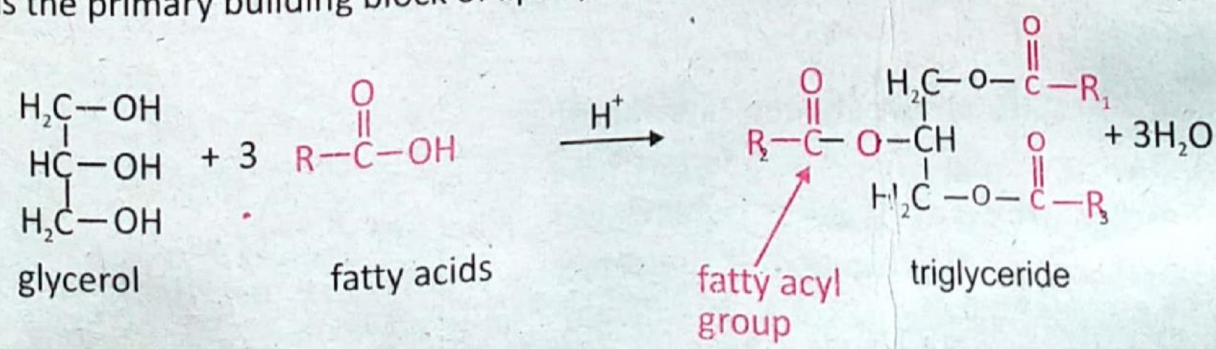
5) **Body Defence System:** Antibodies which increase the body immune power are also of protein nature.

Activity 1

(1) Take an egg.
(2) Boil it in water and see what happens.
(3) Compare and record the observation about the denaturing of protein.

13.3 Lipids

The term lipid is derived from Greek word "lipose" which means "fat". These are naturally occurring organic compounds of animal and plant origin which are insoluble in water but soluble in organic solvents like ether, chloroform, alcohol etc and belong to a very heterogeneous group of substances.
Generally "lipids are esters of long chain fatty acids and alcohols.
Thus the primary building block of lipids, are fatty acids and alcohols (glycerol).



Fats and oils are the most important lipids found in nature.

13.3.1 Classification of Lipids:

Classification of Lipids

Lipids are Classified as

Simple Lipids

Also known as triglycerides, they produce fattyacids and alcohols upon hydrolysis.
Example: Fats, oils & Waxes

Complex Lipids

Those lipids which produces fatty acids, alcohols and some other substances upon hydrolysis are known as complex lipids e.g. Phospolipids, glycolipids, sulfolipids etc.

13.3.2 Sources of Lipids:

Lipids (fats & oils) comes from a variety of natural sources like animals, plants and marine organisms. Animal fats are located particularly in adipose tissue. Butter & ghee are special type of animal fats which are obtained from milk. Vegetable oils are chiefly present in seeds and nuts of plants. Marine oils are obtained from sea animals like salmon and whales.

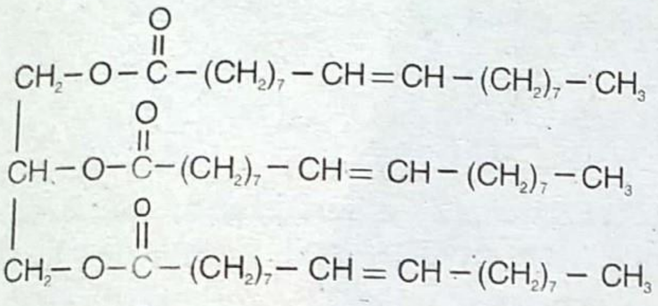
13.3.3 Uses of lipids:

The following are various uses of lipids:

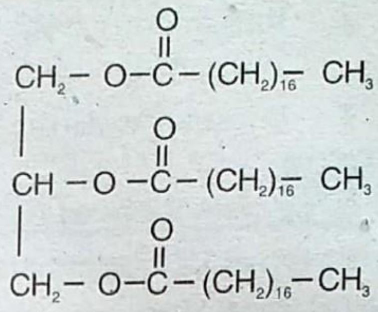
- They are good source of energy and make the food more palatable.
- They exert an insulating effect on the nervous system.
- They are good energy reservoirs in the body.
- Lipids are an integral part of cell protoplasm and plasma membrane.
- Some lipids act as precursors of very important physiological compounds. For example cholesterol is the precursor of steroid hormones.

13.3.4 Difference between Fats and Oils

Animal and vegetable fats and oils have similar chemical structures. They are triesters formed from glycerol and long chain organic acids called fatty acids. The degree of unsaturation of the constituent fatty acids determine whether a triglyceride will be a solid or a liquid. Those glycerides in which long chain saturated fatty acid components predominate tend to be solid or semisolid and are termed as fats e.g. palmitic acid. On the other hand, oils are glycerol esters which contain higher proportion of unsaturated fatty acid components e.g. (oleic acid). This difference can be illustrated by the structural formulas such as.



An oil (unsaturated)



A fat (saturated)

The melting point of mixed Glycerides mainly would depend on the number (ratio) of unsaturated fatty acid components in a molecule. It is a matter of common observation that unsaturated mustard oil (sarsoon) remains liquid while saturated bees wax is in solid state.

Society Technology and Science

Vegetable oils have unsaturated molecules. In industry these oils are converted into saturated solid fat (ghee) by a process called hydrogenation. In this process , hydrogen molecule is added at the double bond of unsaturated molecules of oils in the presence of finely divided nickel catalyst.

13.4 Nucleic Acids

Nucleic Acids were first discovered in the nuclei of pus cells in 1868 and in sperm heads in 1872 by Friedrik Miescher.They are found in every living cell as well as in viruses and have been found to be the essential components of genes. Their structure contain the blueprints for normal growth and development of each and every living organism..

These are complex biomolecules composed of units called nucleotides. Most of the nucleotides are biopolymers of nucleosides and phosphate group.

13.4.1 Types of Nucleic Acids

Naturally occurring nucleotides are of two types which gives two types of nucleic acids i.e. deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA).

13.4.2 Composition of Nucleic –Acids:

Each of nucleotides i.e DNA and RNA are composed of the following components i.e.

1. Sugar either (Ribose ⇒ in RNA) and (deoxyribose ⇒ in DNA)
2. Nitrogenous Base that is heterocyclic amine, which is either purine OR pyrimidine.
3. Phosphate –Group,

13.4.3 Functions of Nucleic Acids:

Both types of nucleic acids deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA) are formed of nucleotides which are joined together through phosphodiester linkages and performs two main functions i.e.

1. Their ability to reproduce, store and transmit genetic information.

   The genetic informations for the cell are contained in the form of specific codes in DNA molecules. These informations are translated and expressed by synthesis of specific proteins, that performs various functions in the cell according to the directions given by the codes in DNA.

   Thus protein synthesis in the cell is completed in two stages i.e. Transcription and Translation.

2. **Mutation:**

   Mutation is a sudden chemical change in a DNA (Deoxy Ribonucleic acid) molecule that could lead to the synthesis of proteins with an altered amino acid sequence.

   Changes in DNA molecules may be caused by mutagens like radiations, chemical agents or viruses.

Majority of changes in DNA are repaired by special enzymes in the cell. Failure in repair by the enzyme system can cause a mutation.

Society Technology and Science

Resin is a natural or synthetic chemical which is in highly viscous state and hardens with treatments. It is soluble in alcohol but not in water.

Natrual resin is a hydrocarbon secretion of many plants specifically of coniferous plants e.g pine sap having specific sharp smell due to the presence of terpene compounds.

Resins have a number of types depending on its chemical composition and potential uses.

Resins have a number of applications especially of polymer production.

Types of Natural Resins:

- Epoxy Resins
- Gum Resins.
- Ion –exchange Resins
- Copals, dammars & mastics

Resins may be used in varnishes, adhesives and organic synthesises.

A chemical substance that has a smell or odour is called fragrance. It gives smell when two conditions meet. The chemical compound must be volatile and much concentrated so that it interacts sufficiently with the olfactory system of nose having olfactory receptors. These compounds can be found in food, wine, spices fragrance oils and perfumes etc.

Odorants / fragrances can be added to odourless dangereous gases e.g (CH_4) in order to detect the leakage of the gas . These also help to improve the flavour & value of food.

Some natural fragrances, their occurence & smell are given as.

Esters $\Rightarrow$ ethyl Acetate $\rightarrow$ sweet fragrance $\rightarrow$ comes from wine

Terpenes $\Rightarrow$ Citrolenellal $\Rightarrow$ lemon smell $\rightarrow$ comes from lemongrass

Aromatic $\Rightarrow$ vanilline $\longrightarrow$ vanilla $\longrightarrow$ comes from vanilla.

Ketones and lactones etc.

Flavours are sensory perception of a food or other chemical substances which are determined mainly by senses of taste and smell.

The flavours of a food can be altered with addition of some natural or synthetic flavours which are known as flavourants.

Flavourants can be defined as substances that give another substance flavour, altering the characteristics of the solutes, causing it either to become sweet, sour or tangy.

Flavourants either enhance the taste, smell or colour of the food. Flavourants can be classified such as.

Natural taste –Flavourants:

- Acetic acid $\Rightarrow$ comes from vinegar $\Rightarrow$ having sour taste to food.
- Citric acid $\Rightarrow$ found in citrus fruits.
- Tartaric acid $\Rightarrow$ found in grapes and wines and gives tart taste.

Natural Smell – Flavourants:

- Ethyl propionate → having fruity smell.
- Methyl anthranalite → comes from grape.
- Iso amyl acetate → comes from banana. etc.

Natural colour Flavourants:

Some flavourants increases the value of food by highlighting its colour e.g. colour of red beverages.

13.5 Vitamins

The name vitamin was originally vitamine because the first one that was found was an amine, hence the name vital amine or vitamine. Subsequent studies of other such substances showed that they were not all amine. So, the "e" was dropped.

Vitamins are organic compounds that can not be synthesized by an organism but are very essential for the maintenance of normal metabolism and therefore must be included in the diet.The absence or deficiency of vitamins in diet results in various diseases.

Carbohydrates, fats and proteins are the three major classes of foods. To remain healthy we must take in relatively large amount of these substances. They are not, however, the only nutrients we require. Some of our needs are satisfied only by vitamins and minerals.

13.5.1 Type of vitamins

Vitamins are of two main types	
Fat soluble vitamins.	Water soluble vitamins.
Vitamins A,D,E and K.	Vitamins B –Complex and C.

Fats soluble vitamins:

Vitamin A:

Vitamin A may be obtained from green vegetables and fruits, fish liver oil, eggs, butter, cheese etc.

Vitamin A is not found in plants as such. It is present in the form of pro vitamin such as β carotene. Vitamin A combines with a protein called opsin to produce a light absorbing compound called rhodopsine. Its deficiency causes night blindness which is inability of a person to see in dim light.

Vitamin D:

Vitamin D is also known as calciferol due to its role in calcium metabolism. The liver oils of fish, milk, vegetable and butter contain good amount of vitamin –D. Vitamin D helps in the absorption of calcium and phosphate from intestine and deposits it in skeleton. Its deficiency produces a disease called rackets.

Vitamin E:

Vitamin E also called "Tocopherols" which means fertility. The main sources of vitamin E are vegetable oil, corn oil, soyabean oil, egg yolk, liver etc. Vitamin -E has also different types. It is used as an antioxidant. It has a major role in reproduction. Its deficiency causes Anemia due to destruction of cell membrane of RBC by oxidation.

Vitamin K:

Vitamin K is a factor related to blood clotting. Its main sources are cabbage, cauliflower, spinach, tomatoes, cheese, meat, egg yolk. Some microorganism synthesize vitamin k in intestine. The defficiency of vitamin k causes hemorrhage in which the blood fails to clott and thus increases the bleeding time.

Water soluble vitamins:

Vitamin B:

Vitamin B is not a single vitamin but consist of vitamin $B_1, B_2, B_3, B_6, B_{12}$ etc. Therefore it is called vitamin B complex. Vitamin B_1 (thiamine) deficiency produces a disease called beriberi which results in loss of weight, nervous disorder. Vitamin B_2 (Riboflavin) is present in milk, meat, fish, eggs, and leafy vegetables. Its deficiency causes inflammation of lips, dryness and burning of eyes. Vitamin B_6 (pyridoxine) is important for fats and protein metabolism. Its deficiency causes anemia.

Vitamin C:

Vitamin C is also known as Ascorbic acid. Most of the animals can synthesize it but human being can not do so due to absence of enzyme.

The main source of vitamin C is citrus fruit such as lemon, orange, strawberries but cereals contain no vitamin C. Its deficiency causes scurvy disease which is characterized by pain in joints and bleeding from gums.

KEY POINTS

- Carbohydrates are polyhydroxy aldehydes and ketones.
- Carbohydrates are classified as monosaccharides, oligosaccharides and polysaccharides.
- Proteins are biopolymers of amino acids.
- Three types of bonding i.e peptide-bonding, hydrogen bonding and disulphide bridges are present in protein molecules.
- Lipids are esters of long chain fatty acids and alcohols.
- Fats and oils are the most important lipids found in nature.
- Deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA) are the two types of nucleic acid.
- Main source of vitamin C is citrus fruit.
- Vitamin A, D, E, K are fats soluble and vitamin B complex and vitamin C are water soluble.
- Deficiency of vitamin causes different diseases.

EXERCISE

Q.1 Select correct answer from the given choices.

i. Polyhydroxy compounds of aldehyde and ketones are called.

   I. Carbohydrates
   II. Protein
   III. Lipids
   IV. Vitamin

ii. Wheat,Rice and honey are the sources of

   I. Vitamins
   II. Proteins
   III. Carbohydrates
   IV. Lipids

iii. ——Is a basic component of paper industry

   I. Cellulose
   II. Maltose
   III. Glucose
   IV. Lipids

iv. Polymers of Amino acid are ______.

   I. Vitamins
   II. Proteins
   III. Lipids
   IV. Carbohydrates

v. Nucleic acids are of ______ types

   I. Two
   II. Three
   III. Four
   IV. Five

vi. Vitamin ______ is called ascorbic acid

   I. A
   II. B
   III. C
   IV. E

vii. Fats and oils are called ______

I. Carbohydrates

II. Lipids

III. Proteins

IV. Vitamins

viii. ______ Is a factor related to blood clotting

i. Vitamin A

ii. Vitamin B

iii. Vitamin C

iv. Vitamin K

Q.2 Write short answers to the following questions.

i. Describe some of the sources and uses of carbohydrates.

ii. Explain Bonding in protein – molecules in your own words.

iii. What is meant by denaturing of proteins, explain.

iv. Describe difference between fats and oils.

v. Write brief composition of Nucleic acid.

Q.3 Comprehensive questions.

i. What are carbohydrates? Explain classification of carbohydrates.

ii. Describe proteins, the nature of bonding in protein and their uses.

iii. Explain lipids with the classification, sources and uses.

iv. What are Nucleic acids? Describe their types, composition and functions.

v. What are vitamins and how are they classified?

Chapter

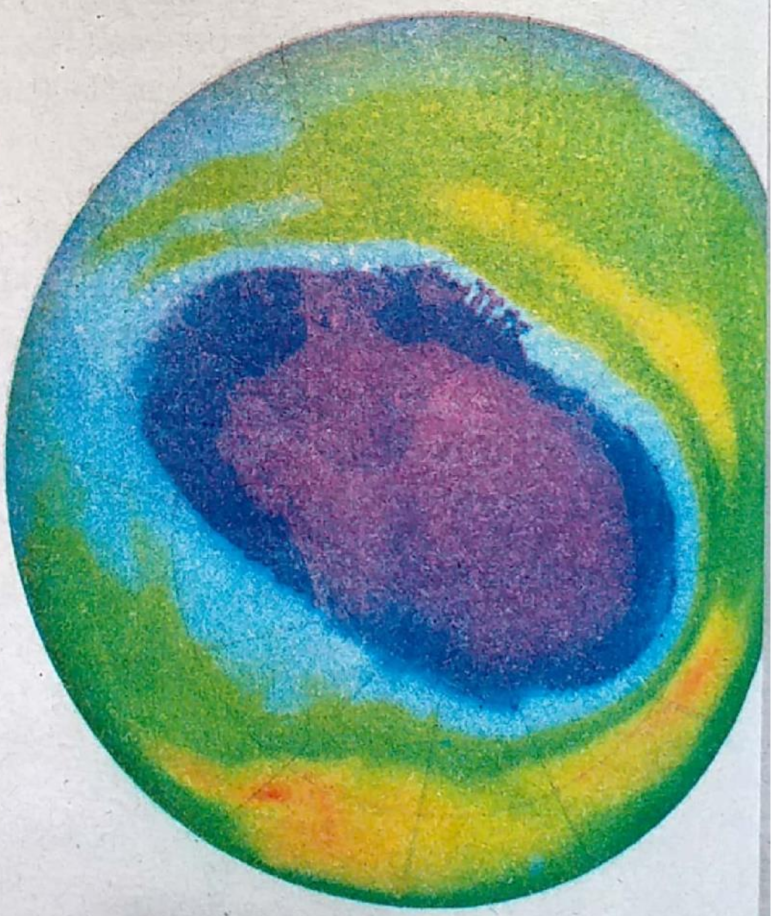
14

Environmental Chemistry I

(The Atmosphere)

In this chapter you will be able to:

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



Introduction

Approximately 4.5 billion years ago, the earth at the time of its formation was a hot mass which could not sustain life. With the passage of time it cooled gradually and due to the condensation of steam into water, the formation of atmospheric gases and ozone layer in the atmosphere (stratosphere) made the earth suitable for life.

The branch of chemistry which deals with the study of environment and the changes occurring in it, is termed as environmental chemistry.

The environment is composed of

a = Lithosphere	b = Hydrosphere
c = Biosphere	d = Atmosphere

Atmosphere

Atmosphere is the protective blanket of the air around the earth surface. It is a mixture of different gases like N_2, O_2, CO_2, Ar etc.

14.1 Composition of atmosphere

The atmosphere is very important segment of the environment because it is responsible for sustaining the life on earth as it absorbs the dangerous cosmic and uv (Ultra-violet) radiations coming from the sun. The major constituents of atmosphere are N_2 and O_2. Its minor constituents are CO_2 and Ar (Argon) and some trace gases.

The mass of atmosphere is approximately 4.5 to 5×10^{15} metric tones. The temperature and pressure of atmosphere changes with the increase in altitude. The temperature ranges from $-92°C$ to $1200°C$. The pressure of atmosphere at the sea level is 1 atm but at high altitude (about 100 km) above the sea level it decreases to 3×10^{-7} atm, the density of atmosphere is 0.0013 g/cm^3, which gradually decreases with altitude.

14.2 Layers of Atmosphere

The total height of atmosphere from the earth surface is about 500 km. Atmosphere can be divided on several basis but the most important division is on the basis of temperature and density. The atmosphere can be divided into the following four layers or zones.

1. Troposphere.
2. Stratosphere.
3. Mesosphere.
4. Thermosphere.

14.2.1 Troposphere:

It is the lowest layer of atmosphere which is close to the earth surface. The average height of this layer from the earth surface is about 11 km. Its height depends upon the latitudes, seasons and pressure.

At equator its height from the earth surface is 16 km and at 45° Latitude is 9.65 km while its average height from the earth surface is 10 to 11 km. The change in temperature of atmosphere with increase with height is called "Lapse rate". If the temperature decrease with height, it is called "negative lapse rate" while temperature increase with height is called "positive lapse rate".

The change from positive lapse rate to negative lapse rate" at the troposphere is called "temperature inversion".

Most of the weather phenomena takes place in troposphere. The cloud formation also takes place at the top of troposphere.

The temperature range is from 60 to $-56^\circ C$.

Major components of troposphere are N_2, O_2, CO_2 and H_2O vapours. It constitutes about 70% of the atmosphere.

14.2.2 Stratosphere:

It is the second layer of atmosphere which is above the troposphere. The stratosphere extends from 11 km to 50 km $(39\,km)$. The major component of stratosphere is ozone "O_3". Therefore, it is also called "ozonosphere"

The concentration of ozone increases with the increase of height and is maximum at 30 km. The stratosphere shows positive lapse rate because the temperature increases from $-56^\circ C$ to $-2^\circ C$ with height. The increase in temperature is due to the presence of ozone which absorbs the uv-radiations of the sun.

The stratosphere absorbs uv radiations, thus protecting living organisms on earth surface from harmful effects of the uv radiations.

14.2.3 Mesosphere:

The third layer of atmosphere above stratosphere is called mesosphere. Its height is from 50 km to 85 km. The major components of this region are O_3^+ and NO^+.

The decrease in temperature from $-2°C$ to $-92°C$ with increasing height is due to low level of U.V absorbing species like O_3.

14.2.4 Thermosphere:

The fourth zone of atmosphere just above mesosphere is thermosphere. This layer ranges from 85 to 500 km. The temperature increases from $-92°C$ to $1200°C$ with increase in height and shows positive lapse rate. The increase in temperature is due to the absorption of uv –radiations by different gases. After absorption of radiations, they undergo ionization process.

$$O_2 \xrightarrow{h\upsilon} O_2^+ + e^-$$

The important components of thermosphere are O_2^+, NO^+, O^+ etc.

Due to the presence of ions, the thermosphere is also called ionosphere.

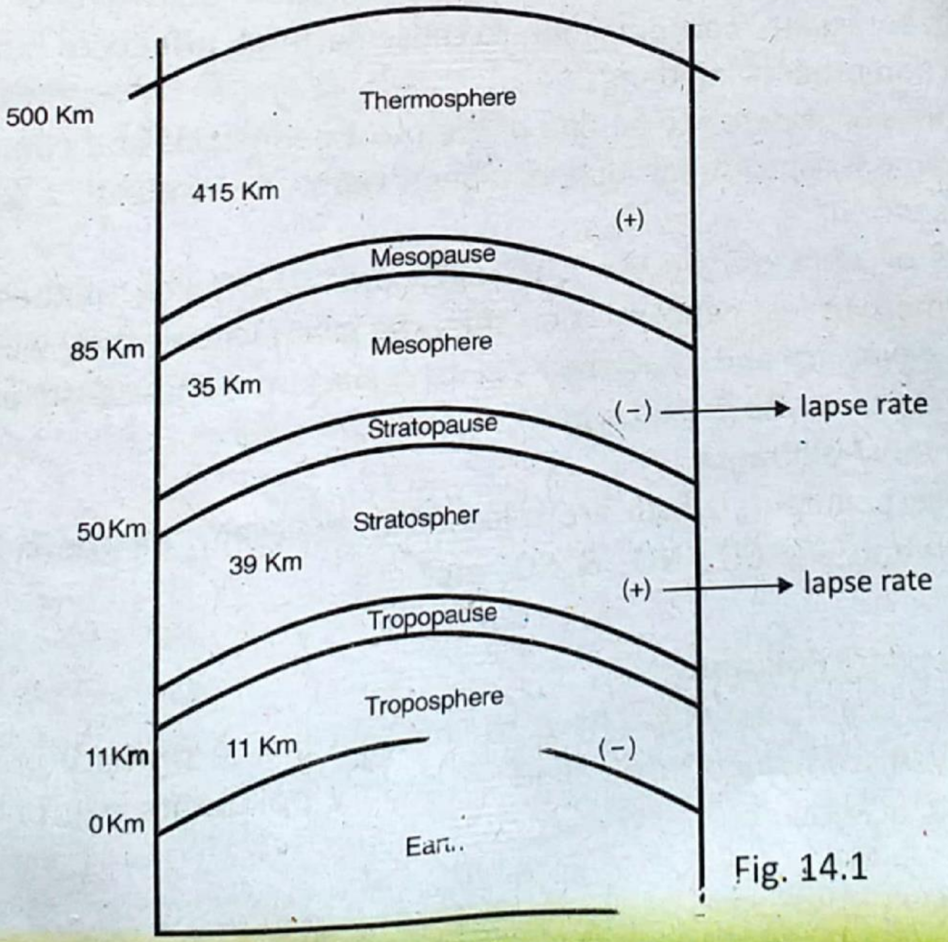


Fig. 14.1

Importance of Atmosphere

Atmosphere plays an important role for living organisms as.

1: It protects earth by absorbing dangerous cosmic rays of the sun.

2: It plays a role in maintaining the heat balance of earth by absorbing the heat radiations reemitted by earth surface.

3: Atmosphere allows visible radiations coming from the sun as a result we can see. If atmosphere did not allow the visible radiations then we would not be able to see any thing.

4: It is the main source of different gases which are important for life i.e. oxygen which is essential for life on earth. Carbon dioxide is essential for plants photosynthesis and nitrogen is also useful macro nutrient for plants.

5: Atmosphere is a vital carrier of the water from oceans to land which is very important for hydrological cycle.

14.3 Air Pollution

According to world Health organization (WHO), air pollution may be defined as.

"The substances released to air either by human activities or by natural activities, in sufficient concentration to cause harmfull effects to human beings, vegetation and other living things."

Air pollution is considered to be one of the most dangerous and common kind of the environmental pollutions that has been reported in most of the industrial parts of the world.

Air consists of 21 % oxygen, 78 % nitrogen and 0.03% CO_2. If these gases are present in more or less concentration than the given values, they will be harmful for living organisms and thus they act as pollutants and cause air pollution.

Major air pollutants are of two types.

i. Primary Pollutants:

Those pollutants which are released directly into air are called primary pollutants e.g. CO_2, NO_2 & SO_2 etc.

ii. Secondary Pollutants:

Those pollutants which have their origin in the primary pollutants and derived from them are called secondary pollutants e.g. photochemical smog ,acid rain etc.

The pollutants may be classified on the basis of state of matter.

1. Particulates: These are the small particles of liquids and solids.
2. Gaseous pollutants: The different gases present in air act as pollutants are CFC, CO, NO, NO_2, SO_2 etc.

14.3.1 Sources of Air pollution

A: Sources of Particulate Pollutants

There are two major sources for the emission of the particulate matter which are.

1. **Natural Sources:**

   The natural sources for particulate pollutants emission are volcanic eruption, soil erosion by wind, dust storms, natural forest fires and salt spray from oceans.

   The contribution of the natural sources towards the particulate emission is greater than man made sources. It has been estimated that natural sources release 800 – 2000 million tonnes of particulate matter per year in air.

2. **Anthropogenic Sources:**

   The anthropogenic or man made sources are the combustion of fuels, wood, construction, mountain blasting, mining and other industrial processes.

   It has been estimated that man made sources release 200 – 400 million tonnes of particulate matter per year.

   The most common anthropogenic source is fly ash from power plants, smelters and smoke from incomplete combustion processes.

B: Sources of Gaseous Air Pollutants:

1: Carbon monoxide

a. **Natural Sources:**

   The contribution of natural sources towards carbon monoxide (CO) emission is not much greater. The natural sources are volcanic eruptions, natural gas emission, electrical discharges during storms, seed germination and marsh gas production etc.

b. **Anthropogenic Sources:**

Most of the CO production results from the human activities.

It has been estimated that about 75% of CO emission results from automobiles due to internal combustion engine. Another major contributor of CO emission is the forest fires (16.9%) and agricultural burning (7.2%).

The third contributor is the iron and steel industries (9.6%). Cigarette smoke also contains fairly highly concentration of CO. Therefore, smoking is also a contributor of CO emission.

2: Oxides of Nitrogen:

Besides the free nitrogen (N_2) different oxides of nitrogen e.g. Nitrous oxide (N_2O), Nitrogen dioxide (NO_2) and nitric oxide (NO) are also present in the atmosphere.

The concentration of nitrous oxide (N_2O) is higher than the other two oxides of nitrogen.

Sources:

Both the natural and anthropogenic sources are responsible for the emission of oxides of nitrogen.

a: **Natural Sources:**

The natural sources for emission of oxides of nitrogen are soil, bacteria and other microorganisms. e.g. pseudomonas bacteria convert atmospheric N_2 gas into oxides of nitrogen.

It is important that the contribution of natural sources towards NO_x emission is greater than anthropogenic sources. It has been estimated that natural sources release about 5×10^8 tonnes of NO_x per year.

b: **Anthropogenic Sources:**

The man made sources responsible for the emission of oxides of nitrogen are automobiles, industries, furnaces, thermal power plants and the most important are the emission from jet engine aeroplanes.

3. Sulphur Oxides SO_x :

Another cause of air pollution is the presence of two colourless gaseous compound i.e. Sulphur dioxide (SO_2) and Sulphur trioxide (SO_3).

a. Natural Sources of SO_x :

The natural sources contribute more pollution of SO_x than man made sources. Out of total SO_x emission 67% is the result of natural sources.

The natural sources are volcanic eruptions, rocks weathering, sulphate spray from oceans and other biological activities. These sources emit either SO_2 or H_2S which then oxidizes to SO_2 as.

$$2H_2S + 3O_2 \longrightarrow 2SO_2 + 2H_2O$$

b. Anthropogenic Sources:

About 33% of total SO_x pollution is caused by man made sources.

The combustion of fossil fuels i.e. coal and oil is the major cause for SO_x emission because these are contaminated with sulphur. Out of 33% about 75% is contributed by these combustion processes. Other man made sources are transportation (2%,) industries (22%) and combustion of other sulphur containing compounds (1%.)

14.4 Acid Rain

Normal rain water which is slightly acidic because of dissolved CO_2 has a pH of 5.6.

During thunder storms, the PH of rain water can be much lower due to nitric acid (HNO_3) and sulphuric acid (H_2SO_4) formed by lightning.

The rain having pH less than 5.6 is called acid rain. Rain with low pH as 2.1 has been reported. This value is lower than the PH of vinegar and lemon juice.

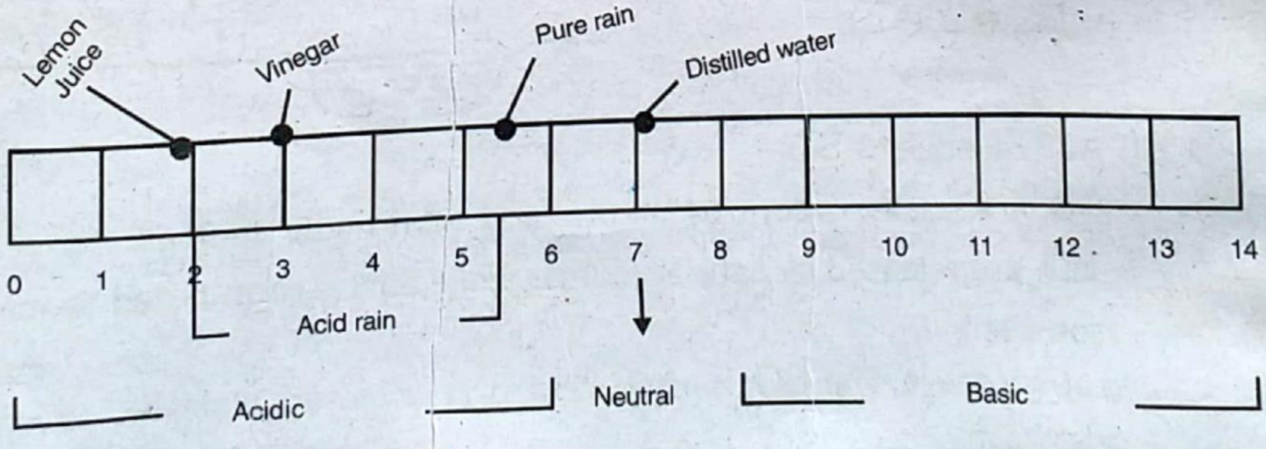


Figure: pH *of acid rain*

In common language the acid rain means the excessive acid in rain water, it is one of the adverse effects of the air pollution.

The energy sources release different pollutants in air which are then converted to different acidic compounds causing increase in acidity of the rain water.

14.4.1 Mechanism:

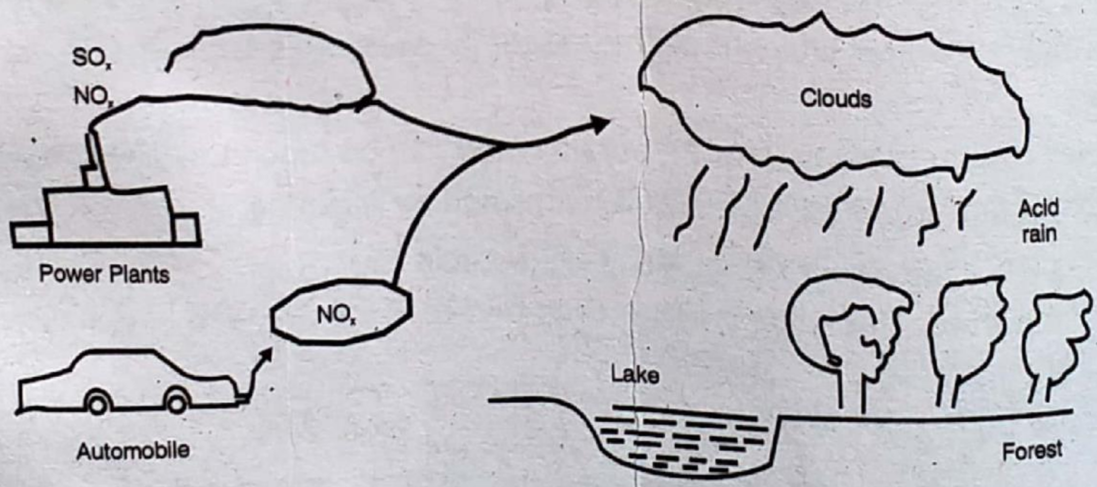
The atmosphere is always loaded with different types of the pollutants like oxides of sulphur "SO_x" oxides of Nitrogen " NO_x " and other organic compounds.

Every energy source that we use like coal, wood and oil contain sulphur (S) nitrogen (N) and other hydrocarbons. When these fuels are burnt in the air then these are converted into their respective oxides as sulphur to SO_x and nitrogen to NO_x.

These oxides are highly soluble in rain water and thus react with rain water producing different acids as

SO_x are converted to H_2SO_4 and NO_x to HNO_3

The organic compounds are oxidized to CH_3COOH.



1. Acid rain due to SO_x.

   SO_x are released both by natural and man made sources. About 67% of SO_x are released by natural sources while 33% is contributed by man made sources

In atmosphere. The SO_2 is oxidized to SO_3.

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

The SO_3 is highly reactive and soluble in rain water producing H_2SO_4.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

2. Acid Rain Due to NO_x

The other major source of acid rain is NO_x.

About 5×10^8 tones of NO_x are released by natural sources and about 5×10^7 tones of NO_x are released by man made sources every year.

The NO_x are converted to HNO_3 as

$$NO + O_3 \xrightarrow{hv} NO_2 + O_2$$

$$NO_2 + O_3 \longrightarrow NO_3 + O_2$$

$$NO_2 + NO_3 \longrightarrow N_2O_5$$

$$N_2O_5 + H_2O \longrightarrow 2HNO_3$$

3. **Acid rain due to CO_2**

$CO_2 + H_2O \longrightarrow H_2CO_3$ carbonic acid.

14.4.2 Effects of Acid Rain

1. **On Human:**

In human, the acid rain mainly causes damage to lungs, skin and hair. The heavy metals released by acid rain may also cause potential threat to human health. Acid rain also increases the acidity of water which gives rise to "water borne diseases".

2. **On Plants:**

Plants are also damaged by acid rain. It destroys the leaves of the plants. The young plants specially the newly growing buds and tips are seriously damaged by acid rain. Thus growth of plants is affected by acid rain.

3. **On Soil:**

The acid rain leads to increase the acidity of soil and thus affects the availability of plant nutrients.

4. **On Aquatic Life:**

The aquatic life for example fishes, plants and other microorganisms are very sensitive to acidity. They are greatly damaged by acid rain e.g. H_2SO_4 and particles of Cd and Pb are deposited on the snow and when it melts, the pollutants enter the rivers and lakes. This occur at a time when fish spawing and hatching take place, thereby destroying the fish eggs.

5. **Effects on Materials:**

Acid rain causes extensive damage to buildings and sculptures as well as other things made of limestone and marbles as.

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + CO_2 + H_2O$$

The $CaSO_4$ is soluble in water and washed away with rain water. The deformation of historical statues in Greece and Italy was reported to be due to acid rain. The Taj Mahal in India faces the same fate at present.

14.5 Ozone

Ozone is an allotropic form of oxygen containing three chemically bonded oxygen atoms and its molecular formula is O_3.

The word "ozone" is derived from Greek word meaning smell and the name ozone was given due to its irritating odour. Two forms of oxygen are found in the stratosphere. Molecular oxygen (O_2), which is made up of two atoms of oxygen (O), and ozone (O_3) which is made up of three oxygen atoms. Ozone is formed when intensive ultraviolet radiation from the Sun breaks down O_2 into two oxygen atoms. These highly reactive oxygen atoms can then react with more O_2 to form O_3.

$$3O_2 \xrightarrow{uv} 2O_3$$

14.5.1 Characteristics of ozone.

i. It is bluish in colour.
ii. It has a characteristic smell.
iii. It is respiratory irritant if present excess in air.
iv. Ozone is soluble in water, turpentine oil, glacial acetic acid, and carbon tetrachloride.
v. It can be liquefied at $-112.4°C$ which has pale blue colour.
vi. Ozone causes rubber to harden and crack.

14.5.2 Occurrence of Ozone:

Ozone is an important specie present in stratosphere. In stratosphere its concentration increases with increase in height and at about 30 km it reaches to its maximum value of 10 ppm (parts per million)

Due to the presence of Ozone the stratosphere is also called ozonosphere. If all the ozone around the earth surface is condensed, it will form a layer of 2.5mm thickness on earth surface. Ozone is also found over densely populated cities but here it works as pollutant and causes respiratory irritation.

14.5.3 Ozone Depletion

The decrease in the concentration of ozone in stratosphere below its normal or natural level is termed as "ozone depletion" or The formation of hole in ozonosphere (ozone layer) is also called ozone depletion.

Ozon depletion results from the human activities as well as natural phenomena which release many pollutants and other chemical species in the atmosphere. These species react with the ozone layer in the stratosphere and decrease its concentration. The ozone layer is also destroyed by chlorine released due to volcanic activity. Chloro fluoro carbon (CFC) is the main lethal compounds which have been implicated in accelerated depletion of ozone layer. CFC originates from industrial, commercial and house hold appliances.

1. Ozone depletion due to NO_x

Three types of oxides of nitrogen are found in atmosphere e.g. NO (nitric oxide), N_2O (nitrous oxide) and NO_2 (nitrogen dioxide).

These oxides may react with ozone photochemically and cause its depletion.

$$NO \xrightarrow{h\nu} \dot{NO}$$

$$\dot{NO} + O_3 \longrightarrow NO_2 + O_2$$

2. Ozone depletion due to atomic (nascent) oxygen

The atomic oxygen as produced by the following reaction.

$$O_2 \xrightarrow{h\nu} O + O$$

This atomic oxygen is very important and consumes about 18% of the O_3 found in atmosphere.

$$O_3 + O \longrightarrow 2O_2$$

3. Ozone Depletion due to oxides of sulphur

Two types of oxides of sulphur are present in atmosphere SO_2, SO_3 out of both the oxides of sulphur, SO_2 may undergo photochemical reaction with O_3 and causes it dissociation as.

$$SO_2 \xrightarrow{hv} \dot{S}O_2$$

$$\dot{S}O_2 + O_3 \longrightarrow SO_3 + O_2$$

14.5.4 Adverse Effects of ozone Depletion

Both living organisms (plants and animals) as well as materials are greatly affected by ozone depletion. Some of the effects are given below.

1. **Effect on Human and Animals:**
   Due to ozone depletion cosmic rays and uv radiations come on earth surface and cause serious problems for both human and animals.
   In minor cases, these radiations cause sun burn disease but in major cases damage the skin tissues and causes skin cancer which kills about 12000 people each year in U.S.A.
   It has been estimated that 1% decrease in ozone causes 5% increase of skin cancer. Similarly these radiations also cause an eye disease known as "CATARACTS". It has been estimated that 12 million people have become blind due to this disease and about 18 million have lost a part of their eye sight. It also causes pulmonary edema and even death.
   Similarly, pink eye and eye cancer cases are also found in cattles when they are exposed to uv radiations by ozone depletion.

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Many people would like to believe that waste disappears when it is burnt. In fact the burnt waste is transformed into ashes and gas. (A large incinerator produces the equivalent of 300 wheelie bins of exhaust gases from its chimneys every second). As this happens, chemical reactions lead to the formation of hundreds of new compounds, some of which are extremely toxic. The number of substances released from a waste incinerator may run into thousands. So far, scientists have identified a few hundred substances as hazardous. Incinerator plants are the source of serious toxic pollutants e.g. dioxins, furans, acid gases, particulates, heavy metals and they all need to be treated very seriously.

2. **Effect on Marine Life:**
The cosmic and uv radiations are highly energetic. They penetrate water (about 20 m) and kill the micro organisms present there in water which are more sensitive to these radiations.

3. **Effect on Crops:**
Ozone depletion causes an adverse effect on the production of crops. UV radiations when passes through ozone layer decrease crop production e.g. It has been estimated that 25% increase in UV radition decrease 25% soya been crop product. UV radiation also affect young tobacco and tomato crops.

4. **Effect on Materials:**
With decrease in ozone layer, the uv radiations reaching the earth surface increase and thus reduce the life time of different commonly used synthetic materials like plastics, cotton nylon and Styrofoam etc.
It causes rubber to harden and crack. Thus shortening the life of automobiles tyres and other rubber items.
Due to ozone depletion, the temperature of the earth surface increases and causes "Global warming".

14.6 Global warming

The gradual increase in the average temperature of earth surface due to emission of green house gases.

Global warming is caused by increasing concentration of green house gases produced by human activities such as deforestration and burning fossil fuel. Green house gases include CO_2, CH_4, NO_2 and O_3.

These gases act like a a green house around the earth. They let the visible and ultraviolet rays from the sun into atmosphere. But does not allow the heat to escape back into space. So this entrapped heat causes global warming.

Global warming adversely affects the climate, sea level, ozone layer, crop yield, precipitation (rain and snow fall) and health.

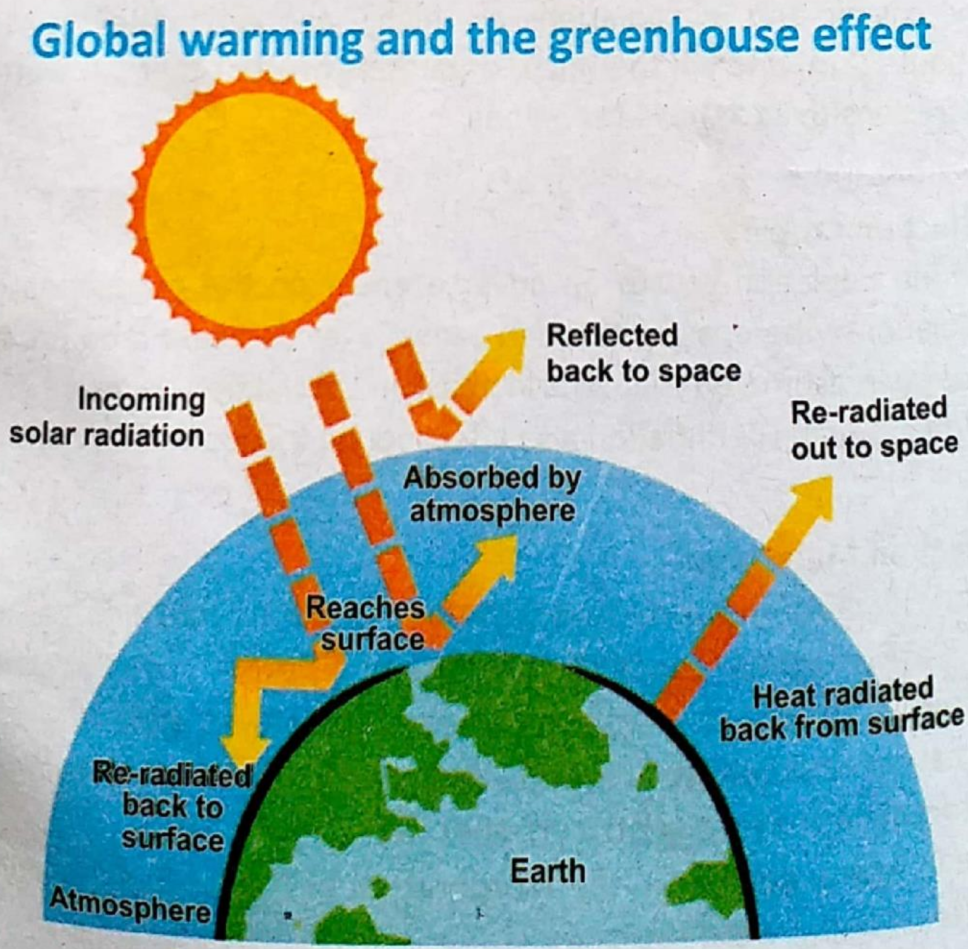


Fig. 14.3

KEY POINTS

- Approximately 4.5 billion years ago the earth was a hot mass which could not sustain life.
- The environment is composed of lithosphere, hydrosphere, biosphere and atmosphere.
- Atmosphere is the protective blanket of the air around the earth surface.
- N_2 and O_2 are major components while CO_2 and Argon are minor components of atmosphere.
- The temperature and pressure of atmosphere changes with increase in height.
- Atmosphere can be divided in four layers or zones i.e. Troposphere, Stratosphere, Mesosphere and Thermosphere.
- The substances released to air by human activities or natural activities which causes harmful affect to human or vegetable are called air pollutants.
- Pollutants are of two types. Primary pollutants and Secondary pollutants.
- Acid rain has a P^H less than 5.6.
- Ozone is an allotropic form of oxygen having molecular formula O_3.
- The formation of hole in ozone layer is called ozone depletion.

EXERCISE

Q.1 Select the suitable option.

i. The major component of troposphere is

a. Argon   b. Nitrogen

c. Hydrogen   d. Carbon

ii. The coldest region in atmosphere is

a. Troposphere   b. Stratophere

c. Mesosphere   d. Thermosphere

iii. Ozone depletion causes

a. Blood cancer   b. Skin cancer

c. Maleria   d. T.B

iv. The PH of acid rain is less than

a. 14   b. 10

c. 7   d. 5.6

v. Ozone is __________ gas.

a. Greenish   b. Yellowish

c. Bluish   d. Redish

Q.2 Write Short answers:

i. What is environmental chemistry.

ii. Write short note on stratosphere.

iii. Effect of acid rain on building materials.

iv. What is the importance of atmosphere.

v. List the physical properties of ozone.

iv. What are primary and secondary Air pollutants.

Q.3 Write Long answers:

i. Explain the composition and layers of atmosphere?

ii. What is air pollution explain the major sources of air pollution.

iii. What is ozone depletion? Write its mechanism.

iv. Discuss Acid rain. How does it affect environment.

v. How does ozone depletion adversely affect our life?

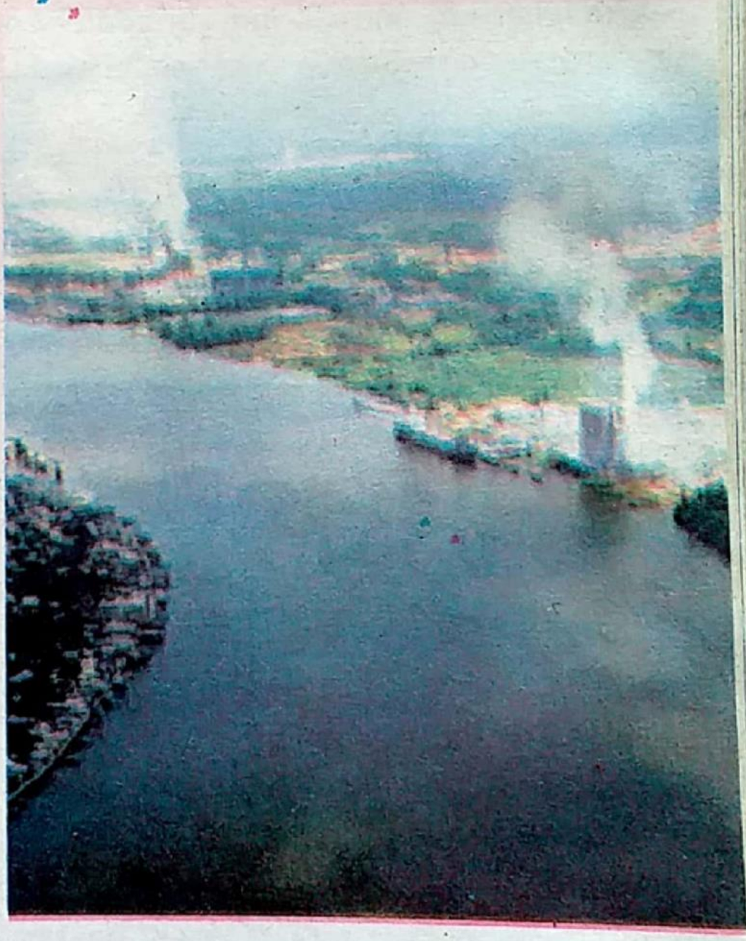
Chapter

15

Environmental Chemistry II
(Water)

In this chapter you will be able to:

- Describe the occurrence of water and its importance in the environment including industry.
- Review our dependence on water and the importance of maintaining its quality.
- Describe the composition and properties of water.
- Differentiate among soft, temporary and permanent hardness of water.
- Identify water pollutants.
- Describe industrial wastes and household wastes as water pollutants.
- Describe the effects of these pollutants on life.
- Describe the various types of water borne diseases.



Introduction

Water is one of the most essential substance for life and wherever living organisms are present, it is invariably found with them. Many elements are important to sustain life on earth, but no single substance is as vital as water. Humans can live without food for more than two months, but they cannot live without water for more than a week. Human body contains about 70 percent of water while plants contains from 50-80 percent of water. It is necessary to maintain various biological processes. The vital function of protoplasm is due to the presence of constant amount of water.

However water is a universal solvent and occurs in nature in impure state. Therefore water present in springs, streams, rivers, lakes and seas contains chlorides, sulphates, carbonates and bicarbonates of sodium, potassium, magnesium and calcium. In addition to the above some man made chemicals also get dissolved in water and make it harmful for human, animals and plants.

15.1 Occurrence of water

Water is one of the most abundant natural resources present on earth. It has been estimated that the total volume of water present on earth surface is about 1.33billion cubic kilometers. It covers nearly 70–75 percent of earth surface.

The major reservoirs of water on earth surface are oceans, ice caps and glaciers, underground water, inland water and atmospheric water. The oceans contain more than 97 percent of the total water. The rest of water is in the form of glaciers, ice caps, underground water and inland water. The inland water includes rivers, lakes, canals, streams and soil moisture. Besides this, atmosphere also contains considerable quantity of water as water vapours.

Although enormous amount of water is present on earth surface, yet the fresh water needed for human requirements is only 0.2 percent of the total. More than 97 percent of the total water is present in oceans which is unfit for human consumption due to high concentration of salts. Another 2.2 percent is locked in ice caps and glaciers. On land most of the fresh water lies underground.

TABLE. 15. 1		
WATER RESERVIORE		AMOUNT OF WATER
i.	Oceans	Approx. 97%
ii.	Glaciers and ice caps	2.2%
iii.	Underground water	0.6%
iv.	Inland water	0.2%
v.	Atmospheric water	0.001%

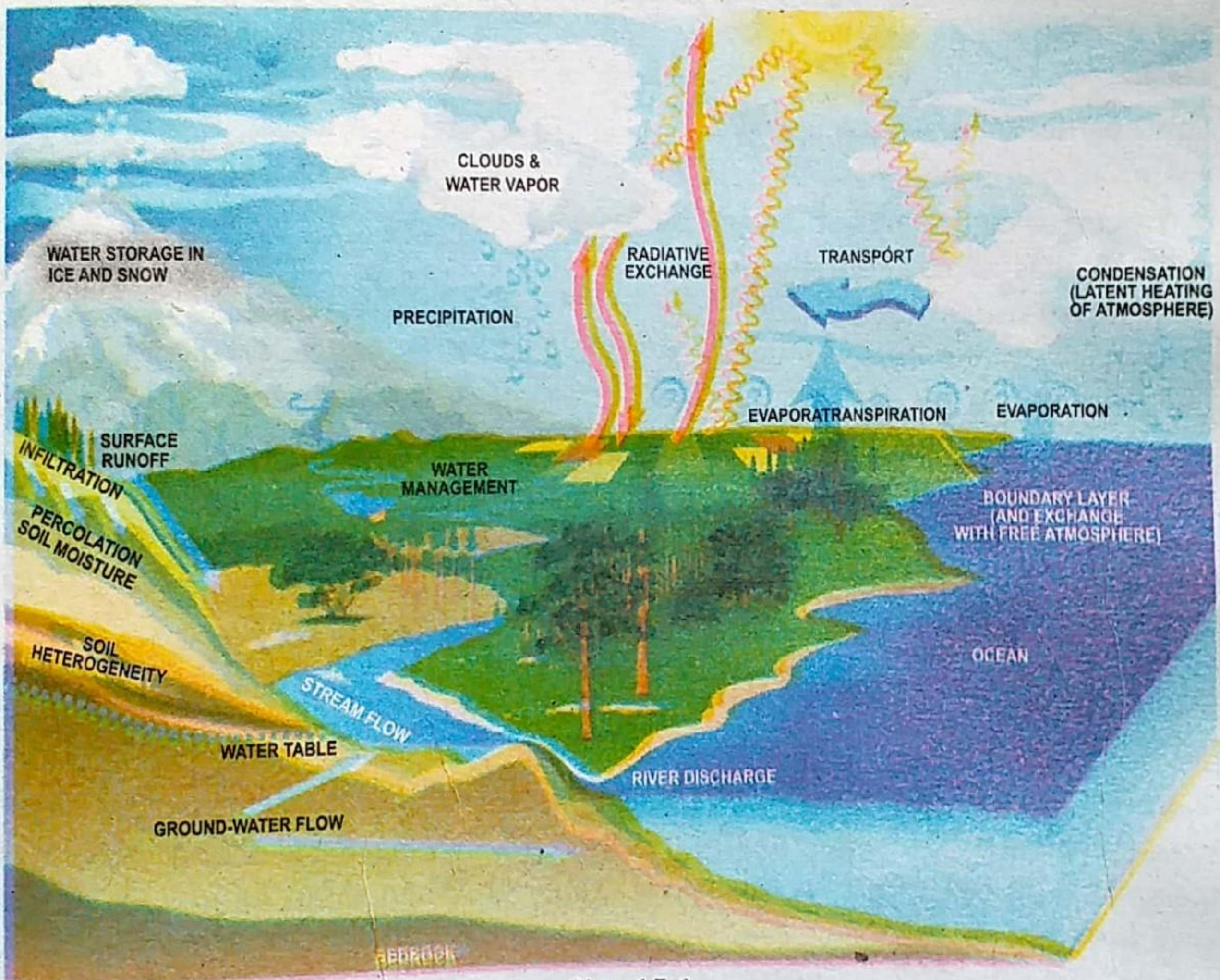


Fig: 15.1

15.2 Composition of water

Water is a compound of hydrogen and oxygen. However before 1776 AD, it was considered as an element. In 1776 AD, Priestly experimentally proved that water is not an element but is a compound of hydrogen and oxygen.

Composition of water by volume

Water contains two parts of hydrogen and one part of oxygen by volume. This ratio can be determined experimentally by the electrolysis of water in Hofmann's voltameter in the presence of an electrolyte. By passing electric current through acidified water, it gives two parts of hydrogen and one part of oxygen (fig 15.2).

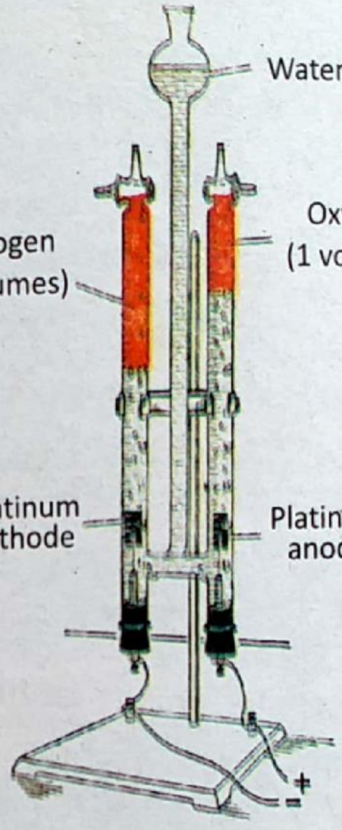


Fig. Analysis of water by volume

Fig:. 15.2

Composition of water by mass

Water is composed of one part of hydrogen to eight parts of oxygen by mass. It was experimentally proved by Joseph Proust that hydrogen and oxygen combined to form water in the ratio of 1:8 by mass. Since, the atomic mass of hydrogen is one, and that of oxygen is sixteen, so according to the formula H_2O, the ratio between hydrogen and oxygen would be 1:8.

15.3 Properties of water

(a) Physical properties of water

i) Physical state

Pure water is colourless(transparent), odourless and tasteless. The taste of drinking water is due to the presence of dissolved gases and salts. Water exists in nature in all the three states i.e. solid (ice), liquid and gaseous (vapour).

ii) Melting point and boiling point

Under normal atmospheric pressure, liquid water changes into solid ice at 0°C and boils to form steam at 100°C. However water vapour in air exists at all temperatures. The melting and boiling points of water are unexpectedly high as compared to other chemically similar compounds. This and other unusual properties of water are due to hydrogen bonding in it.

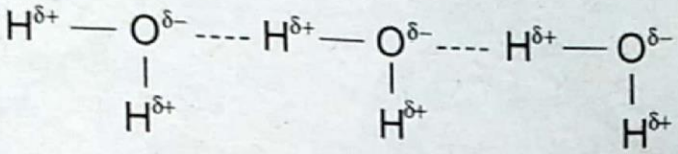


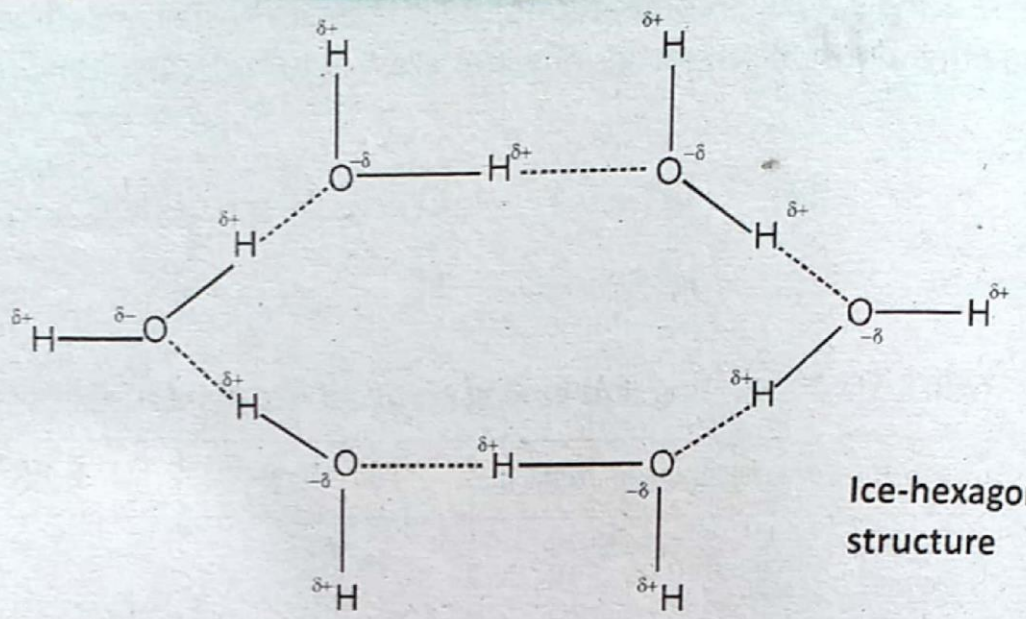
TABLE 15. 2 Melting and boiling points of Group VI A Hydrides

Substances	Molecular mass (g)	M.P(C°)	B.P(C°)
H_2O	18	0	100
H_2S	34	-83	-60
H_2Se	81	-66	-41
H_2Te	129.6	-49	-2

iii) **Density**

The volume of most of the solids and liquids increases with increase in temperature and decreases with decrease in temperature in a regular manner. However water shows a unique behaviour in this regard. This unique property of water is called anomalous behaviour of water. When water is cooled from 100°C, its density gradually increases from 0.9584g/ml to 1.000g/ml at 4°C. Up to this temperature water behaves as other liquids. However on further cooling, below 4°C the effect reverses and the density gradually decreases reaching to 0.917g/ml at 0°C. At this temperature water freezes into ice. Thus ice is lighter and therefore floats on the surface of water. The expansion of ice is due to the formation of hexagonal structures. In these structures six water molecules arrange themselves in the form of a ring having empty spaces. As a result volume increases and density being inversely proportional to volume decreases.

As the water expands on freezing, bottles filled with water when placed in the freezer crack. In cold weather an antifreeze "glycol" is added to car radiator to prevent freezing of water. Similarly water supply pipes may also burst during severe winters if not kept open, due to expansion of water on freezing.



Ice-hexagonal structure

IV. Heat capacity

Heat capacity is the capacity of a substance to absorb heat. The heat capacity of a substance is expressed in terms of specific heat.

"The specific heat capacity of a substance is the amount of heat required to raise the temperature of one gram of a substance through one degree centigrade.

One gram of water requires 4.2 joules of heat to raise its temperature by one degree centigrade. This is much higher than the specific heats of many other common substances.

TABLE 15.03: Specific heat of water compared with that of other substances

SUBSTANCES	SPECIFIC HEAT ($J\ g^{-1}\ ^{\circ}C^{-1}$)
Water	4.2
Ethanol	2.4
Iron	0.45
Copper	0.376
Mercury	0.1

Due to high specific heat, water undergoes temperature changes very slowly as compared to other substances. Therefore it is used in radiators for heating rooms. The vast amount of water on the earth surface acts as a giant thermostat. It regulates the temperature of the earth. Without the huge volume of the water in oceans, the earth would have heated up too much quickly during the day time and cooled too much quickly at night.

V) **Latent heat values**

a) **Latent heat of fusion**

If we take some ice in a beaker and heat it with constant stirring, it will be noticed that although heat is being supplied the temperature does not rise until all the ice in the beaker has melted.

"The amount of energy required to change a given amount of solid into liquid state at its melting point is called latent heat of fusion"

The latent heat of fusion of water is 6kJ/mol (334kj/kg).

b) **Latent heat of vaporization**

When we heat water in beaker, it will start boiling at 100°C. At this point if the supply of heat is continued, the temperature of water does not rise until all of it is converted into steam.

"The amount of energy required to change a given amount of liquid into gaseous state at its boiling point is called latent heat of vaporization"

The latent heat of vaporization of water is 41kJ/mol (2277kj/kg) at 100°C.

VI) **Solvent action**

Water is a remarkable solvent. It has the ability to dissolve many substances. Due to this fact it is termed as universal solvent. This property is very beneficial for us and finds a large number of applications at home and industry. However, the same property of water is responsible for water pollution as well.

Activities

- Put a cube of ice into a beaker containing water. Does it floats on the surface of water? Why?
- Take some ice in beaker and heat it on a burner. Does the temperature increase until all the ice has melted? Why?
- Take some water in a beaker. Add cooking oil into it. Does it dissolve in water? Why?

(b) CHEMICAL PROPERTIES OF WATER

I. Thermal stability

Water is thermally stable compound that only one percent of its molecules decomposes into its components i.e. H_2 and O_2 at about 2000°C.

$$2H_2O_{(g)} \xrightarrow{2000^\circ C} 2H_{2(g)} + O_{2(g)}$$

II. Reaction with metals

Water reacts readily with certain metals in a number of ways. Cold water reacts vigorously with sodium, potassium and calcium forming metal hydroxides liberating H_2 gas.

$$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}\uparrow$$
$$2K_{(s)} + 2H_2O_{(l)} \longrightarrow 2KOH_{(aq)} + H_{2(g)}\uparrow$$
$$Ca_{(s)} + 2H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)} + H_{2(g)}\uparrow$$

Water as steam reacts with less reactive metals like Zinc, Magnesium and Iron to form metal oxides and hydrogen gas.

$$Zn_{(s)} + H_2O_{(l)} \longrightarrow ZnO_{(s)} + H_{2(g)}\uparrow$$
$$Mg_{(s)} + H_2O_{(l)} \longrightarrow MgO_{(s)} + H_{2(g)}\uparrow$$

Steam reacts with red hot iron to form magnetic oxide and H_2 gas

$$3Fe_{(s)} + 4H_2O_{(g)} \longrightarrow Fe_3O_{4(s)} + 4H_{2(g)}\uparrow$$

Other metals like copper, gold, mercury and platinum do not react with water at any conditions.

III. Reaction with non-metals

Water reacts with non-metals under different conditions to form a number of products.

a) With Chlorine

When Cl_2 gas is passed through water it reacts to form hydrochloric (HCl) and hypochlorus (HOCl) acids. Hypochlorus acid is unstable and decomposes to give atomic oxygen which decolourizes the dye molecule. So chlorine can be used as a bleaching agent and as germicide.

$$H_2O_{(l)} + Cl_{2(g)} \longrightarrow HCl_{(aq)} + HOCl_{(aq)}$$
$$HOCl_{(aq)} \longrightarrow HCl_{(aq)} + [O]$$

b) With Carbon

Steam reacts with red-hot coke to form a mixture of carbon monoxide and hydrogen gases ($CO+H_2$). This gaseous mixture is called water gas. Water gas is used as fuel.

$$H_2O_{(g)} + C_{(s)} \longrightarrow \underset{\text{(water gas)}}{CO_{(g)} + H_{2(g)}}$$

c) With Silicon

Steam reacts with silicon to produce silicon dioxide and hydrogen gas.

$$Si_{(s)} + 2H_2O_{(g)} \longrightarrow SiO_{2(s)} + 2H_{2(g)}$$

d) With Sulphur

Steam reacts with sulphur producing hydrogen sulphide and sulphur dioxide gases.

$$3S_{(s)} + 2H_2O_{(g)} \longrightarrow 2H_2S_{(g)} + SO_{2(g)}$$

IV. Reaction with metal oxides :

Water reacts with metal oxides to form metal hydroxides (bases)

$$Na_2O_{(s)} + H_2O_{(l)} \longrightarrow 2NaOH_{(aq)}$$

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

$$ZnO_{(s)} + H_2O_{(l)} \longrightarrow Zn(OH)_{2(aq)}$$

V. With non-metal oxides

Water reacts with non-metal oxides to produce acids as,

$$H_2O_{(l)} + CO_{2(g)} \longrightarrow H_2CO_{3(aq)}$$

$$H_2O_{(l)} + 2NO_{2(g)} \longrightarrow HNO_{3(aq)} + HNO_{2(aq)}$$

$$H_2O_{(l)} + SO_{3(g)} \longrightarrow H_2SO_{4(aq)}$$

VI. Hydrolysis reaction

The reaction of a salt of weak acid or weak base and water to form acidic or basic solution is called hydrolysis.

In this reaction the dissolved salt reacts with water turning the solution either basic or acidic. In this reaction water splits into H^+ and OH^- ions. It is the reverse process of neutraliz

$$NH_4Cl_{(s)} + H_2O_{(l)} \longrightarrow NH_4OH_{(aq)} + HCl_{(aq)}$$

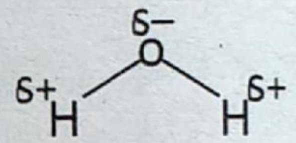
$$CH_3COONa_{(s)} + H_2O_{(l)} \longrightarrow CH_3COOH_{(aq)} + NaOH_{(aq)}$$

Activities

- Add a few drops of phenolphthalein in aqueous solution of sodium acetate. What happens? Why?
- Pass carbon dioxide gas through hard water. Why does it turn milky?
- Put few crystals of potash alum (patakry) in muddy water. What happens?

15.4 Water as a solvent

Water is a universal solvent for many inorganic and certain organic compounds. This characteristic property of water that it dissolves more or less of everything is due to the following two reasons.

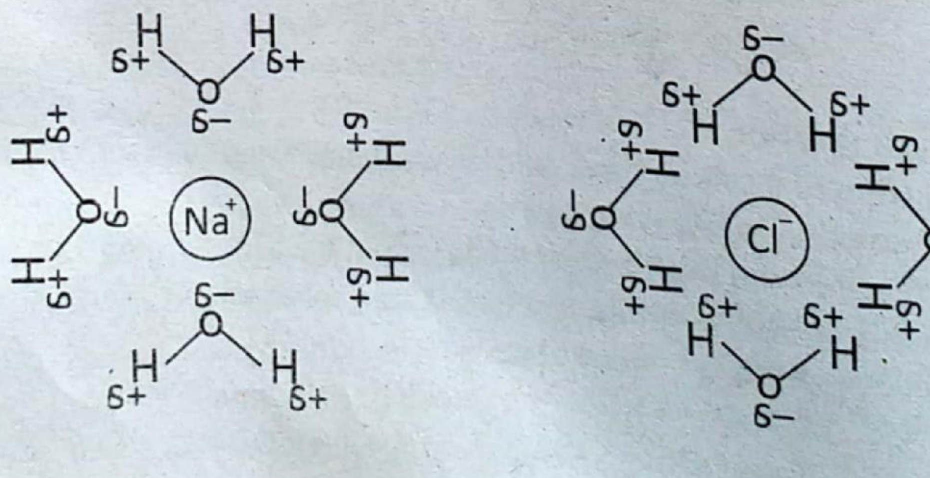


1) Polarity:

Consider the structure of water.

Water molecules have a polar structure, the oxygen end of the water molecules is partially negatively charged while the hydrogen end is partially positively charged. Due to this property polar substances like mineral acids, bases and salts dissolve in water. Some of the covalent compounds having hydroxyl group OH^-, can also be dissolved in water e.g. glucose, sugar and alcohols.

When an ionic compound like NaCl is placed in water, the breaking of the attractive forces or the ionic bonds occur. The water molecules orient in such a way that their negative poles are towards the positive ions. Similarly the positive poles of water molecules orient themselves around the negative ions.



NOT FOR SALE

2) **Dielectric Constant:**

Coulomb's law states that the force of attraction between two oppositely charged bodies is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

Mathematically, force $\propto \frac{(x)(y)}{r^2}$

Where 'x' and 'y' are two opposite charges and 'r' is the distance between them.

or $\text{Force} = \frac{(x)(y)}{Dr^2}$ Where 'D' is the proportionality constant and called the dielectric constant of the medium or water in which the charged ions of solute are present.

The above equation tells us that the greater is the value of 'D' the smaller will be the value of the force of attraction between the charges. The smaller the values of 'D' the greater will be force of attraction between the oppositely charged ions. Thus it will be easier to separate the two opposite charges of ionic solute from one another (to make solution) in a liquid having a high dielectric constant. Water has a high dielectric constant of 80 at 18^0C. Thus the positive and negative ions of a polar salt dissolved in water will have less force of attraction and would remain soluble. Other liquids have the value of dielectric constant extremely small as compared to water and therefore, these are not good solvents.

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Chemistry helps to maintain a clean swimming pool by removing pathogenic organisms. Chlorine based disinfectants are most frequently applied for cleaning of swmming pools. Chlorine is usually added to water as hypochlorous acid (HOCl). Chlorine kills pathogenic microorganisms that are present in the water. When too much chlorine is present, it can cause eye irritation. The minimum concentration of chlorine in swimming pool is 0.5 mg/Land maximum level is 1.5mg/L.

15.5 Soft & Hard Water

Water, which easily gives lather with soap, is called soft water. On the other hand when it forms scum or curds with soap and affects the cleaning action of soap is known as hard water.

Hard water does not form lather readily with soap. It forms scum during washing of clothes and dirt cannot be removed readily. Thus hard water wastes soap. The hardness of water is due to the presence of bicarbonates, sulphates and chlorides of calcium and magnesium in water.

15.5.1 Types of Hard Water

There are two types of hard water.

i. Temporary Hard Water

ii. Permanent Hard Water

(i). Temporary Hard Water

The most common cause of temporary hardness of water is the dissolved calcium bicarbonate or magnesium bicarbonate. Rainwater dissolves carbon dioxide of the air, which reacts, with the calcium carbonate of rocks forming calcium bicarbonate.

$$H_2O_{(l)} + CO_{2\,(g)} + CaCO_{3(s)} \longrightarrow Ca(HCO_3)_{2\,(aq)}$$

These salts are soluble in water and exist in the form of positive and negative ions as shown below.

$$Ca(HCO_3)_2 \longrightarrow Ca^{+2}_{(aq)} + 2HCO_{3\,(aq)}^{-1}$$

$$Mg(HCO_3)_2 \longrightarrow Mg^{2+}_{(aq)} + 2HCO_{3\,(aq)}^{-1}$$

15.5.2 Methods for removal of Temporary Hardness

(i) By Boiling:

The temporary hardness of water is removed by simply boiling.

$$Ca(HCO_3)_{2\,(aq)} \xrightarrow{\text{boil}} CaCO_{3\,(s)} + CO_{2\,(g)} + H_2O_{(l)}$$

Calcium carbonate being insoluble precipitates and settles down. Now any soap added, will form lather easily.

(ii) Clark's Method:

This method is used to remove hardness on a large scale. A calculated amount of lime water $Ca(OH)_2$, is added to the reservoir containing temporary hard water. The soluble hydrogen carbonates of Ca^{++} and Mg^{++} are converted into insoluble carbonates, which settle down at the bottom and soft water is drained off for use.

$$Ca(HCO_3)_{2\,(aq)} + Ca(OH)_{2\,(aq)} \longrightarrow 2CaCO_{3(s)} + 2H_2O_{(l)}$$

$$Mg(HCO_3)_{2\,(aq)} + Ca(OH)_{2\,(aq)} \longrightarrow MgCO_{3(s)} + CaCO_{3(s)} + 2H_2O_{(l)}$$

(2) Permanent Hardness:

Permanent hardness is caused by the presence of soluble salts of calcium or magnesium such as sulphates and chlorides. Simply boiling the water cannot decompose these salts. Calcium and magnesium salts in water are present in ionic form.

$$CaCl_{2\,(aq)} \longrightarrow Ca^{+2}{}_{(aq)} + 2Cl^{-}{}_{(aq)}$$

$$MgSO_{4\,(aq)} \longrightarrow Mg^{+2}{}_{(aq)} + SO_4^{-2}{}_{(aq)}$$

15.5.3 Methods for removal of permanent hardness:

(i) Reaction with Washing Soda

Permanent hardness can be removed by adding chemicals, which convert soluble salts into insoluble salts or precipitates. Thus washing soda is usually added to permanent hard water to remove its hardness. For example; by using Na_2CO_3 (Washing Soda), the salts causing hardness react as follows.

$$Na_2CO_{3(aq)} + CaSO_4 \longrightarrow CaCO_{3\,(s)} + Na_2SO_{4\,(aq)}$$

$$Na_2CO_{3(aq)} + CaCl_{2\,(aq)} \longrightarrow CaCO_{3\,(s)} + 2NaCl_{(aq)}$$

By adding Na_2CO_3, the soluble Ca^{++} or Mg^{++} ions are converted into insoluble $CaCO_3$ or $MgCO_3$, respectively.

(ii) Ion Exchange Method:

Now a days this technique is applied in homes for softening of hard water for the purpose of drinking. Hard water on passing through the resin (sodium zeolite), attract Ca^{++} and Mg^{++} ions. The mode of reaction can be represented as;

$$CaSO_{4\,(aq)} + \text{Sodium Zeolite}_{(s)} \longrightarrow \text{Ca-Zeolite}_{(s)} + Na_2SO_{4(aq)}$$

Na-Zeolite resin can be obtained naturally or may be prepared artificially. After some days, this resin becomes inactive and its activity can be regenerated by treating it with concentrated solution of common salt.

$$\text{Ca-Zeolite}_{(s)} + NaCl_{(aq)} \longrightarrow \text{Na-Zeolite}_{(s)} + CaCl_{2(aq)}$$

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Soaps are the salts of fattyacids. When soap is added to hard water. It gets ionized into sodium ion and stearate ion. The Ca^{++} ion of hard water react with stearate and produce Ca–stearate. So it hampers the lather formation. As a result the cleaning action of soap is also affected.

$$\underset{\text{Sodium stearate}}{C_{17}H_{35}COONa} \xrightarrow{\text{Hard water}} \underset{\text{Stearate ion}}{C_{17}H_{35}COO^-} + \underset{\text{Sodium ion}}{Na^+}$$

$$\underset{\text{Calcium ion}}{Ca^{+2}} + \underset{\text{Stearate ion}}{2C_{17}H_{35}COO^-} \longrightarrow \underset{\text{Calcium stearate (scum)}}{Ca(C_{17}H_{35}COO)_2}$$

15.5.4 Disadvantages of Hard Water

1. A large quantity of soap is used which is wasted in the formation of scum or curd. After that more soap will be required for actual washing.
2. Hard water when used in boilers for producing steam in industries, steam engines or turbines, calcium and magnesium salts settle down at the bottom forming hard insulating scales. As a result more fuel is consumed in producing steam. Besides it damages the material of the boiler due to over heating.
3. Drinking hard water produces numerous diseases of stomach and intestines.

15.3 Water pollution

Water is an excellent solvent and can dissolve vast variety of substances. Therefore natural water, when it flows or seeps through the surface of the earth, dissolves minerals including salts and other substances. Despite of these mineral impurities water of most lakes, rivers, springs, and wells is considered fit for drinking and other domestic uses. Water pollution occurs when undesirable foreign substances are introduced into natural water. The substances may be chemical or biological in nature. Common pollutants include human or animal waste, disease-producing organisms, radioactive material, toxic metals such as lead or mercury, agricultural chemicals such as pesticides, herbicides, and fertilizers. Hot water discharged from power plants causes "thermal pollution". Pollutants in water are dangerous for human or animal consumption and harm crops. Water is considered as polluted and unfit for drinking when it is contaminated with substances (pollutants) which are harmful for human beings and other living organisms.

The substances that cause water pollution are called pollutants. These pollutants get dissolved in water from the soil, atmosphere, fields, factories, farm houses, volcanoes, storms, algae blooms, earthquakes and homes etc.
The major sources of water pollutants are:

- **Industrial wastes**
- **Household wastes**
- **Agricultural wastes**

15.3.1 Industrial wastes

As populations and production grew, industrial and household refuse accumulated, and it became clear that many discarded materials did not simply disappear, but were spread through the water table, absorbed by lower forms of life and passed into the food chain, causing deaths, birth defects, and mental problems.

Water pollution represents a serious problem in developing nations, which have high populations and manufacturing facilities that do not meet safety standards. It is alarming that most industries have been started without proper planning and waste treatment plants. They just dispose of untreated toxic waste into nearby drains, canals or rivers.

Manufacturing and service industries have high demands of water for cooling, processing and for cleaning purposes. Most of it is taken from the adjoining river, canal, stream or underground source and again discharged into these sources laden with toxic wastes. Groundwater pollution occurs when used water is returned to the hydrological cycle. Industrial waste contains highly toxic compounds of mercury, cadmium, lead, chromium, arsenic and antimony. In addition to the above it also contains acids, bases, dyes, oils and grease.

(Fig;. 15.3)

15.3.2 Household waste

Household waste is a waste which is generated in the day to day operations of a household. It can include everything from lawn clippings to burnout light bulbs. A busy household can generate a great deal of waste, and the amount of household waste increases radically in developed nations which rely heavily on packing for a wide variety of products.

Household waste can broadly be divided into three categories.

a) Waste water
b) Untreated sewage
c) Solid waste

a) Waste water or grey water

It includes the water we used in kitchens, washrooms and cleaning floors etc. In most cases this water is directly discharged into the water bodies. The various substances that we use for keeping our houses clean add to water pollution as they contain harmful chemicals. In the past, people mostly used soaps made from animal and vegetable fat for all types of washing. But most of today's cleaning products are synthetic detergents and come from the petrochemical industry. Most detergents and washing powders contain phosphates, which are used to soften the water among other things. These and other chemicals like medicines, acids, bleaches, dyes, insecticides, rodent killer, waxes, hair colour etc affect the health of all forms of life in the water.

b) Untreated sewage or black water

It is the major source of water pollution, because it contains pathogens such as bacteria, viruses, and protozoans. In Pakistan about 2 million tonnes of wet human excreta are annually produced in the urban sector of which about 50% go into water bodies to pollute them. According to National Conservation Strategy about 40% deaths are related to water borne diseases.

In our country, drinking water supply lines and open sewage drains in the streets are laid side by side. As a result water is frequently contaminated when pipes erode. Furthermore, due to low quality of sewage pipes and improper safety seals cause a lot of leakage. This outflow from sewage mixes with the water table and the contamination is carried to deeper levels. Hence the under groundwater which is considered safe becomes adulterated with pollutants.

c) **Solid waste**

It is also called urban waste or domestic waste. It is either in solid or semisolid form. It contain food, newspapers, glass bottles, cans, metals etc. Today, many people dump their garbage into streams, lakes, rivers, and seas, thus making water bodies the final resting place of cans, bottles, plastics, and other household products. In cities, it is collected by municipality within a given area and stored in open fields without proper disposal. Chemicals from this material dissolve into rain water while it is being filtered through that material. The process is called leaching and the resulting mixture is called leachate. It contains decomposed organic matter, rust, newspaper ink, pesticides, fertilizer and other hazardous chemicals. Leachate either seeps into the soil and pollutes underground water or finds its way to rivers and streams through rain water.

(Fig:. 15.4)

15.3.3 Agricultural Wastes

Agricultural waste is waste produced as a result of various agricultural operations. It includes manure and other wastes from farms, poultry houses and slaughterhouses; harvest waste; fertilizer run- off from fields; pesticides that enter into water, air or soils and salt and silt drained from fields.

Agricultural wastes include both natural (organic) and synthetic wastes. Main synthetic waste include packaging, non-packaging plastics (e.g. silage and horticultural films); agrochemicals; animal health products (e.g.used syringes); wastes from machinery (e.g. oil, tyres and batteries) and building waste (e.g. asbestos sheeting).

15.4 Water born diseases and Effects of water pollutants

The effects of water pollutants are not only devastating to people but also to animals, fish, and birds. Polluted water is unsuitable for drinking, recreation, agriculture, and industry. It diminishes the aesthetic quality of lakes and rivers. More seriously, contaminated water destroys aquatic life and reduces its reproductive ability. Eventually, it is a hazard to human health. Nobody can escape the effects of water pollution.

The individual and the community can help minimize water pollution. By simple housekeeping and management practices the amount of waste generated can be minimized.

The major effects of water pollutants are as under.

a) Cause of infectious diseases

Human infectious diseases are among the most serious effect of water pollution, especially in developing countries like Pakistan, where sanitation is inadequate or even non-existent. Water born diseases occur when parasites or other diseases causing microorganisms are transmitted via contaminated water, particularly water contaminated by pathogens originating from excreta. These include typhoid, cholera, dysentery, amoebiasis, ascariasis and hepatitis etc.

b) Nutrient pollution

It is the most chronic environmental problem in the coastal areas, rivers, streams and lakes. The discharges of nitrogen, phosphorus and other nutrients come from agriculture, waste disposal, coastal development and fossil fuel. This enrichment of nutrients in water bodies is called Eutrophication. It stimulates harmful overgrowth of algae, which can have direct toxic effect, as certain types of algae are toxic (red and brown). Zooplankton eat the toxic algae and begin passing the toxins up the food chain, affecting the sea birds, sea mammals and humans. The result can be illness and sometime death. The algal growth also blocks the sun light needed by sea grasses, which serve as nurseries for many important fish species. Furthermore it also reduces the clarity, making it hard for marine animals to find food.

When the algae finally die, they sink to the bottom and begin decomposing. The process uses oxygen from the surrounding water and make it difficult for aquatic animals to survive and the region becomes a dead zone.

c) **Chemical contamination**

Some of the major effects of chemical contamination are as under.

i) Pesticides affect and damage the nervous system, liver, reproductive system and endocrine glands, DNA. They also cause cancer and other acutely toxic and chronic effects.

ii) Oil and petrochemicals can alter the ecology of aquatic habitats and the physiology of marine organisms. In human beings it causes gastro intestinal irritation, liver and kidney damage, and nervous system effects.

iii) Mercury and its compounds are used in many industries. It Find its way into the water bodies primarily through air pollution and industrial waste. Mercury gets into the body through food especially sea food. It accumulates in the blood, liver, kidneys and brain tissues. In young children it causes autism, brain damage, learning defects and incomplete mental development. In adults mercury causes Parkinson, Alzheimer's disease and heart disease.

iv) Persistent organic pollutants (POP) such as DDT, dioxins and PCB enter our body through food. As they are fat soluble, therefore they accumulate in fatty tissues of animals and human. POPs causes disruption of hormones in human and animals, affects reproductive organs and breast cancer in women.

d) **Thermal water pollution**

A lot of heat is generated in most industrial manufacturing processes. The cheapest way to release this heat into the environment is to draw water from the nearby surface water, pass it through the plant and return heated water back into the same source. The warmer water affects the aquatic life in two ways,

i) The warmer water decreases the solubility of oxygen and many aquatic organisms will die due to the shortage of oxygen.

ii) Many aquatic animals especially young can not survive above 30°C and will die.

Society, Technology and Science

Water, which is prepared for different purposes is called treated water e.g distilled water, drinking water and chlorinated water of swimming pools. Water is passed through different process in order to remove impurities from water and make it suitable for drinking.

First water is stored in settling basin and treated with calcium hydroxide and aluminum sulphate to remove suspended impurities and dust. It is then filtered through sand and gravel bed to remove remaining suspended particles. After this water is passed through charcoal to remove colour and odour. At the last stage chlorine is added in water to kill microorganism such as bacteria and germs etc. Now this water is suitable for drinking and other purposes.

KEY POINTS

- Water present in springs, streams, rivers, lakes and seas contains chlorides, sulphates, carbonates and bicarbonates of sodium, potassium, magnesium and calcium.
- The unusual physical properties of water are due to hydrogen bonding in it.
- The vast amount of water on the earth surface acts as a giant thermostat. It regulates the temperature of the earth.
- The amount of energy required to change a given amount of solid into liquid state is called latent heat of fusion.
- The amount of energy required to change a given amount of liquid into gaseous state at its boiling point is called latent heat of vaporization.
- Due to high latent heat values of water make it a useful coolant.
- The dielectric constant of water is 80 at 18°C.
- Water is thermally so stable compound that only one percent of its molecules decomposes into its components i.e. H_2 and O_2 even at 2000°C.
- Steam reacts with red-hot coke to form a mixture of carbon monoxide and hydrogen gases ($CO + H_2$). This gaseous mixture is called water gas. Water gas is used as fuel.
- That water which form scums with soap and affects the cleaning action of soap is called hard water.
- Hardness of water may be temporary or permanent.
- Temporary hardness of water can be removed either by boiling or by Clark's method.
- Water is considered as polluted and unfit for drinking when it is contaminated with substances (pollutants) which are harmful for human beings and other living organisms.

- Most detergents and washing powders contain phosphates, which are used to soften the water.
- Untreated sewage contains pathogens such as bacteria, viruses, and protozoan.
- Leachate contains decomposed organic matter, rust, newspaper ink, pesticides, fertilizer and other hazardous chemicals.
- This enrichment of nutrients in water bodies is called Eutrophication. It stimulates harmful over growth of algae, which can have direct toxic effect, as certain types of algae are toxic (red and brown).
- Pesticides affect and damage the nervous system, liver, reproductive organs, endocrine glands and DNA.
- Mercury accumulates in the blood, liver, kidneys and brain tissues. In young children it causes autism, brain damage, learning defects and incomplete mental development. In adults mercury causes Parkinson, Alzheimer's disease and heart disease.
- The warmer water decreases the solubility of oxygen and many aquatic organisms will die due to the shortage of oxygen.

EXERCISE

1. Choose the correct option for each of the following statements.

i) The total volume of water present on earth surface is,
- a) 1.33 million km^3
- b) 1.33 billion km^3
- c) 1.33 trillion km^3
- d) 1.71 km^3

ii) The vital function of protoplasm is due to the presence of,
- a) Water
- b) Minerals
- c) Fats
- d) calcium

iii) The quantity of fresh water present on earth surface is only about.
- a) 2.6%
- b) 2.2%
- c) 0.04%
- d) 0.2%

iv) In water, ratio of oxygen and hydrogen by mass is,
- a) 2:1
- b) 1:2
- c) 8:1
- d) 1:8

v) The reason of unusual physical properties of water is due to the presence of,
- a) Hydrogen bonding
- b) Covalent bond
- c) Coordinate covalent bond
- d) none of these

vi) The density of water is one gram per centimeter cube at,
- a) 0°C
- b) 4°C
- c) 60°C
- d) 100°C

vii) The volume of water increases, when its temperature decreases below,
- a) 4°C
- b) 5°C
- c) 10°C
- d) 20°C

viii) The enormous quantity of water present on earth surface act as giant thermostat, due to its high,
- a) Boiling point
- b) Density
- c) Heat capacity
- d) Latent heat values

ix) The latent heat of fusion of water is,
- a) 41 kj/mol
- b) 6 kj/mol
- c) 4.2 kj/mol
- d) 2.4 kj/mol

x) Dielectric constant of water at 18°C is,
- a) 60
- b) 68
- c) 75
- d) 80

xi) Water gas is a mixture of,

a) Steam & air
b) hydrogen & oxygen
c) Carbon monoxide & hydrogen
d) None of these

xii) Chlorine acts as bleaching agent in the presence of

a) HCl
b) H_2O
c) NaOH
d) HNO_3

xiii) The chemical formula of magnetic oxide is,

a) Fe_3O_4
b) Fe_2O_3
c) FeO
d) $Fe_2O_3.H_2O$

xiv) Rain water is acidic in nature, because air contain,

a) Oxygen
b) Carbon dioxide
c) Nitrogen
d) All of these

xv) Nutrient pollution of water bodies is caused by,

a) Pathogens
b) Calcium & Magnesium
c) Nitrates & Phosphates
d) Acid rain

xvi) Most of the aquatic animals can not survive above,

a) 20°C
b) 25°C
c) 30°C
d) 40°C

xvii) Which one of the following diseases is caused by mercury,

a) Parkinson
b) Cholera
c) Typhoid
d) Hepatitis

2. Give brief answers to each of the following questions.

i. Why the temperatures of the coastal areas remain moderate throughout the year?

ii. Why ice floats on the surface of water?

iii. Why H_2O is liquid at room temperature while H_2S is gas?

iv. How the enormous quantity of water present on earth surface acts as a giant thermostat?

v. Why water has soothing effect on the body in summer?

vi. Why water is a universal solvent? Explain.

vii. The aqueous solution of ammonium chloride is acidic. Why?

viii. Why fire starts burning on the surface of water, when a piece of sodium metal is put into it?

ix. Explain why it is advisable to drink boiled water.

x. Water extinguishes the burning coal. How both can be used as fuel?

xi. What is Eutrophication? How does it pollute water?
xii. What are the effects of chemical contamination?
xiii. Why chlorine acts as bleaching agent in the presence of water?
xiv. What is leachate? How does it gets dissolved in water?
xv. What is thermal pollution? How does it affect the aquatic life?

3. Comprehensive questions.

i. Describe the physical properties of water.
ii. Write balance chemical equations for the chemical reactions of water with the following.
(a) K (b) Ca (c) Zn (d) Fe
(e) Cl_2 (f) C (g) Na_2O (h) NO_2
(i) CH_3COONa
iii. Discuss the following.
a) Industrial wastes.
b) Household wastes.
iv. Describe in detail, the effects of water pollutants on life.
v. Water is an excellent solvent. Explain how this property is beneficial for life but sometimes a nuisance for us.

Chapter

16

Chemical Industries

In this chapter you will be able to:

- Describe some metallurgical operations.
- Make a list of raw materials for Solvay's process.
- Outline the basic reactions of Solvay's process.
- Develop a flow sheet diagram of Solvay's process.
- Describe the composition of urea.
- Develop a flow sheet diagram for the manufacture of urea.
- List the uses of urea.
- Define petroleum
- Describe the formation of petroleum and natural gas.
- Describe the composition of petroleum.
- Describe briefly the fractional distillation of petroleum

INTRODUCTION

The rapidly growing population and the desire to raise the standard of living has forced the scientists to devise methods for preparing cheaper substitutes of substances obtained from natural sources. All these substitutes involve chemical process carried out on large scales in chemical industries like soaps, fertilizers, detergents etc.

16.1 Metallurgy and Basic metallurgical operation with reference to copper.

Most of the metals such as iron, copper, sodium etc are found in combined state in nature which are called minerals. An aggregate of mineral and other impurities is known as Ore.

"The art and science of making metals and alloys from their ores with properties suitable for practical uses is called metallurgy.

The ores are mined and subjected to various mechanical and chemical processes. There is no single method for extracting metal from their ores. But certain basic operations are required that is concentration of the ores, roasting, reduction and refining.

16.1.1 Concentration of ores.

In mining the metal, the desired mineral from which a metal is to be extracted often constitutes only a few percent of the metal mined. Therefore it is necessary to separate the desired ore from useless material before proceeding with other metallurgical operations. A number of methods are used for the concentration of ores e.g. cyclone separation, vibrating method, floatation method etc.

The most important method of concentration used for copper is Froth Floatation. In this method, the ore is crushed to small size and mixed with water containing a small amount of pine oil. The mixture is thoroughly agitated by passing strong current of air. The particles containing ore are wetted by oil and float at top of the mixture in container from which it is collected. The Froth is washed with water and then filtered to obtain concentrated ore of copper. The useless particles settles down in water.

16.1.2 Extraction of metal

The concentrated ore is ready for extraction of metal. Different method are used for extraction of metal like roasting, reduction etc.

Roasting:

The concentrated ore is mixed with silica and calcium carbonate and is heated in blast furnace, matte is formed.

Reduction:

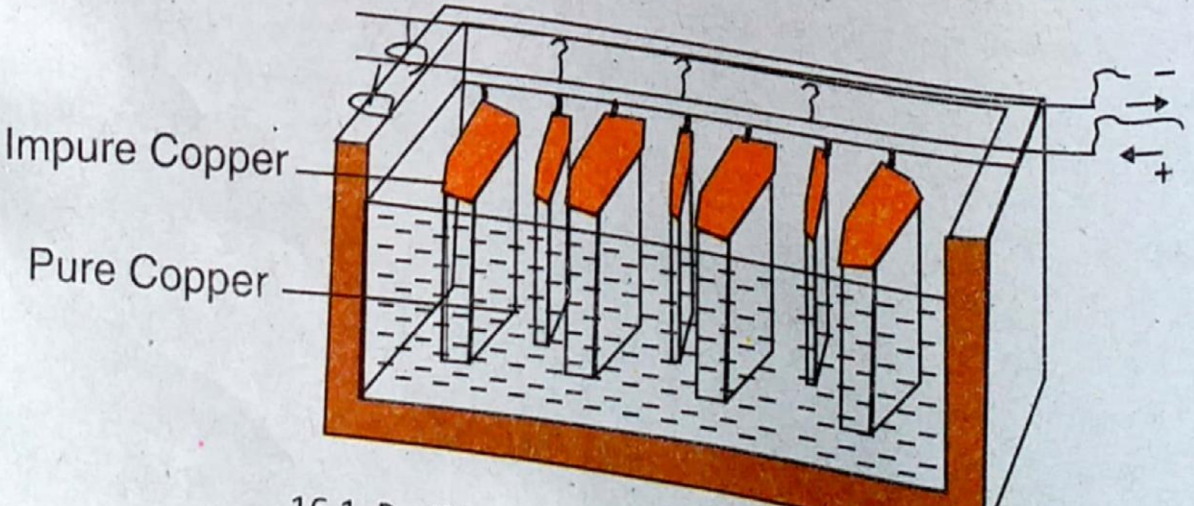
The matte consist of molten copper and iron sulphides. The matte is heated in Bessemer convertor and air is blown through molten copper sulphide which is converted into elemental copper.

$$Cu_2S + O_2 \rightarrow 2\,Cu + SO_2$$

The elemental copper is poured into moulds where it is cooled. It is now called blister copper because it has porous surface which is due to escape of SO_2 gas during solidification.

16.1.3 Electro-refining

The blister copper contains silver, gold etc as impurities. These impurities of copper are removed by electrolytic refining. The blister copper is made anode and a thin sheet of pure copper is made cathode as shown in figure 16.1



16.1 Purification of Copper by electrolysis

The solution of copper sulphate and sulphuric acid is used as electrolyte in electrolytic tank. When current is passed, copper dissolves from impure copper (anode) as copper ions.

$$Cu \rightarrow Cu^{+2} + 2e^- \text{ (at anode)}$$

At cathode copper ion is reduced and gets deposited over it.

$$Cu^{+2} + 2e^- \rightarrow Cu \text{ (at cathode)}$$

The blister copper (at anode) dissolves slowly and sheet of pure copper (at cathode) builds up to a large slab. The inactive impurities (silver, gold) settle at bottom and are called anode mud.

16.2 Manufacture of sodium carbonate by solvay's process

Sodium carbonate is one of the most important chemicals. It is used in the manufacture of glass, paper, textile laundering etc. Sodium carbonate is commercially manufactured by Solvay's process. This process have the following main steps:

16.2.1 Raw material

The raw materials used for manufacture of sodium carbonate are

(i) Sodium chloride ($NaCl$)
(ii) Lime stone ($CaCO_3$)
(iii) Ammonia (NH_3)
(iv) Water (H_2O)

16.2.2 Main process and basic reactions

This process is very simple. Ammonia gas is passed through saturated solution of sodium chloride in saturating tank. The sodium chloride gets saturated with ammonia. Carbon dioxide gas obtained from lime stone is passed into a solution of sodium chloride and ammonia. The series of reaction involved in this process is as under

$$CaCO_3 \xrightarrow{heat} CaO + CO_2$$

$$NH_3 + H_2O + CO_2 \longrightarrow NH^+_4 + HCO^-_3$$

$$NH^+_4 + HCO^-_3 + Na^+ + Cl^- \longrightarrow NaHCO_3 + NH_4Cl$$

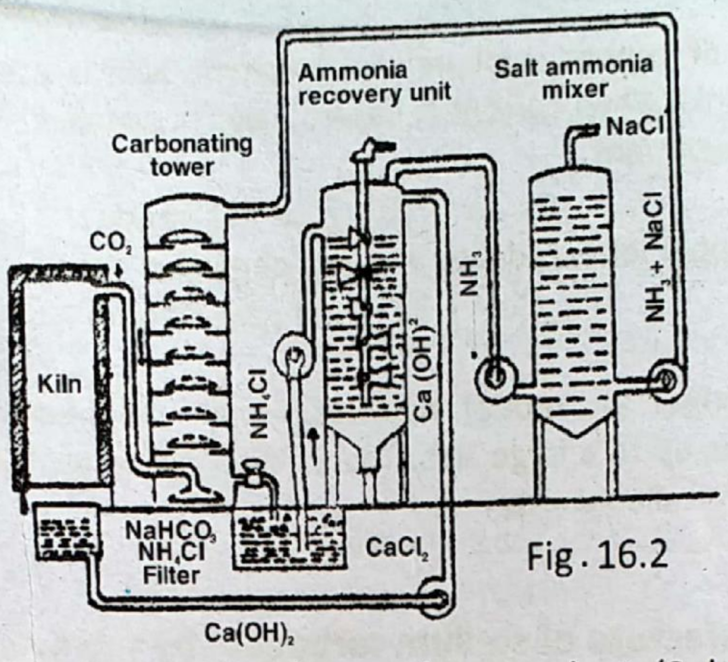


Fig. 16.2

Figure 16.2 Manufacture of sodium carbonate plant. (Solvay's process)

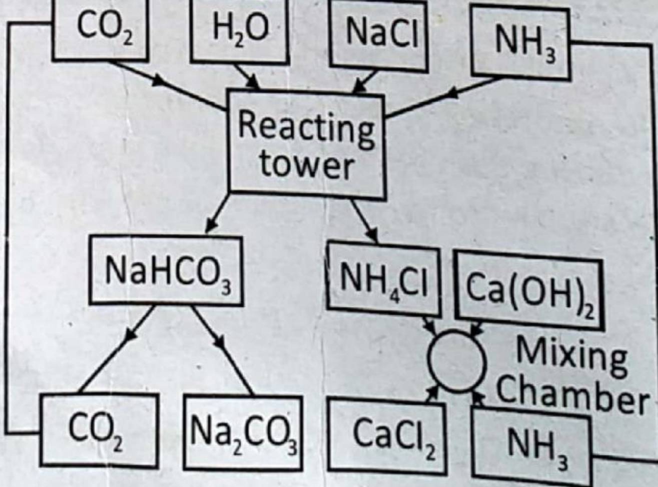
Sodium bicarbonate is precipitated and removed by filtration. The dry sodium bicarbonate is then heated to form sodium carbonate.

$$2\,NaHCO_3 \xrightarrow{heat} Na_2CO_3 + H_2O + CO_2$$

The efficiency of the process is increased by treatment of ammonium chloride (NH_4Cl) solution with calcium hydroxide. Ammonia is recovered and is allowed to enter in the process again and again.

$$Ca\,(OH)_2 + 2\,NH_4Cl \longrightarrow CaCl_2 + 2\,H_2O + 2NH_3$$

The carbon dioxide evolved upon heating the sodium bicarbonate is also returned to process which is shown in flow sheet.



16.3 Flow sheet diagram

16.3 Manufacture of Urea

Agriculture has been one of the oldest industries known to man. Chinese have been using animal manure in their agricultural field. The utility of chemical manure was first pointed out in 1840. Experiments indicate that three elements namely Nitrogen, phosphorus and potassium are very essential for the growth of the plants. Urea is probably the most important nitrogenous fertilizer. It is manufactured as given below.

16.3.1 Raw Materials

Carbondioxide and ammonia are raw materials of urea. Ammonia is prepared by Haber's process from nitrogen and hydrogen and Carbondioxide is obtained from natural gas (CH_4)

16.3.2 Main process and basic reactions

Urea is manufactured by heating ammonia and carbon dioxide at 170–200°C and 100–200 atm pressure.

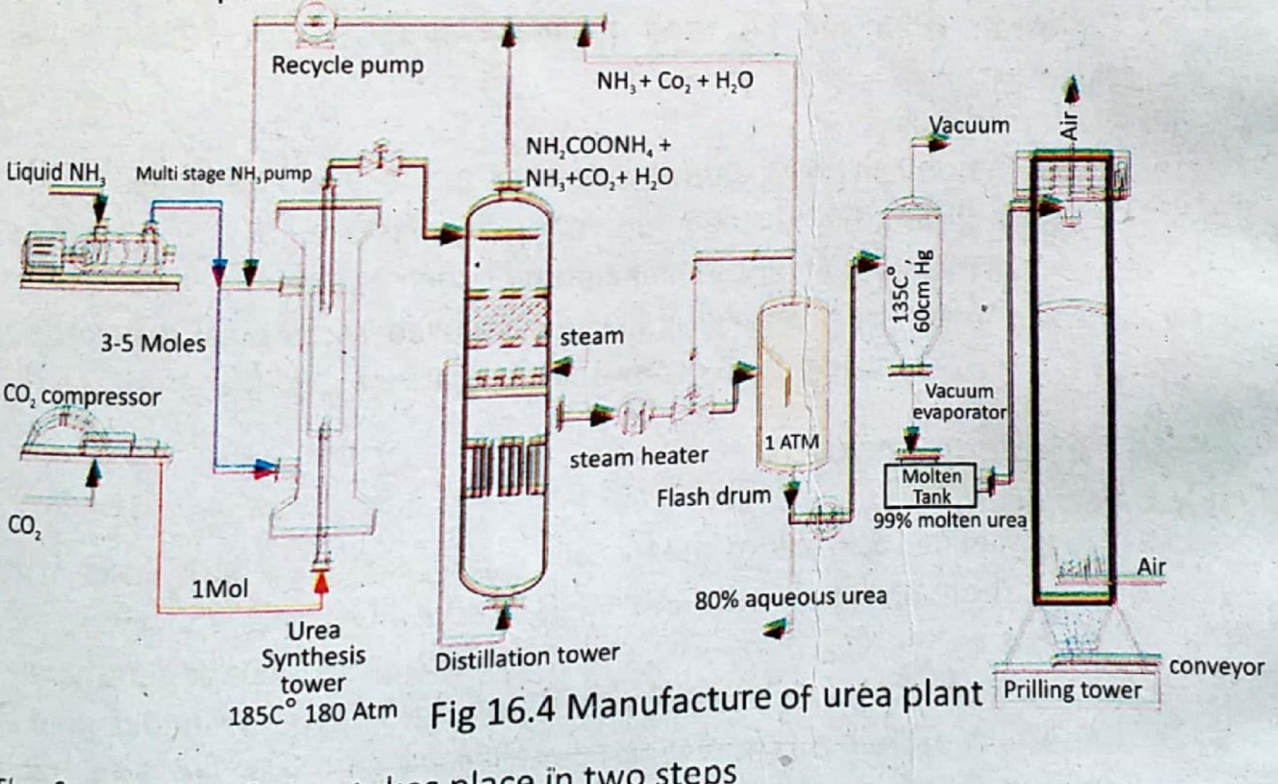


Fig 16.4 Manufacture of urea plant

The formation of urea takes place in two steps

i. Firstly ammonium carbamate is formed by the reaction of ammonia and carbon dioxide. $2NH_3 + CO_2 \longrightarrow NH_2COONH_4$

ii. In second step ammonium carbamate decomposes into urea and water.

$$NH_2COONH_4 \xrightarrow{\text{Heat}} \underset{\text{(urea)}}{NH_2CONH_2} + H_2O$$

The urea solution is concentrated in vacuum evaporators, which is then rapidly cooled and solidified. The flow sheet diagram of manufacture of urea is given below.

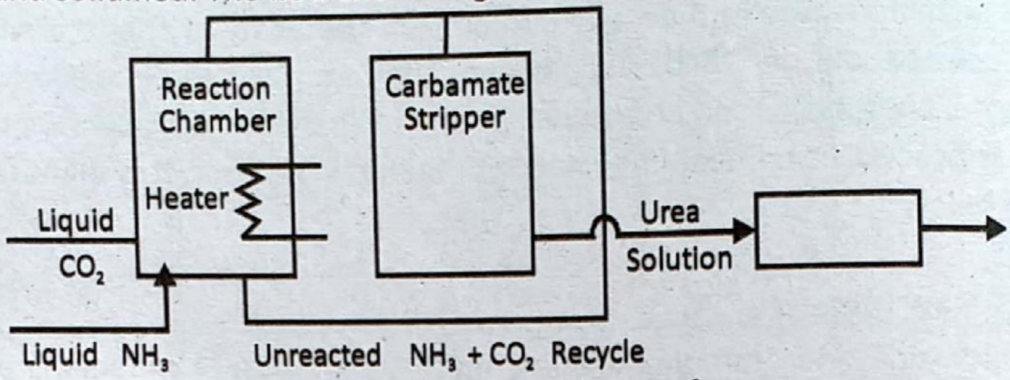


Fig. 16.5 Flow sheet diagram of urea

Urea is used in different fields.

i. Agriculture: Urea is widely used as fertilizer.

ii. Chemical Industries: Urea is used as raw material for manufacture of many important chemical compounds like plastic, resins, various adhesives, etc.

iii. Explosive: Urea can be used to make urea nitrate which is highly explosive.

iv. Commercial uses:
- A non-corroding alternate to rock salt for road de-icing.
- A flavour enhancing additive for cigarettes.
- A main ingredient in hair remover such as veet

v. Medical uses: Urea containing cream are used as tropical dermatological products to promote rehydrations of skin.

16.4 Petroleum industry

16.4.1 Petroleum

Petro means rock, oleum means oil. It is present as dark viscous liquid under the earth. It is also known as crude oil or mineral oil. It mainly consists of hydrocarbons. The wealth of a country may depend upon the presence of crude oil. Therefore it is also known as liquid gold. The important petroleum producing countries are USA, Mexico, Iran, Iraq and other middle-east countries.

16.4.2 Origin of petroleum

The origin of petroleum lies in plants and animals which lived on earth and in the sea, many millions of years ago. These organisms died and their remains became buried under the earth. Due to the bacterial decomposition and under the action of earth heat and pressure these animal and plant remains were converted to liquid hydrocarbon, the petroleum. The gaseous hydrocarbon that were produced constitute the natural gas.

16.4.3 Drilling of petroleum

Petroleum usually occur at depth of 500 feet or more. The crude oil is found in porous rocks. It is often associated with natural gas which exerts pressure on the oil surface and drives it out through natural opening of earth.

In the case of artificial mining, mines are bored. When the oil pocket is pierced the gas pressure, forces the oil out. If there is no natural gas present in pocket, air pressure is applied to raise the oil from the well. The oil obtained from the mine is conveyed by system of pipe lines to refinery for refining.

16.4.4 Important Fractions of Petroleum

Petroleum or crude oil has often been described as a useless mixture of very useful substances. The conversion of crude oil into useful products is called refining which is carried out in a fractionating column.

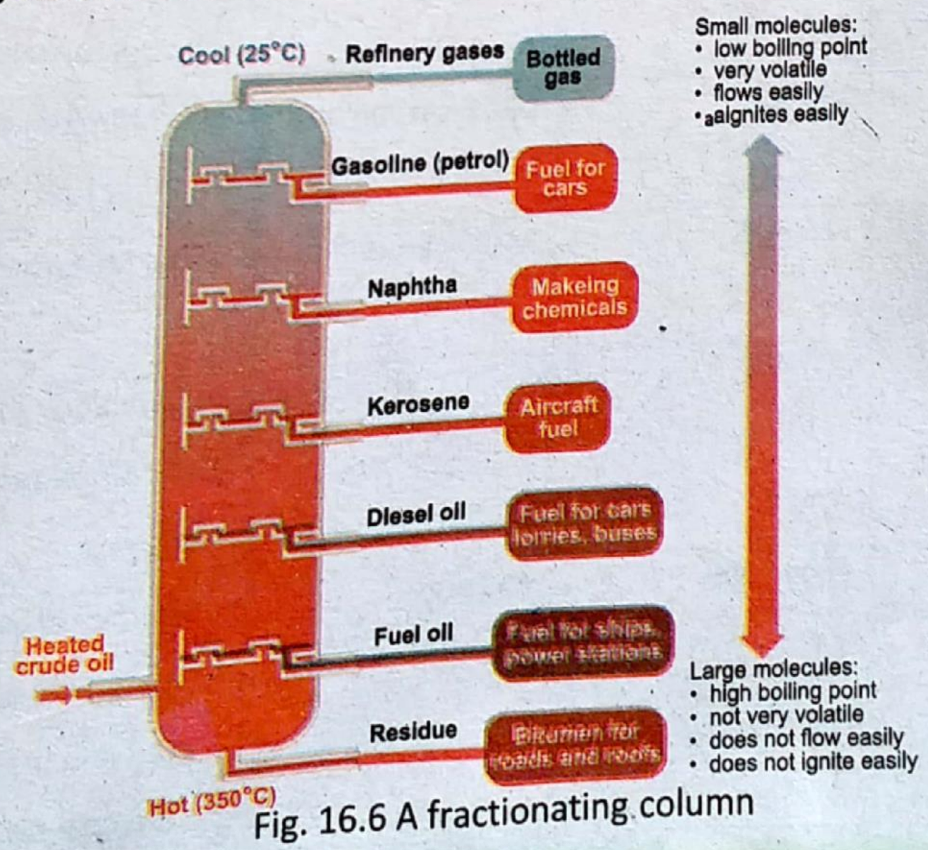


Fig. 16.6 A fractionating column

Different fractions of petroleum are separated by fractional distillation. The fractions are separated according to difference in their boiling points.

The petroleum is heated above 400°C in furnace as shown in fig 16.6. The vapour of petroleum, under high pressure are carried to fractionating column. The column is divided into several compartments, each of which has specific range of temperature. As the petroleum vapours rise up in the column, they condense and separate out into several fractions.

The following are important fractions and uses obtained from the refining of crude oil are given in table below.

Table 16.1

Fraction	Boiling point (°C)	Size of molecule	Uses
Petroleum gases	Below 40	Up to 4 carbon atoms	Methane for cooking and butane for camping gas
Petrol and Naphtha	40-130	4-12 carbon atoms	Naphtha for lighter fuel Petrol for cars
Paraffin Oil (Kerosene)	150-200	10-16 carbon atoms	Paraffin for heating and jet fuel
Diesel Oil (DERV)	225-300	14-25 carbon atoms	Fuel for lorries and ships
Lubricating oil	300-400	20-70 carbon atoms	Lubrication of machines and engines
Bitumen	Above 400	Residue	Bitumen is heated with gravel and sand and made into road coal tar

Organic vs synthetic fertilizers

1. Most organic fertilizer are derived from plants and animals like manure, bone, blood, meat etc. which is broken down by bacteria before they can be used by plants and soils.
   Synthetic fertilizers are commercially produced from petroleum or natural gas and are easy to apply in granular or liquid form.
2. The beauty of organics is that they are slowly released naturally. Therefore they are for entire season. Whereas synthetic fertilizer leach from soil with watering and can be used by plant instantly.
3. Organic fertilizers are present on surface and lot of work is required to mix them with the soil. Synthetic fertilizer are easy in use as they seep into the soil deep as soon as water is applied.

KEY POINTS

- Metal may exist in nature in free or combined state. In combined state it is called mineral.
- The art and science of making metal and alloy from their ore is called metallurgy.
- Metals can be extracted from their ores by means of a process consisting of concentration, roasting and refining.
- The blister copper is refined by electrolysis.
- Sodium carbonate is manufactured commercially by solvay process.
- Raw materials used for the commercial production of sodium carbonate are NaCl, $CaCO_3$, NH_3 and H_2O.
- Chinese were the first to use animal manure in their agriculture fields.
- Urea is probably the most important artificial fertilizer.
- Raw material used for production of urea are CO_2 and NH_3.
- Petroleum is a dark viscous liquid found under the earth crust.
- Different fractions of petroleum are separated by fractional distillation.

EXERCISE

Q.1 Choose the appropriate answer for the following.

I. The metal present in combined state is called__________

(a) mineral (b) metal (d) solid (d) none of these

II. The blister copper is refined by_________

(a) concentration (b) reduction

(c) electrolysis (d) boiling

III. Sodium carbonate is commercially manufactured by________process

(a) Solvay's (b) Ostwald's

(c) Haber's (d) Frasch

IV. Chemical formula of urea is _________

(a) NH_2COONH_4 (b) NH_2CONH_2

(c) NH_4Cl (d) Na_2CO_3

V. Urea is probably most important_________fertilizer.

(a) sulphur (b) nitrogenous

(c) phosphate (d) organic

VI. Raw material used for manufacturing urea are________

(a) CO_2 and NH_3 (b) H_2 and NH_3

(c) HCl and NH_3 (d) non of these

VII. Petroleum is mixture of many_________

(a) hydrocarbons (b) hydroxide (c) acids (d) salt

VIII. Different fractions of petroleum are separated by_________

(a) fractional distillation (b) steam distillation

(c) cooling (d) none of these

IX. Which one is a step of metallurgical process________

(a) roasting (b) rusting

(c) crystallization (d) none of these

X. The blister form of copper is ________copper.

(a) pure (b) impure (c) refined (d) raw

Q.2 Give short answers

i. What is metallurgy?
ii. How blister copper is purified?
iii. How sodium carbonate is commercially prepared?
iv. Describe the concentration of copper ore.
v. What is drilling of petroleum?
vi. Draw flow sheet diagram of solvay's process.
vii. What is origin of petroleum.

Q.3 Comprehensive questions.

i. Describe the composition of petroleum in detail.
ii. How is urea manufactured commercially?
iii. Describe the extraction of copper from its ore.
iv. Describe in detail the solvay's process.
v. Define fractional distillation? How fractional distillation is carried out in petroleum.