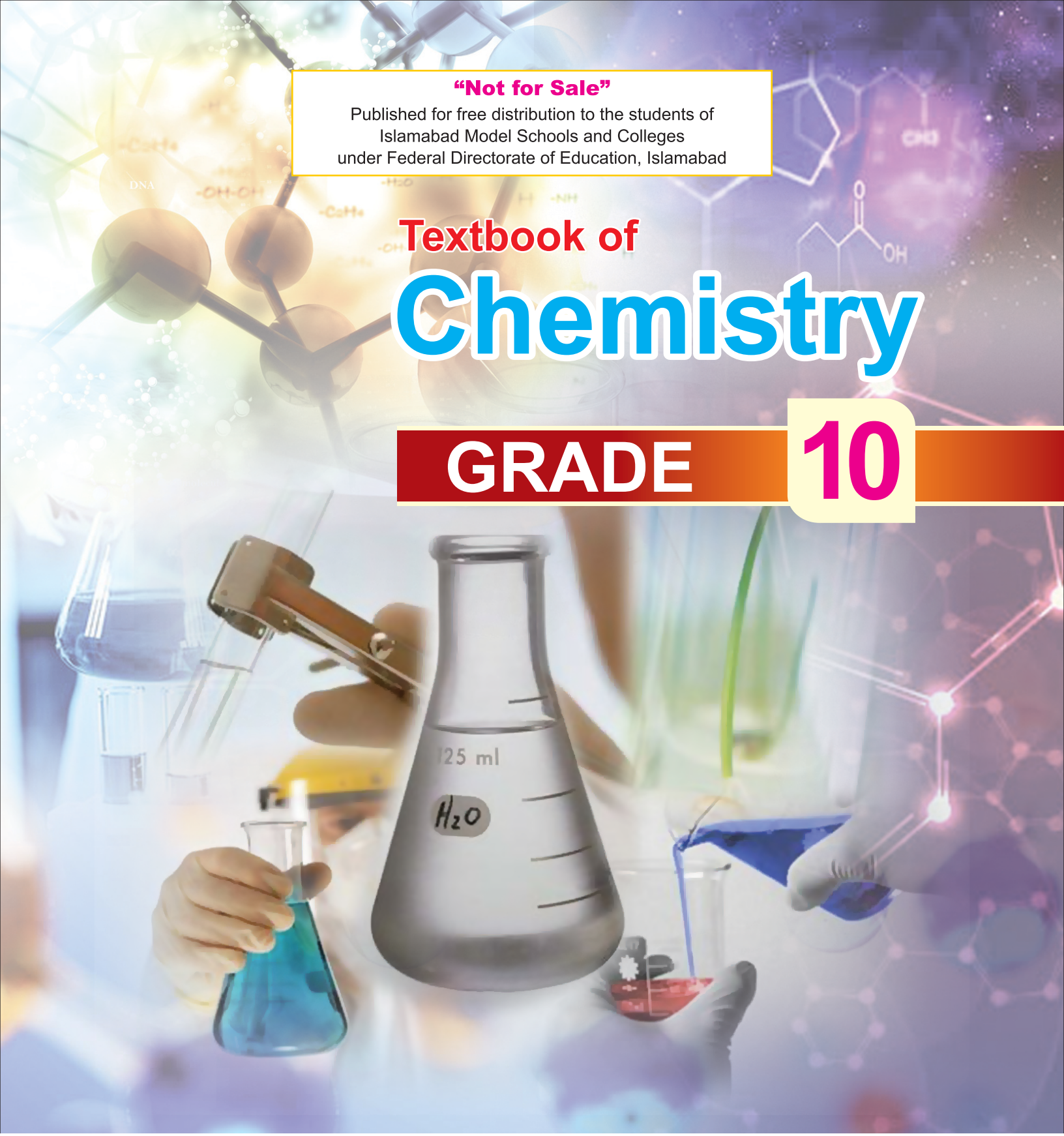
# Textbook of Chemistry

## GRADE 10

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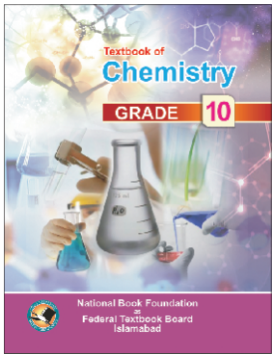
**Chemistry Grade - 10**

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# PREFACE

Textbook of **Chemistry Grade 10** is developed according to the National Curriculum 2006 and National Style Guide. It is being published since 2013 and now it is presented under the new management and supervision of textbook development principles and guidelines with new designing and layout.

Chemistry Grade 10 aims to bring themes and topics closer to the interests of the children. The activities are also intended to encourage them towards taking the responsibility of their own learning. The success of the book will depend upon the ownership of the children towards declaring the book as their favourite.

In the previous sessions the students have gone through a mind map of the chemistry division. Half of this divide was introduced there. Now they will go beyond the organic, bio and usage of chemistry in the industries and their effect on environment.

This book is now presented in a new way so that Chemistry should become a vital subject. The text items given in the exercises are for learning reinforcement. The examination questions are to be prepared according to the SLO's and the Bloom's Taxonomy.

Quality of Standards, Pedagogical Outcomes, Taxonomy Access and Actualization of Style is our motto. With these elaborations, this series of new development is presented for use. After educational feedback and necessary changes, the book is being published again.

**National Book Foundation**

بِسۡمِ اللّٰہِ الرَّحۡمٰنِ الرَّحِیۡمِ ؕ

اللہ کے نام سے شروع جو بڑا مہربان، نہایت رحم والا ہے

# 9

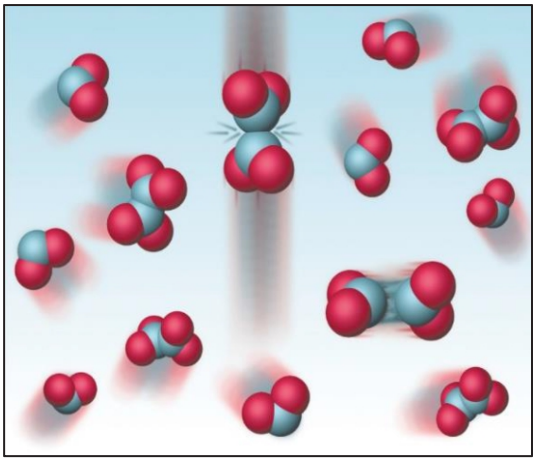
# CHEMICAL EQULIBRIUM

**After completing this lesson, you will be able to:**

**This is 11 days lesson (period including homework)**

- 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.
- Write the equilibrium constant expression for a given chemical reaction.
- Explain how components of atmosphere can be used successfully in producing important chemicals.

## Reading



## INTRODUCTION:

A complete reaction is one in which all the reactants have been converted to products. However, many important chemical reactions do not complete and a mixture of products and reactants are formed. In such a reaction product react together to re-form reactants. At the same time reactants form products. These reactions are called reversible reactions. An understanding of equilibrium is important in the chemical industry. Equilibrium reactions are involved in some of the stages in the commercia,l production of many important chemicals such as ammonia, sulphuric acid etc.

In a closed container, the formation of ammonia from its elements does not proceed to any great extent. Yet as you will learn in this chapter, this vital substance is manufactured on multimillion ton scale annually by applying the principles of equilibrium. How? You will learn many important things about chemical equilibrium in this chapter.

# 9.1 REVERSIBLE REACTIONS AND DYNAMIC EQUILIBRIUM.

**Recall what happens when some liquid is placed in a closed container? You have learnt about it in grade IX.**

Some of the liquid undergoes a physical change by evaporating. As more liquid evaporates, some of the vapours condense due to collision with the surface of the liquid. Eventually the rate of evaporation equals the rate of condensation. At this stage equilibrium is established between forward and reverse changes.

**Liquid $\rightleftharpoons$ Vapours**

Many chemical reactions do not reach completion. In such reactions the conversion of reactants into products and conversion of products into reactants can happen simultaneously. **A reaction in which the products can react together to re-form the original reactants is called reversible reaction OR a reaction which proceeds in the forward direction as well as in the reverse direction under the same conditions is called a reversible reaction. These reactions never go to completion.** All reversible changes (physical and chemical) occur simultaneously in both the directions. The double arrow ( $\rightleftharpoons$ ) in the chemical equation shows that the reaction is reversible. For example:

| | | | | |
|---|---|---|---|---|
| $2SO_{2(g)}$ | + | $O_{2(g)}$ | $\overset{V_2O_5}{\rightleftharpoons}$ | $2SO_{3(g)}$ |
| Sulphur dioxide | | Oxygen | **450°C, 200 atm** | Sulphur trioxide |
| $N_{2(g)}$ | + | $3H_{2(g)}$ | $\overset{Fe}{\rightleftharpoons}$ | $2NO_{2(g)}$ |
| Nitrogen | | Hydrogen | **400°C, 200 atm** | Ammonia |
| $2N_{2(g)}$ | + | $O_{2(g)}$ | $\overset{Electric}{\rightleftharpoons}$ | $2NO_{2(g)}$ |
| Nitric oxide | | Oxygen | **spark** | Nitrogen dioxide |

**Consider what happens when $SO_2$ and $O_2$ gases are mixed in a sealed container (Figure 9.1)**

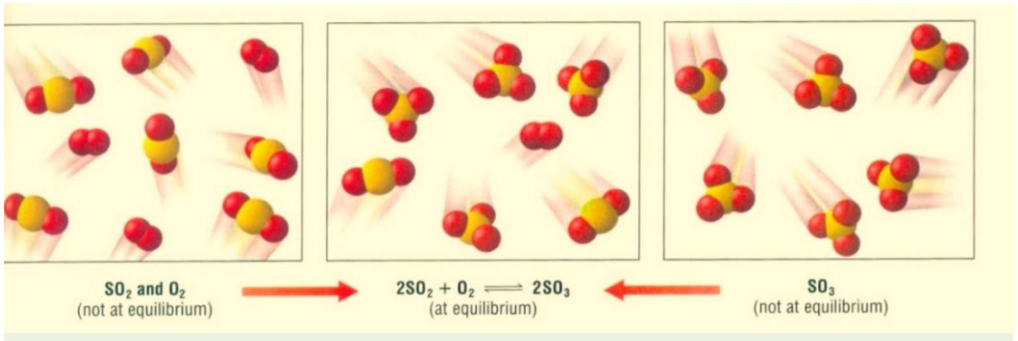



**Figure 9.1 Reaction between $SO_2$ and $O_2$**

## Teacher's Point

Teacher may give more examples of reversible reactions.

**Science Titbits**

When fizzy drinks are made, $CO_2$ is dissolved in the liquid drink under pressure and sealed. When you remove lid of the bottle, bubbles of $CO_2$ suddenly appear. When you put the lid back on the bottle, the bubbles stop. This is due to the following equilibrium.

$$CO_{2(g)} \rightleftharpoons CO_{2(aq)}$$

The forward reaction happens during manufacturing and the reverse reaction happens on opening.

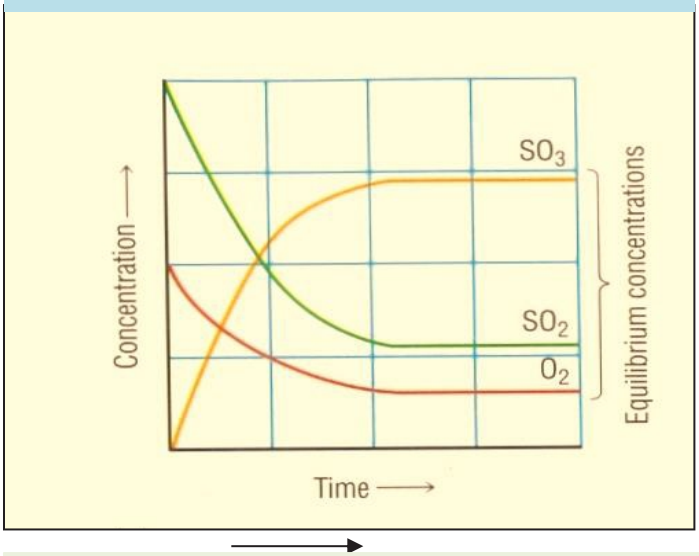



**Figure 9.2 Concentration-time graph**

Molecules of $SO_2$ and $O_2$ react to give $SO_3$. Molecules of $SO_3$ decompose to give $SO_2$ and $O_2$. What types of molecules are present at equilibrium?

In the first reaction (from left to right) $SO_2$ and $O_2$ produce $SO_3$. In the second reaction (from right to left) $SO_3$ decompose into $SO_2$ and $O_2$.

Which reaction is called forward reaction?

Which reaction is called the reverse reaction?

Initially there is no $SO_3$. So the rate of reverse reaction is zero. The rate of forward reaction is the highest, due to the high concentration of reactants. As the reaction proceeds, the concentration of reactants gradually decreases and the rate of forward reaction also decreases proportionately. (Figure 9.1)

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

As the concentration of $SO_3$ increases, a small amount of $SO_3$ slowly decomposes to $SO_2$ and $O_2$. This means reverse reaction has begun. In this reaction $SO_3$ acts as reactant and produces $SO_2$ and $O_2$. So the reverse reaction is

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

As the concentration of $SO_3$ becomes higher, the reverse reaction speeds up. Eventually the two rates become equal. At this stage $SO_3$ decomposes to $SO_2$ and $O_2$ as fast as $SO_2$ and $O_2$ produce $SO_3$. At this stage reaction is said to have reached equilibrium state. (Figure 9.2)

**A state of a chemical reaction in which forward and reverse reactions take place at the same rate is called chemical equilibrium.**

Chemical equilibrium is a dynamic equilibrium. This is because reactions do not stop when they come to equilibrium state. The individual molecules keep on reacting continuously. But

there is no change in the actual amounts of reactants and products. This means concentration of reactants and products become constant at equilibrium stage.

### Example 9.1: Writing the forward and the reverse reactions

Write the forward and the reverse reactions for the following reversible reactions.

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2\,(g)}$$

### Problem Solving Strategy:

1. The reaction from left to right is the forward reaction.
2. The reaction from right to left is the reverse reaction.

### Solution:

Forward reaction

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2\,(g)}$$

Reverse reaction

$$2NO_{2(g)} \longrightarrow 2NO_{(g)} + O_{2(g)}$$

## Self Assessment Exercise – 9.1

Write both forward and reverse reactions and describe macroscopic characteristics of each?

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

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

## Reading

# 9.2. LAW OF MASS ACTION AND DERIVATION OF THE EXPRESSION FOR THE EQUILIBRIUM CONSTANT

Chemists generally express the composition of equilibrium mixture in terms of numerical values. These values relate the amounts of products to reactants at equilibrium. These values can be determined by using a relationship known as "**The law of mass action".**

Two chemists C.M Guldberg and P. Waage in 1864 proposed the law of mass action to describe the equilibrium state.

**It states that the rate at which a substance reacts is directly proportional to its active mass. The rate at which the reaction proceeds, is directly proportional to the product of the active masses of the reactants.**

The term "**active mass**" represents the concentration of reactants and products in mol.dm$^{-3}$ for a dilute solution, and is expressed in terms of square brackets [ ].

Consider a hypothetical reaction in which 'a' moles of reactant A and 'b' moles of reactant B react to give 'c' moles of product C and 'd' moles of product D at equilibrium.

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

According to the law of mass action;

Rate of forward reaction $\propto [A]^a[B]^b$

Rate of forward reaction = $k_f[A]^a[B]^b$

Rate of reverse reaction $\propto [C]^c[D]^d$

Rate of reverse reaction= $k_r[C]^c[D]^d$

Where $K_f$ and $K_r$ are the rate constants for forward and the reverse reactions respectively

At equilibrium state:

Rate of forward reaction = Rate of reverse reaction

Thus

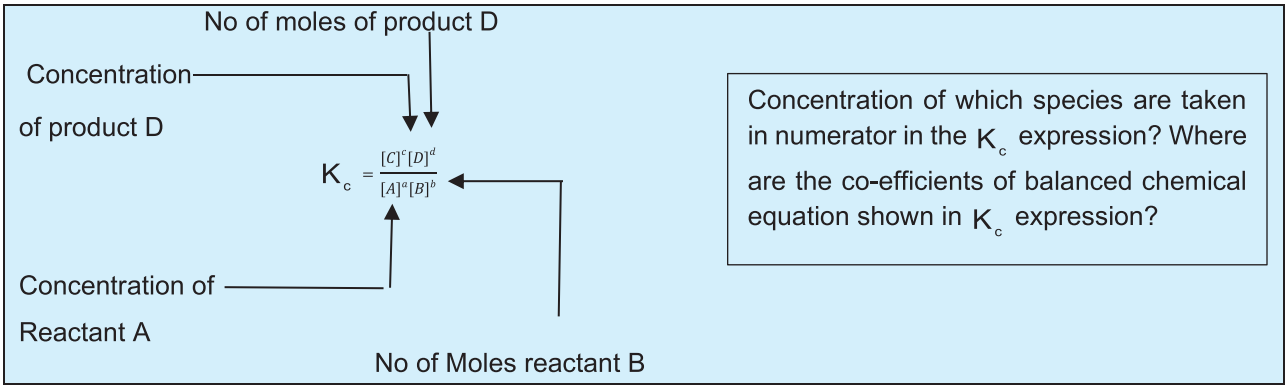
$$k_f\ [A]^a\ [B]^b = k_r\ [C]^c\ [D]^d$$

On rearranging $\frac{k_f}{k_r} = \frac{[C]^c\ [D]^d}{[A]^a\ [B]^b}$

$$K_c = \frac{[C]^c\ [D]^d}{[A]^a\ [B]^b}$$

Where $K_c = \frac{k_f}{k_r}$ and is known as equilibrium constant, and the above equation is called as equilibrium constant expression. The square brackets indicate the concentration of the chemical species at equilibrium in moles/dm$^{-3}$. Thus the equilibrium constant expression for any reaction can be written from its balanced equation. Concentration of products is taken in the numerator and concentration of reactants in the denominator. In $K_c$, the subscript 'c' denotes molar concentration at equilibrium.

Equilibrium constant is defined as the ratio of the product of concentration of products to the product of concentration of reactants each raised to the power equal to the coefficient in the balanced chemical equation. $K_c$ is independent of the initial concentration of reactants but depends upon temperature.




## Example 9.2: Writing Equilibrium Constant Expression.

Coal can be converted to a gaseous fuel as methane. Coal reacts with hot steam to form CO and $H_2$. These gases can react further to give methane.

$$C_{(s)} + H_2O_{(g)} \xrightarrow{1000^oC} CO_{(g)} + H_{2(g)}$$

$$CO_{(g)} + 3H_{2(g)} \longrightarrow CH_{4(g)} + H_2O_{(g)}$$

$$CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_{4\,(g)} + H_2O_{(g)}$$

Write equilibrium constant expression for this reaction.

### Problem Solving Strategy

1. Write products in the numerator and reactants in the denominator in square brackets.
2. Raise each concentration to the power that corresponds to the co-efficient of each species in the balanced chemical equation.

### Solution:

$$\boldsymbol{K_c = \frac{[CH_4][H_2O]}{[CO][H_2]^3}}$$

## Self Assessment Exercise 9.2

1. Following reaction can occur during lightning storms.

$$3O_{2(g)d} \rightleftharpoons 2O_{3(g)}$$

Derive equilibrium constant expression for this reaction.

2. Write equilibrium constant expression for the following reactions.

a. $4HCl_{(g)} + O_2(g) \rightleftharpoons 2H_2O_{(g)} + 2Cl_{2(g)}$

b. $CH_3COOH_{(\ell)} + C_2H_5OH_{(\ell)} \rightleftharpoons CH_3COOC_2H_{5(\ell)} + H_2O_{(\ell)}$

c. $2HF_{(g)} \rightleftharpoons H_{2(g)} + F_{2(g)}$

d. $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

**Reading**

## 9.2.1. Conditions for Equilibrium

Equilibrium is reached when pure reactants, pure products or a mixture of reactants and products is first placed in a closed container. In any such case, the forward and reverse action in the container will occur at the same rate. This leads to a situation where the concentration of reactants and products remain the same indefinitely, for an indefinite time so long the following conditions are observed:

1. Concentration of the reactant or product remains unchanged.
2. Temperature of the system remains constant.
3. Pressure or volume of the system remains constant.

## 9.2.2 Ways to Recognize Equilibrium

When constant concentration of products and reactants is observed, the reaction is at equilibrium. This can be done by both physical as well as chemical methods such as titration, spectroscopy etc. You will learn these methods in detail in Grade XI.

# 9.3 EQUILIBRIUM CONSTANT AND ITS UNITS

Equilibrium constant may or may not have units. In the equilibrium expression each figure within a square bracket represents the concentration in mol $dm^{-3}$. The units of $K_c$ therefore depend on the form of equilibrium expression.

**Example: 9.3.** Determining units of equilibrium constants

Determine the units of equilibrium constants for the following reactions.

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

**(ii)** $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

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

### Problem Solving Strategy

1. Write the equilibrium constant expression.
2. Write units of concentration of each species i.e. mol $dm^{-3}$ within the square bracket.
3. Simplify the expression.

**Solution:-**

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

$$K_c = \frac{[moldm^{-3}]^2}{[moldm^{-3}][moldm^{-3}]}$$

$K_c$ = no units

$K_c$ has no units when the total number of moles of reactants is equal to the total number of moles of products in a balanced chemical equation.

**Do you know?**
A catalyst is a substance which increases the rate of a chemical reaction. Catalysts reduce the time taken to reach equilibrium, but they have no effect on the position of equilibrium once this is reached.

(ii) $K_c = \frac{[NO_2]^2}{[N_2O_4]}$

$$K_c = \frac{[mol\ dm^{-3}]^2}{[mol\ dm^{-3}]}$$

$$K_c = mol\ dm^{-3}$$

(iii) $K_c = \frac{[NO_2]^2}{[NO]^2[O_2]}$

$$K_c = \frac{[mol\ dm^{-3}]^2}{[mol\ dm^{-3}]^2[mol\ dm^{-3}]}$$

$$K_c = dm^3 mol^{-1}$$

**Science Titbits**
The addition of water to the concentrated sulphuric acid produces a vigorous reaction, which often causes acid droplets to spew in all directions. For this reason this must be avoided. Add water to dilute acid.

Examples (ii) and (iii) show that $K_c$ has units. A close observation reveals that reversible reaction in which, the total number of moles of reactants is different from the total number of moles of products in a balanced chemical equation, $K_c$ has units.

## Self Assessment Exercise 9.3

Determine the units of equilibrium constants for the following reactions.

1. $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$
2. $H_{2(g)} + CO_{2(g)} \rightleftharpoons H_2O_{(g)} + CO_{(g)}$
3. $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$
4. $CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$

**Reading**

## 9.4 IMPORTANCE OF EQUILIBRIUM CONSTANT

Equilibrium constant for a reaction can be used to predict many important features of a chemical reaction. It can be used to

(a) determine the equilibrium concentration of equilibrium mixture knowing the initial concentration of reactants.
(b) predict the direction of a chemical reaction.
(c) Predict the extent of a chemical reaction.
(d) predict the effect of change in conditions of the chemical reaction on the equilibrium state.

You will learn about these features in detail in grade XI. Industrial chemists take help from the effects of changes in conditions such as concentrations, temperature, pressure etc. They choose conditions needed for the desired products.

Nitrogen and Oxygen are main gases of the air. They are effectively converted in the large scale production of many important chemicals such as ammonia, sulphuric acid etc.

Ammonia is produced by the reaction of nitrogen with hydrogen at 400ºC, 200 atm pressure and in the presence of a catalyst.

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

This process is known as Haber process . This is a reversible process and produces only 33% $NH_3$ at equilibrium. The high pressure is used to favour the formation of ammonia. Then, cooling the equilibrium mixture gives 98% ammonia.

Sulphuric acid is produced on a large scale by the contact process. In this process sulphur is converted into sulphur dioxide.

$$S_{(s)} + O_{2\,(g)} \longrightarrow SO_{2\,(g)}$$

Sulphur dioxide is purified and further oxidized at 450°C and 200 atm pressures in the presence of Pt or $V_2O_5$ as catalyst.

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

This reaction is a reversible reaction. Here again by the application of principles of chemical equilibrium, maximum amount of $SO_2$ is converted into $SO_3$. Sulphur trioxide is then converted into 100% pure sulphuric acid.

**Society, Technology and Science**

Although reversible reactions do not complete, yet such reactions are not economical for the large scale production of chemicals. However, progress of the science has enabled us to deal with such reactions and obtain maximum amount of products from reversible reactions. An important principle called **Le Chatellier's principle** is very useful about chemical equilibrium systems, it says that **if you impose a change in concentration, temperature or pressure on a chemical system at equilibrium, the system responds in a way that opposes the change.** With the application of this principle, components of air i.e $N_2$ and $O_2$ can be used successfully in producing important chemicals, ammonia and sulphuric acid in 98% yield. Both these processes involve reversible reactions, so inadequate amount of products are formed under normal conditions.

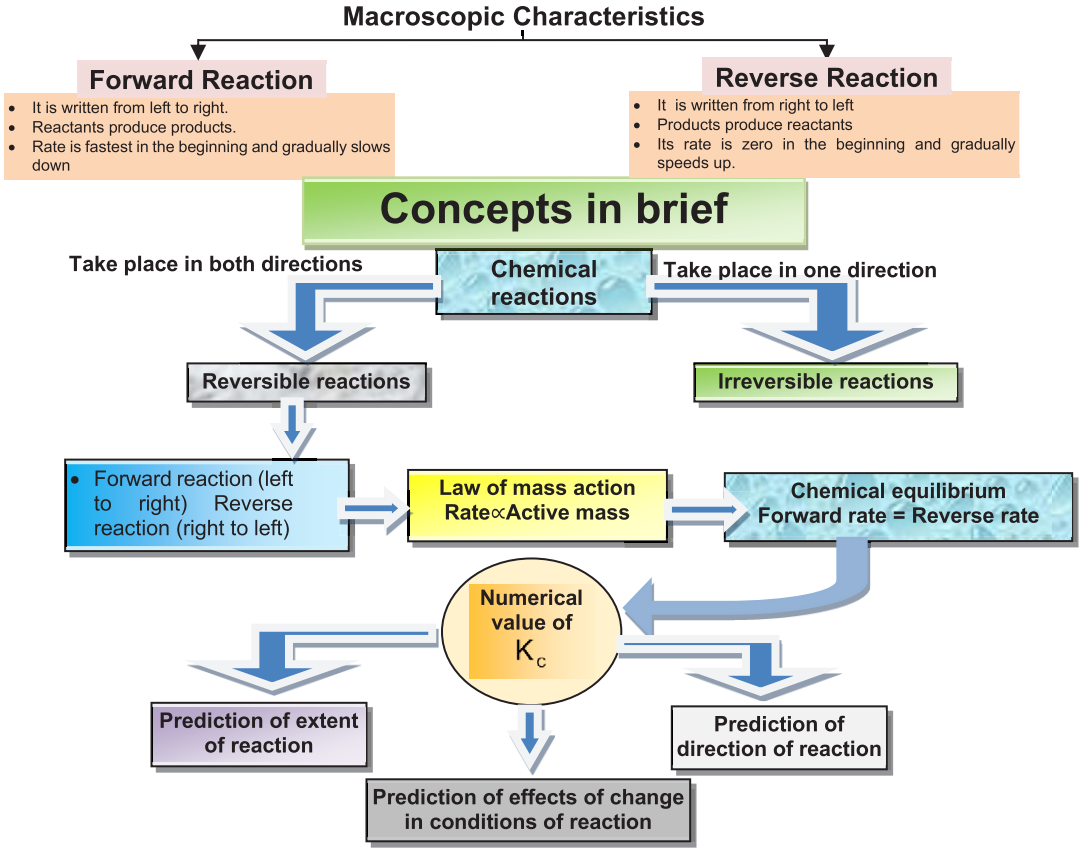
$$2SO_{2(g)} + O_{2(g)} \underset{450^{o}C,200atm}{\overset{V_2O_5}{\rightleftharpoons}} 2SO_{3(g)}$$

Sulphur dioxide Oxygen Sulphur trioxide

$$N_{2(g)} + 3H_{2(g)} \underset{400^{o}C,200atm}{\overset{Fe}{\rightleftharpoons}} 2NH_{3(g)}$$

Nitrogen Hydrogen Ammonia

As such these reactions are uneconomical. However, Le Chatelliers's principle has made it possible to get maximum amount of products. First, equilibrium is established in the presence of catalyst in minimum time and then by increasing pressure and decreasing temperature, equilibrium is shifted towards right. Such conditions tend to increase the yield of $NH_3$ and $SO_3$ to about 98%.



## Key Points

- A reaction in which the products can react together to re-form the original reactants is called reversible reaction.
- A state of a chemical reaction in which forward and reverse reactions take place at the same rate is called chemical equilibrium.
- The law of mass action states that the rate at which a substance reacts is directly proportional to its active mass and the rate at which the reaction proceeds is directly proportional to the product of the active masses of the reactants.
- The term **"active mass"** represents the concentration of reactants and products in $moldm^{-3}$ for a dilute solution.
- Equilibrium constant is defined as the ratio of the product of concentration of products to the product of concentration of reactants each raised to the power equal to the coefficient in the balance chemical equation.

### References for additional information

- Chemistry, Roger Norris, Lawrie Ryen and David Acaster.
- Principals of chemical equilibrium, Kenneth Denbigh.

## Review Questions

**1. Encircle the correct answer.**

(i) Which is true about the equilibrium state?

(a) The forward reaction stops.
(b) The reverse reaction stops.
(c) Both forward and reverse reactions stop.
(d) Both forward and reverse reactions continue at the same rate.

(ii) When a mixture of $H_2$ and $I_2$ is sealed in a flask and temperature is kept at 25ºC, following equilibrium is established.

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

Which substance or substances will be present in the equilibrium mixture?

(a) $H_2$ and $I_2$
(b) HI only
(c) $H_2$ only
(d) $H_2$, $I_2$ and HI

(iii) What are the units for

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

(a) mol.dm$^{-3}$

(b) mol$^2$. dm$^{-6}$

(c) dm$^3$.mol$^{-1}$

(d) No units

(iv) Which of the following reaction will not have any units for $K_c$?

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

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

(c) $2A_{(g)} + B_{(g)} \rightleftharpoons 3AC_{(g)}$

(d) All of these

(v) Concentration of reactants and products at equilibrium remains unchanged if

(a) concentration of any reactant or product is not changed.

(b) temperature of the reaction is not changed.

(c) pressure or volume of the system is not changed.

(d) all of the above are observed

(vi) Which of the following does not happen, when a system is at equilibrium state?

(a) forward and reverse reactions stop.

(b) forward and reverse rates become equal.

(c) concentration of reactants and products stop changing.

(d) reaction continues to occur in both the directions.

(vii) For which reaction, $K_c$ has units of mol.dm$^{-3}$.

(a) $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

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

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

(d) $2ICl_{(g)} \rightleftharpoons I_{2(g)} + Cl_{2\,(g)}$

(viii) In an irreversible reaction equilibrium is

(a) established quickly

(b) established slowly

(c) never established

(d) established when reaction stops.

(ix) Active mass means

(a) total mass of reactants

(b) total mass of products

(c) total mass of reactants and products

(d) mass of substance in moles per $dm^3$ in a dilute solution

(x) For a reversible reaction

$$K_c = \frac{[C]^2}{[A][B]}$$

Which substance is product of the reaction?

(a) A

(b) B

(c) Both A and B

(d) C

**2. Give short answer.**

(i) Differentiate between forward and reverse reactions.

(ii) What is chemical equilibrium?

(iii) Write the law of Mass Action.

(iv) Write down the conditions for equilibrium.

(v) What is the importance of equilibrium constant for a chemical reaction?

**3. Following reaction can occur during lightning storms**

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

For this reaction write

(i) Equilibrium constant expression.

(ii) Determine the units of equilibrium constant.

(iii) Forward and reverse reactions.

**4. Coal reacts with hot steam to form CO and $H_2$. These substances react further in the presence of a catalyst to give methane and water vapour.**

$$CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_{4(g)} + H_2O_{(g)}$$

(i) Write forward and reverse reactions for it.

(ii) Derive $K_C$ expression for the reaction.

(iii) Determine units for $K_C$

**5. Write equilibrium constant expression for each of the following reactions.**

(i) $H_2O_{(g)} \rightleftharpoons H_{2(g)} + \frac{1}{2}O_{2(g)}$

(ii) $CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$

(iii) $COCl_{2(g)} \rightleftharpoons CO_{(g)} + Cl_{2(g)}$

(iv) $4HCl_{(g)} + O_{2(g)} \rightleftharpoons 2Cl_{2(g)} + 2H_2O_{(g)}$

**6. Determine the units of equilibrium constants for the following reactions.**

(i) $COCl_{2(g)} \rightleftharpoons 2CO_{(g)} + Cl_{2(g)}$

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

(iii) $2H_{2(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)}$

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

**7. State the ways that equilibrium can be recognized.**

**8. Describe the macroscopic characteristics of an equilibrium reaction.**

## Think-Tank

**1. Bromine chloride (BrCl) decomposes to form chlorine and bromine. For this reaction write.**

(i) Chemical equation

(ii) $K_c$ expression

(iii) Units of $K_c$

**2. $K_C$ expression for a reaction is given below**

$$\boldsymbol{K_c = \frac{[NO_2]^2}{[N_2O_4]}}$$

Choose reactant and product to derive the units of $K_C$ for this reaction.

**3. For which of the following reactions are both reactants and products likely to be found when the reaction appears to be complete. Justify.**

(i) $\boldsymbol{C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}}$

(ii) $\boldsymbol{2HF_{(g)} \rightleftharpoons H_{2(g)} + F_{2(g)}}$

Cobalt chloride forms pink crystals $(CoCl_3.6H_2O)$. When they are heated water is evolved and they turn blue $(CoCl_3)$. Can you use Cobalt chloride as a test for water, argue.

$$\boldsymbol{CoCl_3.6H_2O \rightleftharpoons CoCl_3 + 6H_2O}$$

10

# ACIDS, BASES AND SALTS

**After completing this lesson, you will be able to:**

**This is 13 days lesson (period including homework)**

- Define and give examples of Arrhenius 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 acid or bases.
- Write the equation for 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.
- Use litmus paper, pH paper and other indicators for measuring pH of solutions.
- Perform acid base titrations and related calculations.
- Identify areas of work for analytical chemists.
- Explain why the quantity of preservatives in food is restricted by government regulations.
- Explain pH-dependent foods.
- Explain process of etching in arts and industry.
- Explain the reactions between industrial pollutants and atmospheric water leading to formation of acids.
- Describe harmful effects of acid rain.
- Explain stomach acidity.

## Reading

## INTRODUCTION:

You frequently use acids and bases in every aspect of life. For instance, vinegar, aspirin, lemon juice, cola drinks, apple, tomato and toilet bowl cleaner contain acids. Substances such as drain cleaner, antacid tablets, baking powder, washing soda etc. contain bases. You eat and drink certain acids and bases, and your bodies produce them. From "**acid indigestion**" to "**acid rain**" the word **acid** occurs frequently in the news and advertisements.

What is an acid rain? This chapter will enable you to understand which substances are called acids and which are called bases. How they are classified? What happens when an acid reacts with a base? Why do we use lemon juice on fish? In this chapter you will learn some of the chemistry of acids and bases. This will help you to gain a better understanding of these important classes of compounds. What do we mean by the pH of a solution such as that of acid rain? Acids are widely used in the manufacturing of fertilizers and in food industry.

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Acid rain can damage trees, kill huge areas of forest. It washes out aluminum ions from the soil. These aluminum ions run into rivers, lakes and ponds. Aluminum is very toxic to fish and other aquatic life. They cannot survive in it and may be killed. Acid rain can also damage buildings and statues. The acid reacts with carbonates in lime stone. The lime stone dissolves and the statue gradually crumbles away. Thus acid rain is an important environmental issue.

**Do you know?**

Sulphur dioxide and oxides of nitrogen are also produced by smoking of cigarettes. Smokers breathe in a lot of sulphur dioxide. Over long period of time, they have an increased risk of suffering from cold, bronchitis and asthma.

# 10.1 CONCEPTS OF ACIDS AND BASES

Acids and bases are generally recognized by their characteristic properties. Table 10.1 shows such properties.

**Table 10.1 Some characteristic properties of acids and bases**

| Sr. No. | Property | Acid | Base |
|---|---|---|---|
| 1 | Taste | Sour | Bitter |
| 2 | Effect on blue litmus | Turns red | No effect |
| 3 | Effect on red litmus | No effect | Turns blue |
| 4 | Effect on skin | Corrosive | Corrosive |
| 5 | Electrical conductivity | Aqueous solutions conduct electricity | Aqueous solutions conduct electricity |

## 10.1.1 Arrhenius Concept of Acids and Bases

In 1887, a Swedish chemist Svante Arrhenius proposed the first successful theory of acids and bases. According to this theory

**An acid is a substance that ionizes in water to produce $H^+$ions and a base is a substance that ionizes in water to produces $OH^-$ions.**

**For example,**

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

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

Which substances in the following reactions are acids or bases?

$$HNO_{3\,(l)} \xrightleftharpoons{H_2O} H^+{}_{(aq)} + NO_3^{-1}{}_{(aq)}$$

$$H_2SO_{4\,(l)} \xrightleftharpoons{H_2O} 2H^+_{(aq)} + SO_4^{-2}{}_{(aq)}$$

$$KOH_{(s)} \xrightleftharpoons{H_2O} K^+_{(aq)} + OH^-_{(aq)}$$

$$NH_4OH_{(aq)} \xrightleftharpoons{H_2O} NH_4^+{}_{(aq)} + OH^-_{(aq)}$$

**Table 10.2 shows some common acids and table 10.3 shows some common bases.**

**Table 10.2 Some Common Acids**

| Name | Formula | Common use |
|---|---|---|
| Hydrochloric acid | $HCl$ | Cleaning of metals, bricks and removing scale from boilers |
| Nitric acid | $HNO_3$ | Manufacture of fertilizers, explosives |
| Sulphuric acid | $H_2SO_4$ | Manufacture of many chemicals, drugs, dyes, paints and explosives. |
| Phosphoric acid | $H_3PO_4$ | Manufacture of fertilizers, acidulant for food |

**Table 10.3 Some Common Bases**

| Name | Formula | Common use |
|---|---|---|
| Sodium hydroxide | $NaOH$ | Soap making, drain cleaners |
| Potassium hydroxide | $KOH$ | Making liquid soap, shaving cream |
| Calcium hydroxide | $Ca\,(OH)_2$ | Making mortar, plasters, cement |
| Magnesium hydroxide | $Mg(OH)_2$ | Antacid, laxative |

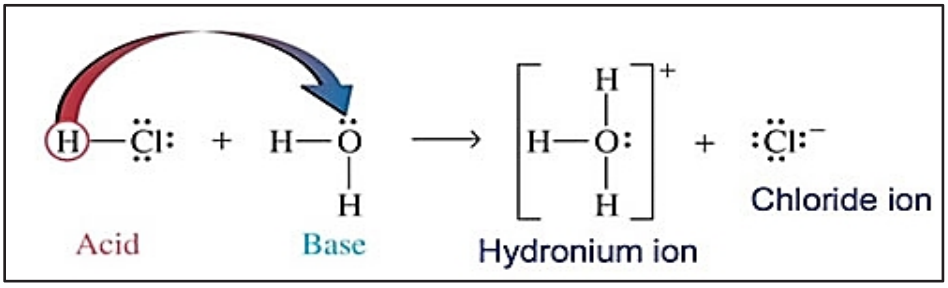
## 10.1.2 The Bronsted-Lowery Concept of Acids and Bases

Arrhenius theory has its limitations. It applies to aqueous solutions. It does not explain why compounds such as $CO_2$, $SO_2$ etc., are acidic. Why substances like $NH_3$, are bases? There is no H in $CO_2$ and OH in $NH_3$.

In 1923 J.N Bronsted and T.M Lowery independently proposed another theory to overcome the shortcomings of Arrhenius theory. This theory is known as **Bronsted-Lowery theory**.

According to this theory **an acid is a proton donor and a base is a proton acceptor.**

Consider the following example



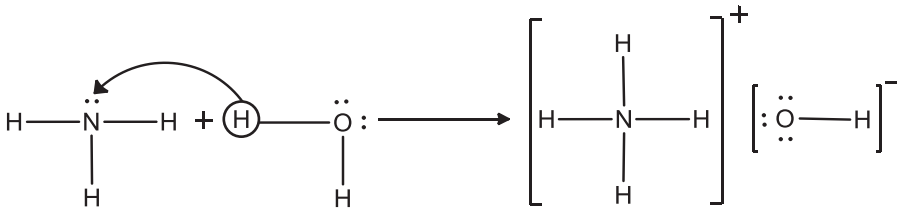
Q.1. Which substance is donating proton? _____

Q. 2. Which substance is accepting proton? _____

Q. 3. Which substance is acid? _____

Q. 4. Which substance is base? _____

Where does the $OH^-$ come from in the ionization of bases such as ammonia? The Arrhenius theory is inadequate to answer this question, but the Bronsted-Lowry theory explains how ammonia acts as a base in water. Ammonia is a gas at room temperature. When it is dissolved in water, the following reaction occurs.



Which substance is donating proton, $NH_3$ or $H_2O$? Which substance is proton acceptor? All the acids included in the Arrhenius Theory are also acids in the Bronsted-Lowery Theory. However, all the bases included in Bronsted-Lowery theory except $OH^-$ are not Arrhenius bases. Consider above two examples. In one example, water molecule accepts a proton and in the other water donates a proton. This means water behaves like an acid as well as a base. It is amphoteric in nature. Substances that react with both acids and bases are called amphoteric substances.

**Society Technology and Science**

Fossils Fuels contain small amounts of sulphur and nitrogen. They produce sulphur dioxide and oxides of nitrogen when the fuel is burned. Large amounts of these oxides are released from coal-burning factories and power stations. They react chemically with the water vapours in clouds and oxygen in the air, forming acids.

$$SO_{2(g)} + \frac{1}{2}O_{2(g)} + H_2O_{(l)} \longrightarrow H_2SO_{4(aq)}$$

$$4NO_{2(g)} + O_{2(g)} + 2H_2O_{(l)} \longrightarrow 4HNO_{3(aq)}$$

These acids mix up with rain drops and fall as acids rain or acid snow.

**Example 10.1: Classify substances as acids or bases or as proton donor or proton acceptor**

Identify Bronsted-Lowery acids or bases in the following reactions.

$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

$$H_2O + NH_3 \longrightarrow NH_4^+ + OH^-$$

**Problem solving strategy:**

1. An acid is a proton donor. After donating proton, an acid forms a negative ion.
2. A base is a proton acceptor. After accepting proton from an acid it forms a positive ion.

**Solution:**

1. Because HCl is converted to $Cl^-$ by donating proton, HCl is an acid.
2. Because $H_2O$ accepts the proton that HCl donates and forms $H_3O^+$, *water* is a base.
3. $H_2O$ is converted to $OH^-$ by donating a proton, so $H_2O$ is an acid. Because $NH_3$ accepts the proton and forms $NH_4^+$ so it is a base.

## Self Assessment Exercise 10.1

Identify Bronsted acids and Bronsted bases in the following reactions.

1. $H_2SO_4 + H_2O \rightleftharpoons HSO_4^- + H_3O^+$
2. $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$
3. $H_2S + NH_3 \rightleftharpoons NH_4^+ + HS^-$

## Reading

### 10.1.3 Lewis Concept of Acids and Bases:

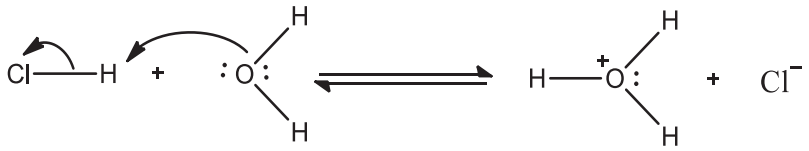
Certain substances like $SO_2$, $CO_2$, CaO, $BF_3$ etc. behave as acids or bases although they do not have ability to donate or accept protons. Nature of such substances cannot be explained by Arrhenius theory or the Bronsted-Lowry theory.

In 1923, G.N Lewis proposed an acid base theory that focuses on reaction. This concept is more general than either the Arrhenius theory or the Bronsted - Lowery theory.

**A Lewis acid is substance that can accept a pair of electrons to form a coordinate covalent bond.**

**A Lewis base is a substance that can donate a pair of electrons to form a coordinate covalent bond.**

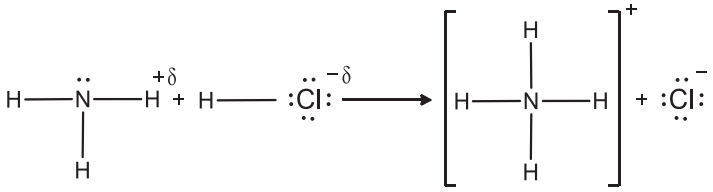
**In a Lewis acid-base reaction a coordinate covalent bond is formed between the acid and the base. Consider the following reaction.**




Electron pair acceptor  Electron pair donor

(i) Which species is donating an electron pair?
(ii) Which species is accepting an electron pair?
(iii) Which species is a Lewis acid?
(iv) Which species is a Lewis base?

This theory can explains gas phase neutralization reactions.

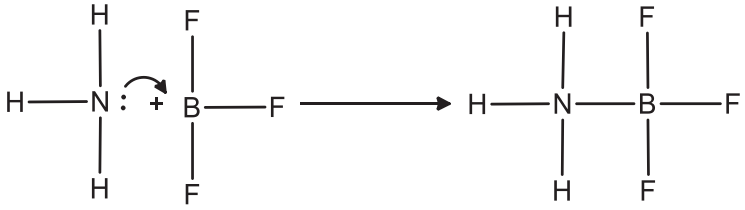


Nitrogen atom in ammonia donates an electron pair to H- atom in HCl. Which species in Lewis acid? $HCl$ or $NH_3$.

The Lewis structure demands that the central atom or atom of Lewis acid has a deficiency of an electron pair and can accommodate an unshared electron pair. On the other hand, the central atom of a Lewis base has complete octet possessing one or more unshared electron pairs. Hence base has an ability to donate an unshared electron pair.

### Example 10.2: Classifying substances as Lewis acids or Lewis bases.

Identify the Lewis acid and Lewis base in the following reactions.

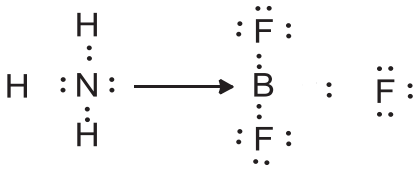


### Problem Solving Strategy

1. Draw electronic structures of both the species.
2. Look for the species that has a lone - pair of electron or negative charge. Such a species has complete octet, so it does not need any electron. It can however, donate an electron pair. This species is a Lewis base.
3. Look for the species that can accommodate an electron pair. Such a species has incomplete octet. So this species can accept an electron pair. This species is a Lewis acid.

### Solution

**(i)**



**(ii)** $NH_3$ has a lone pair on N-atom. So it is electron pair donor. $NH_3$ is a Lewis base.

**(iii)** Boron in $BF_3$has incomplete octet. It has six electrons (3 electron pairs). So it needs an electron pair to complete its octet. Hence $BF_3$ is an electron pair accepter or Lewis acid.

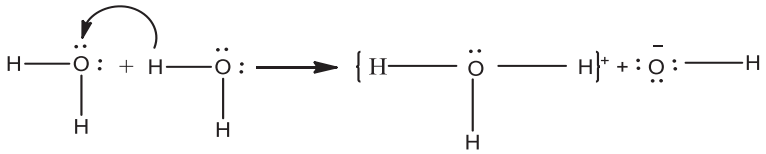
## Self Assessment Exercise 10.2

Identify the Lewis acid and the Lewis base in the following examples.

1. $Cl^- + AlCl_3 \longrightarrow [AlCl_4]^-$
2. $H^+ + OH^- \longrightarrow H_2O$

# 10.2. SELF-IONIZATION OF WATER – THE pH SCALE

Water molecules are highly polar. Occasionally, the collisions between water molecules are energetic enough to transfer a proton from one water molecule to another.



A water molecule that donates or loses a proton becomes a negatively charged hydroxide ion $OH^-$. The other water molecule which gains or accepts the proton becomes positively charged hydronium ion, $H_3O^+$.

This reaction can be written as

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

The reaction in which two water molecules produce ions is called as the self-ionization or auto-ionization of water. This reaction can also be written as a simple ionization of water.

$$H_2O_{(l)} \longrightarrow H^+{}_{(aq)} + OH^-{}_{(aq)}$$

Hydrogen ion  Hydroxide ion

Water is a weak electrolyte. The self-ionization of water occurs to a very small extent. At 25ºC the experimentally determined concentrations of $H^+$ ions and $OH^-$ ions are as follows.

$$[H^+] = [OH^-] = 1 \times 10^{-7} M$$

You can write equilibrium constant expression for the self-ionization of water as follows.

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

Since $H_2O$is a weak electrolyte, so the concentration of $[H_2O]$ will remain constant.

$$K_c[H_2O] = [H^+][OH^-]$$

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

Where $K_w = K_c[H_2O]$ is called ionization constant for water. It is also called the ion- product for water. For water

$$K_w = (1 \times 10^{-7})\,(1 \times 10^{-7}) = 1 \times 10^{-14} at\ 25^oC$$

in pure water, the concentration of $H^+$ and $OH^-$ ions are equal.

$$[H^+] = [OH^-] = 1 \times 10^{-7} at\ \ 25^oC$$

In 1909, the Danish biochemist Soren Sorenson proposed a convenient method to express such a small concentration of $H^+$ ions and $OH^-$ ions by pH or pOH

**pH is defined as the negative logarithm of the molar concentration of $H^+$ ions in aqueous solutions.**

$$pH = -log[H^+]$$

For pure water at 25°C

$[H^+] = 1 \times 10^{-7} M,\ \ [OH^-] = 1 \times 10^{-7} M$

$$pH = -log\,(1 \times 10^{-7}) = 7$$

Thus pH of water is 7. All aqueous solutions with pH= 7 at 25°C are neutral. If pH is less than 7, the solutions become acidic, $[H^+]$ increases and $[OH^-]$ decreases.

**Society, Technology and Science**

Certain plants grow successfully at a particular pH range

| Plant | pH range |
|---|---|
| Apple | 5.5 - 7.0 |
| Broad Bean | 6.5 - 7.0 |
| Carrot | 6.0 - 7.5 |
| Onion | 6.5 - 7.5 |
| Potato | 5.5 - 6.5 |
| Tomato | 5.5 - 7.0 |

**What is the importance of $K_w$?**

$K_w$ is temperature dependent. In any aqueous solution at 25°C, no matter what does it contain the product of $H^+$ ion concentration and $OH^-$ ion concentration is always equal to $1.0 \times 10^{-14}$. This means that if $[H^+]$ increases, the $[OH^-]$ must decrease so that the product of the two is still $1.0 \times 10^{-14}$. What will happen if $[OH^-]$ increases?

When $[H^+] = [OH^-] = 1 \times 10^{-7}$, solution is neutral

When $[H^+] > 1 \times 10^{-7}$, solution is acidic

When $[H^+] < 1 \times 10^{-7}$, solution is basic

If pH is greater than 7, the solution is basic. As solution becomes basic, $[OH^-]$ increases and $[H^+]$ decreases. If pH is less than 7, the solution is acidic. As solution become acidic, $[H^+]$increases and $[OH^-]$decreases.

Figure 10.1 shows pH scale and pH values of some common substances.

| pH | Examples of solutions |
|---|---|
| 0 | Battery acid, strong hydrofluoric acid |
| 1 | Hydrochloric acid secreted by stomach lining |
| 2 | Lemon juice, gastric acid, vinegar |
| 3 | Grapefruit juice, orange juice, soda |
| 4 | Tomato juice, acid rain |
| 5 | Soft drinking water, black coffee |
| 6 | Urine, saliva |
| 7 | "Pure" water |
| 8 | Sea water |
| 9 | Baking soda |
| 10 | Great Salt Lake, milk of magnesia |
| 11 | Ammonia solution |
| 12 | Soapy water |
| 13 | Bleach, oven cleaner |
| 14 | Liquid drain cleaner |

**Figure 10.1:** pH scale and pH values of common substances

## Example 10.3: Classifying a solution as neutral, acidic or basic

1. Unrefined hydrochloric acid is used to clean stone buildings and swimming pools. If the $[H^+]$ in a solution of HCl is $1 \times 10^{-6}$ M. Is the solution acidic, basic or neutral?
2. Solution hydroxide (NaOH) is commonly used as a drain cleaner. If the concentration of $OH^-$ in a solution of NaOH is $1.0 \times 10^{-5}$ M. Is the solution acidic basic or neutral?

### Problem Solving Strategy:

1. Compare the given concentrations of $[H^+]$ ions in solution with that of neutral water.
2. If $[OH^-]$ is given, calculate $[H^+]$ from $K_w = [H^+][OH^-]$.

3. Remember that

If $[H^+] = [OH^-] = 1 \times 10^{-7}$ solution is neutral.

If $[H^+] > 1 \times 10^{-7}$, solution is acidic.

If $[H^+] < 1 \times 10^{-7}$, solution is basic.

**Solution:**

1. $[H^+] = 1.0 \times 10^{-6} M > 1.0 \times 10^{-7}$ M, the solution is acidic.
2. $[OH^-] = 1.0 \times 10^{-5} M$

   $[H^+]$ = ?

   $K_w = [H^+][OH^-]$.

   $1.0 \times 10^{-14} = [H^+]1.0 \times 10^{-5}$

   $[H^+] = 1.0 \times 10^{-9} M$

   Because $1.0 \times 10^{-9} M < 1.0 \times 10^{-7} M$, the solution is basic.

## Self Assessment Exercise 10.3

1. A soft drink has $[H^+] = 3 \times 10^{-3} M$. Is the drink acidic drink neutral or basic?
2. Ordinary vinegar is approximately 1M $CH_3COOH$. Concentration of $H^+$ in it is $4.2 \times 10^{-3}$ M. Is vinegar acidic, basic or neutral?
3. A student determines the $[OH^-]$ of milk of magnesia, a suspension of solid magnesium hydroxide in its saturated solution and obtains a value of $4.2 \times 10^{-3}$M. Is the solution acidic, basic or neutral?

## Reading

### 10.2.1 The pH Scale

Chemists use a number scale from 0 to 14 to describe the concentration of $H^+$ions in a solution. It is known as pH scale. Figure 10.1 shows pH scale and pH values of some common substances.

- A pH of 7 indicates a neutral solution.
- Acids have pH less than 7.
- Bases have pH greater than 7.

**Important Information**

The optimum pH range of a swimming pool is 7.2 to 7.6 because in human tears, when the pH is outside this range, eye irritation can occur.

## Teacher's Point

Teacher may give examples of applications of pH in daily life.

## Measurement of pH

Scientist use different methods to measure pH of a solution. pH paper or universal indicator paper is used to measure pH of a solution. For this purpose pH paper is dipped in the solution. The colour that develops on the pH paper is compared to the colour corresponding to a known pH on the chart. Each colour is linked to a specific pH value. (Figure 10.2)


**Figure 10.2:** Colours of pH paper or universal indicator

One of the most commonly used methods in chemistry laboratory is the use of litmus paper. It is used to give a general indication of whether a solution is acidic or basic. Litmus paper may be red or blue. An acid turns blue litmus paper into red. A base turns red litmus paper into blue.

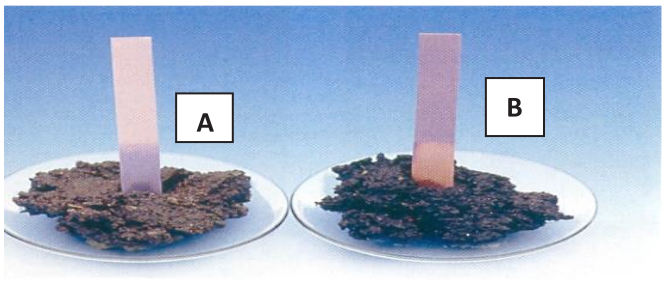



**Figure 10.3:** The soil sample A turns red litmus blue. The soil sample B turns blue litmus red. Which soil is acidic? Which soil is basic?

**Society, Technology and Science**

Acidity of stomach

The main component of digestive or gastric juice in the stomach is hydrochloric acid. Almost two litre of it is secreted each day by gastric glands. However sometimes too much acid is secreted in the stomach which causes indigestion. This is called acidity of the stomach.

Acid - base indicators are also used to estimate the pH of a solution. Indicators are intensely colored organic compounds. They change colour within small pH change and indicate the pH of solution by the colour. We add few drops of an indicator to an aqueous solution of unknown pH and measure pH of the solution from the resulting colour. (Figure 10.5)

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Analytical chemist measures pH of solutions. pH measurement has valuable applications. For instance, it helps analytical chemist to **(i)** to create soil conditions ideal for plant growth **(ii)** medical diagnosis**(iii)** maintaining the correct acid-base balance in swimming pools**(iv)** electroplating **(v)** manufacture of medicine etc. tap water and waste water.

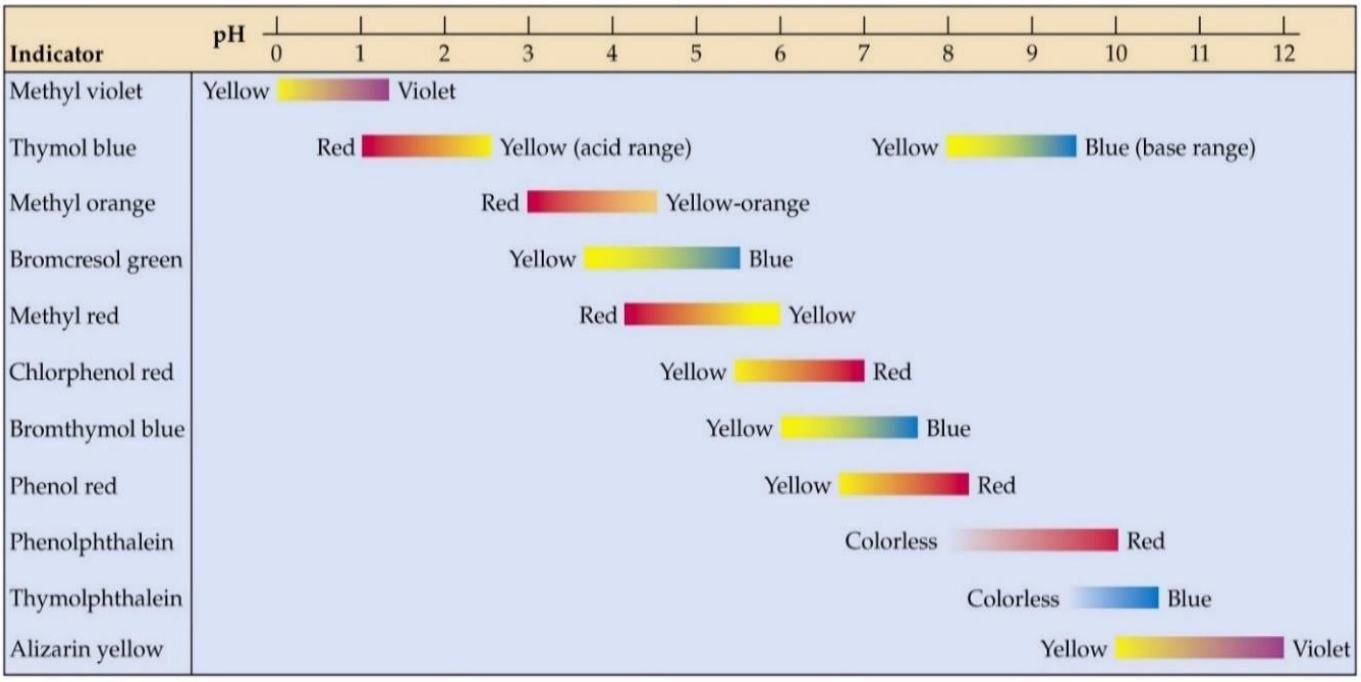



**Figure 10.5** Colour changes of some acid base indicators

Methyl red changes color from red to yellow at pH 5. At what pH stage phenolphthalein changes its colour? At what pH stage bromothymol blue changes colour from yellow to blue?

## Self Assessment Exercise 10.4

1. Write names of three acid - base indicators.
2. What is the colour of methyl red in solution of (i) pH =4 (ii) pH=9?
3. Bromothymol blue added to a solution imparts blue colour,
4. What is the pH of this solution? pH = 5 or 9

## Reading

**Table 10.3 pH ranges of some common indicators**

| Indicator | pH at which colour changes | Colour in acidic solution | Colour in basic solution |
|---|---|---|---|
| Methyl red | 5.5 | Red | yellow |
| Bromothymol blue | 7 | Yellow. | Blue |
| Phenolphthalein | 9 | Colourless | Pink |

## Activity 10.1

Use litmus paper, pH paper and other indicators for measuring pH of solutions

You will need:

- Lemon juice
- Vinegar
- Soap solution
- HCl solution
- NaOH solution

**Use of litmus paper: Carry out the following**

- Take each solution in separate beakers and write the name of each solution on each beaker.
- Take about 2-3 $cm^3$ of each solution in separate test tubes and dip red and blue litmus paper in each solution.
- Note the colour change in each case and record.

**Result:** This test will classify each solution as acid or base or has pH less than 7 or greater.

**Use of pH paper:**

- Take about 2-3 $cm^3$ each solution in separate test tubes and dip pH paper in each solution.
- Note the colour developed on pH paper.

Now compare this colour with the pH scale given in figure 10.2 and find pH of solution.

**Complete the following table**

| Substance | pH |
|---|---|
| Lemon juice | |
| Vinegar | |
| Soap solution | |
| HCl solution | |
| NaOH solution | |

**Use of methyl orange**

- Take about 2-3 $cm^3$ of each solution in separate test tubes and add 1-2 drops of methyl orange in each test tube and note the colour of solution.

**Key:**

Yellow colour indicates pH > 4

Red Colour indicates pH< 4

**Complete the following table,**

| Substance | Colour of methyl orange | pH |
|---|---|---|
| Lemon juice | | |
| Vinegar | | |
| Soap solution | | |
| HCl solution | | |
| NaOH solution | | |

**Society, Technology and Science**

Etching is an art that uses acid to carve patterns into metal, glass and other materials. For this a piece of metal or glass is covered with wax, and then a design is etched on to the plate through the wax. The plate is then dipped into a tank of acid. The acid eats away at the exposed portion, which leaves behind textured mark. The plate is then taken out of the acid and cleaned. Ink can also be applied on etching to create colourful design.

**SKILLS**

Activity 10.2: Perform acid base titration and related calculations.

## Activity 10.2

To standardize the given solution of hydrochloric acid

**Note:** Perform this activity in chemistry laboratory.

**You will need:**

- Burette, Pipette, burette stand, beakers, conical flash, glass rod.
- Standard 0.1M NaOH solution and phenolphthalein.

**Chemical equation**

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

$n_1$ = 1 mole $n_2$ = 1 mole

### Carry out the following:

- Fit up a clean burette in the burette stand vertically.
- Fill burette with HCl solution up to zero mark.
- Take 10 $cm^3$ of NaOH solution in a conical flask with the help of pipette.
- Add few drops of phenolphthalein in it as indicator.
- Note the initial reading on the burette.
- Run the acid solution in the conical flask drop by drop, and shake the flask constantly.
- Go on adding the acid solution till the pink colour just disappears.
- Note down the final reading from the burette.
- The difference between the final and initial reading gives the volume of the acid used to neutralize 10.0 $cm^3$ of NaOH solution.
- Repeat the experiment to get three concordant readings.
- Find the mean volume of HCl solution used.

### Observations and calculations

Suppose volume of HCl solution used = $V_1 = 10\ cm^3$

Molarity of HCl solution = $M_1 = ?$

Volume NaOH solution used = $V_2 = 10\ cm^3$

Molarity of NaOH solution = $M_2 = 0.1M$

No. of moles of HCl = $n_1 = 1$

No. of moles of NaOH = $n_2 = 1$

$$\frac{M_1 \times V_1}{n_1} = \frac{M_2 V_2}{n_2}$$

$$\frac{M_1 \times 10}{1} = \frac{0.1 \times 10}{1}$$

$$M_1 = 0.1\ M$$

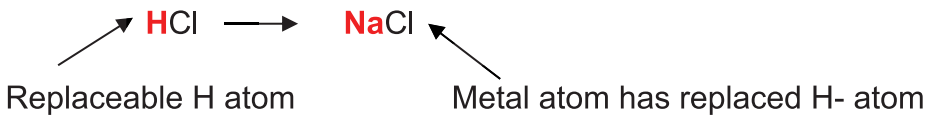
**Do you know?**

We make use of chemistry when we put lemon juice on fish. The unpleasant fishy odour is due to amines. The citric acid present in lemon juice converts amines to non-volatile salts, thus reducing the odour.

**Result:** Molarity of HCl solution is 0.l M

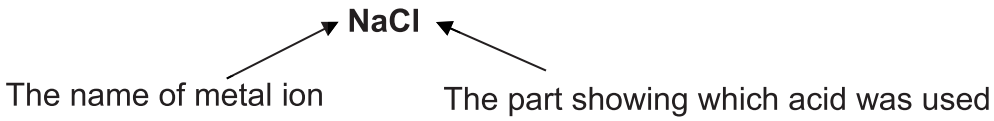
## 10.3 SALTS

An acid contains replaceable hydrogen atoms. When these are completely or partially replaced by metal atoms, a compound called salt is formed.



Which is a salt HCl or NaCl?

Salts are ionic compounds. The first part of the name is of the metal ion and second part of the name is of the negative part of the acid. g. Sodium Chloride.




Which acid forms$NaNO_3$? Which acid forms $CaSO_4$? Table 10.4 shows some common acids and their salts.

**Table 10.4 Some common acids and their salts**

| Acid | Salt name | Example |
|---|---|---|
| Hydrochloric $HCl$ | Chloride $Cl^-$ | $NaCl, KCl, CaCl_2$ |
| Nitric $HNO_3$ | Nitrate $NO_3^{-1}$ | $NaNO_3, KNO_3, Ca(NO_3)_2$ |
| Sulphuric $H_2SO_4$ | Sulphate $SO_4^{-2}$ | $Na_2SO_4, K_2SO_4, CaSO_4$ |
| Phosphoric $H_3PO_4$ | Phosphate $PO_4^{-3}$ | $Na_3PO_4, K_3PO_4, Ca_3(PO_4)_2$ |

Neutralization is the specific term used for the reaction of acids with bases.

$$Acid + Base \longrightarrow Salt + Water$$

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

Neutralization is the reaction between $H^+$ ions of an acid and $OH^-$ ions of a base.

$$H^+{}_{(aq)} + OH^-{}_{(aq)} \longrightarrow H_2O_{(l)}$$

Reactions of acids with bases are used in the experimental procedure of titration. You will do this work in your laboratory. (Activity 10.2)

## Example 10.4: Writing complete and balanced chemical equation for a neutralization reaction

1. Soda ash, $Na_2CO_3$ is used to make glass. It can be made by the reaction of carbonic acid $(H_2CO_3)$and Sodium hydroxide$(NaOH)$. Write complete and balanced chemical equation for this neutralization reaction.
2. Barium nitrate $Ba\ (NO_3)_2$is used to produce a green colour in firework. It can be made by the reaction of nitric acid $(HNO_3)$with barium hydroxide, $Ba(OH)_2$. Write complete and balanced chemical equation for this neutralization reaction.

## Problem Solving Strategy

1. Write word equation describing the neutralization reaction.
2. Write chemical formulas of the substances involved in the chemical reaction. Salt consists of cations from the base and anions from the acid.
3. During neutralization reaction one H - atom of an acid combines with one OH group of the base to form one water molecule. So, place a suitable number before acid or base to balance H in acid with OH in base.
4. Balance remaining equation by inspection method.
5. Show the state of each of the substance involved.

## Solution

1. Carbonic acid + Sodium hydroxide ⟶Sodium carbonate + water

   $H_2CO_3 + NaOH \longrightarrow Na_2CO_3 + H_2O$

   $H_2CO_3$ contains two neutralizable H-atoms and NaOH contain only one OH. So multiply NaOH by 2.

   $H_2CO_3 + 2NaOH \longrightarrow Na_2CO_3 + H_2O$

   Now balance H-atoms on the right side by placing 2 before $H_2O$.

   $H_2CO_3 + 2NaOH \longrightarrow Na_2CO_3 + 2H_2O$

   $H_2CO_{3(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2CO_{3(aq)} + 2H_2O_{(l)}$

2. Nitric acid + Barium hydroxide ⟶ Barium nitrate + water.

   $HNO_3 + Ba(OH)_2 \longrightarrow Ba(NO_3)_2 + H_2O$

   $HNO_3$ contains one neutralizable H-atom and $Ba(OH)_2$ contains two OH-groups. So multiply $HNO_3$ by 2.

   $2HNO_3 + Ba(OH)_2 \longrightarrow Ba(NO_3)_2 + H_2O$

   Now balance H-atoms on the right side by placing 2 before $H_2O$.

   $2HNO_3 + Ba(OH)_2 \longrightarrow Ba(NO_3)_2 + 2H_2O$

   $2HNO_{3(aq)} + Ba(OH)_{2(aq)} \longrightarrow Ba(NO_3)_{2(aq)} + 2H_2O_{(l)}$

## Self Assessment Exercise 10.5

1. Hydroxides such as $Mg(OH)_2$ called milk of magnesia is used as antacid. It neutralizes excess stomach acid (HCl). Write complete and balanced chemical equation for this neutralization reaction?
2. Hydrochloric acid (HCl) and Potassium hydroxide (KOH) react and produce potassium chloride. Write complete and balanced chemical equation for this neutralization reaction?
3. Balance following neutralization reactions

   (i) $H_2SO_{4(aq)} + NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(l)}$

   (ii) $H_3PO_{4(aq)} + NaOH_{(aq)} \longrightarrow Na_3PO_{4(aq)} + H_2O_{(l)}$

Some acids form more than one salts. For example Carbonic acid $(H_2CO_3)$ has two replaceable H-atoms. Its partial neutralization forms hydrogen carbonate. On complete neutralization it forms carbonate.

$$H_2CO_{3(aq)} + NaOH_{(aq)} \longrightarrow NaHCO_{3(aq)} + H_2O_{(l)}$$

$$H_2CO_{3(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2CO_{3(aq)} + H_2O_{(l)}$$

$$H_3PO_{4(aq)} + NaOH_{(aq)} \longrightarrow NaH_2PO_{4\,(aq)} + H_2O_{(l)}$$

A salt containing a replaceable H- atom or formed by partial neutralization of an acid is called **acid salt** whereas a salt which is formed by the complete neutralization of an acid is called a **normal salt.**

Which salt is acid salt, $NaHCO_3 or\ Na_2CO_3$?

Which salt is normal salt, $NaHCO_3 or\ Na_2CO_3$?

Phosphoric acid $(H_3PO_4)$ has three replaceable H-atoms, it forms three series of salts,$NaH_2PO_4, Na_2HPO_4, Na_3PO_4$. Which of these salts is/are acid salt?

A salt containing replaceable OH group or formed by the partial neutralization of a polyhydroxy base is called as basic salt.

$$\boldsymbol{Zn(OH)_{2(aq)} + HCl_{(aq)} \longrightarrow Zn(OH)Cl_{(aq)} + H_2O}$$

$$\boldsymbol{Pb(OH)_{2(aq)} + CH_3COOH_{(aq)} \longrightarrow Pb(OH)CH_3COO_{(aq)} + H_2O}$$

## Self Assessment Exercise 10.7

Classify following salts as normal or acid salt.

(a) $NaHSO_4$
(b) $Na_2SO_4$
(c) $KHCO_3$
(d) $K_2CO_3$

## Reading

### 10.3.1 Methods for making salt

There are five methods for making salts.

1. $\boldsymbol{Acid + Base \longrightarrow Salt + Water}$

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

2. $\boldsymbol{Acid + Metal\ oxide \longrightarrow salt + water}$

$H_2SO_{4(aq)} + CuO_{(s)} \longrightarrow CuSO_{4(aq)} + H_2O_{(l)}$

3. $\boldsymbol{Acid + Metal \longrightarrow Salt + Hydrogen}$

$2HCl_{(aq)} + Mg_{(s)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$

4. $\boldsymbol{Acid + Metal\ carbonate \longrightarrow Salt + Carbon\ dioxide + water}$

$HCl_{(aq)} + CaCO_{3(s)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$

5. $\boldsymbol{Salt_{(aq)} + Salt_{(aq)} \longrightarrow Salt_{(s)} + Salt_{(aq)}}$

$$AgNO_{3(aq)} + NaCl_{(aq)} \longrightarrow AgCl_{(s)} + NaNO_{3(aq)}$$

## 10.3 USES OF SALTS

Food preservation keeps food from spoiling and allows it to be stored for later use. Ancient methods for preserving include, drying fruits and vegetables, salting, boiling etc. Today, methods for preserving food also include the addition of preservatives. They are inhibitors of physical and chemical processes that cause food to spoil. Many foods are grown or produced in one location and then sent across the country or even overseas. Without preservatives, these foods would spoil long before they reach their destinations. Many salts such as sulphites and benzoates are being used in food for thousands of years.

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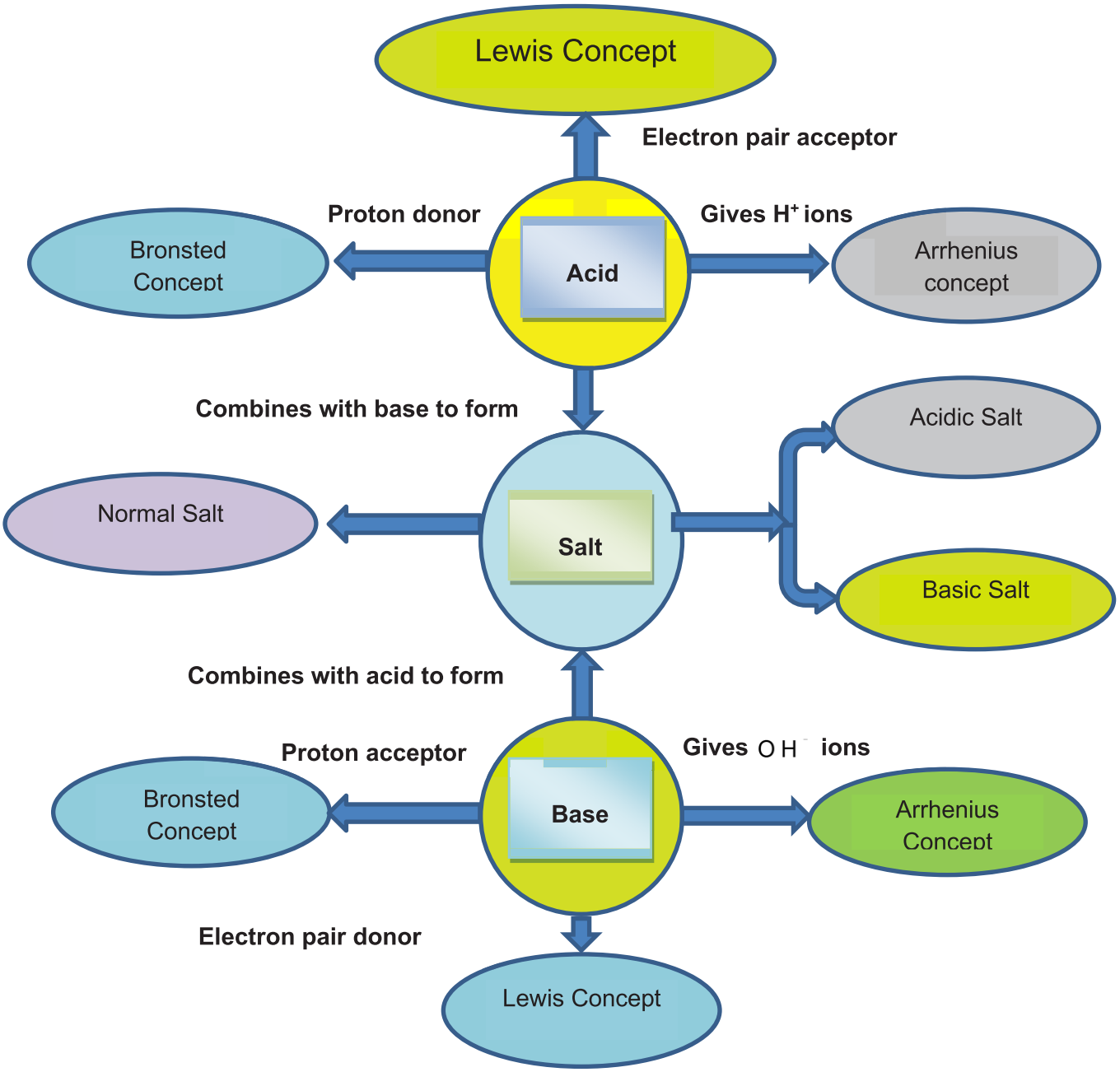
Preservatives in food are designed to prevent bacteria growth and spoilage. But sometimes they can affect your health. Some preservatives may cause breathing difficulties, can weaken heart tissues and can transform into carcinogens.

Many people are allergic or sensitive to preservatives. Some preservatives are safe in small amount and toxic in larger amounts. Hence, Food and Drug Administration Department is given the responsibility for approving the safety and use of preservatives. Government regulations restrict the quantity of preservatives in food.

# Concepts in brief



## Key Points

- ❖ According to Arrhenius theory, an acid is a substance that ionizes in water to produce $H^+$ ions and a base is a substance that ionizes in water to produce $OH^-$ ions.
- ❖ A Bronsted-Lowry acid is a proton donor and a base is a proton acceptor.
- ❖ A Lewis acid is a substance that can accept a pair of electrons to form a coordinate covalent bond.
- ❖ A Lewis base is a substance that can donate a pair of electrons to form a coordinate covalent bond.
- ❖ The reaction in which two water molecules react to produce ions is called as self-ionization of water.
- ❖ Ionization constant for water is also called as the ion-product constant for water. Its value is $1 \times 10^{-14} at\ 25°C$.
- ❖ $If [H^+] = 1 \times 10^{-7} M$ solution is neutral
  - $If [H^+] > 1 \times 10^{-7} M$ solution is acidic
  - $If\ [H^+] < 1 \times 10^{-7} M$ solution is basic
- ❖ A pH of 7 indicates a neutral solution
- ❖ Acids have pH less than 7.
- ❖ Bases have pH greater than 7.
- ❖ Indicators change colour within a small pH range and indicate the pH of solution by the colour.
- ❖ Methyl orange, bromothymol blue and phenolpthalein are common acid-base indicators.
- ❖ Salt is an ionic compound formed when replaceable hydrogen atom in an acid is replaced by a metal atom.
- ❖ Reaction between an acid and a base is called neutralization reaction.
- ❖ Acid salts contain one or more replaceable H-atoms.
- ❖ Normal salts are formed by the complete neutralization of acids.

**References for additional informations.**

- ❖ Longman Chemistry for IGCSE.
- ❖ IGCSE Chemistry.
- ❖ Cambridge IGCSE, Chemistry.
- ❖ Theories of Acids and Base Chemi guide.

## Review

### 1. Encircle the Correct answer

**(i)** Which of the following cannot be classified as Arrhenius acid?

(a) $\boldsymbol{HNO_3}$ (b) $\boldsymbol{H_2CO_3}$

(c) $\boldsymbol{CO_2}$ (d) $\boldsymbol{H_2SO_4}$

**(ii)** $NH_3$ cannot be classified as a base by

(a) Lewis theory (b) Bronsted -Lowry theory

(c) Arrhenius theory (d) All of these theories

**(iii)** Which of the following is a Lewis base?

(a) $BF_3$ (b) HCl

(c) $AlCl_3$ (d) $F^-$

**(iv)** Choose Lewis acid

(a) $CN^-$ (b) $NH_3$

(c) $H_2O$ (d) $H^+$

(v) A drain cleaner solution contains $1.0 \times 10^{-8}$ M, $OH^-$ concentration. This Solution is

(a) acidic (b) basic

(c) neutral (d) cannot be predicted

(vi) Milk of magnesia contains $\boldsymbol{Mg(OH)_2}$. It is used as antacid. It neutralizes excess stomach acid. Which salt is formed in this reaction?

(a) $\boldsymbol{MgSO_4}$ (b) $\boldsymbol{MgCO_3}$

(c) $\boldsymbol{MgCl_2}$ (d) MgO

(vii) Ammonia is a base, because it

(a) Ionizes in water to give $OH^-$ ions (b) Contains OH group

(c) Can accept an election pair (d) Can accept proton

(viii) Consider the following reaction?

$$\boldsymbol{H_2O + HCl \rightleftharpoons H_3O^+ + Cl^-}$$

Which species is an electron pair acceptor in this reaction?

(a) $H_2O$ (b) HCl

(c) $H_3O^+$ (d) none

(ix) In the following reaction which species is donating an electron pair?

$$\boldsymbol{NH_3 + BF_3 \longrightarrow [H_3N - BF_3]}$$

(a) H (b) B

(c) N (d) $BF_3$

(x) An aqueous solution of NaOH is used as a drain cleaner. If the concentration of $OH^-$ ions in this solution is 1.0 x $10^{-5}$M, the concentration of $H^+$ ions in it would be?

(a) $1.0 \times 10^{-5} M$ (b) $1.0 \times 10^{-7} M$

(c) $1.0 \times 10^{-9} M$ (d) $1.0 \times 10^{-14} M$

**2. Give short answers?**

(i) Write the equation for the self-ionization of water.

(ii) Define and give examples of Arrhenius acids.

(iii) Why $H^+$ ion acts as a Lewis acid?

(iv) Why $\boldsymbol{NH_3}$ acts as Bronsted-Lowry base?

(v) Why $\boldsymbol{BF_3}$ acts as Lewis acid?

**3. Ammonium hydroxide and nitric acid react and produce ammonium nitrate and water. Write balanced chemical equation for this neutralization reaction.**

**4. Write balanced chemical equations for the following neutralization reactions.**

(i) $Sulphuric\ acid + Magnesium\ hydroxide \longrightarrow magnesium\ sulphate + water.$

(ii) $Sulphuric\ acid + Sodium\ hydroxide \longrightarrow Soduimsulphate + water.$

(iii) $Hydrochloric\ acid + calcium\ hydroxide \longrightarrow calcium\ chloride + water$

**5. Identify Bronsted –Lowry acids or bases in the following reactions.**

(i) $HNO_3 + H_2O \longrightarrow H_3O^+ + NO_3^-$

(ii) $NH_3 + HNO_3 \longrightarrow NH_4NO_3$

**6. Identify Lewis acid and Lewis base in the following reactions.**

(i) $F^- + BF_3 \longrightarrow [BF_4]^-$

(ii) $H^+ + NH_3 \longrightarrow [NH_4]^+$

(iii) $NH_3 + AlCl_3 \longrightarrow [H_3N - AlCl_3]$

**7. Classify the following solutions as acidic, basic or neutral.**

(i) $A\ solution\ that\ has\ hydrogen\ ion\ concentration\ 1.0 \times 10^{-3} M.$

(ii) $A\ solution\ that\ has\ hydrogen\ ion\ concentration\ 1.0 \times 10^{-10} M.$

(iii) $A\ solution\ that\ has\ hydroxyl\ ion\ concentration\ 1.0 \times 10^{-3} M.$

(iv) $A\ solution\ that\ has\ hydroxyl\ ion\ concentration\ 1.0 \times 10^{-10} M.$

**8. Classify following substance as Lewis acid and bases.**

$NH_3,\quad F^-,\quad H_2O:\quad ,\quad BF_3$

**9. Give the Bronsted-Lowry definition of an acid. Write an equation that illustrates the definition.**

**10. Identify Bronsted acids and Bronsted bases in the following reactions.**

(i) $CH_3COOH_{(aq)} + H_2O \rightleftharpoons CH_3COO^-{}_{(aq)} + H_3O^+{}_{(aq)}$

(ii) $HCO_3^-{}_{(g)} + H_2O_{(l)} \rightleftharpoons CO_{3(aq)}^{-2} + H_3O^+_{(aq)}$

(iii) $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

(iv) $HCl_{(aq)} + HCO_3^-{}_{(aq)} \rightleftharpoons H_2CO_{3(aq)} + Cl^-{}_{(aq)}$

(v) $HS^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons S^{-2}{}_{(aq)} + H_3O^+{}_{(aq)}$

**11. Identify the Lewis acids and the Lewis bases in the following reactions.**

(i) $H^+{}_{(aq)} + CN^-{}_{(aq)} \longrightarrow HCN_{(aq)}$

(ii) $B(OH)_{3(s)} + OH^-{}_{(aq)} \longrightarrow B(OH)_4^-{}_{(aq)}$

(iii) $Cu^{+2}{}_{(aq)} + 4NH_{3(aq)} \longrightarrow [Cu(NH_3)_4]^{+2}{}_{(aq)}$

(iv) $OH^-_{(aq)} + Al(OH)_{3(s)} \longrightarrow Al(OH)^-_{4(aq)}$

**12. Identify Lewis acids and Lewis bases from the following.**

$AlCl_3$, $Ag^+$, $CH_3—\ddot{O}H$, $CH_3—\ddot{N}H_2$, $FeCl_3$

**13. Classify water as proton donor or proton acceptor.**

**14. Write equations showing the ionization of the following as Arrhenius acids.**

(a) $HI_{(aq)}$ (b) $HNO_{2(aq)}$

**15. Write equations showing the ionization of the following as Bronsted-Lowry acids.**

(a) $HNO_{2(aq)}$ (b) $HCN_{(aq)}$

## Think-Tank

**16. Compare the relative concentrations of hydrogen ions and hydroxide ions in each kind of solution?**

(a) acidic (b) basic (c) neutral

**17. Codeine, $C_{18}H_{21}NO_3$ is a commonly prescribed pain killer. It dissolves in water by the following reaction?**

$$C_{18}H_{21}NO_3 + H_2O \rightleftharpoons [C_{18}H_{21}HNO_3]^+ + OH^-$$

Differentiate Codeine and water as Bronsted-Lowry acid or base.

**18. Examine some ways in which you might determine whether a particular water solution contains an acid or a base.**

**19. The table below shows the colours of two indicators in acidic and alkaline solutions.**

| Indicator | Colour in Acidic Solution | Colour in Alkaline Solution |
|---|---|---|
| A | Red | Blue |
| B | Colourless | Red |

a) Predict the colour of the indicator A?

i. in a solution of pH 3

ii. in a solution of pH 10

b) Predict the colour of the indicator B in a solution of pH 5?

c) When a few drops of indicator B are placed in a solution X, it turns red immediately. Evaluate the properties of solution X?

**20. Bacteria in our mouth feed on small particles of food stuck to our teeth and change it into acid. A toothpaste of pH 10 can help to prevent the acid from damaging our teeth. Defend the statement.**

**21. Can a substance be a Lewis acid without being a Bronsted-Lowry acid? Argue.**

**Project**

Examine the labels of at least three antacid preparations. Make a list of the ingredients in each. Write a balanced chemical equation for the neutralization reaction that takes place when these antacids react with HCl in the stomach.

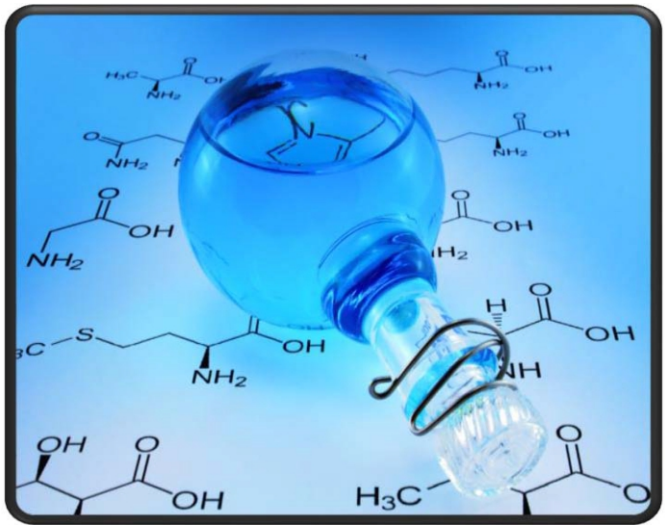
11

# ORGANIC CHEMISTRY

**After completing this lesson, you will be able to:**

**This is 13 days lesson (period including homework)**

- Recognize structural, condensed and molecular formulas 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 compounds.
- List the uses of organic compounds.
- Recognize and identify molecule's functional groups.
- Distinguish between saturated and unsaturated hydrocarbons.
- Name the alkanes up to decane.
- Convert alkanes into alkyl radicals.
- Differentiate between alkane and alkyl radicals.
- Define functional group.
- Differentiate between organic compounds on the basis of their functional groups.
- Classify organic compounds into straight chain, branched chain and cyclic compounds.
- Identify carboxylic acids, phenols, amines, aldehydes and ketones in terms of functional groups in the lab.
- Distinguish between saturated and unsaturated compounds using iodine, bromine and potassium permanganate solutions.
- Show how pharmaceutical chemists work towards the partial and total synthesis of effective new drugs.
- Explain how substances produced by plants and animals can also be produced in the lab.



**Reading**

## INTRODUCTION:

The Study of Carbon containing compounds and their properties is called organic chemistry. However, few compounds of carbon such as carbon dioxide, carbon monoxide, carbonates and carbides are considered to be inorganic substances. This is

because they have totally different properties than organic compounds. Organic compounds play a vital role in the bodies of living things. Products of industrial organic chemistry such as plastics, rubber, synthetic fibers, paints, glues, varnishes, artificial sweeteners and flavors, drugs, dyes, soaps and detergents etc. are important part of modern life. In addition, the energy on which we rely heavily is based mostly on organic materials found in coal, petroleum and natural gas.

# 11.1. ORGANIC COMPOUNDS

The Chemistry of carbon compounds pervades every aspect of our lives. We use thousands of carbon compounds every day. They are carrying out important chemical reactions within our bodies. Many of them are so vital that we cannot live without them. A detailed study of organic compounds confirms that carbon is their essential constituent in combination with H, O, N, S, P and halogens. They may also (rarely) contain metal atoms. **Organic compounds are defined as the hydrocarbons and their derivatives. (see sction 11.4 and Chapter 12)**

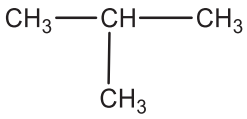
## 11.1.1 Chemical Diversity and Magnitude of Organic Compounds

Carbon has four bonding electrons in its valence shell. Carbon therefore forms four bonds with other atoms.

The Chemical diversity of organic compounds arises from carbon's ability to bond to each other to form long chains, branched chains and rings. This self-linking ability of carbon is called **catenation.** There appears to be almost no limit to the number of different structures that carbon can form. (See 11.1.6). No other element can compete with carbon in this regard. Silicon and few other elements can form chains, but only short one. Carbon chains may contain thousands of carbon atoms. For these reasons carbon forms almost infinite number of molecules of various sizes, shapes and structures. Another reason for the large number of organic compounds is the phenomenon of **isomerism.**

**The compounds that have same molecular formula but different arrangement of atoms in their molecules are called isomers. This phenomenon is called isomerism. For example two compounds have molecular formula $C_4H_{10}$**

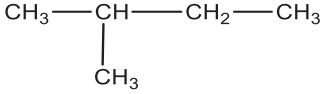
**n – Butane**



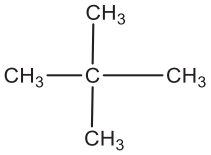
**iso – Butane**

What is the molecular formula of the following compounds?

**n – Pentane**



**iso – Pentane**



**neo - Pentane**

**Teacher's Point**

A teacher may give examples of petrol, kerosene, diesel, mobile oil as hydrocarbons.

This means three compounds have molecular formula $C_5H_{12}$.As the number of carbon atoms in an organic compound increases, the number of possible isomers also increase. What is the number of isomers in pentane? Hexane has five isomers.

Carbon can also form stable single and multiple bonds with other atoms like oxygen, nitrogen and sulphur.

Carbon can also make **multiple bonds** to itself i.e. $C{=}C$, $C{\equiv}C$, $C{=}O$, $C{\equiv}N$ etc. This further increase the number of organic compounds. In fact, many common groups of atoms can occur within organic molecules. These groups are called functional group. (See 11.4). That is why of more than 20 million known chemical compounds; over 95% are compounds of carbon. Millions of organic compounds are already known and new ones are being discovered every day.

In fact many common groups of atoms can occur within organic molecules. These groups are called functional groups. (See 11.5).

## 11.1.2 General Characteristics of Organic Compounds

### (i) Occurrence:

Most of them come from living things or from the things that were once living.

### (ii) Covalent nature:

Organic compounds are generally covalent in nature. They may have polar or non-polar bonds.

### (ii) Composition:

Carbon is the main constituent of organic compounds. Hydrogen is also frequently present in organic compounds. Other elements like oxygen, nitrogen, sulphur, phosphorous and halogens are present in many organic compounds.

### (iv) Melting and boiling point:

Generally organic compounds are volatile. So they have low melting and boiling points.

### (v) Solubility:

Organic compounds are mostly non-polar in nature therefore they are soluble in organic solvents such as ether, benzene, carbon disulphide etc. Polar Organic Compounds are soluble in alcohols such as methyl alcohol and ethyl alcohol.

### (vi) Similarity in behaviors (Homology):

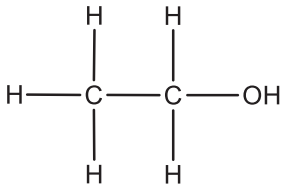
There exists a close relationship between different organic compounds. This similarity in behavior has made the study of millions of organic compounds easier. They can be classified into few families. A series of related compounds in which any two adjacent molecules differ by $–CH_2–$ group is called homologous series.

**(vii) Reaction rates:**

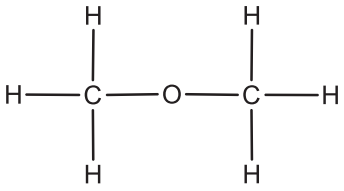
Organic compounds are generally less stable than inorganic compounds. Due to covalent bonding in them, their reaction rates are often slow.

## 11.1.3 Condensed Structural Formulas

Frequently more than one organic compounds are represented by the same molecular formula. However, they have different properties. They have different structural formulas. For example, two organic compounds have the molecular formula $C_2H_6O$. they have different arrangements of atoms.



**Ethanol**

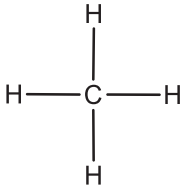


**Dimethy ether**

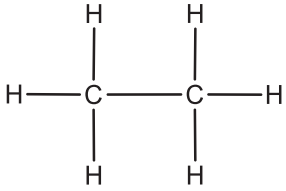
These formulas clearly show that the atoms are bonded to one another differently. In ethanol, the oxygen atom is bonded to only one carbon atom and a hydrogen atom. Whereas in dimethyl ether, the oxygen atom is bonded to two carbon atoms.

**A formula that describes the arrangement of atoms in a molecule is called as structural formula.**

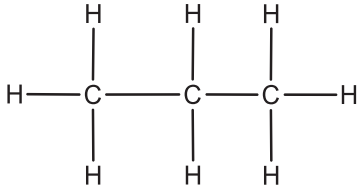
The simple alkanes are straight-chain hydrocarbons. First three members of alkanes have following structural formulas.



**Methane**



**Ethane**



**Propane**

The condensed structural formulas of these alkanes are

$$CH_4 \quad , \quad CH_3CH_3 \quad , \quad CH_3CH_2CH_3$$

The corresponding molecular formulas are $CH_4, C_2H_6, C_3H_8$ respectively

A condensed formula is a structural formula that uses established abbreviation for various groups of chain. In condensed structural formula, we list the main chain carbon atoms and the hydrogen atoms attached to them in the sequence in which they appear in the naming system.

For instance,

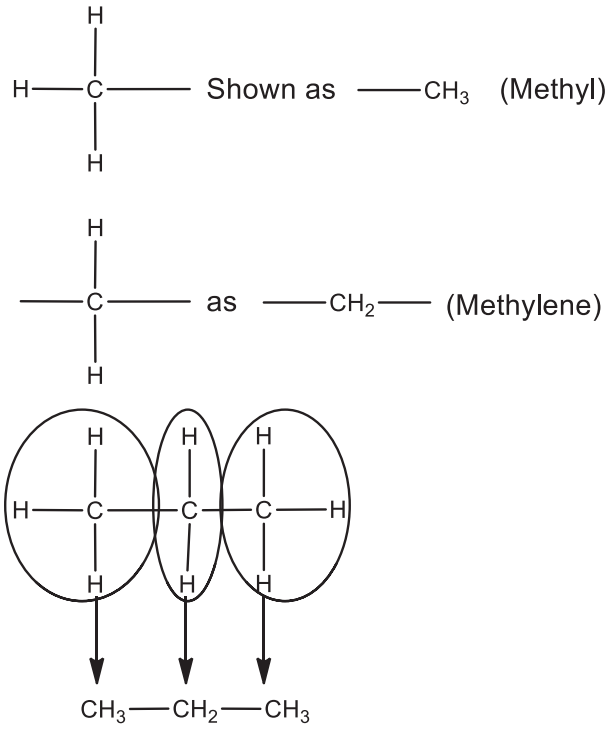



Table **11.1** shows the condensed structural formulas of some alkanes.

**Table 11.1 Condensed structural formula of some alkanes**

| Name | Molecular Formula | Condensed Formula |
|---|---|---|
| Butane | $C_4H_{10}$ | $CH_3CH_2CH_2CH_3$ |
| Pentane | $C_5H_{12}$ | $CH_3CH_2CH_2CH_2CH_3$ |
| Hexane | $C_6H_{14}$ | $CH_3CH_2CH_2CH_2CH_2CH_3$ |
| Heptane | $C_7H_{16}$ | $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$ |
| Octane | $C_8H_{18}$ | $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ |
| Nonane | $C_9H_{20}$ | $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ |
| Decane | $C_{10}H_{22}$ | $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ |

**Example 11.1:** Give the molecular formula, the structural formula and the condensed structural formula for pentane.

**Problem Solving Strategy**

i) The stem pent –means five carbon atoms.

ii) The ending -ane indicates an alkane.

iii) Write a string or chain of five carbon atoms.

iv) Attach hydrogen atoms to the carbons to give each carbon atom four bonds. This requires three hydrogen atoms on each end carbon and two each on others.

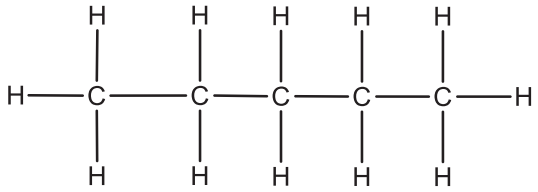
v) For the condensed molecular formula, write each carbon atom's set of hydrogen atoms next to the carbon.

vi) For molecular formula, simply count the carbon and hydrogen atoms or use the general formula $C_nH_{2n+2}$with n=5.

**Solution:**

C - C - C - C -C

**Structural formula**



**Condensed Structural formula**

$CH_3—CH_2—CH_2—CH_2—CH_3$

**Molecular formula**

$$C_5H_{2x5+2} = C_5H_{12}$$

**Self-Assessment Exercise 11.1**

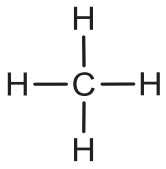
Give the molecular, structural and condensed structural formulas for

(a) Butane (b) Hexane (c) Octane

**Reading**

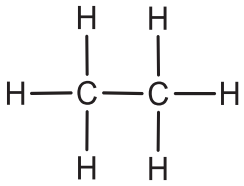
## 11.1.4 Saturated and Unsaturated Hydrocarbons

Hydrocarbons are compounds containing carbon and hydrogen only. **Hydrocarbons whose carbon – carbon bonds are all single bonds are called saturated.** Saturated hydrocarbons are also called alkanes. In alkanes each carbon atom is bonded to four other atoms. Methane is the simplest alkane. Other examples are ethane, propane, butane etc. (**See section 11.1.3** for more examples). The general formula of alkanes is$C_nH_{2n+2}$, where n is the number of carbon atoms.

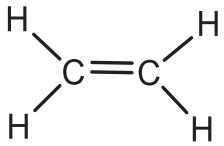


**Methane**

**Hydrocarbons containing carbon-carbon multiple bonds are called unsaturated.** Which of the following are unsaturated hydrocarbons?



**Ethane**



**Ethene**

**Ethyne**

Unsaturated hydrocarbons are further divided into:

(i) **Alkenes.**

(ii) **Alkynes.**

Unsaturated hydrocarbons containing at least one carbon-carbon double bond are called alkenes. They have general formula $(H_2SO_4)$, for example ethene. Unsaturated hydrocarbons that have at least one carbon-carbon triple bond are called alkynes. They have general formula $C_nH_{2n-2}$, for example ethyne.

## Self-Assessment Exercise 11.2

Choose saturated and unsaturated compounds from the following.

(i) $CH_3-CH_2-CH_3$ (ii) $CH_3-C\equiv CH$

(ii) $CH_3-CH=CH_2$ (iv) $CH_2=CH-CH=CH_2$

## Reading

## 11.1.5. Naming Alkanes

An international body, the international union of pure and applied chemistry (IUPAC) has devised a system of naming organic compounds that depends on their structure. These names

indicate the number of carbon atoms present in the organic compounds. We can easily recognize organic compound by its IUPAC name. Such names are also called systematic names.

The key point in naming a straight chain alkane is that the name is based on the number of carbon atoms in the chain. The IUPAC name has two parts.

### (i) Stem:

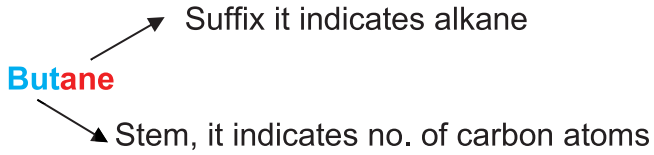
The stem tells the number of carbon atoms in the chain. Table 11.2 shows these stems.

**Table 11.2: Numerical stems for carbon chains**

| Stem | Number of C - atoms |
|---|---|
| Meth- | 1 |
| Eth- | 2 |
| Prop- | 3 |
| But- | 4 |
| Pent- | 5 |
| Hex- | 6 |
| Hept- | 7 |
| Oct- | 8 |
| Non- | 9 |
| Dec- | 10 |

### (ii) Suffix:

Suffix is placed after the stem, it tells the class of compound. For alkane, the suffix “ane” is used.




### Example 11.2: Writing names of alkanes

**Write IUPAC names of the following compounds.**

**(i)** $\boldsymbol{CH_3 - CH_2 - CH_2 - CH_3}$ **(ii)** $CH_3 - CH_2 - CH_2 - CH_2 - CH_3$

### Problem solving strategy

**(i)** Count number of carbon atoms in the chain and select stem for it.

**(ii)** Add suffix – ane to the stem.

**Solution**

**(i)** No. of Carbon atoms 4

Stem ⟶ But

Name: Butane

**(ii)** No. of Carbon atoms 5

Stem ⟶ Pent

Name: Pentane

## Self-Assessment Exercise 11.3

**Write IUPAC names of the following alkanes.**

(i) $CH_3- CH_2- CH_2- CH_2- CH_2- CH_3$

(ii) $CH_3- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_3$

(iii) $CH_3- CH_2- CH_2- CH_2- CH_2- CH_2- CH_3$

(iv) $CH_3- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_3$

(v) $CH_3- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_3$

## Reading

# 11.2 SOURCES OF ORGANIC COMPOUNDS

The major commercial sources of alkanes are coal, natural gas, petroleum, and living organisms.

### Coal

Coal is a source of many organic compounds. When coal is heated in the absence of air at high temperature, it is converted into coal gas, coal tar and coke. This process is called destructive distillation. Coal is also used as solid fuel.

Coal gas contains methane, hydrogen and carbon monoxide gases. It is mainly used as a fuel in industry. Coal tar is a source of many organic compounds such as benzene and its derivatives. These compounds can be separated by fractional distillation. These are very useful substances in synthetic organic chemistry. These are used to synthesize plastics, dyes, fibers, drugs, paints, varnishes etc. The residue left behind called pitch is used to metal roads and roofs.

### Natural gas

Natural gas is a mixture of low boiling hydrocarbons. Natural gas is mostly methane. It also contains smaller amounts of ethane, propane and butane.

### Petroleum

Petroleum contains a wide variety of alkanes including those having very long chains. On fractional distillation petroleum separates into various hydrocarbon components, known as fractions. Can you name these fractions? Each fraction is not a pure compound but a mixture of different compounds that boil in a certain range of temperature. (See section 16.4)

### Living Organisms

Many important organic compounds such as proteins, fats, carbohydrates, vitamins, drugs and medicines are obtained from plants and animals.

### Synthesis in Laboratory:

Over ten million organic compounds have been prepared in the laboratories. They are being used in medicines, cosmetics, paints, plastics, fertilizer, detergents, etc.

## 11.3 USES OF ORGANIC COMPOUNDS.

- Natural gas and petroleum are used primarily as fuels (see figure 16.9). These are also used as starting materials for the productions of variety of organic compounds.
- Propane and butane which are gases obtained from natural gas are widely available as liquids in fuel cylinders (LPG).
- Ethylene is the major starting material for the manufacture of organic chemicals and products such as polyethylene (plastic), ethyl alcohol, acetic acid and ethylene glycol called antifreeze.
- Acetylene is widely used in the oxy-acetylene welding and cutting metals. Acetylene is also used in the preparation of polymers like PVC (polyvinyl chloride), polyvinyl acetate, synthetic rubber, nylon etc.
- Acetylene is used for artificial ripening of fruits.
- Compounds of phenol help to ensure antiseptic conditions in hospital operating rooms.
- Methanol is used as a solvent for fats, oils, paints and varnishes.
- Many organic compounds are used in the manufacturing of drugs, dyes, cosmetics, detergents and soaps, nylon, emulsions and paints etc.

### Self-Assessment Exercise 11.4

1. List the names of major sources of alkanes.
2. What is natural gas?
3. Write some uses of acetylene.

### Teacher's Point

Teacher may show different organic compounds to students.

Reading

# 11.4. ALKANE AND ALKYL RADICALS

Recall that an alkane is a hydrocarbon containing only single bonds and have general formula $C_nH_{2n+2}$.

**An alkyl radical is a group of atoms obtained by removing one hydrogen atom from an alkane**. Alkyl radicals are represented by the symbol R.

### Example 11.3 Converting alkanes into alkyl radicals

Convert following alkanes into alkyl radical.

**(i)** Methane **(ii)** Ethane

### Problem Solving Strategy

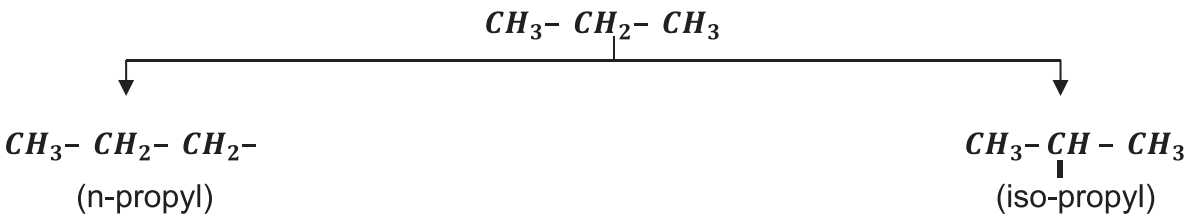
**(i)** Write condensed structure formula for the given compound.
**(ii)** Remove a hydrogen atom from the terminal carbon atom.
**(iii)** Write name of the radical by removing ending -ane of alkane by -yl

### Solution

**(i)** $CH_4$ $CH_3-$
**Methane** **Methyl**

**(ii)** $CH_3CH_3$ $CH_3CH_2-$
**Ethane** **Ethyl**

What is the difference between methane and methyl radical? Which one contain a free valency? Alkanes containing more than two carbon atoms form more than one alkyl groups. For instance, propane forms two alkyl groups or radicals. The group obtained by removing terminal hydrogen atom is called n-propyl and that obtained by removing H-atom from central carbon atom is called iso-propyl group.




Self-Assessment Exercise 11.5

Derive alkyl radicals from the following alkanes.

a. Ethane b. Butane c. Propane

## Reading

## 11.1.6. Classification of Organic Compounds

There are millions of organic compounds. It is not possible to study each compound individually. To make the study easy, they are classified into various groups and sub-groups. It is helpful to pick out these compounds which have similar structure. So you will learn here, the classification of organic compounds on the basis of carbon skeleton. They are broadly classified into two main groups.

**Do you know?**

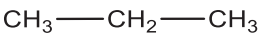
Alkyl radical contains one less hydrogen than its parent alkane.

**(i)** Open chain compounds or Acyclic compounds.

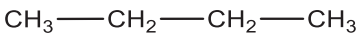
**(ii)** Closed chain or Cyclic Compounds.

### (i) Open chain compounds.

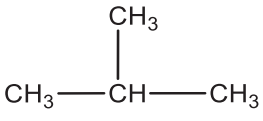
Open chain compounds contain an open chain of carbon atoms. For instance



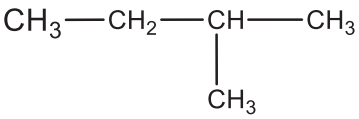
**Propane**



**Butane**

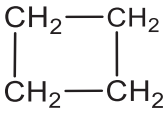


**iso-Butane**



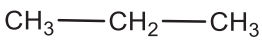
**iso – Pentane**

Is the compound having following structure an open chain compound?



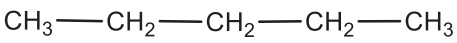
Open chain compounds may be either straight-chain or branched-chain. Those compounds which contain any number of carbon atoms joined one after the other in a chain or row are called **straight – chain compounds.**

**For example**



**Propane**

**Butane**

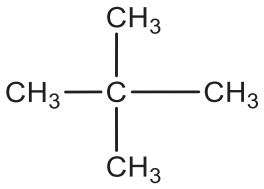


**Pentane**

## Teacher's Point

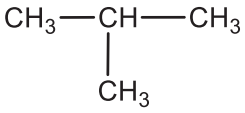
Teacher may tell students that Sui Gas is mainly methane containing small amount of ethane, propane and butane.

Those compounds which contain carbon atoms on the sides of chain are called branched chain compounds. Which of the following is a branched chain compound?



neo-Pentae

Butane

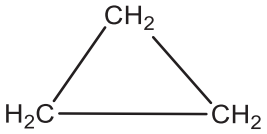


iso-Butane

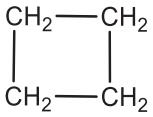
Open chain compound are also called alicyclic compounds

### (ii) Closed Chain or Cyclic Compounds

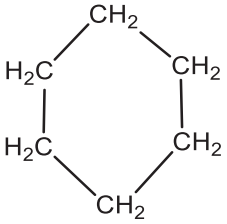
Organic compounds which contain rings of atoms are called closed chain or cyclic compounds. For example



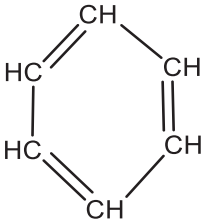
Cyclopropane



Cyclobutane



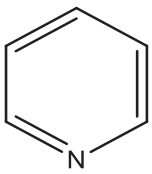
Cyclo hexane



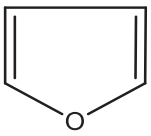
Benzene

or

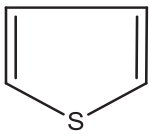
Cyclic compounds which contain rings of carbon atoms are called homocyclic or carbocyclic compounds. Which of the above cyclic compounds are carbocyclic? Cyclic compounds that contain one or more atoms other than carbon atoms in the ring are called heterocyclic compounds e.g.



Pyridine



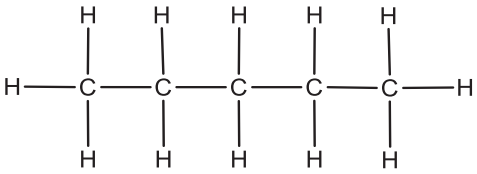
Furan



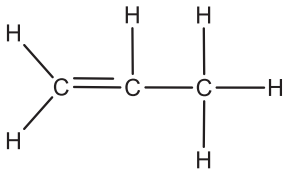
Thiophene

## Self-Assessment Exercise 11.6

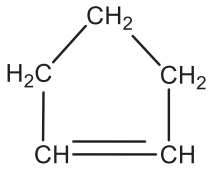
A to E are the structural formulas of some organic compounds.



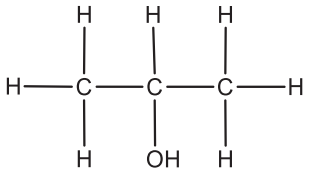
A



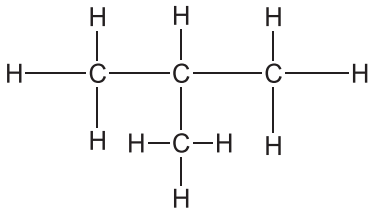
B



C



D



E

**Give the letters which represents**

(i) A branched chain compound.

(ii) A cyclic compound.

(iii) Two straight chain compounds.

## Reading

# 11.4 FUNCTIONAL GROUPS

The vast majority of organic compounds contain elements in addition to carbon and hydrogen. Most of these compounds are considered as derivatives of hydrocarbons. This means that they are basically hydrocarbons but they have additional atom or groups of atoms in place of one or more hydrogen atoms called functional groups. In many simple molecules, a functional group is attached to an alkyl group.

**An atom or groups of atoms that give a family of organic compounds its characteristic chemical and physical properties is called a functional group.**

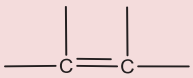
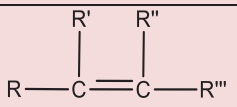
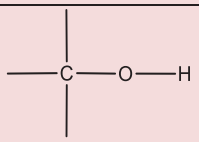
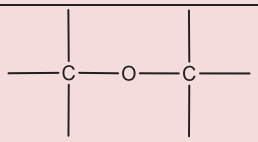
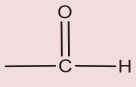
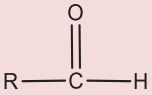
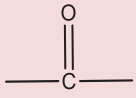
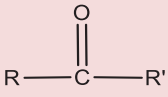
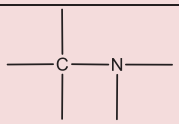
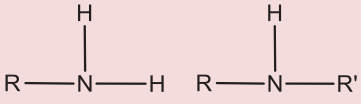
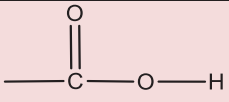
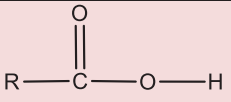
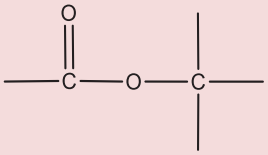
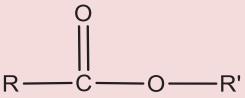
What is the difference in the following compounds?

| $CH_4$ | $H_3C—OH$ | $H_3C—Cl$ |
|---|---|---|
| Methane | Methyl alcohol | Methyl Chloride |

The common functional groups are listed in the table 11.2.

The study of organic chemistry is organized around functional groups. Each functional group defines a family of organic compounds. Although, there are millions of organic compounds, yet there are only a handful of functional groups. So functional groups make the study of millions of organic compounds easier.

### Table 11.2: Some Common Functional groups

| Name of class | Functional group | General formula |
|---|---|---|
| Alkane | None | R—H |
| Alkane |  |  |
| Alkyne |  |  |
| ALcohol |  |  |
| Ether |  |  |
| Aldehyde |  |  |
| Ketone |  |  |
| Amine |  |  |
| Carboxylic acid |  |  |
| Ester |  |  |

**Each functional group exhibits character**

## 11.5.1 Functional groups containing Carbon, Hydrogen and Halogens: Haloalkanes

Haloalkanes are characterized by the presence of the halogen atom. The haloalkane is compound in which one hydrogen atom of an alkane is substituted by one halogen atom. Which of the following molecules are haloalkanes?

| $CH_4$ | $H_3C—Cl$ | $H_3C—Br$ | $CH_3CH_3$ | $CH_3CH_2—Cl$ |
|---|---|---|---|---|
| Methane | Chloromethane | Bromomethane | Ethane | Chloroethane |

## 11.5.2 Functional groups containing Carbon, Hydrogen and Oxygen: Alcohols

Alcohols are characterized by the presence of the hydroxyl group. (-OH) attached to a hydrocarbon chain.

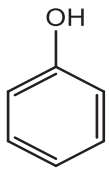
| $H_3C—OH$ | $CH_3CH_2—OH$ |
|---|---|
| Methanol (Methyl alcohol) | Ethanol (Ethyl alcohol) |

R – OH is the general formula for alcohols. Which of the following compounds is alcohol?

| $CH_3CH_2CH_2OH$ | $CH_3CH_2CH_2CH_2OH$ |
|---|---|
| 1-Propanol | 1-Butanol |

### Phenols

When an – OH group is attached to a benzene ring, the compound is called a phenol.




or $C_6H_5—OH$

Phenol

Phenol was the first antiseptic used in an operation theatre.

### Ethers

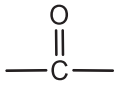
Organic compounds that have two alkyl groups attached to the same oxygen atom are called ethers. These compounds have C–O–C linkage in their molecules.

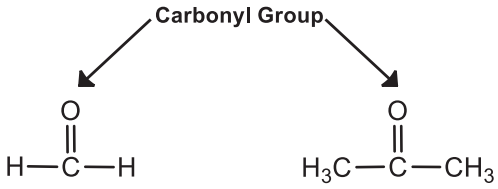
| $CH_3—O—CH_3$ | $CH_3—O—CH_2—CH_3$ | $CH_3—CH_2—O—CH_2—CH_3$ |
|---|---|---|
| Dimethyl ether | Ethyl methyl ether | Diethyl ether |

The general formula for ethers is R-O-R$^{/}$. Where R and R$^{/}$ are alkyl groups which may be same or different.

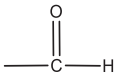
## Aldehydes and ketones

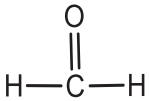
Aldehydes and ketones contain the carbonyl group


or —CO—




An aldehyde has at least one hydrogen atom or two hydrogen atoms attached to the carbonyl carbon atom. A ketone has two hydrocarbon groups (alkyl) bonded to the carbonyl carbon atom. Which of the above compound is an aldehyde? Which is a ketone?

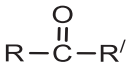
 group in condensed form is written as –CHO. It is characteristic group of aldehydes.

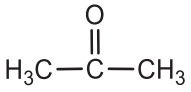
HCHO or 

Methanal (Formaldehyde)

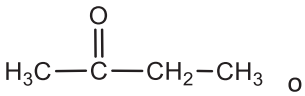
$CH_3CHO$ or 

Ethanal (Acetaldehyde)

The general formula for ketone is  and in condensed form it is written as $RCOR^{/}$. Where R and $R^{/}$ are alkyl groups which may be same or different. For example

 or $CH_3COCH_3$

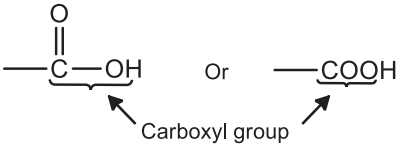
Propanone (Acetone)

 or $CH_3COCH_2CH_3$

Butanone

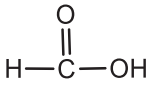
## Carboxylic Acids:

The functional group of organic acid is called the carboxyl group.

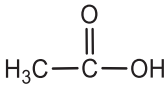



What is the difference between a carbonyl group and a carboxyl groups?

## Examples:

 or HCOOH

(Formic acid) Methanoic acid

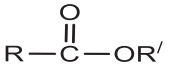
 or $CH_3COOH$

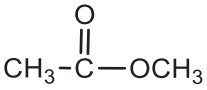
(Acetic acid) Ethanoic acid

The general formula for carboxylic acids is R – COOH

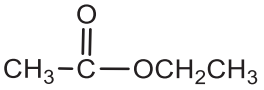
Where R = H or alkyl group

### Esters:

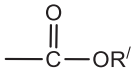
Compounds having general formula  are called esters. R and R/ are alkyl groups which maybe same or different.



(Methyl acetate) Methyl ethanoate



(Ethyl acetate) Ethyl ethanoate

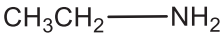
 is the functional group for esters.

## 11.5.3 Functional groups containing Carbon, Hydrogen and Nitrogen

### Amines

The functional group of amines is – $NH_2$

Methyl amine



Ethyl amine

The general formula for amines is $R-NH_2$

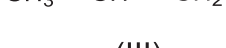
## 11.5.4 Functional groups containing Double and Triple bond

An alkene is a hydrocarbon that contains one or more carbon-carbon double bond. -C=C- is the functional group for alkenes. An alkyne is a hydrocarbon that contains one or more carbon-carbon triple bond. -C≡C- is the functional group for alkynes. Which of the following compound is alkene, which is alkyne?

(II)



(II)



(III)

**Example11.4: Differentiating different organic compounds on the basis of their functional groups.**

Classify the following compounds as an alcohol, ether or a phenol.

(a) $CH_3CH_2OCH_2CH_3$, is an anesthetic, but its' use as an anesthetic is now limited. This is because it is inflammable and causes nausea.

(b) $C_6H_5OH$ is a strong germicide. It is commonly used as disinfectant for floors, furniture and washrooms.

(c) $CH_3OH$ is poisonous and can cause blindness or death if taken internally.

### Problem Solving Strategy:

(i) Identify alkyl group in the molecule and functional group.

(ii) When –OH group is attached to an alkyl group, the compound is an alcohol, but when –OH is attached to benzene ring, the compound is a phenol.

(iii) When O– atom is attached to two alkyl groups, the compound is an ether.

**Solution**

(a) Ether (b) Phenol (c) Alcohol

## Self-Assessment Exercise 11.7

Classify the following compound as alcohol, ether or phenol.

(a) $CH_3CH_2OCH_2CH_3$ (b) $CH_3CH_2CH_2OH$

(c) $C_6H_5OH$ (d) $C_2H_5OH$

## Reading

**Example 11.5: Classify the following organic compounds on the basis of functional group.**

**Identify the following compounds as an aldehyde or a ketone or a carboxylic acid.**

(a) $CH_3COCH_3$is a common solvent for organic materials such as fats, rubbers, plastic and varnishes.

(b) $CH_3CH_2CHO$has a foul irritating odour.

(c) $CH_3COOH$is present in vinegar and is used to flavor food and making a polymer called polyvinyl acetate.

**Problem Solving Strategy**

**Remember that**

(i) In an aldehyde a hydrogen atom is attached to the carbonyl carbon atom.

(ii) In a carboxylic acid –OH group is attached to the carbonyl carbon atom.

(iii) In a ketone, the carbonyl carbon is between two other carbon atoms.

**Solution**

(a) A ketone (b) An aldehyde (c) An organic acid

## Self-Assessment Exercise 11.8

Identify the following compounds as an aldehyde, or a ketone or a carboxylic acid.

(a) $CH_3COCH_2CH_3$ (b) $CH_3CH_2\overset{\overset{O}{\|}}{C}H$ (c) $CH_3CH_2\overset{\overset{O}{\|}}{C}OH$

Almost all synthesis involve the inter conversion of at least one functional group to another. A functional group is the active portion of the molecule. It plays a key role in the

synthesis of new compounds. The key to design most organic synthesis is the functional group in the target molecules.

## SKILLS

**Society, Technology and Science**

Pharmaceutical chemists seek ideas for new drugs not only from plants but also from any part of animals. They isolate the active ingredients for drug material methods include cold maceration and methanolic or ethanolic extraction. Then, they test drug on animals and perform, other clinical tests. After successful tests, pharmacists develop a manufacturing process for new effective drug in a laboratory. They use computer-aided software for drug design.

To develop a synthesis scheme for a particular substance produced by plants and animals or new effective drug, pharmaceutical chemists first analyze the target molecule. They look for a suitable starting material. The synthesis involves two steps.

(i) Changes in the carbon skeleton

(ii) Inter conversion of functional groups.

So, pharmaceutical chemists determine whether the reaction changes the carbon skeleton or inter converts the functional groups. If both the molecules have the same number of carbon atoms, then they can accomplish the synthesis by one or more functional group inter-conversion. If they are of different sizes, then they modify the carbon skeleton. For this they look for a molecule that allows them to make a possible carbon containing skeleton to obtain the product. Then they look for ways to obtain the functional groups of the target molecule.

## Activity 11.1

Differentiate between saturated and un-saturated compounds using, iodine bromine and potassium permanganate.

### Carry out the following:

- Dissolve 2-3 $cm^3$ of mustard oil in 5 $cm^3$ of carbon tetrachloride. Divide this solution into three parts.
- To one part add few drops of bromine water and shake. What happens?
- To the second part add few drops of iodine solution and shake. What happens?
- To the third part add few drops of dilute alkaline $KMnO_4$solution and shake (Baeyer's test). What happens?
- Repeat these steps with kerosene oil. What do you observe?

### Un-Saturated Compounds Discharge

i) Reddish brown colour of bromine water.

ii) Purple colour of iodine solution

iii) Purple colour of alkaline $KMnO_4$

Saturated compounds do not give these tests.

## Activity 11.2

Identifying carboxylic acids, phenols, amines, aldehydes and ketones in terms of functional groups.

Perform this activity in chemistry laboratory

**Carry out the following:**

### i) Test for carboxylic acids

- Take 5 $cm^3$ of vinegar in a test tube and a pinch of $NaHCO_3$, test the gas evolved with lime water: what happens?
- Dip blue litmus paper in vinegar. What happens? These two tests indicate the presence of carboxylic group in vinegar.

### ii) Test for phenol

- Dissolve a pinch of carbolic acid (phenol) in 5 $cm^3$ of water in a test tube.
- Add bromine water in the above solution.
- What happens? Phenol gives white ppt with bromine water.

### iii) Test for amine

- Heat pinch of an amine in 2 $cm^3$ of alcoholic solution of KOH and 0.5 $cm^3$ of chloroform.
- Note the odour of fumes given out.

An amine gives extremely unpleasant or foul odour.

### iv) Test for Aldehyde

- Mix equal volumes of Fehling's solution A and B in a test tube.
- Add a pinch of glucose init and boil for some time.
- What happens?

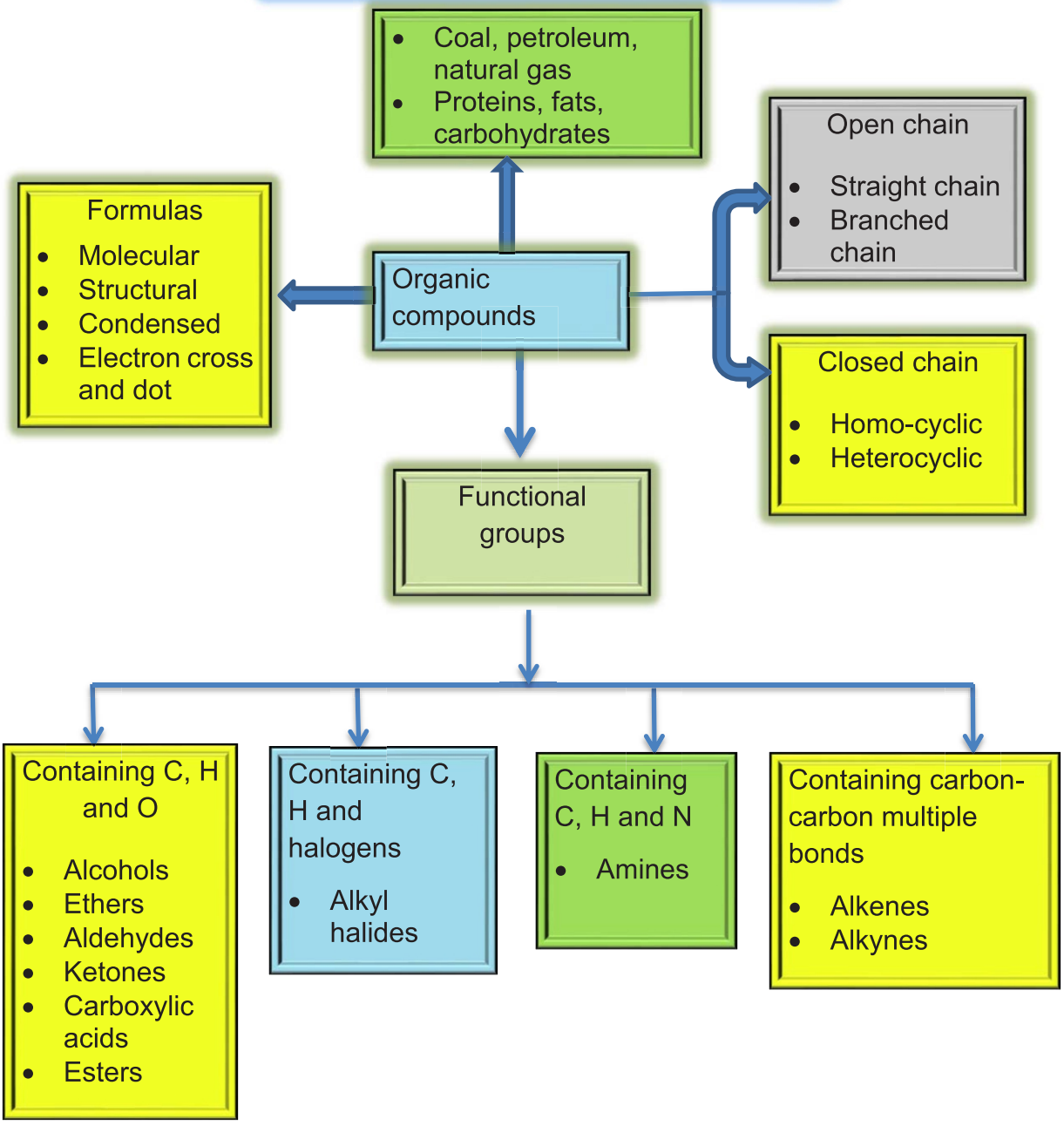
Aldehydes give red precipitate with Fehling's solution.

### v) Test for ketone

- Take 2-3 $cm^3$ of sodium nitro-prusside solution in a test tube and few drops of NaOH solution.
- Add one $cm^3$ of acetone in the above test tube.
- What happens?

Ketones give red colour with alkaline sodium nitro-prusside solution.

# Concepts in brief



## Key Points

- The study of hydrocarbons and their derivatives is called organic chemistry.
- The self-linking ability of carbon atoms is called catenation.
- Structural formula describes the arrangement of atoms in a molecule.
- Condensed structural formula shows abbreviations for various group of chain.
- Hydrocarbons whose carbon-carbon bonds are all single bonds are called saturated hydrocarbons
- Hydrocarbons containing carbon-carbon multiple bonds are called unsaturated hydrocarbons.
- The stem is the part of the name of an organic compound that tells the number of carbon atoms in the chain.
- The suffix in the name of the compound tells the class of compound.
- Heating the coal in the absence of air at high temperature is called destructive distillation.
- Destructive distillation of coal gives coal gas, coal tar and coke.
- Fractional distillation of petroleum gives various hydrocarbon components known as fractions.
- An alkyl radical is a group of atoms obtained by removing one hydrogen atom from an alkane.
- Open chain compounds contain an open chain of carbon atoms.
- Straight chain compounds contain carbon atoms joined one after the other in a chain.
- Branched chain compounds contain carbon atoms on the side of chain.
- Cyclic compounds contain rings of carbon atoms.
- An atom or a group of atoms that give a family of organic compounds, its characteristics properties, is called a functional group.

**References for additional information.**

- Chemistry for changing times, John W. Hill, Doris K. Kolb.
- Longman chemistry for IGCSE, Jin Clark and Ray Oliver.

## Review Question

**1. Encircle the correct answer.**

(i) Condensed structural formula for butane is

(a) $CH_3- CH_2- CH_3$ (b) $CH_3- CH_2- CH_2- CH_3$

(c) $CH_3- CH_2- CH_2- CH_2- CH_3$ (d) $CH_3- CH_3$

(ii) $CH_3- CH_2- CH_3$ is the chemical formula for

(a) Ethane (b) Propane (c) Butane (d) Pentane

(iii) Which compound is not a saturated hydrocarbon?

(a) $CH_3—CH_3$ (b) $CH_4$

(c) $CH_3—CH=CH_2$ (d) $CH_3—CH_2—CH_3$

(iv) Stem "But" stands for how many Carbon atoms.

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

(V) Pitch is produced by

(a) Coal (b) Coal tar (c) Coal gas (d) Petroleum

(vi) The functional group $—\overset{\overset{O}{\|}}{C}—$ is found in

(a) Alcohols (b) Ketones (c) Carboxylic acids (d) Esters

(vii) In which of the following Compounds, oxygen is attached to two alkyl carbon atoms?

(a) Alcohol (b) Phenol (c) Ether (d) Ester

(viii) Which of the following is an alcohol?

(a) $CH_3- CH_2- O- CH_2- CH_3$ (b) $CH_3- CH_2- COOH$

(c) $C_6H_5- OH$ (d) $CH_3- CH_2- OH$

(ix) The functional group of amines is

(a) –OH (b) – COOH (c) – $NH_2$ (d) – CHO

(x) Formic acid contains functional group

(a) – OH (b) – CO – (c) –COOH (d) – CHO

**2. Give short answer.**

(i) What is catenation?

(ii) Define isomerism.

(iii) Give three examples of alkyl groups.

(iv) Define a functional group.

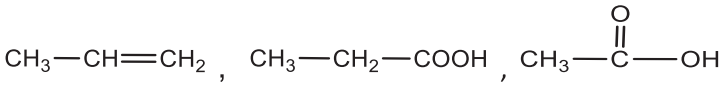
(iv) What is the difference between an alkane and an alkyl radical?

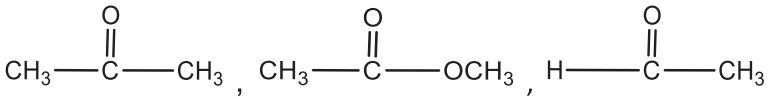
3. **What do you mean by the term destructive distillation?**

4. **List some general properties of organic compounds.**

5. **List major commercial sources of alkanes.**

6. **Identify the following compounds on the basis of functional groups they contain and encircle the functional group.**





7. **What is the name of alkane having seven carbon atoms in the chain?**

8. **What is the name of the alkyl group obtained by removing an end hydrogen atom from (i) propane (ii) ethane?**

9. **Give the structural formula of two simple alkanes and one alkyne.**

10. **What is meant by the term functional group?**

11. **Identify the type of following compounds as an alcohol, aldehyde or ketone:**

(a) HCHO, which is used to manufacture polymers, such as urotropine which is used to treat urinary tract infection.

(b) $CH_3COCH_3$, which is used in nail polish remover.

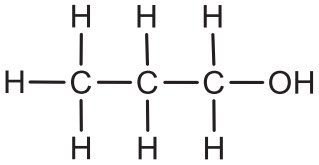
(c) $CH_3CH_2OH$, which is used in the preparation of many organic substances such as plastics, cosmetics, tinctures etc.

## Think-Tank

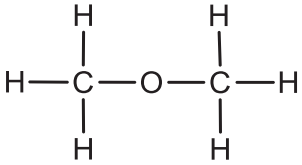
11. **Give molecular formula of a compound containing C, H and O and single bonds. List all the possible functional groups this compound can have?**

12. **Give the condensed structural formulas of the following compounds and classify each on the basis of functional group.**

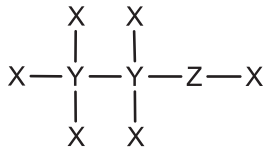
**(a)**



**(b)**



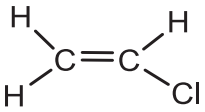
**13. The diagram represents an organic compound that contains three different elements.**



Select the possible compound from the following.

a) Ethanoic acid b) Propene c) Ehanol d) Propane.

**15. Polyvinyl chloride (PVC) is a polymer. It is used for making vinyl sheets, drainage pipes, wire insulation etc. It is obtained from vinyl chloride**

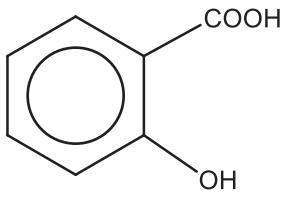


Classify Vinyl chloride as saturated or unsaturated compound.

**16. For each of the following, sketch the structural formulas of a two–carbon compound containing the indicated functional group.**

(a) alcohol (b) aldehyde (c)carboxylic acid (d) alkene

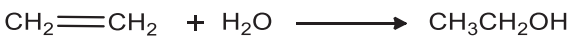
**17. Aspirin is a mild pain killer and fever reducer. It is manufactured from salicylic acid.**



Select functional groups present in it and encircle them. Justify your selection.

**18. General formula for alkane is $C_nH_{2n+2}$. Construct the general formula for alkyl radical?**

**19. Water adds to ethene according to the following reaction**



Compare the functional groups in the reactant and product molecules.

**20. Bonding of carbon atom to heteroatoms increases the number of organic compounds. Justify it.**

12

# HYDROCARBONS

**After completing this lesson, you will be able to:**

**This is 10 days lesson (period including homework)**

- Explain why 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 from reduction of alkyl halides.
- Draw structural formulas 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 dehydrohalogenation of 1, 2- dihalides and dehalogenation of tetrahalides.
- Write chemical equations showing halogenation of alkanes, alkenes and alkynes.
- Write chemical equations showing reaction of $KMnO_4$ with, alkenes and alkynes.
- Determine the boiling point of alcohol.
- Explain hydrocarbons as fuel.
- Explain hydrocarbons as feed stock in industry.

## Reading

## INTRODUCTION

The simplest organic compounds are hydrocarbons. **The organic compounds which contain only two elements, carbon and hydrogen are called hydrocarbons.** There are several kinds of hydrocarbons. They are classified according to the type of bonding between the carbon atoms. You have learnt differences between alkanes, alkenes and alkynes in the previous chapter.

About 90% of the energy used to sustain our way of life comes from **fossil fuels.** Coal, natural gas and petroleum are called **fossil fuels**. Why are these

fuels called as fossil fuels? Natural gas is a mixture of low molecular weight hydrocarbons. Mainly it contains methane. Petroleum is a liquid mixture of mainly hydrocarbons. When these fuels are burnt, they produce carbon dioxide, water and heat. It has been estimated that the concentration of carbon dioxide in the atmosphere has increased up to 20% by the end of twentieth century. Carbon dioxide and other gases produce **greenhouse effect** (section 14.3.1).

**Do you know?**

Carbon dioxide and other gases in the air let the sun rays in, to warm the surface of earth. When the earth tries to radiate this heat back into the space, molecules of these gases trap this energy

About 25 billion tons of carbon dioxide is released into the atmosphere each year, 22 billion tons of it comes from the burning of fossil fuels. About 15 billion tons per year is removed by the plants. Thus 10 billion tons of carbon dioxide remains in the air. This is causing global warming. (For detail see section 14.3.1)

Although hydrocarbons burn, many of them are not generally used as fuel. They are mostly used as feed stock in industry. These hydrocarbons are starting raw materials for the synthesis of large number of organic compounds. These compounds have commercial importance.

**Society, Technology and Science**

Alkenes are starting materials for the synthesis of many valuable materials, especially polymers. Some alkenes and alkynes serve as starting materials for synthesis. For instance ethene and ethyne are used to synthesize a number of polymers. Polymers are made from smaller molecules such as ethene. Look around you, you will find polymers everywhere. Your clothes, carpets, curtains, towels, sheets, floor tiles, furniture, toys etc. are polymers made from ethene and ethyne. Even in your car, the dash board, seats, tyres, floor mat, ceiling, are also made of polymers. Hydrocarbons are also used as raw materials for the synthesis of synthetic rubber, plastic, films, adhesives, drugs and dyes. In the field of medicine, body replacement parts are made from polymers. In future we will have artificial bones that can stimulate bone growth. We can also expect to have artificial lungs as well as artificial hearts. Industries are day and night busy in synthesizing marvelous new products. Is there anything that can replace petroleum as raw material for making plastics and other polymers?

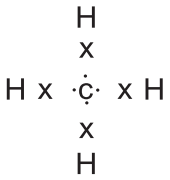
Millions of organic compounds exist. To understand, recognize and classify these compounds, systematic naming of organic compounds is necessary. Organic chemists began in the last century to devise a system of naming organic compounds that depends on their structure. An international body, **the International Union of Pure and Applied chemistry (IUPAC, pronounced "eye-you-pac")** constantly reviews the rules for naming organic compounds. IUPAC system of naming organic compounds is based on the following principle.

**Each different organic compound should have a different name.**

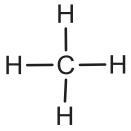
## 12.1 ALKANES

Alkanes are saturated hydrocarbons. They have general formula $C_nH_{2n+2}$.Each carbon atom forms four bonds and each hydrogen atom forms only one bond. So the simplest alkane

molecule that is possible is $CH_4$. It is called methane. Methane is the main component of natural gas. Electron dot and cross structure for methane is as follows.

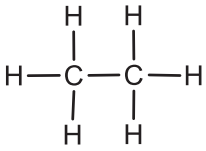


So the structural formula for methane is



Recall that structural formula shows which atoms are bonded to each other. The next member of alkane series is ethane, $C_2H_6$.

Ethane molecules has following structure



**Example 12.1: Writing structural formula for an alkane.**

Write structural formula for propane.

**Problem Solving Strategy**

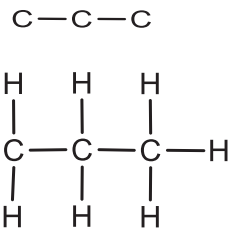
(i) Prop-means three carbon atoms.

(ii) Ending –ane indicates an alkane.

(iii) Write a string of three carbon atoms.

(iv) Attach hydrogen atoms to the carbon atoms to give each carbon atom four bonds.

**Solution**



**Self-Assessment Exercise 12.1**

Write structural formulas for **(a)** Butane **(b)** Pentane

### Example 12.2: Writing electron dot and cross structure for alkanes.

Draw the electron dot and cross structure for ethane.

**Do you know?**

Many halogenated hydrocarbons have important commercial uses. Methyl chloride is a gas at room temperature. Dichloromethane, trichloromethane and tetra chloromethane are liquids. These three liquids can be used as solvents for grease, oils and other organic substances. Chloroform is used as an anesthetic. Tetrachloromethane has carcinogenic effects at high concentration.

### Problem Solving Strategy

(i) Write carbon atoms in a row.

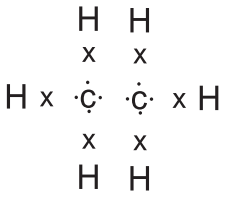
(ii) Show four elections by dots around each carbon atom.

(iii) Arrange hydrogen atoms around carbon atoms so that each carbon is surrounded by four atoms.

(iv) Show valence electrons of hydrogen by cross.

(v) Connect atoms by electron pairs

### Solution



### Self-Assessment Exercise 12.2

Draw electron dot and cross structures for the following.

**(a)** Propane **(b)** Butane

## Reading

## 12.1.1. General Methods of Preparations of Alkanes

### 1. By Hydrogenation of alkenes and alkynes

Addition of hydrogen molecule across carbon-carbon multiple-bond is called hydrogenation. Hydrogenation takes place in presence of finally divided nickel at 200 – 300° C and high pressure. Hydrogenation can also be done in presence of Pt or Pd at room temperature.

Alkynes add two molecules of hydrogen. Why?

$$\underset{\text{Ethyne}}{CH \equiv CH} + H_2 \xrightarrow{Ni,200-300^oC} \underset{\text{Ethene}}{CH_2 = CH_2}$$

$$CH_2 = CH_2 + H_2 \xrightarrow{Ni,200-300^oC} CH_3 - CH_3$$

Ethene Ethane

## Self-Assessment Exercise 12.3

Complete the following reactions

$$CH_3 - CH = CH_2 + H_2 \xrightarrow{Ni,200-300^oC}$$

$$CH_3 - C \equiv CH + 2H_2 \xrightarrow{Ni,200-300^oC}$$

## Reading

### 2. By the reduction of alkyl halides

When an alkyl halide is treated with Zn in presence of an aqueous acid, an alkane is produced. Usually aqueous solution of HCl or $CH_3COOH$ is used.

$$CH_3 - Cl + 2[H] \xrightarrow{Zn/HCl_{(aq)}} CH_4 + HCl$$

Zn reacts with aqueous acid to liberate atomic hydrogen called nascent hydrogen. Nascent hydrogen reduces alkyl halide. Addition of nascent hydrogen is called reduction.

## Self-Assessment Exercise 12.4

**Complete the following reactions.**

(a) $CH_3—\underset{\displaystyle Cl}{\underset{|}{CH_2}} + [H] \xrightarrow[HCl_{(aq)}]{Zn}$

(b) $CH_3—\underset{\displaystyle Cl}{\underset{|}{CH}}—CH_3 + 2[H] \xrightarrow[H_2SO_{4(\,aq)}]{Zn}$

## Reading

## 12.1.2. Properties of Alkanes

Alkane molecules are essentially non-polar. They are less dense than water and are insoluble in it. Chemically alkanes are unreactive towards most ionic compounds. This lack of

reactivity makes them useful solvents. For instance hexane is used to extract vegetable oils from Corn, Soya beans, Cotton seed etc.

Alkanes containing upto four carbon atoms are colourless, odourless gases. Alkanes containing five to seventeen atoms are colourless, odourless liquids. Higher alkanes are solids which are also colourless and odourless.

## 1. Halogenation

Although unreactive towards ionic substances, alkanes readily react with halogens in sunlight. The reaction of an alkane and a halogen is a **substitution reaction.** In this reaction a halogen atom substitutes for one or more of the hydrogen atoms of an alkane.

For examples the reaction of methane and chlorine in diffused sunlight occurs as follows.

$$CH_{4(g)} + Cl_{2(g)} \xrightarrow{diffusedsunlight} CH_3Cl_{(g)} + HCl_{(g)}$$

**Chloromethane**

$$CH_3Cl_{(g)} + Cl_{2(g)} \xrightarrow{diffusedsunlight} CH_2Cl_{2(g)} + HCl_{(g)}$$

**Dichloromethane**

$$CH_2Cl_{2(g)} + Cl_{2(g)} \xrightarrow{diffusedsunlight} CHCl_{3(g)} + HCl_{(g)}$$

**Trichloromethane**
**(Chloroform)**

$$CHCl_{3(g)} + Cl_{2(g)} \xrightarrow{diffusedsunlight} CCl_{4(g)} + HCl_{(g)}$$

**Tetrachloromathene**
**(carbon tetrachloride)**

In direct sunlight the reaction of methane with chlorine is explosive and forms carbon and HCl.

$$CH_{4(g)} + 2Cl_{2(g)} \xrightarrow{directsunlight} C_{(s)} + 4HCl_{(g)}$$

The chlorination of methane usually produces a mixture of products. The trend in reactivity of halogen with an alkane is as follows

$$\boldsymbol{F_2 > Cl_2 > Br_2 > I_2}$$

Fluorine reacts explosively; chlorine reacts slowly in dark at room temperature but rapidly in strong sunlight. Bromine is less reactive than chlorine and requires high temperature or strong sun light. Iodine is essentially unreactive.

## 2. Combustion

A reaction of a substance with oxygen or air that causes the rapid release of heat and the appearance of a flame is called combustion. Complete combustion of an alkane produces carbondioxide, water and heat. Most of alkanes burn with blue flame.

For example, following reaction occurs when natural gas is burned.

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

The lighter alkanes are widely used as fuel. This is because:

(i) Their combustion can be controlled.

(ii) They produce large amount of heat per gram.

(iii) They are cheap and readily available.

Incomplete combustion occurs in presence of limited supply of oxygen. Incomplete combustion of methane gives CO, C and $H_2O$.

$$3CH_{4(g)} + 4O_{2(g)} \longrightarrow 2CO_{(g)} + C_{(s)} + 6H_2O_{(g)}$$

### Uses of methane

Methane is used

(i) as domestic fuel (Sui gas).

(ii) as a fuel for automobiles (CNG).

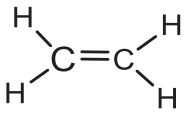
(iii) to manufacture urea fertilizer.

## 12.2. ALKENES

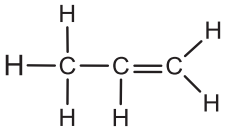
Alkenes have one or more double bond between carbon atoms. They have the general formula $C_nH_{2n}$. When two carbon atoms share two pairs of electrons, they form a double bond between the carbon atoms. How many electrons are left on each carbon atoms? Doubly bonded carbon atoms form single bond with two other atoms.

**Do you know?**

Ethylene or ethene is the most important commercial organic chemical. It is used in the manufacturing of polythene, one of the most familiar plastics. It is also converted to ethylene glycol which is used as antifreeze in auto mobile radiators.



Ethene



Propene

### Example12.3: Writing structural formulas for alkenes.

Draw structural formulas for

(a) 1- Butene

(b) 2- Butene

### Problem Solving Strategy

(i) But- means four carbon atoms.

(ii) Ending – ene indicates and alkene.

(iii) Write a string of four carbon atom and assign number to each carbon atom from one side.

### Teacher's Point

Teacher may give example of blackening of cooking pots for in complete combustion of CH 4.

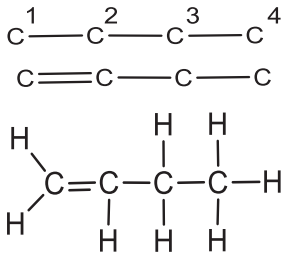
(iv) Number written before the name indicates the position of double bond. Make a double bond between indicated carbon-atom and the atom next to it.

(v) Attach enough hydrogen atoms to the carbon atoms to give each carbon atom four bonds.

**Solution**

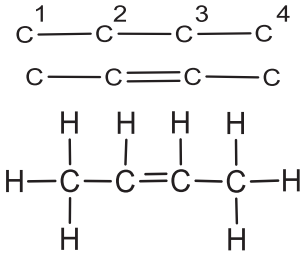
(a) 1 – Butane

**Indicates double bond between $C^1$ and $C^2$**



(b) 2 - Butene

**Indicates double between $C^2$ and $C^3$**



**Self-Assessment Exercise 12.5**

Draw structural formulas for the following compounds.

**(a)** 1 - Pentene **(b)** 2 – Pentene

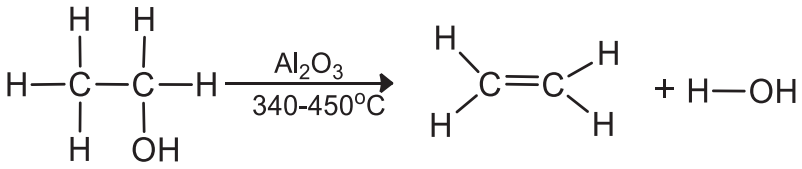
## Reading

## 12.2.1. General Methods of Preparation of Alkenes

Alkenes are prepared by the following methods.

### 1. By Dehydration of Alcohols

Dehydration means loss of water. Alcohols dehydrate when their vapour are passed over heated alumina.




Ethanol Ethene

Phosphoric acid $(H_3PO_4)$ and phosphorus pentaoxide $(P_4O_{10})$ can also be used as catalyst for dehydration of alcohols.

Concentrated sulphuric acid is also used for dehydration.

$$CH_3-\underset{\underset{OH}{|}}{CH_2} \xrightarrow[140\text{-}170^oC]{\text{Conc. } H_2SO_4} H_2C=CH_2 + H_2O$$

Note that in dehydration reaction -OH group is removed from one carbon and H atom from the adjacent carbon atom. Two such carbon atoms form double bond. Such a reaction is called elimination reaction.

Which alkene is formed by the dehydration of following alcohol?

$$CH_3-CH_2-\underset{\underset{OH}{|}}{CH_2}$$

### 2. Bydehydrohalogenation of alkyl halides

Dehydrohalogenation means loss of hydrogen halide. Alkyl halides on heating with alcoholic potassium hydroxide undergo dehydrohalogenation.

$$CH_3-\underset{\underset{Cl}{|}}{CH_2} + KOH \xrightarrow{\text{Alcohol}} CH_2=CH_2 + KCl + H_2O$$

Note that removal of H and halogen takes place from two adjacent carbon atoms. Is dehydrohalogenation an elimination reaction?

**Self-Assessment Exercise 12.6**

**Complete the following reactions.**

1. $CH_3-\underset{\underset{OH}{|}}{CH_2}-CH_2 \xrightarrow[170^oC]{\text{Conc. } H_2SO_4}$

2. $CH_3-\underset{\underset{Br}{|}}{CH_2}-CH_2 + KOH \xrightarrow{\text{Alcohol}}$

**Science titbits**

Alkenes occur widely in nature. Ripening fruits and vegetables give off ethene which helps in further ripening. So artificially ethene is used to hasten the normal ripening process. For example 1 kg of tomatoes can be ripened by exposure to 0.1mg of ethene for 24 hours. The red color of tomatoes is due to an alkene called Lycopene.

**Reading**

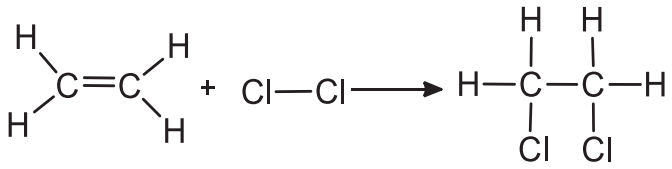
## 12.2.2 Properties of Alkenes

Alkenes are unsaturated hydrocarbons. First three members i.e. ethene, propene and butene are gases while $C_5$-$C_{15}$ members are liquids and the higher members are solids. They are insoluble in water but soluble in organic solvents such as alcohol etc. The two carbons atoms

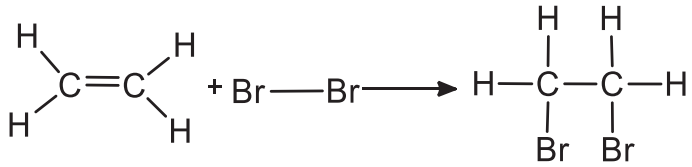
forming double bond are joined to only three atoms. Since a carbon atom can join to four atoms. So other molecules can attack at this site of double bond.

### Reaction with halogens

Chlorine and bromine add to the double bond. One chlorine atom becomes attached with one carbon and the one with other carbon atom.



Such a type of reaction is called addition reaction. Alkenes react with bromine water in the same way.

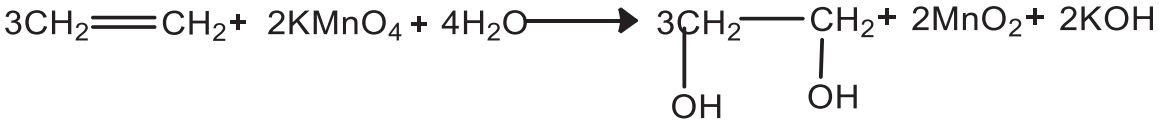


Ethene (colourless) (Reddish-brown) 1,2-Dibrome ethane (colourless)

Bromine is a reddish-brown liquid and the product is colourless. When bromine water is added to an alkene, the red-brown color disappears. The decolourization of bromine solution is frequently used as a simple test for the presence of unsaturation. Alkynes also give this reaction. (See section 12.3.2)

### Reaction with $KMnO_4$

When an alkene is treated with dilute alkaline aqueous solution of $KMnO_4$ (1%) addition of two hydroxyl groups occurs across the double bond. The pink colour of $KMnO_4$ solution is discharged during the reaction. This reaction is used as a test for the presence of an alkene and is known as Baeyer's test.



Ethene Ethylene Glycol

Ethylene glycol is used as an anti-freeze.

## Self-Assessment Exercise 12.7

**Complete the following reactions**

1. $CH_3 - CH = CH_2 + Br_2 \longrightarrow$
2. $CH_3 - CH = CH_2 + KMnO_4 + H_2O \longrightarrow$
3. $CH_3 - CH = CH_2 + Cl_2 \longrightarrow$

Reading

## 12. 3. ALKYNES

**Do you know?**
Acetylene is used in oxy-acetylene torches for cutting and welding metals. Such torches can produce temperature as high as 3000° C.

Hydrocarbons which have at least one triple bond between carbon atoms are called alkynes. Those with one triple bond have the general formula $C_nH_{2n-2}$.

**Structure:**

Ethyne, also called acetylene is the simplest member of alkyne family. In ethyne the two carbon atoms share three pairs of electrons. This means the carbon atoms are joined by a triple bond. How many hydrogen atoms can share electrons with each triply bonded carbon atoms? Structure of ethyne is

H – C ≡ C – H

**Example 12.4: Writing structural formulas of alkynes**

**Draw structural formulas for**

(a) 1-Butyne (b) 2-Butyne

**Problem Solving Strategy**

(i) But– means four carbon atoms.

(ii) Ending –yne indicates an alkyne.

(iii) Write a string of four carbon atoms and give number to each carbon atom form one side.

(iv) Number written before the names indicates the position of triple bond. Make a triple bond between this Carbon atom and next to it.

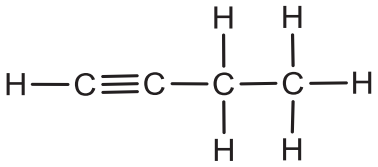
(v) Attach required number of hydrogen atoms to the carbon atoms to give each carbon atom four bonds.

**Solution**

**(i)**

$C^1—C^2—C^3—C^4$

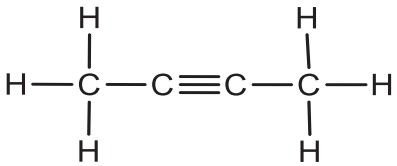
$C^1 \equiv C^2—C^3—C^4$



**(ii)**

$C^1—C^2—C^3—C^4$

$C^1—C^2 \equiv C^3—C^4$

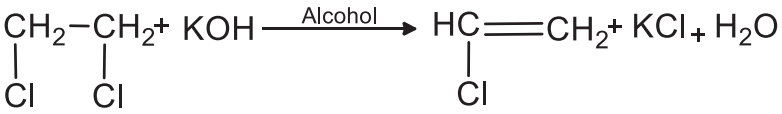


## 12.3.1. General Methods of Preparation of Alkynes

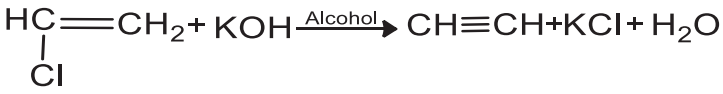
### 1. By Dehydrohalogenation of vicinal dihalides

A vicinal dihalide has two halogen atoms on adjacent carbon atoms. Which is vicinal dichloride?


Vicinal dihalide on treatment with alcoholic potassium hydroxide eliminates two molecules of hydrogen halides from adjacent carbon atoms. Removal of two molecules forms a triple bond between two carbon atoms. Reaction occurs in two steps.

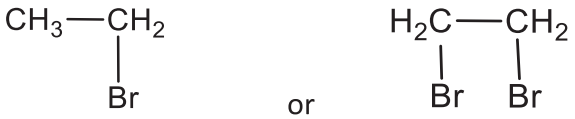



1,2Dichloroethane (Vicinal dihalide) Vinylchloride



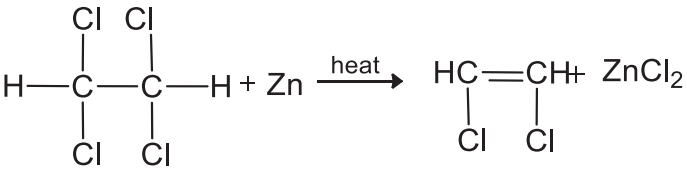

Ethyne

Which of the following alkyl halide will form alkyne on treatment with alcoholic KOH?

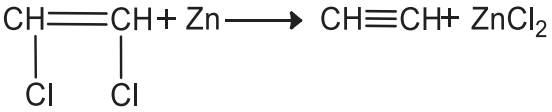



### 2. By Dehalogenation of Tetrahalides.

Tetra halides on treatment with Zn dust undergo dehalogenation forming an alkyne.




1, 1, 2, 2-Tetrachloroethane 1, 2-Dichloroethene




Ethyne

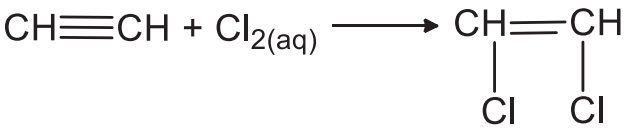
## 12.3.2. Properties of Alkynes

Like alkenes, alkynes are also unsaturated hydrocarbons. The first three members are gases, next eight members are liquids and higher members are solids. They are non-polar and dissolve readily in organic solvents. Ethyne has garlic like odour. Alkynes are reactive compounds due to presence of a triple bond. Alkynes undergo addition reaction across the triple bond.

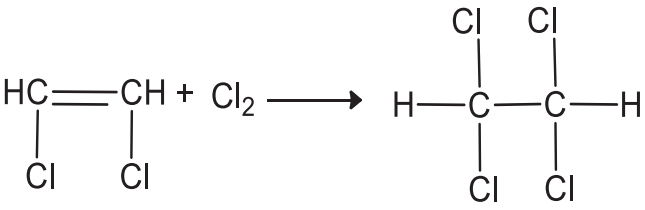
One molecule is added across the double bond in an addition reaction. Alkynes also undergo addition reactions like alkene. How many molecules will add across the triple bond?

### 1. Addition of Halogens

Alkynes add two molecules of halogens.



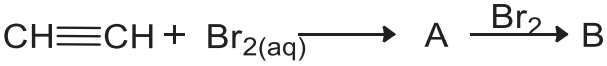
Ethyne 1,2 – Dichlorethene



**Tetrachloroethane**

**Self-Assessment Exercise 12.8**

Write chemical reaction of ethyne and bromine. Why this reaction is used to identify the unsaturation in a molecule?

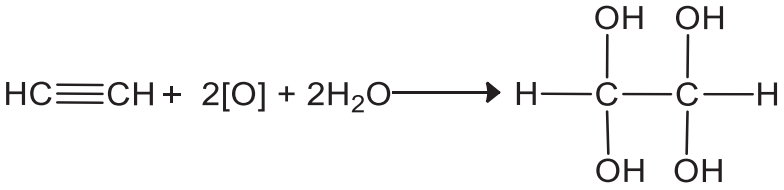


**Reading**

### 2. Reaction with $KMnO_4$

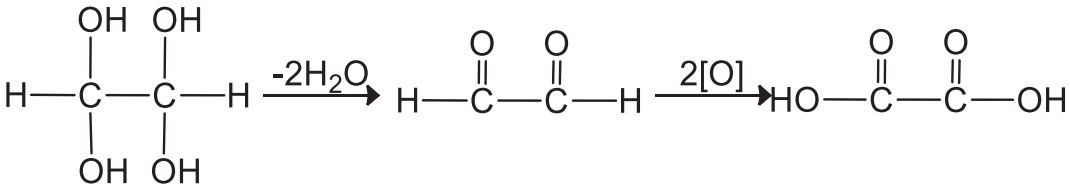
Alkynes do not react with dilute alkaline aqueous solution of $KMnO_4$. However, they are oxidized by strong alkaline solution of $KMnO_4$to give oxalic acid. First four hydroxyl groups are added across the triple bond.

$$4KMnO_4 + 4KOH \longrightarrow 4K_2MnO_4 + 4[O] + 2H_2O$$



Tetrahydroxy ethane

Tetrahydroxy ethane is unstable compound; it loses two water molecules to form glyoxal which finally oxidizes to oxalic acid.



Glyoxal Oxalic acid

**Society, Technology and Science**

Natural gas, petroleum and coal are important sources of hydrocarbons. These hydrocarbons are major source of energy. When they burn in air a highly exothermic reaction occurs. This reaction is called combustion reaction.

For example

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

Hydrocarbons are used as fuel to meet our energy needs in homes, industries, motor vehicles and power generation.

Uses of Ethyne (Acetylene)

Ethyne is used:

(i) In oxy-acetylene torch for welding and cutting metals.

(ii) For ripening of fruits.

(iii) For the manufacture of polyvinyl acetate (PVA), polyvinyl chloride (PVC), polyvinyl ethers and rubber.

## Self-Assessment Exercise 12.9

**Complete the following reaction**

$$CH_3—C\equiv CH + 2Br_2 \longrightarrow$$

$$CH_3—C\equiv CH + 2Cl_2 \longrightarrow$$

SKILLS

## Activity 12.1

**Determining boiling point of alcohol**

Perform this activity in the laboratory.

**You will need:**

- Bunsen burner, stand, wire gauze, stirrer, thread, fusion tube, capillary tube, beaker, thermometer and match box.
- An alcohol such as ethyl alcohol.

**Carry out the following:**

1. Place small amount of alcohol in the fusion tube and tie it to the thermometer with thread. The ends of fusion tube and thermometer should be equal.
2. Place a long capillary tube in the fusion tube.
3. Place the beaker containing water on the stand.
4. Suspend thermometer along with fusion tube in water. **(See figure 12.1)**
5. Heat the beaker and stir water with the stirrer.
6. Continue heating and stirring until bubbles start rising from the lower end of the capillary tube.
7. See the temperature on the thermometer when bubbles start to come from lower end of capillary tube. This is the boiling point of the liquid.

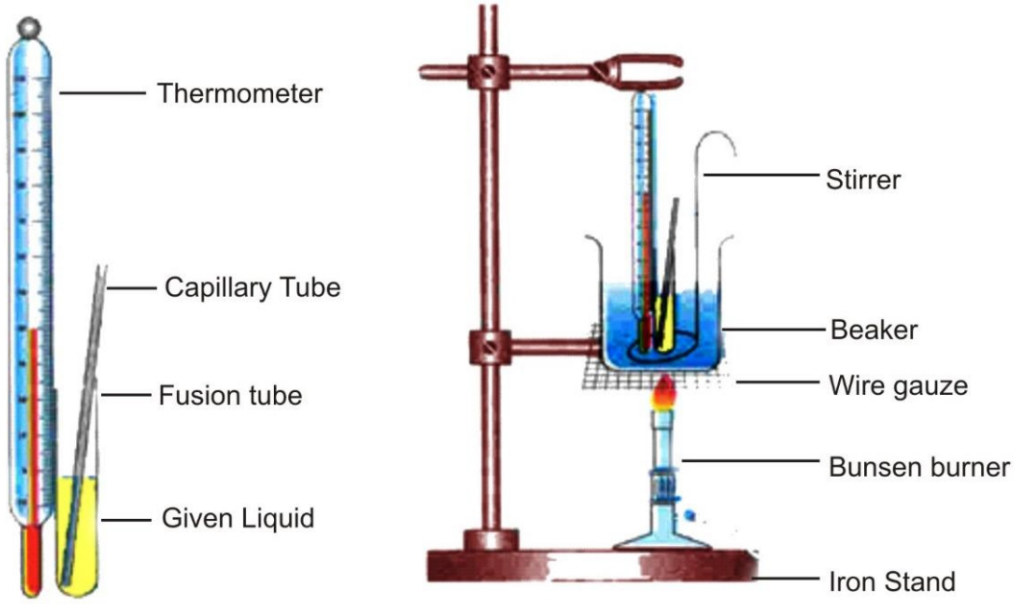
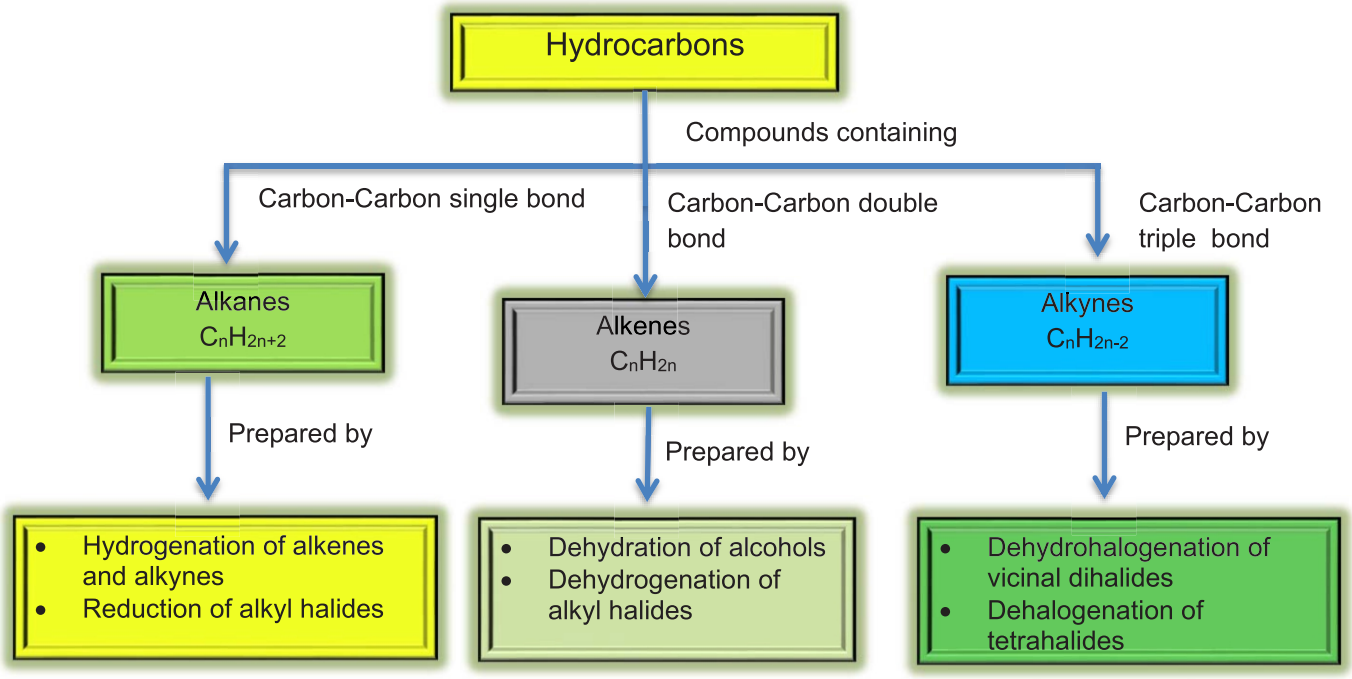



**Figure 12.1: Determination of the boiling point of alcohol.**

# Concepts in brief




## Key Points

- Hydrocarbons are compounds that contain carbon and hydrogen only.
- The simplest hydrocarbon that is possible is $CH_4$.
- Addition of hydrogen across carbon-carbon double or triple bond is called hydrogenation.
- Hydrocarbons that have at least one carbon-carbon double bond are called alkenes.
- Hydrocarbons that have at least one carbon-carbon triple bond are called alkynes.
- Dehydration is the loss of water.
- Removal of hydrogen halide is called as dehydrohalogenation.
- Alkenes and alkynes are unsaturated hydrocarbons.
- 1% alkaline aqueous solution of $KMnO_4$ is used to detect the presence of an alkene. The reaction is known as **Baeyer's test.**
- In alkynes the two carbon atoms share three pairs of electrons.
- A vicinal dihalide has two halogen atoms on adjacent carbon atoms.

### References for additional informations.

- Longman chemistry for IGCSE.
- Chemistry, Addison, Wesley. Fifth Edition.

## Review Questions

**1. Encircle the correct answer**

(i) Which molecule contains a carbon-carbon double bond?

(a) Ethane (b) Ethene (c) Ethyne (d) Ethyl alcohol

(ii) Which product is obtained when chloromethane (or methyl chloride) is reduced?

(a) Ethane (b) Ethene (c) Methane (d) Ethyne

(iii) Which reacts explosively with methane?

(a) $F_2$ (b) $Cl_2$ (c) $Br_2$ (d) $I_2$

(iv) By dehydration we mean, the removal of

(a) Hydrogen (b) Water (c) Halogen (d) Hydrogen halide

(v) Ethene and ethyne can be differentiated by

(a) Hydrogenation (b) Bromine water

(c) Strong alkaline aqueous solution of $KMnO_4$ (d) Hydrohalogenation

(vi) Which is used for dehydrohalogenation?

(a) $Br_2$ water (b) Conc. $H_2SO_4$ (c) $Al_2O_3$ (d) Alcoholic KOH

(vii) Which substance reacts with $KMnO_4$ to produced oxalic acid?

(a) Ethane (b) Ethene (c) Ethyne (d) Ethyl alcohol

(viii) The reduction of alkyl halides takes place in the presence of

(a) $Al_2O_3$ at 350°C (b) Conc. $H_2SO_4$ at 170°C

(c) Zn + Dust (d) Zn + HCl

(ix) Which process produces an alkane?

(a) Combustion (b) Hydration (c) Dehydration (d) Hydrogenation

(x) Does not react with aqueous solution of bromine

(a) $C_2H_6$ (b) $C_2H_4$ (c) $C_2H_2$ (d) $C_3H_6$

**2. Give short answers.**

(i) Give three examples of unsaturated hydrocarbons.

(ii) Draw electron dot and cross structure for ethene.

(iii) Draw structural formulas of an alkane, an alkene and an alkyne containing five carbon atoms.

(iv) How can you differentiate ethane from ethene?

(v) What do you mean by dehydration reaction? Give one example

3. **How can you convert**

(i) ethene into ethane (ii) methane into carbontetrachloride

(iii) ethene into glycol (iv) ethyl chloride into ethane

(v) ethyl bromide into ethene

4. **Write a chemical equation to show the preparation of an alkane from an alkene and an alkyne.**
5. **Write a chemical equation to show the preparation of ethene from dehydration of an alcohol and dehydrohalogenation of alkyl halides.**
6. **Write a chemical equation to show the preparation of ethyne from dehalogenation of 1,2 -dihalide and a tetrahalide.**
7. **Write chemical equations showing reaction of $KMnO_4$ with ethene and ethyne.**
8. **List some industrial uses of ethene and ethyne.**
9. **Explain why a systematic method of naming chemical compounds is necessary.**
10. **Draw electron dot and cross structure for**

(a) Propane (b) Propyne (c) Propene

## Think-Tank

11. **Write chemical equations for the preparation of propene from**

(a) $CH_3–CH_2–CH_2–OH$ (b) $CH_3–C \equiv CH$

12. **Write down structural formulas for the products which are formed when 1-butene is reacted with**

(a) $H_2$ /Ni (b) dilute alkaline aqueous $KMnO_4$ solution

(c) bromine water (d) chlorine

13. **Identify A, B, C, D in the following reactions.**

(i) $Propene \xrightarrow{Br_2} A \xrightarrow{alcoholKOH} B$

(ii) $Ethylalcohol \xrightarrow{Conc.H_2SO_4} C \xrightarrow{Br_2} D$

14. **Construct a scheme to convert ethene into ethyne?**
15. **You are given two flammable liquid hydrocarbons. One of them is an alkene and the other is an alkane. Design an experiment to find out which is which.**
16. **How many possible products are there when chlorine reacts with ethane? Sketch them all.**
17. **Differentiate between ethene and ethyne.**

# 13

# BIOCHEMISTRY

**After completing this lesson, you will be able to:**

**This is 11 days lesson (period including homework)**

- 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 oils.
- Describe the importance of nucleic acids.
- Define and explain vitamins and their importance.
- Check the relative solubility in water of starch and sugar.
- Observe and explain the denaturing of proteins.
- Explain why agricultural and nutritional sciences are vital.
- Explain the use of natural products in the preparation of flavors, fragrances, resins and pharmaceuticals.
- List and describe the commercial uses of enzymes.
- Explain hydrogenation of vegetable oil.
- Explain the use of dextrose in drips.

## Reading

## INTRODUCTION

Life requires energy. Where this energy comes from? Can you use the energy of sun light directly to perform all life activities? Plants trap this energy and convert it into chemical energy.

How? They store this energy in substances such as carbohydrates, proteins and lipids. We need these compounds for existence. For proper nutrition, our diet should include balanced proportions of carbohydrates, proteins and lipids. We also need adequate amount of vitamins, minerals and fibre.

Some compounds found in every living cell, serve as the information and control centers of the cell. They have ability to reproduce, store and transmit genetic

information. What are these compounds? This chapter will enable you to recognize these important compounds.

# 13.1 CARBOHYDRATES

Carbohydrates are the most abundant class of organic compounds. Carbohydrates have the general formula $C_x(H_2O)_y$. This formula suggests that they are hydrates of carbon with few exceptions. Recall that plants synthesize carbohydrates through photosynthesis.

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

Plants convert glucose into starch and cellulose. Carbohydrates are monomers and polymers of aldehydes and ketones that have numerous hydroxyl groups attached.

**Society Technology and Science**

As the world population is increasing, the demand for food is also increasing. To grow more crops, new method and techniques are used.

Protein deficiency leads to physical and mental retardation. Excess lipids or fats may lead to heart diseases or a stroke, cancer, diabetes and other health problems. The nutritional chemists recommend that no more than 30 % of your daily caloric intake come from fat. Healthy crops, fruits and vegetables are necessary for our proper growth and health. So both agricultural and nutritional sciences are vital for us.

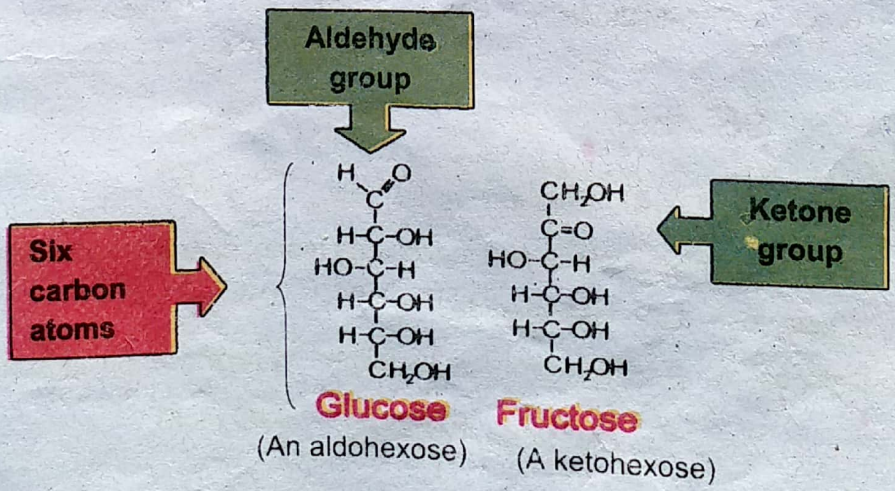
## 13.1.1 Classification of Carbohydrates

Carbohydrates are clarified as

i) Monosaccharide
ii) Oligosaccharides
iii) Polysaccharides

### Monosaccharides

Monosaccharides are the simplest carbohydrates. They cannot be hydrolyzed. They have general formula $(CH_2O)_n$ where n is 3 to 6 carbon atoms. So monosaccharides contain 3 to 6 carbon atoms. They are further classified as trioses, tetroses, pentoses, hexoses etc. This classification is based on the number of carbon atoms they contain. The two most familiar



monosaccharides are glucose and fructose. Both have molecular formula $C_6H_{12}O_6$. Is glucose a pentose? Glucose is a pentahydroxy aldehyde, whereas fructose is a pentahydroxy ketone. Their open chain structures are as follows. They are called simple sugars.

Some monosaccharide molecules can rotate the plane of plane polarized light to right (clockwise). They are called dextro-rotatory or dextrose sugars.

Glucose, manose, galactose are dextrose sugars. Monosaccharides are white crystalline solid. They are soluble in water and have sweet taste. They cannot be hydrolyzed. They are reducing in nature.

### Oligosaccharides

**Carbohydrates which upon hydrolysis form 2 to 9 molecules of monosaccharides or simple sugars are called oligosaccharides.**

Therefore, depending upon the number of monosaccharide units they produce on hydrolysis, they are further clarified as disaccharides, trisaccharides etc. Prefixes di, tri, tetra, penta etc. indicate the number of monosaccharide units, they produce on hydrolysis. They are white crystalline solids. They have sweet taste and are soluble in water.

**Society, technology and Science**

5%m/v aqueous solution of dextrose is used in drips. 5% m/v aqueous solution means 5 grams of dextrose dissolved in water to form 100 $cm^3$ of solution. It is intravenously given to patient who is severely dehydrated or is unable to eat or is not allowed to eat.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

Sucrose — Glucose — Fructose

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

Lactose — Glucose — Galactose

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

Maltose — Glucose — Glucose

### Self-Assessment Exercise 13.1

1. Classify sucrose, lactose and maltose as mono, di or tri-saccharides. Give reason.
2. Is galactose, a monosaccharide?
3. Raffinose, $C_{18}H_{32}O_{16}$ hydrolyses as follows. Is raffinose a disaccharide?

$$C_{18}H_{32}O_{16} + 2H_2O \longrightarrow 3C_6H_{12}O_6$$

### Polysaccharides

Carbohydrates which upon hydrolysis form 100 to 1000 units of simple sugars are called polysaccharides. Starch and cellulose are polysaccharides. They are amorphous solids. They are tasteless and insoluble in water. They are non-reducing in nature.

## 13.1.2 Sources and Uses of Carbohydrates

Carbohydrates are the most abundant class of carbon containing compounds. They have varied sources. (Figure 13.1)

- Monosaccharides such as glucose, fructose and galactose are obtained from furits, vegetables and cereals. They are also present in honey.
- Disaccharide such as sucrose is obtained in sugarcane, sugar beet and fruits. Maltose is found in cereals. Lactose is main sugar in milk and dairy products.
- Cellulose is obtained from plants e.g. Cotton is pure cellulose.
- Starch is present in cereals, wheat, barley, rice, maize, potato, sweet potato etc.

**Figure 13.1: Some sources of carbohydrates**

### Uses

- Carbohydrates store and transport energy in both plants and animals. 1g of glucose provides us 15.6 KJ of energy.
- They serve as food source for most organisms.
- Carbohydrates serve as structural material for plants. Cellulose in the human diet is referred as fibre. It is found in bran, whole meal bread, fruit and vegetables. We cannot digest it but it is very important for us. It helps the muscles of our intestines to move food efficiently through the digestive track. It absorbs and carries away toxic chemicals in food that would otherwise harm us. It also helps in lowering cholesterol and regulates blood pressure.
- Sucrose is used as common table sugar.
- Glucose is stored in animal muscles and liver cells in the form of glycogen. Glycogen serves as long term energy reservoir. It can be converted back to glucose when needed for energy. Plants store excess energy as starch.
- Starch is used to make rectified spirit by fermentation process.
- Starch is converted to dextrin which is used as an adhesive for stamps and as wallpaper glue.
- Cows, cattle, goats, deer, sheep and termites derive nutrition from cellulose.

- We use cellulose in the form of wood for heat, housing and furniture.
- Wood is also used to make paper and wood pulp.
- Cellulose fibre of cotton is used to make rayon and cellulose acetate, which are used in textile industry for making cloth.

## Self-Assessment Exercise 13.2

1. List a) Three examples of monosaccharides. fructose glucose, manose, galactose, dextrose
   b) Three examples of disaccharides sucrose, lactose, maltose
   c) One example of trisaccharide raffinose
   d) Two examples of polysaccharides cellulose, starch
2. List sources of
   a) Sucrose sugar cane, sugar beet, fruits
   b) Maltose cereals
   c) Lactose milk & dairy products

## Activity 13.1

**To check the relative solubility in water of starch and sugar.**

**Carry out the following**

- Mix a tea spoon full of starch in a beaker, half filled with water. Stir well. What happens?
- Mix a tea spoon full of sugar in another beaker, half filled with water. Stir well. What happens?

Which is soluble in water, starch or sugar?

# 13.2 PROTEINS

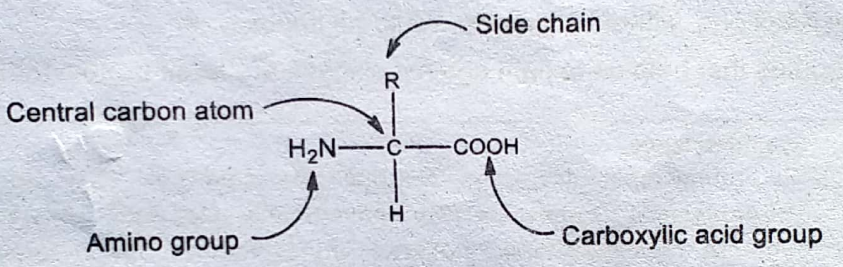
Animals require protein as one of the three major classes of food. What are two other major classes of food? The human body contains tens of thousands of different proteins. Proteins have many functions in the human body.

- They transport and store oxygen and nutrients.
- They act as catalysts for the thousands of reactions that make life possible.
- They regulate many important systems in our bodies.

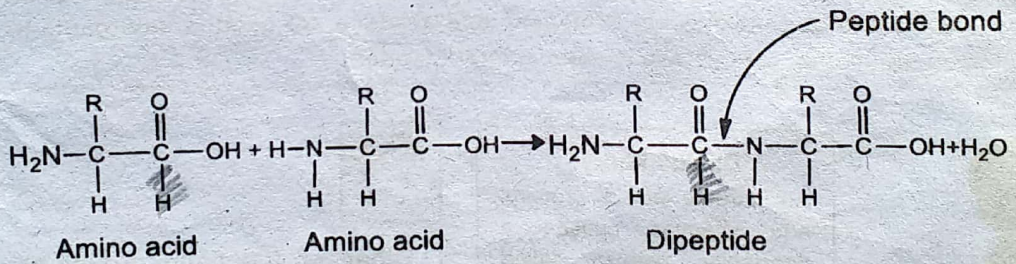
Proteins are high molecular weight polymers. The building blocks of all proteins are the amino acids therefore, all proteins produce amino acids on hydrolysis. **Proteins are complex nitrogenous substances that produce amino acids on complete hydrolysis.**

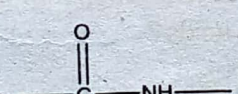
## 13.2.1 Amino Acids as Building Block

An amino acid has two functional groups. What are those? Amino acids are building blocks of protein synthesis. Twenty different amino acids are involved in protein synthesis. Out of twenty amino acids, our bodies can synthesize only ten amino acids. Such amino acids are called **non-essential amino acids.** The remaining ten are called **essential amino acids.** Essential amino acids must be present in our diet. Why?




Molecules of amino acids join together through amino ($-NH_2$) group of one molecule and carboxyl ($-COOH$) group of another molecule by eliminating a molecule of water.




The linkage  which joins two amino acid units is called a **peptide bond.** The resulting molecule is called a dipeptide. There is still an amino group on the left and a carboxyl group on the right. Each of these groups can react further to join more amino acid units. In this way thousands of amino acid units join to form a giant molecule of protein.

## 13.2.2 Sources and Uses of Proteins

Most proteins obtained from animal sources contain all the essential amino acids in adequate amounts. Meat, fish, eggs, milk and cheese are important sources of proteins. Plants also provide us proteins. For example, pulses, beans, meat, egg, fish etc. are rich in proteins. (Figure 13.2)

**Do you know?**
Most of the growth occurs in the first 2 years of life. The human brain reaches nearly full size by this age. Protein deficiency leads to both physical and mental retardation.

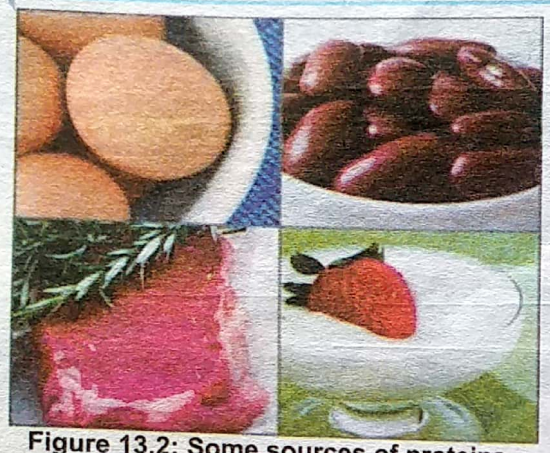


Figure 13.2: Some sources of proteins

- We require proteins in our diet, to provide amino acids to make muscles, hair, enzymes and repair of body tissues.
- Proteins are essential for the formation of protoplasm and components of cells.
- Proteins are essential for both physical and mental growth especially in children.
- A protein called gelatin is obtained by heating bones and tendons in water. It is used in bakery goods.
- Enzymes are proteins that catalyze specific biological reactions, without which life would be impossible.
- The antibodies that help us to fight against disease are large protein molecules.

**Society, Technology and Science**

Enzymes are large protein molecules. They are biological catalysts. They catalyze chemical reactions in living organisms. Enzymes are also commercially important. They are used in the production of sweeteners, chocolate syrup, bakery products, infant foods, detergents to remove food stains, in cheese making, in paper and pulp industries to remove sticky matter, to prepare fabrics for clothes, furniture and other household items. For example (a) enzymes like diastase, invertase and zymase are used in the fermentation of molasses and starch to produce ethanol. (b) Amylase is used in bread making. (c) Proteases and amylase are used in detergents to remove food stains on the cloths. (d) Lactase is used in infant foods.

**Do you know?**

An extreme lack of proteins and vitamins causes a deficiency disease called kwashiorkor. The symptoms include retarded growth, discolouration of skin and hair, bloating, a swollen belly and mental apathy.

## Self-Assessment Exercise 13.3

1. What two functional groups are found in amino acids?
2. Define
   (a) protein (b) Amino acids
3. Draw peptide linkage
4. Define

a) Essential amino acids b) Non-essential amino acids

## Activity 13.2

**To observe and explain the denaturing of proteins.**

## Reading

Carry out the following:

- Carefully break an egg and pour its contents in a bowl. Observe its contents.
- Boil another egg for few minutes, remove covering shell and cut it into two pieces and observe.

White viscous fluid or albumin present in an egg is protein. When egg is boiled, this protein solidifies or coagulates. This change of protein is called denaturing of protein. The denaturing may also occur due to change in pH.

# 13.3 LIPIDS

A lipid is any component of plant or animal tissue that is insoluble in water, but soluble in solvents of low polarity such as ether, hexane, benzene and carbon tetrachloride. Lipids include:

a) Fats and oils
b) Cholesterol
c) Sex hormones
d) Components of cell membrane called phospholipids
e) Some vitamins (A,D,E and K)

## 3.3.1 Fatty Acids

Fats and oils are referred as simple lipids. They are esters of fatty acids with a trihydroxy alcohol, glycerol. For this reason they are called glyceryl esters or glycerides. Fatty acids are long chain carboxylic acids. They are the building blocks of lipids. For example, stearic acid, $C_{17}H_{35}COOH$ is one such acid that occurs in animal fat. Some common fatty acids are given in table 13.1

Table 13.1 Some Common Fatty Acids in Natural fats

| No. of carbon atoms | Condensed structure | Name | Source |
|---|---|---|---|
| 4 | $CH_3 - CH_2 - CH_2 - COOH$ | Butyric acid | Butter |
| 6 | $CH_3 - (CH_2)_4 - COOH$ | Caproic acid | Butter |
| 16 | $CH_3 - (CH_2)_{14} - COOH$ | Palmitic acid | Plam oil |
| 18 | $CH_3 - (CH_2)_{16} - COOH$ | Stearic acid | Beef fat |
| 18 | $CH_3\text{-}(CH_2)_7\text{-}CH{=}CH\text{-}(CH_2)_7\text{-}COOH$ | Oleic acid | Olive oil |

Palm oil

Which of these fatty acids form oil?

**A lipid is called fat if it is solid at room temperature.**
**A lipid is called oil if it is liquid at room temperature.**

The differences in melting points are due to the degree of unsaturation of constituent fatty acids. Fats contain larger proportion of saturated fatty acid units. Oils contain larger proportion of unsaturated fatty acid units.

## Review Exercise 13.4

1. Define (a) Lipids (b) Fats (c) Oils
2. Consult table 13.1 and write
   i) the names two fatty acids that are components of fats.
   ii) the name of one fatty acid that is component of an oil.

**SCIENCE TITBITS**

All the cholesterol in human diet comes from animal products such as milk, meat, cheese and eggs. No vegetable product contains cholesterol.

## Reading

### 13.3.2 Sources and Uses of Lipids

**Figure 13.3: Some sources of lipids**

Animals, plants and marine organisms such as salmon and whales are rich source of lipids. Milk is an important source of animal fats from which butter, ghee, cheese etc. are obtained. Seeds of many plants such as sunflower, corn, cotton, ground nut, coconut, olive etc. are good source of vegetable oils. Cod liver oil is obtained from salmon and whales. Some sources of lipids are shown in figure 13.3.

**Fats and oils have several important functions in living organisms.**

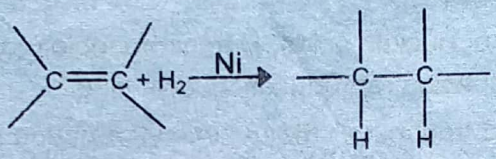
- Butter, ghee and vegetable oils are used for cooking and frying of food, preparing bakery products and sweets.
- In mammals a layer of fat is present under the skin. This layer acts as a thermal insulator.
- Fats protect delicate organs from shocks. A layer of fat around our heart and kidneys protect these organs from injury.
- Lipids provide some vitamins such as A, D and E which are essential for health. These vitamins are insoluble in water and soluble in lipids.

- Fats and oils are important food stores in living organisms. They provide about twice, as much energy per gram as do carbohydrates.
- Vegetable oils are converted into vegetable ghee or margarine by catalytic hydrogenation.
- Fats and oils are also used for the manufacture of materials like soaps and detergents, cosmetic, polishes, paints and varnishes.
- In our bodies cholesterol is essential for the synthesis of several hormones, vitamin D and bile acids.

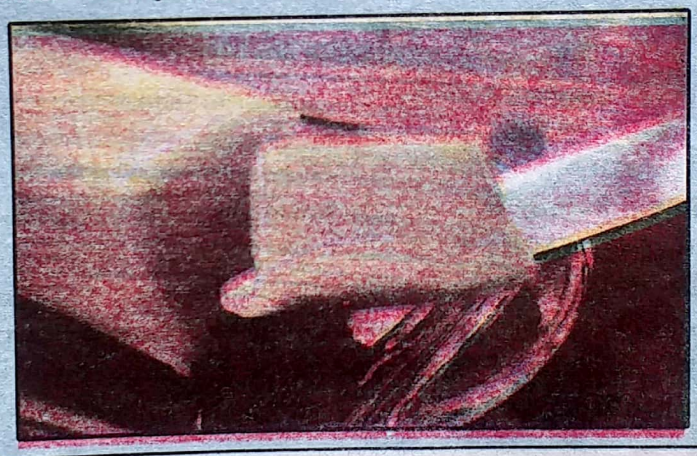
**Society, Technology and Science**

Addition of hydrogen to an alkene is called hydrogenation. This reaction takes place in the presence of Ni, Pd or Pt as catalyst.

Q13




This reaction is used to make margarine or vegetable ghee. Fatty acid component of vegetable oil contains carbon-carbon double bonds. When hydrogen is added to these oils, they become saturated and harder.



**Do you know?**

Insulin is a protein coded by DNA. It is required for the proper use of glucose by cells. People with diabetes formerly had to use insulin from cattle. Now human insulin is made using recombinant DNA technology. Scientists take the human gene for insulin production and paste it into the DNA of E coli, a bacterium commonly found in the human digestive track. The bacterial cell multiply rapidly, making billions of copies of themselves and each new E. Coli cell carries in its DNA, a gene for human insulin.

**Important Information**

It has recently been shown that feeding hens, a diet containing a lot of flax seeds lowers the amount of cholesterol in eggs.

## 13.4 NUCLEIC ACIDS

More than 100 years ago, a Swiss biochemist discovered a class of nitrogen-containing compounds in the nuclei of cells. These nitrogen-containing compounds which were first obtained from the pus of infected wounds are called nucleic acids.

Nucleic acids are vital components of all life. They are found in every living cell. They serve as the information and control centers of the cell. They are long chain molecules made up of nucleotides. Each nucleotide consists of three components.

(i) Nitrogenous base.

(ii) A pentose sugar or five carbon sugar.

(iii) Phosphate group.

There are two kinds of nucleic acids, Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). How is it that each species reproduces its own kind?

DNA can store and transmit all the genetic information needed to build organisms. For instance, in human beings, the single fertilized egg cell carry the information for making legs, hands, head, liver, heart, kidneys etc. DNA is found primarily in the cell nucleus.

Structure of DNA was discovered by J. Watson and Francis Crick in 1953. They were awarded the 1962 Nobel Prize for their work. This discovery initiated the field of molecular biology. Cancer research involves an extensive study of nucleic acids.

### 13.4.1 Deoxyribonucleic Acid (DNA)

DNA exists in the form of two strands twisted around each other in a spiral formation called a double helix (Figure 13.4). Each chain or strand is made up of a deoxyribose sugar, phosphate unit and a nitrogen base. The strands are held together by hydrogen bonds. The order of the base pairs in a strand is a code that stores information which is used to produce proteins. The key to the ability of DNA to store genetic information and to pass it on from generation to generation is its double stranded structure.

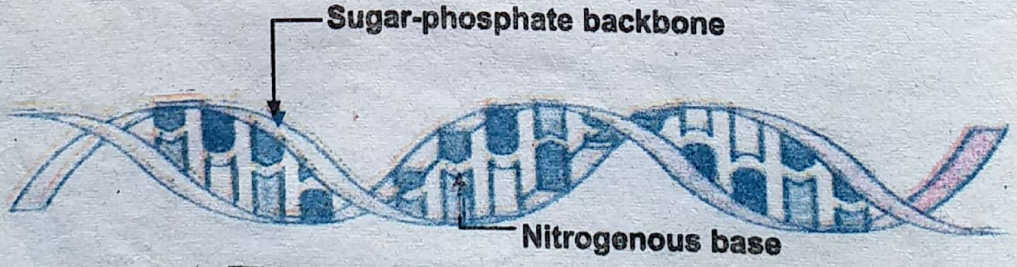



Figure 13.4 Structure of DNA

### 13.4.2 Ribonucleic Acid (RNA)

RNA exists in the form of single strand. It is made of a ribose sugar, phosphate unit and nitrogen base. RNA is synthesized by DNA to transmit the genetic information. RNA is

responsible for directing synthesis of new proteins. RNA receives, reads, decodes and uses genetic information from DNA to synthesize new proteins.

**Science Titbits (Chemistry in action)**

The variation in DNA of individuals forms the basis of a method for identifying a person from samples of their hair, skin cells or body fluid. Because DNA sequences like fingerprints are unique for each individual, this method is called DNA fingerprinting. Only a tiny sample is needed. The pattern is compared with the DNA of a sample from a known individual. If the DNA fingerprints are identical, it can be stated with a high degree of chemistry that the DNA in the known sample is from individual.

## Review Exercise 13.5

1. How do DNA and RNA differ in structure?
2. Name the two kinds of nucleic acid?
3. Write differences between DNA and RNA.
4. What is the sugar unit in DNA?
5. What sugar is found in RNA?
6. Which nucleic acid is involved in protein synthesis?

i) Nitrogenous Base
ii) Phosphate Unit
iii) A pentose sugar
iv) Ribose sugar
v) Deoxyribose sugar

## 13.5 VITAMINS

In 1897 the Dutch scientist C. Eijkman discovered that polished rice lacked something found in the hull. Lack of something caused the disease beriberi. A British scientist F.G Hopkins experimentally proved that in addition to carbohydrates, fats, proteins, and minerals, certain missing factors were also needed to sustain healthy growth. In 1912 Casmir Funk, Polish biochemist used the word 'vitamine' (from Latin word vita meaning life) for these missing factors. He thought all these factors contained the amino group. However, the final 'e' was dropped after it was found that all these factors were not amines. So the generic name of these compounds became Vitamin. Vitamins are accessory growth factors.

(a) (b)

Figure 13.5 (a) Vitamin D deficiency causes softening of bones (b) vitamin $B_3$ deficiency causes inflammation and abnormal pigmentation.

**Vitamins are specific organic compounds which are required by our bodies to prevent specific diseases but cannot be produced by our bodies.** They must be present in our diet in addition to proteins, fats, carbohydrates and minerals.

Vitamins are substances that are essential for our bodies. Vitamin A is important in vision. It helps in the chemical transmission of images from the eye to the brain. It also keeps the cornea moist. Vitamin C is required for the formation of blood and boosting the immune system that protects against illnesses ranging from common cold to cancer.

Vitamin B helps to regulate nerve impulse transmissions, in the formation of haemoglobin and activates more than 100 different enzymes. Vitamin D regulates blood calcium. It is necessary for proper bone and tooth growth. (See figure 13.5)

## 13.5.1 Types of Vitamins

There are two types of vitamins

### (a) Fat soluble vitamins

**A vitamin that dissolves in fat is called fat soluble vitamin.** For example, vitamin A, D, E and K. Taking excess amount of fat soluble vitamins may be harmful. For instance large excess of vitamin A can cause irritability, dry skin and feeling of pressure inside the head. Too much vitamin D can cause pain in bones, hard deposits in joints and kidneys, and weight loss.

### (b) Water soluble vitamins

**A vitamin that dissolves in water is called water soluble vitamin.** For example, vitamins B (complex) and C. Our body has limited capacity to store these vitamins. If taken in excess, these are readily excreted from the body. Water soluble vitamins are not toxic even if taken in excess.

**Society, technology and Science**

A natural product is a compound or substance produced by living organism (plants, animals and microorganism). The term natural products for commercial purposes also refer to cosmetics, flavours, fliorgance, dietary supplements, foods, resins and pharmaceuticals.

Some natural products are added in the prepared food to enhance colour, flavor and fragrance. Many of such substances are extracted from fruits and other plant materials. For instance vanilla, banana oil, grape flavouring, almond flavouring, strawberry flavouring, pine apple flavouring etc., corn syrup is used in greatest amounts as resins in many food preparations.

A number of natural products are also added to the food to prevent deficiency diseases. Vitamin C is frequently added to fruit juices and flavoured drinks to prevent scurvy and elimination of rickets. Vitamin A is added to margarine to prevent night blindness.

Plants have always been a rich sources of pharmacologically active natural products e.g alkaloids, morphine, cocaine, digitalis, quinone, nicotine etc. Many of these are useful drugs in themselves and others are starting materials for synthetic drugs. Most of the compounds derived from microorganism are used in antibiotics e.g., penicillin, cephalosporin, tetracycline etc. Many natural compounds are used as drugs against diseases such as cancer, viral or bacterial infections, malaria etc.

## Self-Assessment Exercise 13.6

1. Define vitamins
2. Is vitamin C soluble in fat or in water?
3. Give examples of fat soluble vitamins.

Sources and uses of vitamins are given in table 13.2.

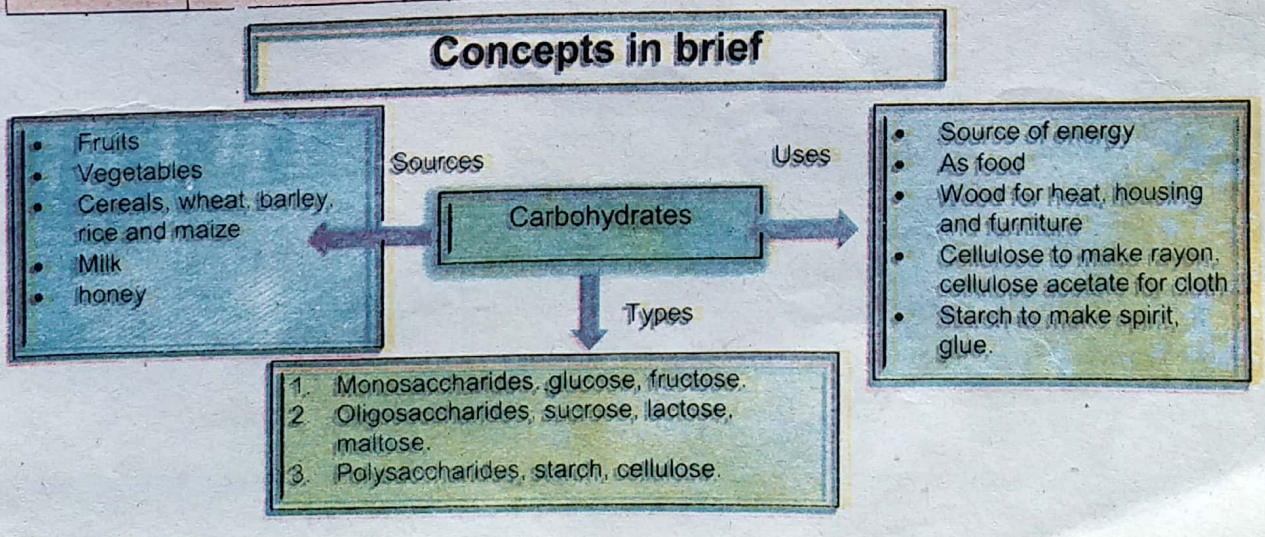
**Science Titbits**

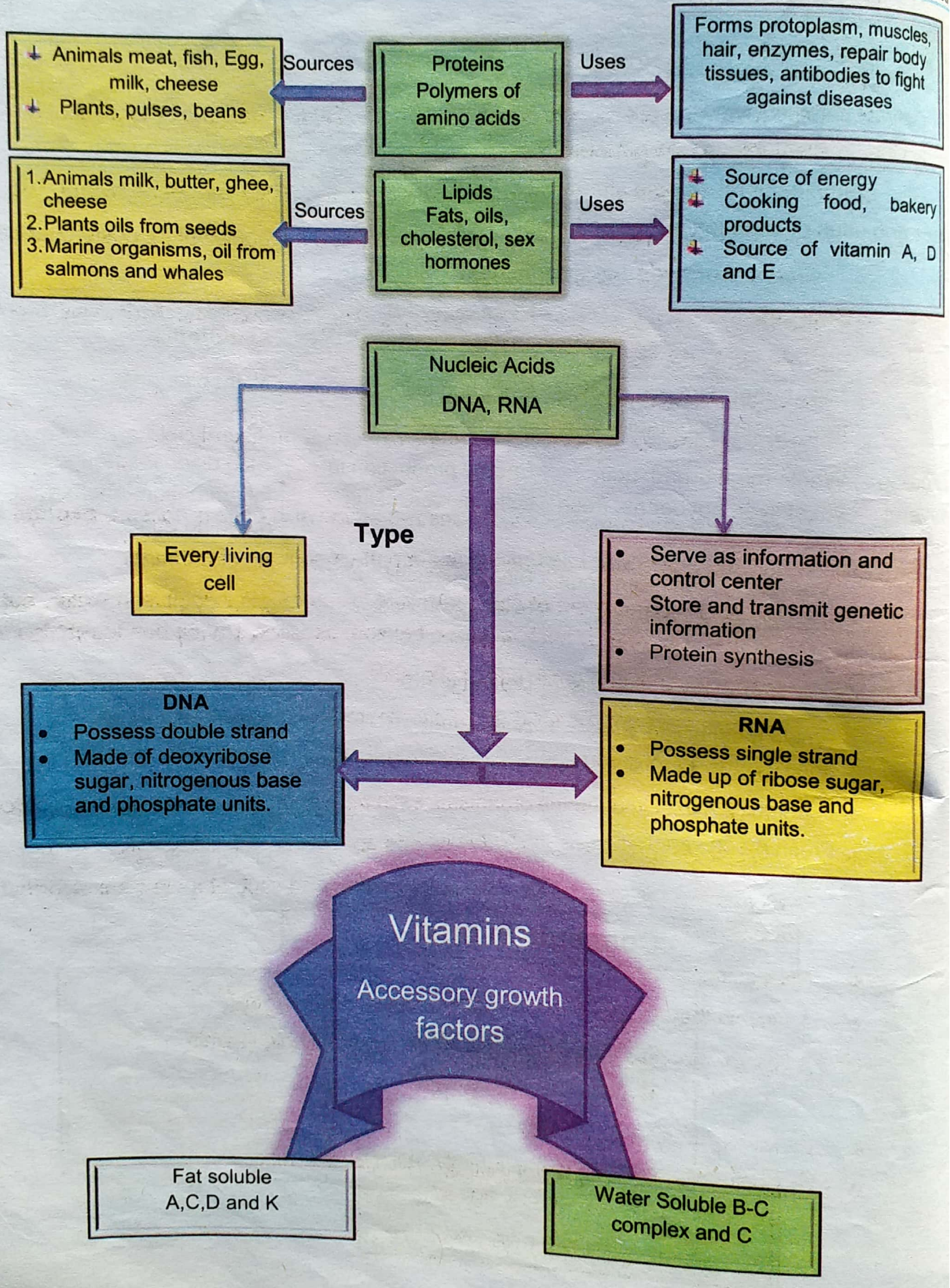
Some foods lose their vitamin contents when they are cooked in water and then drained. The water soluble vitamins go down the drain with water. For example rice, pulses, beans, gram, peas etc.

**Table 13.2Sources, uses of vitamins and diseases due to their deficiency** Part 2

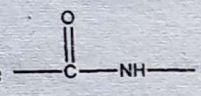
| Vitamin | Sources | Necessary for | Deficiency symptoms |
|---|---|---|---|
| A | Milk, butter, fish oils eggs, fresh green vegetable | Eyes and skin | Night blindness, dry skin |
| B (a group of several vitamins) | Whole meal bread, rice, yeast liver, soybeans, fresh green vegetables | Energy production in cells, nerves, skin | Skin diseases, tongue inflammation, anemia, bleeding gums |
| C | Oranges, lemons tomatoes fresh green vegetables. | Blood vessels, gums, healing wounds, preventing colds | Scurvy |
| D | Milk, butter, eggs, fish oils | Bones, teeth | Rickets, osteomalacia |
| E | Whole meal bread, rice eggs, butter, fresh green vegetables | Antioxidant | Haemolysis of red blood cells, sterility |
| K | Fresh green vegetables liver | Clotting blood | Haemorrhage delayed blood clotting |

## Concepts in brief




Animals meat, fish, Egg, milk, cheese
Plants, pulses, beans
Sources
Proteins
Polymers of amino acids
Uses
Forms protoplasm, muscles, hair, enzymes, repair body tissues, antibodies to fight against diseases
1. Animals milk, butter, ghee, cheese
2. Plants oils from seeds
3. Marine organisms, oil from salmons and whales
Sources
Lipids
Fats, oils, cholesterol, sex hormones
Uses
Source of energy
Cooking food, bakery products
Source of vitamin A, D and E
Nucleic Acids
DNA, RNA
Type
Every living cell
Serve as information and control center
Store and transmit genetic information
Protein synthesis
DNA
Possess double strand
Made of deoxyribose sugar, nitrogenous base and phosphate units.
RNA
Possess single strand
Made up of ribose sugar, nitrogenous base and phosphate units.
Vitamins
Accessory growth factors
Fat soluble
A,C,D and K
Water Soluble B-C complex and C

## Key Points

- Carbohydrates are monomers and polymers of aldehydes and ketones that have numerous hydroxyl groups attached.
- Monosaccharides are the simplest carbohydrates. They cannot be hydrolyzed.
- Carbohydrates which upon hydrolysis form 2 to 9 molecules of monosaccharides or simple sugars are called oligosaccharides.
- Starch and cellulose are polysaccharides. They on complete hydrolysis produce 100 to 1000 units of simple sugars.
- 1g of glucose provides us 15.6 KJ of energy.
- Proteins are substances that produce amino acids on hydrolysis.
- The linkage  which joins two amino acid units is called a **peptide bond.**
- Meat, fish, eggs, milk and cheese are important sources of proteins.
- A lipid is any component of plant or animal tissue that is insoluble in water, but soluble in solvents of low polarity such as ether, hexane, benzene and carbon tetrachloride.
- . Fatty acids are long chain carboxylic acids.
- A lipid is called fat if it is solid at room temperature.
- A lipid is called oil if it is liquid at room temperature.
- Animals, plants and marine organisms such as salmon and whales are rich source of lipids.
- Nucleic acids serve as the information and control centers of the cell.
- DNA exists in the form of two strands twisted around each other in a spiral formation called a double helix
- RNA exists in the form of single strand.
- A vitamin that dissolves in fat is called fat soluble vitamin.
- A vitamin that dissolves in water is called water soluble vitamin.

**References for additional informations.**


- Chemistry, Addison - Wesley.
- Chemistry for changing times John W. Hill, Doris K. Kolb.

## Review Questions

1. **Select the correct answer.**

i) Which compound found in every living cell, serves as the information and control center?

(a) amino acid (b) protein (c) lipid (d) DNA

ii) Plants convert glucose into

(a) starch (b) lipids (c) proteins (d) amino acids

iii) Glucose is a

(a) tetrose (b) pentose (c) disaccharide (d) hexose

iv) Which is not a dextrose sugar

(a) glucose (b) mannose (c) galactose (d) fructose

v) Raffinose, $C_{18}H_{32}O_{16}$ on hydrolysis forms ___ simple sugars.

(a) 1 (b) 2 (c) 3 (d) 3 to 9

vi) Which is not a source of starch?

(a) wheat (b) rice (c) cotton (d) potato

vii) Which is not a protein?

(a) gelatin (b) antibodies (c) enzymes (d) cholesterol

viii) Soaps and detergents are made from

(a) proteins (b) carbohydrates (c) fats and oils (d) all of these.

ix) Which is not present in DNA

(a) deoxyribose sugar (b) ribose sugar (c) phosphate unit (d) nitrogen base

x) Raffinose $C_{18}H_{32}O_{16}$ is a

(a) monosaccharide (b) disaccharide (c) oligosaccharide (d) polysaccharide

2. **Give short answers.**

i) Decide, whether sucrose is a disaccharide or monosaccharide. Give reason

i) What is a dextrose sugar?

ii) Write the formula of an amino acid and identify functional groups in it.

iv) What is a peptide bond?

v) Which compounds are included in lipids?

vi) What is the function of DNA?

3. Distinguish between mono, di-, and tri-saccharides. Give examples.
4. Describe bonding in a protein molecule.
5. Explain sources and uses of lipids.
6. Give sources and uses of proteins.
7. Give sources and uses of carbohydrates.
8. Differentiate between fats and oils.
9. Define and explain vitamins.
10. Why are vitamins important for us?
11. Describe the importance of nucleic acids.
12. Explain why agricultural and nutritional sciences are vital.
13. Explain hydrogenation of vegetable oil.
14. List commercial uses of enzymes.
15. Explain the use of dextrose in drips.
16. Separate water soluble vitamins from the following.

**Vitamin A, Vitamin C, Vitamin E, Vitamin B**

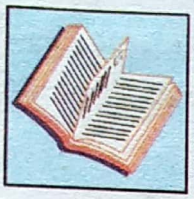
## Think-Tank

17. Compare components in both proteins and carbohydrates?
18. What is the name of the bond that forms between two amino acids in building a protein?
19. How many molecules of water are needed to allow a disaccharide to form monosaccharides? Illustrate with a chemical equation.
20. Draw the structure of each of the following molecules.

    a) An amino acid having $-CH_3$ as R group.

    b) A protein containing two amino acids.

21. Distinguish between DNA and RNA?
22. Hydrogenation is an important reaction in food industry. Interpret this statement.



# 14

# ENVIRONMENTAL CHEMISTRY I: ATMOSPHERE

**After completing this lesson, you will be able to:**

This is 12 days lesson
**(period including homework)**

- 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.
- Perform filtration experiments in the lab on different water samples having suspended impurities.
- Explain how incineration of waste material contributes to the problem of air pollution.
- Debate whether the government should do more to control the pollution resulting from auto exhaust.

## Reading

## INTRODUCTION

Many times in a day you come across mixtures, for instance you start your day by drinking a cup of tea at breakfast, tea is a mixture, it is composed of water, milk, tea leaves and sugar, or if you take milk instead of tea, it also is a mixture of water, minerals, proteins, vitamins and fats. You also know that if some mud is added to a cup of tea, the tea does not remain fit for drinking. If you drink you will fell ill. Similarly from your previous knowledge of grade VI you know that air is a mixture of various gases i.e. nitrogen, oxygen, hydrogen, carbon dioxide, noble gases, and water vapour. This chapter will enable you to understand what is meant by atmosphere? You will also learn about the types and composition of different layers of atmosphere. How the atmosphere gets unhealthy or polluted? Which substances make the atmosphere unhealthy or polluted? What are the sources of common air pollutants and what are their harmful effects on living things and the environment? You will also learn why the span of summer season has extended and why the summer is getting hotter all over the world than it

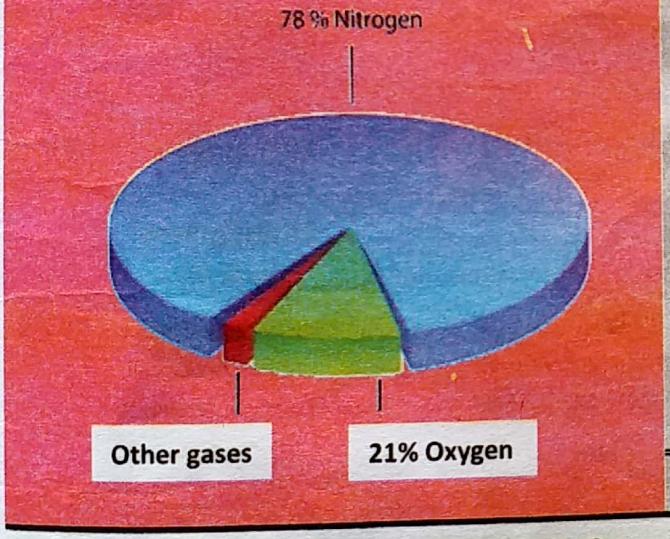
was about ten years before? You will also be able to know why the iron nails get rusty more quickly in rain water than in tap water or in mineral water. This knowledge will help you in grade XII to understand.

- Chemistry of Troposphere and Stratosphere
- Green house effect and global warming as resulting in climatic changes.

## 14.1 COMPOSITION OF ATMOSPHERE

Air is a mixture of gases. Can you name the main gases that make up the air? The pie chart given below shows the composition of dry air by volume. (Figure 14.1)

**Composition of Dry Air**




| Other gases | % by volume |
|---|---|
| Argon | 0.93 |
| Carbon dioxide | 0.038 |
| Neon | 0.0018 |
| Helium | 0.00052 |
| Methane | 0.00015 |
| Krypton | 0.00011 |
| Hydrogen | 0.00005 |

**Figure 14.1 Composition of dry air**

Besides gases, there are varying amount of water vapour in the air. There is little water in the air over the desert. Whereas in the tropical rain forest, the air may contain up to 4% water vapour. This means the amount of water vapour in air varies from place to place and time to time.

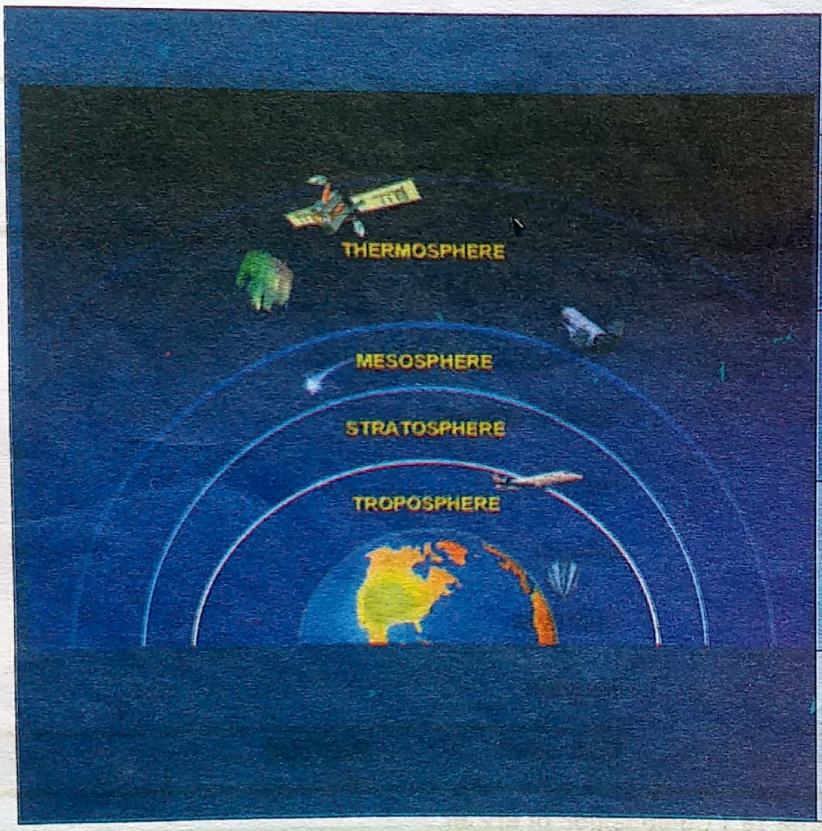
**The envelope of gases and water vapour surrounding the planet earth is called atmosphere.**

### Self-Assessment Exercise 14.1

1. What two gases make up most of the air?
2. Which gas has highest percentage in the air?
3. Which gas has lowest percentage in the air?
4. Why the percentage of water has not been mentioned in the pie chart?

# 14.2 LAYERS OF ATMOSPHERE

The atmosphere is divided into four layers, the troposphere, the stratosphere, the mesosphere and the thermosphere (Figure 14.2). The thermosphere is further divided into the ionosphere and the exosphere. Each atmospheric layer has its own temperature and precise chemical composition.




| Altitude of atmospheric layers |
|---|
| Thermosphere (Above 80 km) -93°C to 1800°C |
| Mesosphere (50-80 km) -5°C to -93°C |
| Stratosphere (12-50 km) -55°C to -5°C |
| Troposphere (0-12 km) 17°C to -55°C |

**Figure 14.2 Layers of Atmosphere**

## The Troposphere

Tropo- means "turning" or "changing". Conditions in troposphere are more variable than in the other layers. Troposphere extends to about 12km above Earth's surface. The atmospheric layer closest to the Earth's surface is called troposphere. What is the height of the troposphere? What is the minimum and maximum temperature of this layer?

Troposphere contains most of the mass (75-80%) of the atmosphere. It is the layer of atmosphere in which we live. Nearly all the dust particles and water vapour are in the troposphere. Weather occurs in this layer. Most of the clouds are formed in the troposphere. Aircrafts fly in this region. As altitude increases in the troposphere, the temperature decreases from 17°C to about -55°C. On average, for every 1 km increase in altitude, the air gets about 6.5°C cooler.

## The Stratosphere

The second layer as one moves upward from the Earth's surface is called stratosphere. The stratosphere extends from top of the troposphere to about 50km above Earth's surface. Strato- means "layer" or "spread out". What is the height of the stratosphere? What are the minimum and the maximum temperature of this layer?

The lower stratosphere is cold about -55°C, but the upper stratosphere is warmer than the lower stratosphere. This layer contains little water vapour. Interesting information about this layer is that it contains maximum amount of ozone (about 10ppm). The presence of ozone is responsible for the rise in temperature in stratosphere. Ozone saves us from harmful effects of incoming ultraviolet radiations from the sun. When ozone absorbs energy from the sun, the energy is converted into heat, warming the air. The ozone layer protects the living things on the Earth from dangerous ultraviolet radiation from the sun. In the stratosphere, temperature varies from -55°C to -5°C

Q2 (iii)

## The Mesosphere

The mesosphere extends from the top of stratosphere to about 80 km from the earth's surface. Meso- means "middle", so the mesosphere is the middle layer of the atmosphere. Above the stratosphere, a drop in temperature is observed. In the outer mesosphere, temperature approaches -93°C. This layer protects Earth's surface from being hit by most meteoroids.

## The Thermosphere

The outermost layer of atmosphere is the thermosphere. It extends from 80 km above Earth's surface outward into space. Thermo- means heat. This layer is very hot up to 1800°C. This is because sunlight strikes the thermosphere first. Oxygen and nitrogen molecules convert this energy into heat.

The thermosphere is divided into two layers. The lower layer called the ionosphere extends from 80 km to 400 km above the surface of Earth. The outer layer of thermosphere is the exosphere. It extends from 400 km to thousands of kilometer from Earth's surface.

**Do you know?**

**Aurora Borealis**

In the northern hemisphere, brilliant light displays, such as shown in the figure occur in the ionosphere.

These light displays are called aurora borealis. Auroras are caused by particles from the sun that enter the ionosphere near the poles. These particles strike atoms in the ionosphere, causing them to glow.

## Activity 14.1

**Shows how the temperature changes with altitude?**

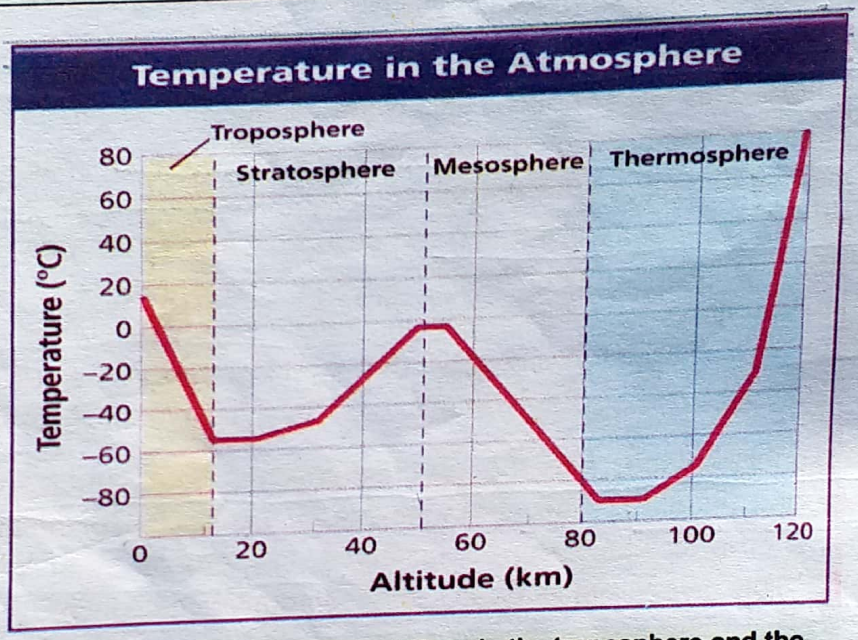



**Figure 14.3 Temperature variations in the troposphere and the stratosphere.**

**Complete the following table.**

| Layer of atmosphere | Temperature (°C) | |
|---|---|---|
| | At the bottom | At the highest point |
| Troposphere | | |
| Stratosphere | | |

## Self-Assessment Exercise 14.2

Describe how temperature changes as one moves from Earth's surface into the atmosphere up to 50 km?

# 14.3 AIR POLLUTANTS

Think of a situation when you are in a park or a vegetable farm and in second case you are near a kiln or a garbage dump. Where would you feel fresh?

Pollutants are things like industrial wastes, herbicides, pesticides, insecticides, particles of dust and smoke, carbon monoxide, nitrogen dioxide, sulphur dioxide, ozone and lead

containing paints. These things have a negative impact on the environment. Such substances effect environment as a result of human activity.

**Anything that is in the air, water or soil which has a harmful effect on some part of the environment is called pollutant.**

Pollutants damage the environment, health and quality of life. Important air pollutants are as follows:

### Sulphur Oxides (SOx)

You might have noticed that the colour of silk clothes fades away, if left in open air for a week or so. What due to it is? In the air sulphur dioxide is converted into sulphur trioxide, which is responsible for acid rain.

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

Sulphur dioxide is readily absorbed in the respiratory system. Being powerful irritant, it aggravates the symptoms of people who suffer form asthma, bronchitis, emphysema and other lung diseases.

### Self-Assessment Exercise 14.3

1. What are pollutants?
2. List some effects of sulphur dioxide on human beings.
3. List some of the air pollutants.

### Carbon Monoxide

When you burn a piece of wood or any other organic material, mainly two types of gases, carbon monoxide and carbon dioxide are produced. Carbon monoxide is a poisonous gas. It causes headache and dizziness, when inhaled for a long time it may cause death. It is soluble in water.

$$2C_{(s)} + O_{2(g)}\ (\text{limited}) \longrightarrow 2CO_{(g)}$$

$$C_{(s)} + O_{2(g)}\ (\text{Excess}) \longrightarrow CO_{2(g)}$$

Carbondioxide is not an air pollutant. Rather, plants consume $CO_2$ in photosynthesis and produce $O_2$. It is also not poisonous. However, it causes global warming (see section 14.3.1).

### Nitrogen Oxides (NOx)

The important oxides of nitrogen that cause air pollution are nitric oxide (NO) and nitrogen dioxide $(NO_2)$. Collectively they are represented as NOx. Nitric oxide is a colourless, odourless gas. It is heavier than air and sparingly soluble in water. Nitrogen dioxide is a reddish brown gas

with pungent odour. It dissolves readily in water. Both these oxides are highly toxic gases, damage lungs, cause headache, and cough.

### Methane

Methane is produced when dead plant material decays in the absence of air. It is released in the air from marshes, swamps and rice paddy- fields. As a result of photochemical reactions in the air, methane forms irritating and toxic compounds. Methane is excellent heat absorber and cause global warming. (See section 14.3.1)

### Chlorofluorocarbons (CFCs)

Chlorofluorocarbons are a group of chemically uncreative compounds that have been widely used as solvents. CFCs trap heat in the atmosphere and cause global warming. They have been attacking the ozone layer in the stratosphere very badly for the last three decades. CFCs may also cause skin allergy, damage to liver, kidneys and nervous system.

### Lead Compounds

Lead particles in the air come mainly due to the combustion of leaded petrol or fuel used in motor vehicles or from the lead based paints etc. Lead and its compounds in the air affect the brain development in human beings especially among children. At high level it can be fatal.

### Ozone

Ozone is a light blue gas and has an unpleasant odour. In the troposphere, ozone causes breathing difficulties, asthma and eye irritation.

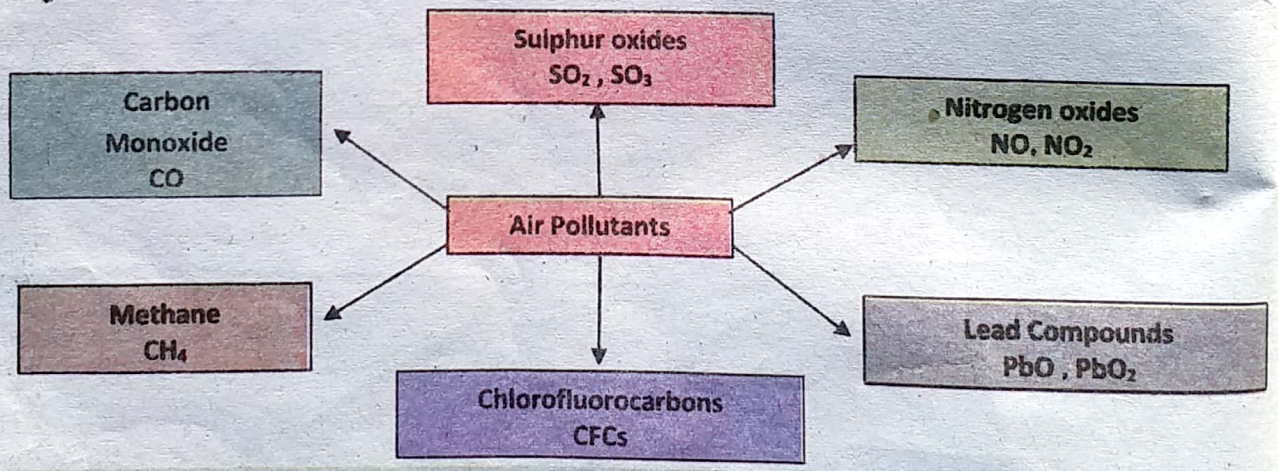



**Figure 14.4 Air pollutants**

## Self-Assessment Exercise 14.4

1. Write the names of main pollutants in the air.
2. Complete the following reactions.

   a) $SO_{2(g)} + O_{2(g)} \longrightarrow$

b) $C_{(s)} + O_{2(g)} \longrightarrow$

c) $CO_{(g)} + O_{2(g)} \longrightarrow$

## 14.3.1 Sources of Air Pollution

Air that contains harmful particles and gases is said to be polluted. Some air pollution occurs naturally. But many types of air pollution are the result of human activities.

### Natural Sources

Many natural processes such as forest fires and dust storms release smoke and dust particles into the air. Volcanos emit clouds of dust and poisonous gases along with ash. Which gas is emitted by volcanoes? Termites and cows also release large amount of methane in the air. Considerable electrical discharges in the atmosphere produce nitrogen oxides.

### Human Activities

Most of the air pollution is the result of burning fossil fuels, such as coal, petroleum and natural gas. Nearly half of the air pollution comes from cars and other motor vehicles. Factories and power plants that burn coal or oil release poisonous gases in the air. Burning fossil fuels and incineration release carbon monoxide (CO), nitrogen oxides (NO, $NO_2$) and sulphur oxides ($SO_2$, $SO_3$).

$$C_{(s)} + O_{2(g)}\,(\text{limited}) \longrightarrow CO_{(g)}$$

$$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$$

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

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$$

Chlorofluorocarbons have been widely used as solvents for cleaning electronic circuit boards, as refrigerant in fridges and air-conditioning units and as propellants in aerosol sprays (air fresheners, hairsprays, deodorants, spray paints). Such products are not "Environment friendly". During manufacture, in use and after disposal, these compounds escape into the air. Lead particles in the air come mainly due to the combustion of leaded petrol or fuel used in motor vehicles or from lead based paints.

Ozone is produced when electrical discharges pass through oxygen in the air. You can feel its presence near photocopier, television set, microwave oven and other electrical equipment.

$$3O_{2(g)} \xrightarrow[\text{discharge}]{\text{Electrical}} 2O_{3(g)}$$

Table 14.1 shows effect produced by air pollutants.

## Self-Assessment Exercise 14.5

1. Write three human activities that are responsible for air pollution.
2. Write three natural processes that are contributing in air pollution.
3. List main sources of the following air pollutants.

   (a) $SO_2$ (b) CO (c) $NO_2$

### Table 14.1 Shows effect produced by air pollutants

| Air pollutant | Physical properties | Sources | Harmful effects |
|---|---|---|---|
| Carbon monoxide | Colourless, odourless and poisonous gas | Incomplete burning of wood, fuels and vehicle exhaust. | Headache, brain damage, death. |
| Sulphur dioxide | Colourless gas with unpleasant and irritating odour | Power stations and industries using fossil fuels | Breathing difficulties, bronchitis, emphysema, lung cancer, acid rain and green house effect |
| Oxides of nitrogen | NO is colourless, odourless gas soluble in water. $NO_2$ is reddish brown gas with pungent odour soluble in water. Both are highly toxic gases | Exhaust fumes of motor vehicles, power stations and industries using fossil fuels | Coughs, headaches lung diseases, acid rain and greenhouse effect (global warming) |
| CFCs chlorofluorocarbons | Colourless gases | Aerosol sprays foams, refrigerants, air-conditioning systems. | Green house effect (Global warming), thinning of ozone layer |
| Lead compounds | Poisonous solid particles | Exhaust fumes form motor vehicles | Brain damage, forest decline |

## Global Warming

The increasing use of fossil fuels and the deforestation have led to an increase in the levels of $CO_2$ in the air. Gases like water vapour, methane and CFCs also act in a similar way in the atmosphere. These gases are called greenhouse gases. Molecules of these gases absorb much of the infrared radiation given out by the surface of earth. (See figure 14.5). This increases

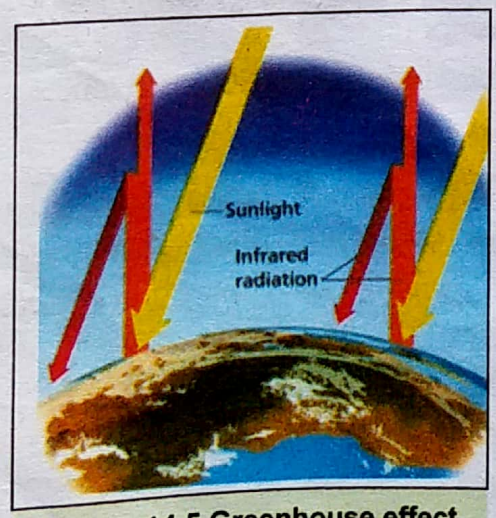



**Figure 14.5 Greenhouse effect**

**Do you know?**

Green-houses are constructed from glass or transparent polymer films. Sun light can pass through these materials and is used by the plants for photosynthesis. The plants radiate some energy in the form of infrared or heat radiations which cannot pass through these materials and is reflected back. As a result the atmosphere inside the green-house becomes hot enough to promote plant growth. The temperature inside a greenhouse can be 10°C to 15°C higher than outside.

their kinetic energy. So the atmosphere becomes hotter. The higher the concentration of greenhouse gases in the air, the greater is the greenhouse effect, and greater will be the increase in temperature. The green-house effect is a natural phenomenon of the energy distribution mechanism of the earth. However, certain human activity is threatening to cause a significant increase in the greenhouse effect. What are such activities?

**The warming of the atmosphere which is due to our influence on the greenhouse effect is known as global warming.**

Global warming is due to an upset in the natural balance of the concentration of greenhouse gases in the atmosphere. If global warming continues, then

- Temperature of the earth will gradually increase.
- The earth climate may change, affecting both where there is rainfall and how much there is of it. This could cause both increased risks of flooding in some regions and drought in others.
- Polar ice may melt and cause significant increase in sea levels.
- So the atmosphere becomes hotter.

### Self-Assessment Exercise 14.6

1. Define global warming
2. List some effects of global warming
3. List some substances that are responsible for global warming.

**Society, Technology and Science**

Incineration is a waste treatment process in which solid waste is burned at high temperature. Incineration consumes all combustible materials, leaving behind ash residue and non-combustible material. This process generally reduces the volume of waste by two third, but it is not a clean process. It produces air pollution. It generates considerable smoke and odour. This smoke may contain oxides of nitrogen and sulphur.

## 14.3.2 Acid Rain and Its Effects

Normal rain water is saturated with carbon dioxide. It has pH of 5.6 However, the acidity of rain greatly increases in polluted areas during thunderstorm. Sulphur dioxide from power plants using fossil fuels and nitrogen oxides from exhaust fumes of automobiles dissolve in rain water producing acids.

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

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

$$2NO_{2(g)} + 3O_{2(g)} + 2H_2O_{(l)} \longrightarrow 4\ HNO_{3(aq)}$$

Therefore, during thunderstorm, the pH of rain water can be much lower because of sulphuric acid and nitric acids formed by lightening. This rain may have pH as low as 2.1. This value is lower than the pH of vinegar or lemon juice.

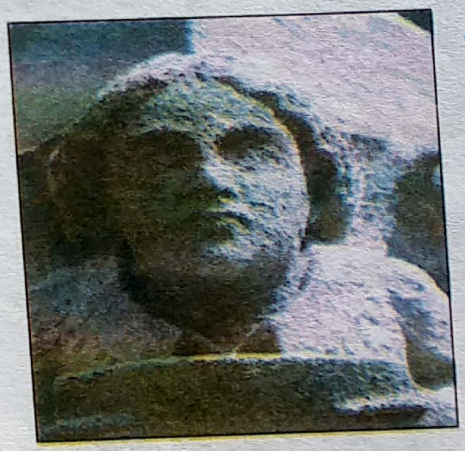


**Figure 14.6 Marble statues are slowly eroded by acid rain.**

**Acid rain is defined as rain having pH less than 5.6.**

Acid rain may often fall hundreds of kilometer away from their sources. Acid rain corrodes metals, stone buildings and statues (Figure 14.6)

Sulphuric acid eats away metals to form water soluble salts and hydrogen

$$Fe_{(s)} + H_2SO_{4(aq)} \longrightarrow FeSO_{4(aq)} + H_{2(g)}$$

Marble buildings and statues are disintegrated by acid rain

$$CaCO_{3(s)} + H_2SO_{4(aq)} \longrightarrow Ca\ SO_{4(aq)} + H_2O_{(g)} + CO_{2(g)}$$

$$CaCO_{3(s)} + 2HNO_{3(aq)} \longrightarrow Ca\ (NO_3)_{2(aq)} + H_2O_{(g)} + CO_{2(g)}$$

Acid rain also kills fish, and destroys trees. Lakes and river may become too acidic for living things to survive. (Figure 14.7 and 14.8)

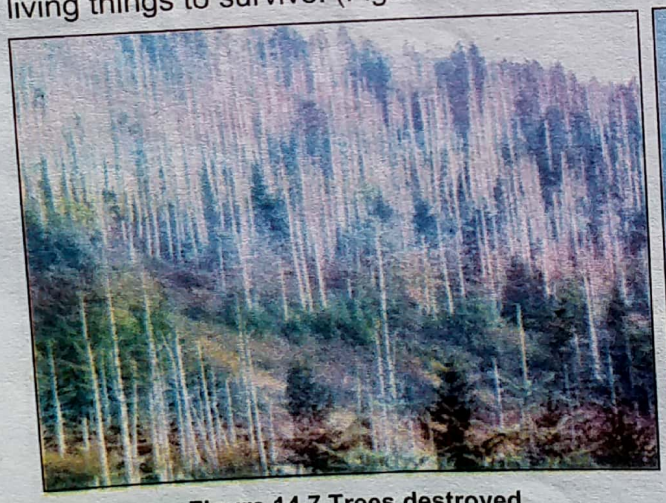


**Figure 14.7 Trees destroyed by acid rain**

**Figure 14.8 Fish are killed by acid rain**

## Self-Assessment Exercise 17.7

1. Define acid rain.
2. Write names of gases that cause acid rain.
3. What is the effect of acid rain on iron and marble? Give balanced chemical equation.

4. List some effects caused by acid rain.

### Society, Technology and Science

A catalytic converter transforms CO into $CO_2$, NO into $N_2$ and $O_2$, and unburned hydrocarbons to $CO_2$ and $H_2O$. Metals like platinum, palladium and rhodium are used as catalyst in the converter. Government of Pakistan should direct car manufacturers to install catalytic converters in car exhaust system. Government should make strict laws in this regards. This would help to reduce the emission of air pollutants from car exhaust system.

## 14.4 OZONE DEPLETION AND ITS EFFECTS

Ozone is an allotropic form of oxygen comprising there oxygen atoms, $O_3$' Ozone is an important gas in the stratosphere. (Figure 14.9 )

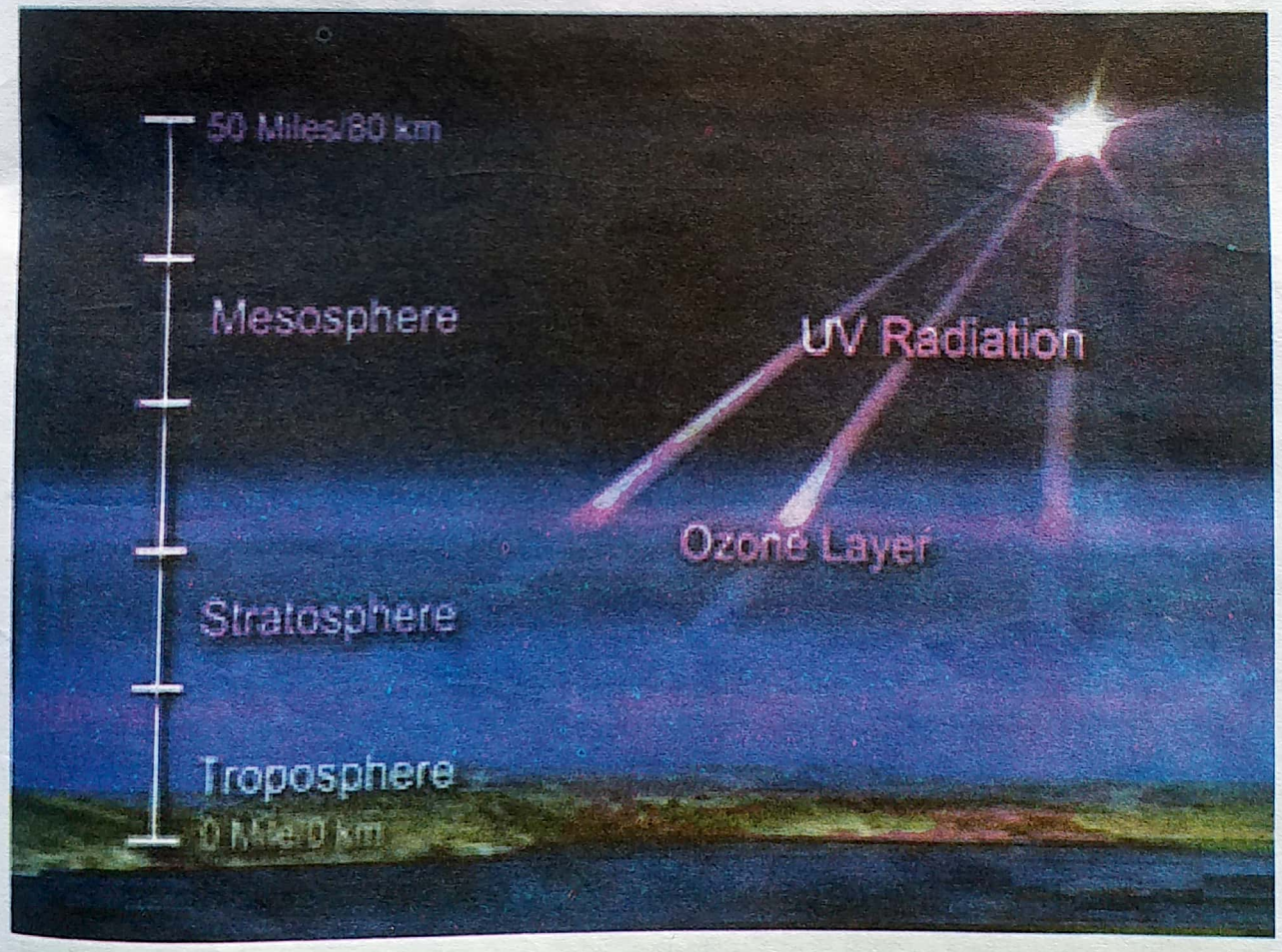



**Figure 14.9: Ozone Layer**

Most of the ultraviolet (UV) radiations coming from sun are **filtered** or **screened** out by the ozone layer. Otherwise, sunlight would be much more hazardous for human beings, animals and plants. On absorbing UV radiation, ozone molecule breaks up to form a oxygen molecule and atomic oxygen.

$$O_{3(g)} \xrightarrow{UV} O_{2(g)} + O_{(g)}$$

Atomic oxygen is very reactive. Atomic oxygen reacts readily with an oxygen molecule to form ozone, thereby releasing heat

$$O_{2(g)} + O_{(g)} \longrightarrow O_{3(g)} + \text{heat}$$

These reactions maintain level of ozone in the stratosphere. Both the destruction and the reformation of ozone are powered by UV radiation. In the absence of outside intervention, the rates of ozone destruction and formation are equal. However, human activities disturb this natural balance.

Human activity releases many compounds in the atmosphere. Such compounds threaten the stability of ozone layer. Over recent years, scientists have discovered a reduction in the amount of ozone in the stratosphere.

**The region in which the amount of ozone has been reduced is called as ozone hole.** Ozone hole was first observed in October, 1980 over Antarctica.

Chlorofluorocarbons (from aerosol cans, air conditioning systems, refrigerators etc) escape into the atmosphere. CFCs are gases or low boiling liquids. They are so inert that they do not react with any other chemicals in the troposphere. They slowly diffuse into the ozone layer. UV radiation break CFCs molecule producing chlorine free radicals.

$$CCl_3F_{(g)} \xrightarrow{UV} \dot{C}Cl_2F + Cl^{\cdot}$$

Chlorine free radical reacts with ozone to form chlorine monoxide (ClO) and molecular oxygen. ClO reacts with atomic oxygen produced by the decomposition of ozone by UV radiations.

$$Cl^{\cdot}_{(g)} + O_{3(g)} \longrightarrow Cl\dot{O}_{(g)} + O_{2(g)}$$

$$Cl\dot{O}_{(g)} + O_{(g)} \longrightarrow Cl^{\cdot}_{(g)} + O_{2(g)}$$

**Net reaction:** $$O_{3(g)} + O_{(g)} \longrightarrow 2O_{2(g)}$$

The chlorine free radical that reacts in step 1 is regenerated in step 2. One $Cl^{\cdot}$ can, therefore, destroy thousands of ozone molecules. Is chlorine free a radical or a catalyst in the destruction of ozone? Figure 14.10 shows depletion of ozone layer over the years.

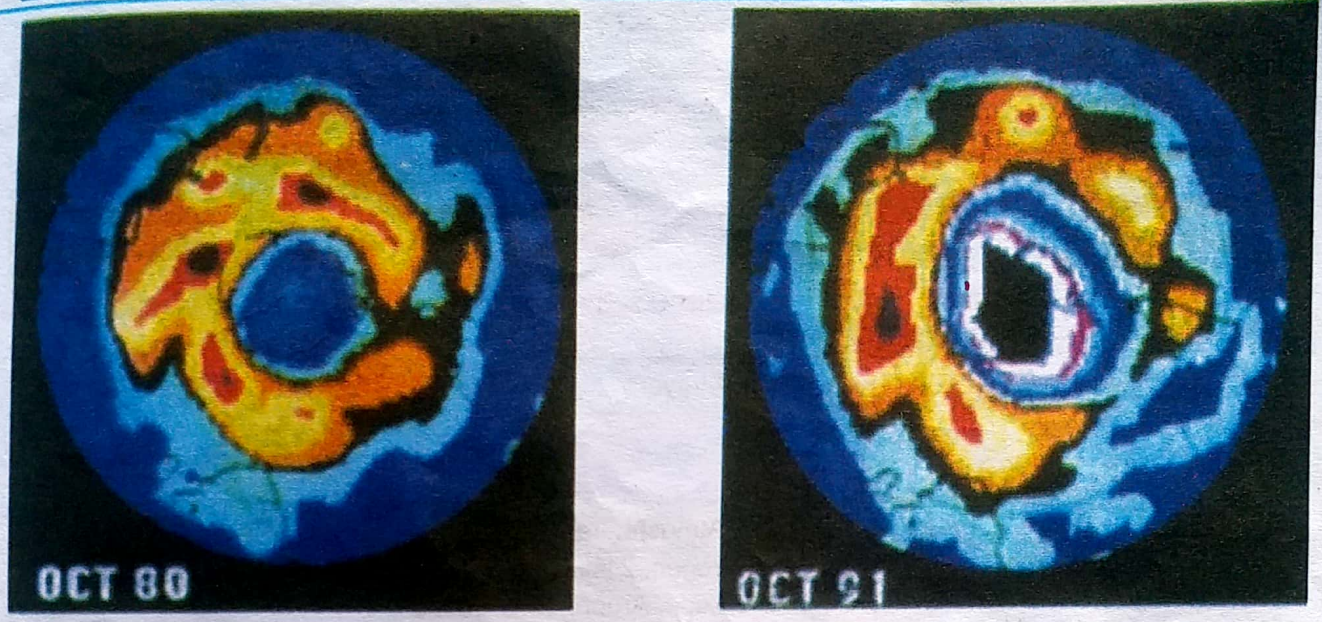



**Figure 14.10 Satellite images, the blue area of normal ozone level is getting progressively smaller as time goes**

## SKILLS

## Activity 14.2

**To separate suspended impurities from water samples.**

- Obtain sample of water from a lake, pond, stream or river.
- Pour this water onto the filter paper as shown in figure 14.11.
- What happens?

Recall that filtration is the process of separation of insoluble solid particles from a liquid.

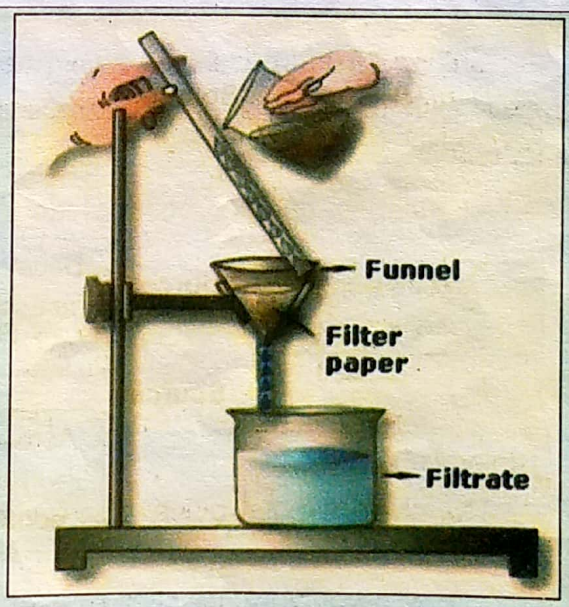
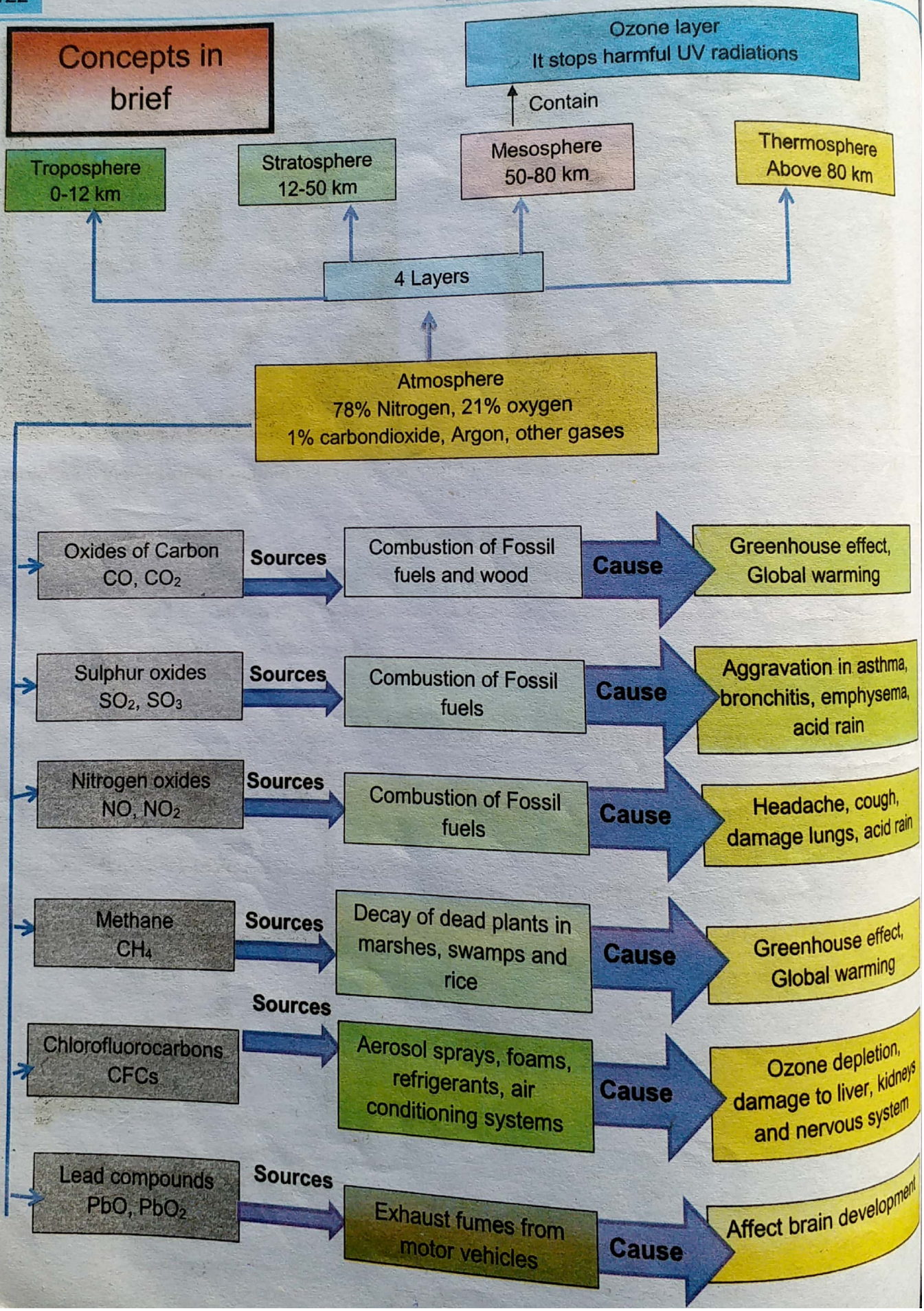



**Figure 14.11: Filtration of water**

# Concepts in brief



## Key Points

- The envelope of gases and water vapour surrounding the planet earth is called atmosphere.
- The atmosphere is divided into four layers, the troposphere, the stratosphere, the mesosphere and the thermosphere.
- The atmospheric layer closest to the Earth's surface is called troposphere. Earth's weather occurs in this layer.
- The stratosphere is the second layer of the atmosphere and contains the ozone layer.
- Each atmospheric layer has its own temperature and precise chemical composition.
- Anything that is in the air, water or soil which has a harmful effect on some part of the environment is called pollutant.
- Some air pollution occurs naturally. But many types of air pollution are the result of human activities.
- Methane is produced when dead plant material decays in the absence of air.
- Air that contains harmful particles and gases is said to be polluted.
- Ozone is produced when electrical discharges pass through oxygen in the air.
- The warming of the atmosphere which is due to our influence on the greenhouse effect is known as global warming.
- Acid rain is defined as rain having pH less than 5.6.
- Ozone is an allotropic form of oxygen comprising three oxygen atoms, $O_3$.
- Most of the ultraviolet (UV) radiations coming from sun are filtered or screened out by the ozone layer.
- The region in which the amount of ozone has been reduced is called as ozone hole.

**References for additional information**


- Chemistry in context.
- Chemistry, Kelter, Carr, Scott.
- Environmental Sciences, Cheris D.D. 1991.


## Review Questions

**1. Select the correct answer.**

i) Which gas has highest percentage in the air

(a) $O_2$ (b) $CO_2$ (c) $N_2$ (d) $O_3$

ii) Lowest temperature in stratosphere is
(a) -5°C (b) -55°C (c) 5°C (d) 55°C

iii) Which is/are responsible for acid rain?
(a) $SO_2$ (b) $NO_2$ (c) Both $NO_2$ and $SO_2$ (d) $O_3$

iv) Which is reddish brown gas?
(a) NO (b) $NO_2$ (c) $SO_2$ (d) $O_3$

v) Troposphere extends up to
(a) 50 km (b) 12 km (c) 18 km (d) 80 km

vi) Stratosphere extends up to
(a) 12 km (b) 15 km (c) 50 km (d) 80 km

vii) The ozone layer is found in
(a) The troposphere (b) The mesosphere
(c) The thermosphere (d) The stratosphere

viii) Most air pollution is caused by
(a) Ozone (b) Acid rain
(c) Carbon monoxide (d) The burning of fossil fuels

ix) Which layer is closest to the Earth?
(a) The stratosphere (b) The troposphere
(c) The mesosphere (d) The thermosphere

x) The outermost layer of earth atmosphere is
(a) The mesosphere (b) The stratosphere
(c) The troposphere (d) The thermosphere

**2. Give short answer**

i) List two main sources of acid rain.
ii) List four human activities which contribute to air pollution.
iii) What is the importance of stratospheric ozone?
iv) What is the role of automobile in air pollution?
v) Define atmosphere.

**3. Explain temperature variation in stratosphere and troposphere.**

**4. List components of stratosphere and troposphere.**

**5. Describe sources of air pollutants.**

**6. Describe acid rain and its effects.**

**7. Describe ozone depletion and its effects.**

8. Describe global warming.
9. Differentiate between stratosphere and troposphere
10. Explain ozone formation.
11. Why is global warming often referred to as the greenhouse effect?
12. There is scientific evidence that CFCs contribute to the depletion of ozone. Why?
13. Sulphur dioxide is a common pollutant from burning coal. State two effects caused by this pollutant.

## Think-Tank

14. Dibenzothiophene $(C_{12}H_8S)$ is a common sulphur containing compound of coal. It is responsible for acid rain. Elaborate this statement.
15. There have been various attempts to remove sulphur from coal before it is burned. Illustrate.
16. Examine the option there are some ways to reduce pollution caused by cars?
17. Certain human activities are responsible for a significant increase in greenhouse effect, argue.
18. As a global citizen, how can you play a part to reduce air pollution at a personal level? Argue.
19. Compare and contrast between stratosphere and troposphere.

## Project

Global warming has become one of the most serious environmental issues in the world in recent times. Prepare a report on this issue in terms of:

(a) The gases contributing to the problem and their sources.

(b) Which of these gases are causing the most concern?

(c) Suggest some ways to reduce this problem.

# 15

# ENVIRONMENTAL CHEMISTRY II: WATER

**After completing this lesson, you will be able to:**

**This is 12 days lesson (period including homework)**

- 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 hard water.
- Describe methods for eliminating 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 waterborne diseases.
- Test water quality by checking its color, odor, hardness and conductivity.
- Determine the boiling point of water.
- Perform distillation of impure water samples.
- Explain how hard water hampers the cleansing action of soap.
- Explain how and why water treatment is essential for water to be drinkable.
- Compare modern water treatment and sewage treatment centers and processes.
- Explain how chemistry helps maintain a clean swimming pool.

## Reading

Where does the water in your kitchen and bathroom come from? Because water comes from different sources, it varies in quality. Would you drink water that has colour, bad taste or unpleasant odour? In the morning when you get up, what do you do? You brush your teeth, take shower, flush the toilet etc. What happens to the water that goes down the drain? Can you use this water again? Waste water is often dumped into open gutters and allowed to run directly into streams, rivers and oceans. This practice spreads diseases and threatens aquatic life also. How? This you will learn in this chapter. The presence of disease causing bacteria affects the quality of water. Water from both public and private supplies often needs some kind of treatment

to ensure that it is clean and safe to drink. Waste water should also be passed through some treatment process to remove un-wanted substances, before it is released into lakes, rivers or oceans. Otherwise, it would also affect marine life and through food chain, the human beings. This knowledge will help you in grade XII to understand

- Water quality
- Waste water treatment.

# 15.1 PROPERTIES OF WATER

## 15.1.1 Occurrence:

Water is one of the most important substances on Earth. It is present in enormous quantity on Earth. It has been estimated that total amount of water present on earth is about 1.33 billion cubic kilometers which nearly covers 71% of the Earth's crust. Figure 15.1 shows the distribution of water on earth.

Although an enormous amount of water is found on the Earth, but the fresh water available to man is only 0.2% of the total. Even this small percentage of water is not evenly distributed. Some areas are rich in fresh water while certain areas have little or no fresh water.

Sea water contains large amount of dissolved salts. Sodium chloride is the most abundant salt in sea water. It is present up to 3.4% in it. This water is unfit for human use.

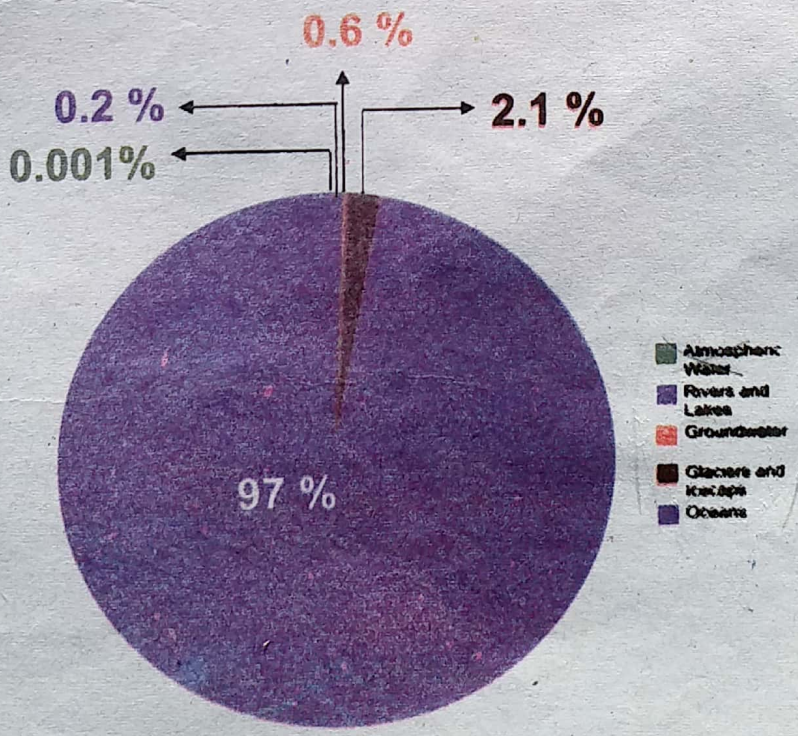



**Figure 15.1 Distribution of water on Earth**

## 15.1.2 Importance of water

Earth is the only planet in the solar system that contains water. All living things need water for their survival. You can live without food for 3 to 4 weeks, but cannot survive without water for more than 3 or 4 days. Our body cannot work without water just as car cannot run without gas or oil. In fact, all the cell and organ functions of our body depend on water. It serves as a lubricant in digestion and joints. The water in saliva helps facilitate chewing and swallowing. Water also regulates our body temperature, through perspiration.

- Water is crucial for sustaining the reactions that keep us alive. For instance digestion, distribution of food through blood, removal of waste matter from the body.
- It cools automobile engines, nuclear power plants, steel mills and parts of heavy machinery in industrial units.
- It provides means of transportation on the earth surface.
- Farmers need a large amount of water for their fields for growing fruits, vegetables and crops.
- We need water for drinking, cooking and cleaning.
- It is also used to generate electricity.

**Self-Assessment Exercise 15.1**

List household, industrial and agricultural uses of water

## 15.1.3 Properties of water:

- Water is the only substance that exists in three different states on Earth. Can you name these states?
- Pure water is transparent, colourless, odourless and tasteless. It boils at 100°Cand freezes at 0°C at the sea level.
- Density of most of the solids and liquids, generally increases on heating and decreases on cooling. Water, however, shows strange behavior in this regard. On cooling it contracts up to 4°C. A. this temperature its density becomes maximum. On further cooling water expands, hence its density decreases. So water expands when freezes. Because of this ice floats on the top of water. The consequences of this strange behavior are immense for life on earth. Ice forms on the surfaces of lakes only and insulates the lower layers of water. This enables fish and other aquatic organisms to survive in winter.
- Water has a high **heat capacity.** So much heat is required to raise the temperature of 1.0 g of water by 1°C.Conversely, much heat is given off by water for even a small drop in temperature. The vast amount of water on the surface of Earth thus acts as a giant heat

reservoir to moderate daily temperature variations. For this reason water is an excellent cooler in industries.

- Water has a high heat of **vaporization.** So a large amount of heat is required to evaporate small amount of water. This is of enormous importance for us. How? Large amount of body heat can be dissipated by the evaporation of small amount of water (perspiration) from the skin. This property also accounts for the climate-modifying property of lakes and oceans. Thus in summer it is cooler near a large water body of water (lakes, river, and seas) than in interior land areas.

### 15.1.4 Composition of Water

How can you split water?

Water is normally a poor conductor of electricity. However, when electricity is passed through acidified water in a voltameter, water decomposes (Figure 15.2). It gives hydrogen and oxygen. At which electrode hydrogen is produced?

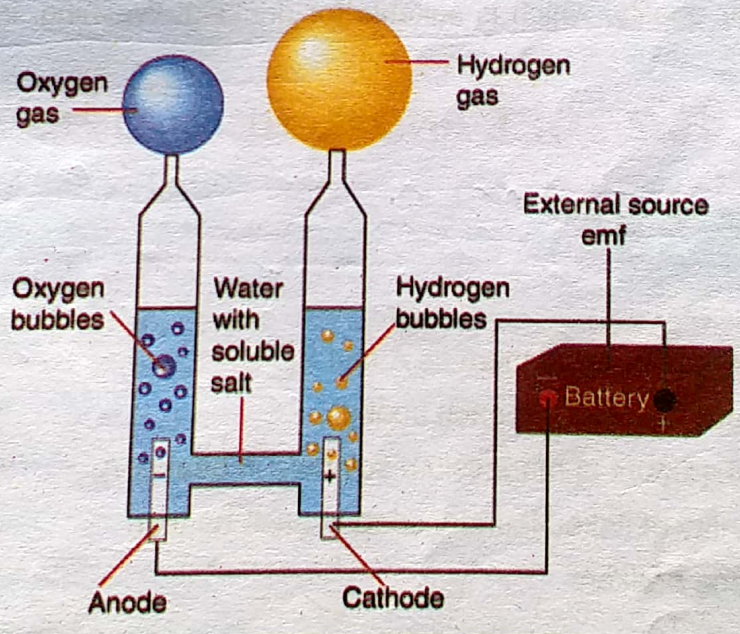



**Figure 15.2The electrolysis of water**

The process is called electrolysis and the reaction can be written as

$$2H_2O_{(l)} \longrightarrow 2H_{2(g)} + O_{2(g)}$$

The splitting of water molecules produces double amount of hydrogen as compared to oxygen. This means hydrogen and oxygen in water are in the ratio of **2:1** by volume.

## 15.2 WATER AS SOLVENT

Water is very good at dissolving substances. For this reason natural water such as rainwater and groundwater is not pure water. As water falls through the atmosphere, it dissolves, a little oxygen, nitrogen, carbon dioxide, and dust particles. During thunder storms, it also

dissolves nitric acid. Ground water dissolves minerals from rocks and soils as it moves along on or beneath Earth's surface. Ground water also dissolves many substances from decaying plants and animals.

The ability of water to dissolve a wide variety of substances is due to its two properties, the polarity of water molecules and the ability of water molecules to form hydrogen bonds. You have learned about these properties in grade IX. Water molecules are strongly attracted to ions and polar molecules with which water can form hydrogen bonds. If these attractions are strong enough, they overcome the attractions between the molecules or ions of the other substance and in this way the substance dissolves. Thus water soluble substances include a wide range of substances. They may be ionic solids, polar substances and hydrogen bonded compounds.

Water quality is defined by its physical, chemical, biological and aesthetic characteristics. A healthy environment is one in which the water quality supports community of organisms and protect public health. If water quality is not maintained, not only environment will suffer but the commercial and recreational value of our water resources will also diminish. Many of our own uses depend on water quality, which is suitable for drinking. Washing, irrigation, fishing and recreation.

## 15.3 SOFT AND HARD WATER

### Activity 15.1

- Take two beakers and label them as A and B.
- Place 50 $cm^3$ distilled water in each beaker.
- Dissolve small amount of magnesium sulphate in beaker A.
- Put small quantity of flaked laundry soap in each beaker.
- Stir well both the beakers.
- What happens?

**Water that easily gives lather with soap and does not form scum is called soft water.**

**Water that gives little lather or forms scum with soap is called hard water.**

Which water is soft, tap water or distilled water?

Have you ever noticed that the pan which is regularly used for boiling water gets white or yellowish deposits at its bottom and sides?

Rainwater dissolves carbon dioxide as it falls through the atmosphere. Carbon dioxide reacts with water to produce carbonic acid, which is a weak acid.

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

This carbonated water passes over or through the rocks containing calcium carbonate or magnesium carbonate, the acid present in it attacks these rocks. It slowly dissolves them, forming calcium and magnesium hydrogen carbonates.

$$CaCO_{3(s)} + H_2CO_{3(aq)} \longrightarrow Ca(HCO_3)_{2(aq)}$$

$$MgCO_{3(s)} + H_2CO_{3(aq)} \longrightarrow Mg(HCO_3)_{2(aq)}$$

Some rocks may contain gypsum ($CaSO_4.2H_2O$)or anhydride ($CaSO_4$) or Kieserite ($MgSO_4.H_2O$)which is sparingly soluble in water. The presence of these dissolved salts causes the water to become hard.

### Self-Assessment Exercise 15.2

1. List substances that cause hardness in water,
2. Differentiate between soft and hard water.

## 15.4 TYPES OF HARDNESS OF WATER.

### Activity 15.2

- Take two beakers and label them as A and B.
- Place 50 $cm^3$ of distilled water in beaker. A and 50 $cm^3$ tap water in beaker B.
- Mix small amount of calcium or magnesium sulphate in beaker A.
- Heat both the beaker on burner to boil water.
- Continue boiling for some time and cool.
- Add small amount of flaked laundry soap in each beaker.
- Stir well and observe.
- Which water produces good lather with soap?

Hardness in water can be divided into two types, **temporary** and **permanent.**

Temporary hardness is so called because it can be removed by boiling.

Permanent hardness is so called because it cannot be removed by boiling

Temporary hardness is caused by the presence of dissolved calcium or magnesium hydrogen carbonates. Whereas permanent hardness is caused by the presence of dissolved sulphates and chlorides of calcium or magnesium.

Hard water hampers cleansing action of soap. Hard water keeps soap from getting laundry and dishes really clean, causing to spend more on extra soap and cleaning products.

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It is difficult to make the soap lather in hard water. Instead, the water becomes cloudy. This cloudiness is due to the formation of a white precipitate by the reaction of $Ca^{+2}$ or $Mg^{+2}$ ions present in hard water and soap. This white precipitate is known as scum. Hard water leaves scum on the fabrics, which gives a grey or yellow appearance to white fabrics. So hard water hampers cleansing action of soap. Why?)

**Science Titbits**

To overcome the problem of scum formation in hard water, detergents have been produced. Detergents do not produce a scum. This is because they do not react with calcium or magnesium ions present in hard water. Also detergent molecules are biodegradable. Bacteria can easily break these molecules, So they do not persists in the environment.

## 15.5 METHODS OF REMOVING HARDNESS

### Activity 15.3

- Take some temporary hard water in a pan.
- Heat it to make water boil.
- Boil it for about 10 to 15 minutes.
- Cool it and test with soap, what happens?

### a) Methods to remove temporary hardness

#### i) By Boiling

Hardness of water can be removed simply by boiling. During boiling the soluble calcium and magnesium hydrogen carbonates are decomposed forming insoluble carbonates. Since $Ca^{+2}$ and $Mg^{+2}$ ions are removed as insoluble carbonates, water becomes soft.

$$M(HCO_3)_{2(aq)} \longrightarrow MCO_{3(s)} + CO_{2(g)} + H_2O_{(l)}$$

Where M = $Ca^{+2}$ or $Mg^{+2}$

Unfortunately, this method is too expensive to remove temporary hardness of water on the large scale.

## Self-Assessment Exercise 15.3

Write chemical equations to show the changes that occur when hard water containing calcium hydrogen carbonate and Calcium hydrogen carbonate is boiled.

## Activity 15.4

- Place some temporary hard water in a pan.
- Add small amount of slaked lime, $Ca(OH)_2$ in it.
- Mix it well and leave for some time.
- Transfer, supernatant liquid in another pan.
- Mix some soap in it.
- What happens?

**ii) By adding slaked lime (Clark's method)**

Temporary hardness in water on the large scale can be removed by adding an estimated amount of slaked lime in it. The slaked lime reacts with the hydrogen carbonates to form insoluble carbonates.

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

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

**b) Methods to remove permanent hardness**

**i) By adding washing soda.**

On the large scale permanent hardness in water can be removed by adding washing soda ($Na_2CO_3.10H_2O$). $Ca^{+2}$ and $Mg^{+2}$ ions are removed as their insoluble carbonates.

$$M^{+2}_{(aq)} + CO_3^{-2}{}_{(aq)} \longrightarrow MCO_{3(s)}$$

Where M = $Ca^{+2}$, $Mg^{+2}$

**ii) By Ion Exchange Resins**

The hard water is passed through a container filled with a suitable resin containing sodium ions. Zeolite is one of the natural ion exchanger. Chemically it is sodium aluminum silicate. It is usually written as $Na_2Z$. The $Ca^{+2}$ or $Mg^{+2}$ ions causing the hardness are exchanged with $Na^+$ ions in the resin.

$$M^{+2}_{(ag)} + Na_2Z_{(s)} \longrightarrow 2Na^+_{(ag)} + MZ_{(s)}$$

Where $M^{+2}$ = $Ca^{+2}$, $Mg^{+2}$

The used up zeolite can be regenerated by heating with concentrated solution of NaCl. This makes the process economical.

$$CaZ_{(s)} + 2NaCl_{(aq)} \longrightarrow Na_2Z_{(s)} + CaCl_{2(aq)}$$

## Self-Assessment Exercise 15.4

Complete the following reactions

i) $Ca(HCO_3)_{2(aq)} \xrightarrow{heat}$

ii) $Ca(HCO_3)_{2(aq)} + Ca(OH)_2 \longrightarrow$

iii) $Ca^{+2}_{(aq)} + Na_2Z \longrightarrow$

iv) $Mg^{+2}_{(aq)} + Na_2Z \longrightarrow$

v) $Mg^{+2}_{(aq)} + CO_3^{-2}{}_{(aq)} \longrightarrow$

vi) $Ca^{+2}_{(aq)} + CO_3^{-2}{}_{(aq)} \longrightarrow$

## 15.6 DISADVANTAGES OF WATER HARDNESS

- Hard water wastes a lot of soap, when used for washing.
- The soap forms scum with hard water, which adhere to the clothes being washed. Scum can spoil the finish of some fabrics.
- Cause kettles to fur.
- Can cause hot water pipes, boilers and car radiators to block due to the formation of insoluble calcium and magnesium salts, causing great damage.

## 15.7WATER POLLUTION

Water is very good at dissolving substances. This is due to the polarity of the water molecules and the ability of its molecules to form hydrogen bonds. As water from rain and snow flows over rocks and through soil, it dissolves minerals. The fresh water we drink or use for our daily life processes is a dilute solution containing a number of minerals. When these minerals are in sufficient concentration, water becomes unfit for human use. Many human activities also result in the contamination of the surface and ground water. Several forms of pollutants affect water bodies. The human activities such as house hold wastes, agricultural wastes, livestock wastes, pesticides, oil leaks, detergents, septic tanks, petroleum; natural gas production may result in contamination of water bodies. We will discuss about household wastes and industrial wastes in this unit. You will learn about other types of wastes in higher grades.

## Household Wastes

Household wastes include, human wastes, livestock wastes, soaps and detergents, paints and oil, food and vegetable wastes, garbage etc. Although detergents have strong cleansing action than soap, but they remain in water for a long time and make water unfit for aquatic life. When household water containing detergents is discharged in lakes, ponds, rivers etc. it causes death of aquatic life. Chemical and bacterial contents in household water can contaminate surface and underground water. Bacterial contents may cause infectious diseases such as cholera, jaundice, hepatitis, typhoid, dysentery etc.

## Industrial Wastes

Manufacturing of industrial products is always accompanied by some by-products and waste effluents. These waste products may be in the form of waste heat, smoke, solid or waste water effluents. These wastes may contain highly toxic compounds and heavy metals such as Pd, Cd, Cr, Hg, As, Sb etc. These toxic substances cause serious health problems, such as nervous disorder, anemia, high blood pressure, kidney diseases, nausea, dizziness and cancer.

Industrial units generally discharge their wastes either to open land or into water bodies, lakes, ponds, rivers or oceans. Water from leather tanneries contains large quantities of chromium (VI) salts. Chromium (VI) ions are highly toxic and known to cause cancer. Industrial wastes cause irreversible degeneration of the environment causing serious health problems for public and marine life.

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Water treatment is essential for many reasons.

- Through water purification, we can avoid drinking impure and containimated water, which causes many epidemic diseases and unsafe for healthy life.
- It removes bacteria, viruses and parasites which may cause diarrhoea, dysentery, botulism, typhoid, cholera, polio and hepatitis.
- It also removes heavy metals like, As, Ba, Cr and Pb which can cause long term neurological problems, kidney diseases, nausea, dizziness and cancer.
- It also improves the flavor and appearance.

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**Raw Water treatment**

The raw water is treated in a municipal water purification plant, to make it fit for drinking and domestic purposes (See figure 15.3). Various stages in this treatment are

1. **Sedimentation:** It is the process in which water is allowed to stand in a reservoir. The suspended matter sinks to the bottom.

2. **Coagulation:** It is the process in which water is treated with slaked lime and alum. These materials react to form a gelatinous mass of aluminum hydroxide

$$3Ca(OH)_{2(aq)} + Al_2(SO_4)_{3(aq)} \longrightarrow 2Al(OH)_{3(s)} + 3CaSO_{4(aq)}$$

The aluminum hydroxide carries down dirt particles and bacteria.

3. **Filtration:**

The water is then filtered through sand and gravel. Sometimes it is filtered through charcoal to remove coloured and odorous compounds.

4. **Chlorination:**

In the final step, chlorine is added to kill any remaining bacteria. Chlorine reacts with water to form hypochlorous acid HClO which kills bacteria.

$$Cl_{2(aq)} + H_2O_{(l)} \longrightarrow HClO_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)}$$

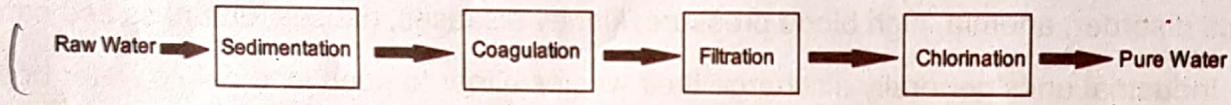


**Figure 15.3: Flow sheet diagram for water purification plant**

Long Question

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**Sewage Water Treatment** 2016 Paper

In many countries, sewage water is passed through certain treatment stages before it is discharged into a lake, stream, river or ocean. This treatment involves following steps.

1. **Primary sewage treatment** (See figure 15.4)

Primary treatment removes some of the solids as sludge. For this purpose waste water is allowed to stand in a large sedimentation tank to remove suspended particles.

2. **Secondary Sewage Treatment**

Effluent from the primary treatment is passed through sand and gravel filters. There is some aeration in this step, and aerobic bacteria convert most of the organic matter to stable inorganic materials.

3. **Activated Sludge Treatment**

The sewage is then placed in tanks and aerated with large blowers. This results in the formation of large, porous clumps, which absorbs contaminants. The aerobic bacteria further convert the organic material to sludge. This sludge is stored on land or sometimes used as fertilizer.

4. **Chlorination**

The effluent from sewage plant is treated with chlorine to kill any remaining pathogenic microorganisms.

## Self-Assessment Exercise 15.5

Compare modern water treatment and sewage treatment centers and processes.


**Figure 15.4** Flow sheet diagram for primary sewage treatment plan


**Figure 15.5 Flow sheet diagram for secondary sewage treatment plant**

## 15.8. WATERBORNE DISEASE

Human wastes are dumped on the ground or into the nearest stream. Human waste contains pathogenic microorganisms. These organisms are transmitted though food, water and direct contact. These microorganisms may cause typhoid fever, dysentery and hepatitis. Chemical and bacterial contents in livestock waste can pollute surface and ground water causing above mentioned diseases. Hepatitis a viral disease occasionally spread through drinking water.

**Do you know?**

Chlorination is not effective against viruses such as those that cause hepatitis.

Unclean water supplies, poor sanitation and poor hygiene kill 2,668,000 people worldwide each year.

Water in swimming pools is purified from pathogenic organisms by aeration and chlorination.

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Swimming is an important recreational activity. Biological contamination has also lessened the recreational value of water. However, aeration and chlorination treatment of swimming pool water has lessened the threat of biological contamination.

Some waterborne diseases are given below.

### Cholera

Cholera is an intestinal disease. It is caused by bacteria such as vibrio cholerae, E.coli etc. which may be present in water contaminated with human wastes. It is characterized by vomiting and purging.

### Dysentery

Dysentery is also an intestinal disease. It is caused by parasite, Entamoeba. This infection is transmitted by faecal contamination of water or food by encysted organism. Patients have mild

to severe abdominal cramps, diarrhea, chocolate coloured stool with mucous and sometimes with blood.

### Jaundice

This disease proceeds from obstruction of liver. Excess of bile from the liver enters in the blood and causes yellowness of skin and eyes. It leads to loss of appetite, weakness and fatigue.

### Hepatitis

Hepatitis is acute inflammation of liver. It is caused by viruses, and classified as Hepatitis A, B, C, D and E. Hepatitis A and E spreads through polluted water.

### Typhoid

Typhoid is a dangerous intestinal disease. It spreads by polluted water containing bacteria such as salmonella typhi, salmonella paratyphi, and salmonellaenteritidis. It is characterized by continuous fever between 101°F to 104°F and irregular pulse.

## Self-Assessment Exercise 15.6

1. List some water borne diseases.
2. List sources of water borne diseases.
3. List steps used in sewage water treatment.
4. List steps used in raw water treatment.
5. Write effects produced by industrial wastes.
6. Write names of six household wastes.

## SKILLS

## Activity 15.5

**To test water quality by checking its colour, odour, hardness and conductivity**

**Carry out the following:**

Obtain water samples from nearest water body and carry out the following.

- Note its colour and odour.
- Check hardness as described in activity 15.4.
- Determine boiling point of water.
- Check the electrical conductivity of water.

- Good quality water is colourless, odorless and tasteless. It produces good lather with soap. Pure water has least conductivity. Pure water boils at 100°C

**To purify impure water by distillation**

.Perform this activity in the laboratory.

**You will need:**

- A round bottom flask with side arm, thermometer, a glass condenser, a conical flask.
- Tripod stand, plastic tubes, stand, Bunsen burner.
- Sample of impure water.

**Carry out the following:**

1. Place water sample in the round bottom flask and place it on the tripod stand.
2. Fix thermometer on the mouth of the flask.

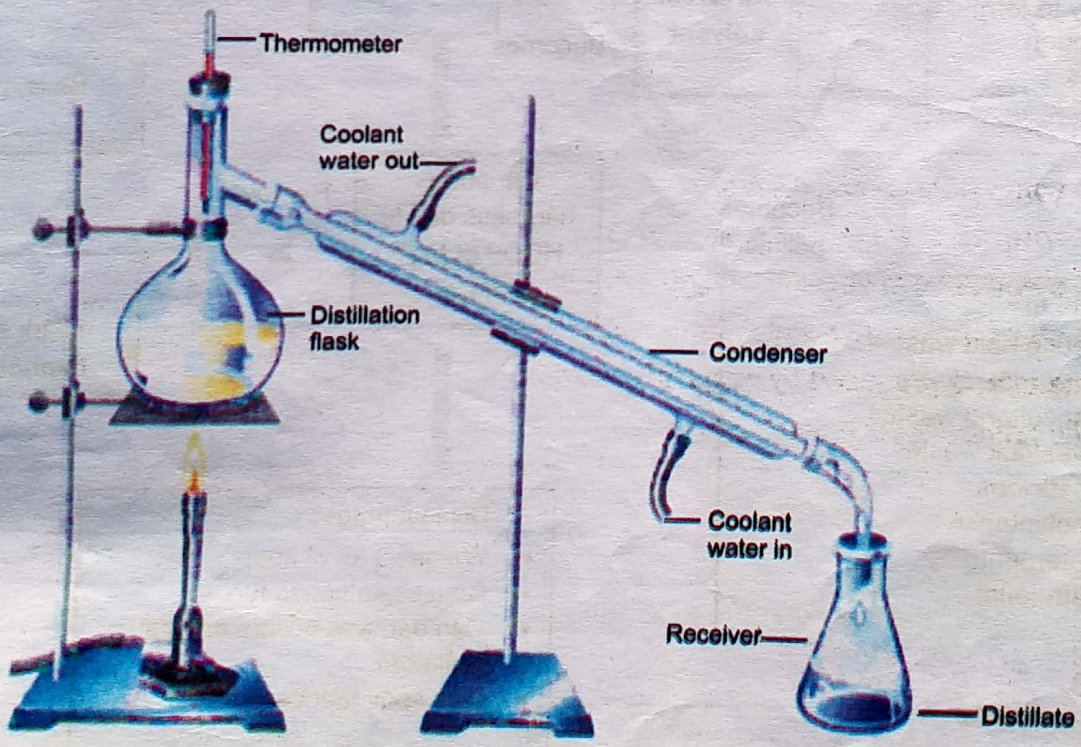
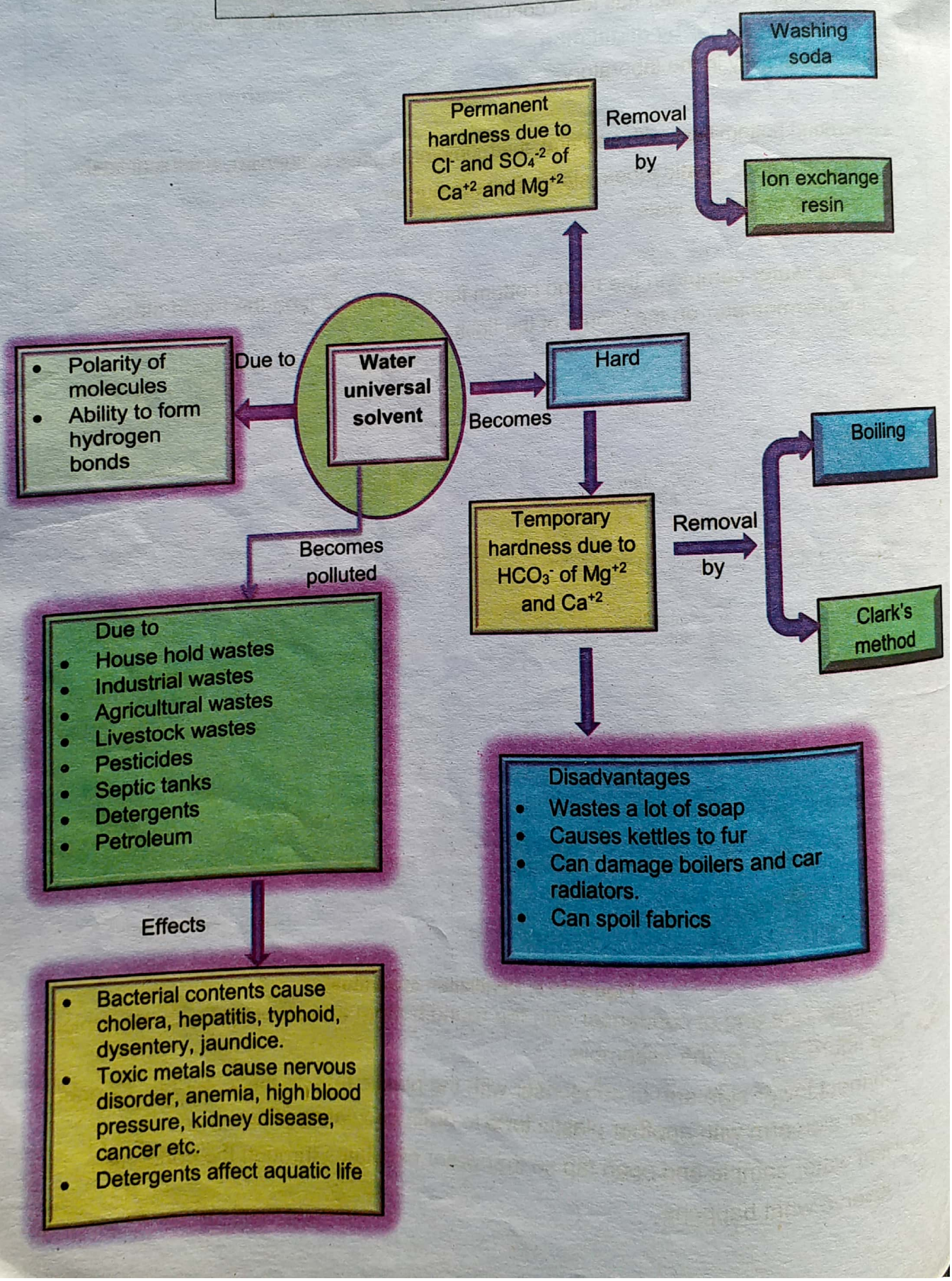



**Figure 15.6: Distillation apparatus**

Connect one end of condenser with the round bottom and other end with the conical flask. See figure 15.6 for the assembly.

3. Connect lower side arm of condenser with the plastic tube to the water tap. Connect upper side arm with another plastic tube to drain circulating water.
4. Heat water sample and open tap so that water circulates through the condenser.
5. Observe what happens.

## Concepts in brief



## Key Points

- An enormous amount of water is found on the Earth, but the fresh water available to man is only 0.2% of the total.
- Water that easily gives lather with soap and does not form scum is called soft water.
- Water that gives little lather or forms scum with soap is called hard water.
- Temporary hardness is the one which can be removed by boiling.
- Permanent hardness is the one which cannot be removed by boiling
- Hard water hampers cleaning action of soap.
- Hepatitis a viral disease occasionally spreads through drinking water.
- Unclean water supplies, poor sanitation and poor hygiene kill 2,668,000 people worldwide each year.

**References for additional informations.**


- Chemistry Kelter, Carr, Scott.
- Environmental Chemistry, Barid, Colin.
- Environmental Science, Richard Wright, R.T. W right.


## Review Questions

**Q.1. Select the correct answer.**

i) Percentage of sodium chloride in sea water is

a) 0.02 b) 3.4 c) 97 d) 2

ii) The density of water is maximum at

a) O°C b) 4°C c) 100°C d) -4°C

iii) Which salt does not cause the water to become hard?

a) calcium hydrogen carbonate

b) magnesium hydrogen carbonate

c) magnesium sulphate.

d) Sodium chloride.

iv) Which salt causes temporary hardness in water?

a) magnesium sulphate
b) calcium sulphate
c) both calcium sulphate and magnesium sulphate
d) magnesium hydrogen carbonate

v) Heating calcium hydrogen carbonate produces

a) $CO_2$ b) $H_2O$ c) $CaCO_3$ d) all of these

vi) Which of the followings is not a water born disease?

a) hepatitis b) typhoid c) dysentery d) anemia

vii) Which human activity results in contamination of water bodies?

a) livestock waste b) pesticides
c) septic tanks d) all of these

viii) Which is used to remove permanent hardness in water?

a) slaked lime b) washing soda
c) boiling water d) all of these

**2. Give short answers.**

i. List the impurities present in rain water
ii. List toxic substances present in household wastes.
iii. In what ways, industrial wastes pollute water.
iv. What is water pollution?
v. List some waterborne diseases
vi. What are pathogenic microorganisms?

**3. What is hard water? Why is it sometimes undesirable?**

**4. List two ways in which lakes and streams become polluted.**

**5. Give chemical equations for the**

a) reaction of slaked lime with alum.
b) carbonated rain water with lime stone.
c) reaction that occurs when temporary hard water is boiled.
d) $Ca^{+2}$ ions interact with sodiumzeolite.

**6. How can buildings made of limestone be affected by acid rain?**

**7. Make a list of main methods of softening hard water. In each case write a chemical equation to summarize the chemical reactions involved.**

**8. List some disadvantages of water hardness.**

9. What are the Earth's four main water sources? Pg#127
10. How does hard water differ from soft water?
11. What is the purpose of coagulation in water treatment?
12. Explain how hard water hampers the cleansing action of soap.
13. Why are municipal water supplies treated with aluminiumsulphate and slaked lime?
14. What are some health effects of biological contamination of water?
15. Write a word and balanced chemical equation to show the effect of heat on magnesium hydrogen carbonate in an aqueous solution.

## Think-Tank

16. Why is it cooler near a lake than inland during summer?
17. Evaluate the option, ion exchange resins can be used to remove temporary hardness.
18. Public health depends on water quality. Give arguments.
19. Hard water causes kettles to fur. This fur can be removed by using an acid. Justify.
20. The following chemical equation is about a calcium compound.

    Comp A + $Ca(OH)_2$ → Comp B + $H_2O$

    Comp B + $H_2CO_3$ → Comp C

    a) Name and give the formula of
       i. Compound A
       ii. Compound C

    b) Describe with the aid of a balanced chemical equation. What happens when compound C is heated?

    c) Compound C is soluble in water. Write a balanced chemical equation to show what happens when its aqueous solution is treated with washing soda?

21. How chemistry helps maintain a clean swimming pool? Explain.
22. It is advisable to wash hands well with soap after using bathrooms, evaluate it.
23. Differentiate between raw water treatment and sewage treatment process.
24. Evaluate the advantages of waste water treatments.
25. Water born diseases are no longer common in developed countries. Defend this statement.

# 16

# CHEMICAL INDUSTRIES

**After completing this lesson, you will be able to:**

**This is 11 days lesson (period including homework)**

- Describe some metallurgical operations.
- Make a list of raw materials for Solvay process.
- Outline the basic reactions in Solvay Process
- Develop a flow sheet chart for Solvay process.
- Describe the composition of Urea.
- Develop a flow sheet diagram for the manufacturing 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
- Relate the study of chemistry to careers in industry.
- Describe the link between chemistry, business and communication skills in order to promote chemical sales.
- Describe how different types of fire (wood, oil, electric) require different chemistry to put them out.
- Explain how technology impacts the production of common chemicals.
- Debate the use of synthetic fertilizers versus organic/natural fertilizers.

## Reading

In grade VI you learned about metals and how important the metals are in our life...? Most of our kitchen utensils, parts of sewing machine, washing machine, parts of our car, electrical cables etc. are made of metals. Think what will happen if the base of our iron is made of plastic instead of metal...? Your mother asks you to bring dhobi soda or washing soda when she plans for her scheduled washing... Do you know the chemical name of dhobi soda...? We put fertilizer in our fields, gardens and flower pots...? Think what will happen if we don't put fertilizer to these...? Have you ever thought of how we get diesel, petrol, etc., for running our vehicles? Where from we get natural gas (Sui gas) and kerosene oil for our kitchen stoves and our factories etc.? What is coal tar? Where from it comes? In this era of high technology all of us depend too much on plastic items...? Did you ever try to know what these things are? What is the source of these things? In this chapter you will learn about how metals are extracted from their ores? How sodium carbonate or dhobi soda and sodium bicarbonate or baking soda are manufactured. How urea is manufactured and what are its important uses? What is petroleum?

TABLE 16.1: Some important ores

| Metal | Name of ore | Formula |
|---|---|---|
| Iron | Haematite | $Fe_2O_3$ |
| Iron | Magnesite | $Fe_3O_4$ |
| Copper | Chalcopyrite | $CuFeS_2$ |
| Aluminum | Bauxite | $A_2O_3.xH_2O$ |
| Sodium | Halite | NaCl |
| Lead | Galena | PbS |
| Zinc | Zinc blende | ZnS |
| Mercury | Cinnabar | HgS |
| Chromium | Chromite | $FeO.Cr_2O_3$ |
| Tin | Cassiterite | $SnO_2$ |
| Silicon | Silica | $SiO_2$ |

## 16.1 BASIC METALLURGICAL OPERATIONS

Metals are very important for us. We use them for structural applications, cooking utensils, tools, electrical wires and many other things. However, being electropositive, almost all the metals in nature are found in the form of their compounds. **The naturally occurring metallic compounds are called minerals.** The debris, such as sand, rock and clay attached with the mineral is called gangue. Some important ores are given in table 16.1. **An ore is a solid deposit containing a sufficiently high percentage of a mineral to make extraction of metal economically feasible.** To recover and use these metals, we separate them from ores and reduce the metal ion. **The process of separating a metal from its ore and preparing it for use is known as metallurgy**

The main steps in metallurgy are:

1. Crushing, grinding or pulverizing of the ore
2. Concentration of the ore
3. Extraction of metal
4. Refining of metal.

### 16.1.1 Concentration

After mining ore though crushing, grinding or pulverizing steps is converted into the powder. Then mineral is separated from gangue by some physical method. This process is called concentration. Some of these methods are as follows.

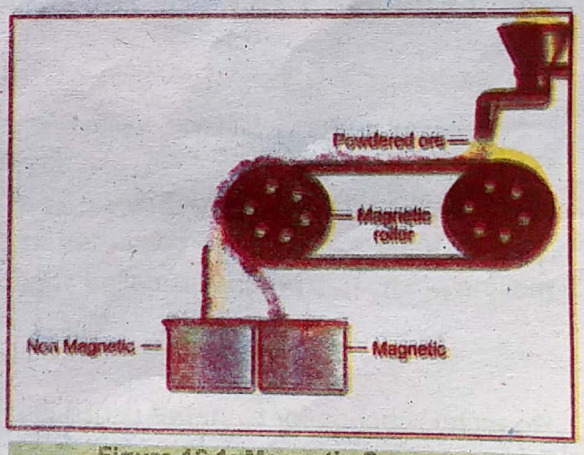



Figure 16.1: Magnetic Separator

### a) Magnetic Separation:

For magnetic ore, a magnet is used to remove mineral, leaving the gangue behind. The powered ore is dropped over a moving belt. Belt moves over two wheels, one of which is magnetic. It attracts the magnetic ore, so it falls nearer to the magnetic wheel. While non-magnetic impurities fall further away, as shown in figure 16.1.

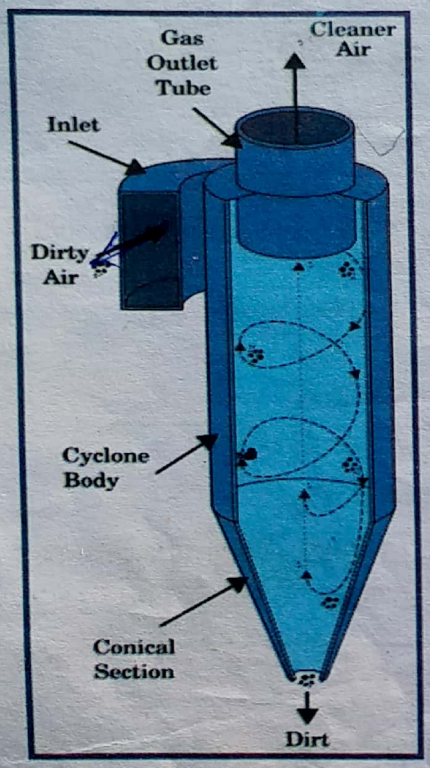



Figure 16.2 Cyclone Separator

### b) Cyclone Separation:

Where large density differences exist between ore and impurities, a cyclone separator is used. In this method air under high pressure is blown through the pulverized ore. The lighter gangue is blown away through the top. But the denser mineral rich particles hit the walls by centrifugal force. They fall down the funnel.

(Figure 16.2)

### c) Flotation Process:

Pulverized ore is fed into a tank containing water and an oil-detergent mixture. The mixture is agitated with air. Detergents wet the mineral particles but not the silicate gangue. The mineral particles rise to the top of the mixture as a forth, from where they are skimmed off. Particles of the gangue fall down to the bottom. The copper ore is concentrated generally by flotation process. (Figure 16.3)

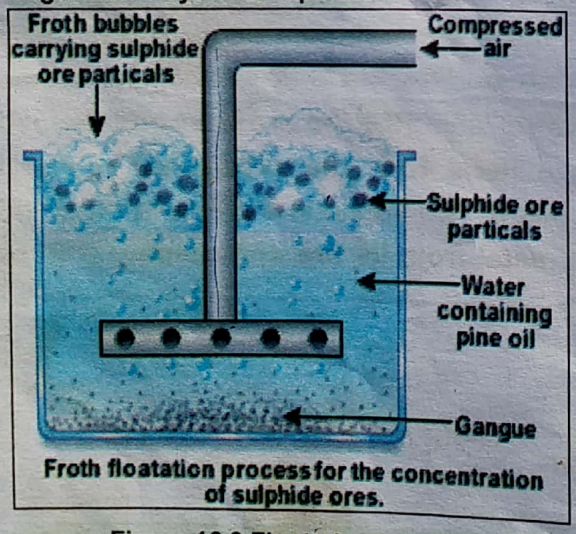



Figure 16.3 Floatation process

## 16.1.2 Extraction of Metals

After the mineral has been freed of gangue and concentrated it is passed through some chemical process to extract metal.

### (a) Roasting

Some minerals are converted to oxide by heating in the air at temperature below their melting point. This process is called **roasting.** For example, the roasting for zincblende (ZnS) is

$$2ZnS_{(s)} + 3O_{2(g)} \xrightarrow{\text{heat}} 2ZnO_{(s)} + 2SO_{2(g)}$$

Roasting reaction for cinnabar (HgS) is

$$HgS_{(s)} + O_{2(g)} \longrightarrow Hg_{(l)} + SO_{2(g)}$$

Roasting reaction of copper pyrite ore is

$$2CuFeS_{2(s)} + O_{2(g)} \xrightarrow{heat} Cu_2S_{(s)} + 2FeS_{(s)} + SO_{2(g)}$$

### (b) Smelting

**The method to reduce metal ions to free metal is called smelting.**

The most common reducing agents are coke, carbon monoxide and hydrogen. Some examples are:

$$Fe_2O_{3(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(l)} + 3CO_{2(g)}$$

$$WO_{3(s)} + 3H_{2(g)} \longrightarrow W\ (s) + 3H_2O_{(l)}$$

$$ZnO_{(s)} + C_{(s)} \longrightarrow Zn_{(s)} + CO_{(g)}$$

However, smelting of copper ore is done in two steps.

i) **The roasted copper ore** is heated with coke and sand at about 1100°C. The materials melt and separate into two layers. The bottom layer that contains mixture of $Cu_2S$ and FeS is called matte. While the upper layer is a silicate slag formed by the reaction of FeO and sand

$$2FeS_{(s)} + O_{2(g)} \longrightarrow 2FeO_{(s)} + 2SO_{2(g)}$$

$$FeO_{(s)} + SiO_{2(s)} \longrightarrow FeSiO_{3(s)}$$

ii) **Bessemerization:**

In this process air is blown through the molten copper matte in a Bessemer converter (Figure 16.4). Any remaining iron sulplide (FeS) is oxidized and removed as slag $(FeSiO_3)$. In the final smelting step cuprous sulphide $(Cu_2S)$ is oxidized to form cuprous oxide, which reacts with remaining cuprous sulphide to form metallic copper.

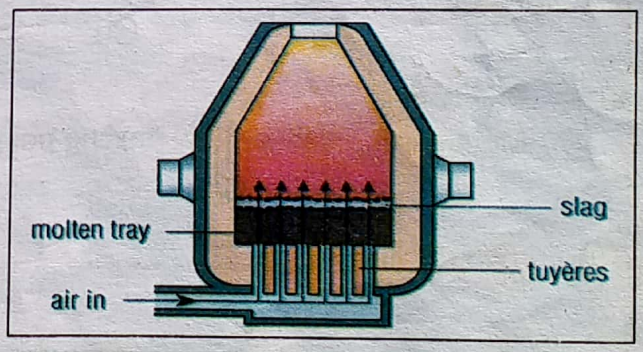



**Figure 16.4 Bessemer Converter**

$$2Cu_2S_{(l)} + 3O_{2(g)} \longrightarrow 2Cu_2O_{(l)} + 2SO_{2(g)}$$

$$Cu_2S_{(l)} + 2Cu_2O_{(l)} \longrightarrow 6Cu_{(l)} + SO_{2(g)}$$

The product, called blister copper is about 97 to 99% pure Cu, with entrapped bubbles of $SO_{2(g)}$.

Bessemerization is also used to convert pure iron into steel.

### (c) Refining or purification of metals

The metal obtained as a result of smelting contains some impurities. So it must be refined. Following methods may be used.

### i) Electro-refining:

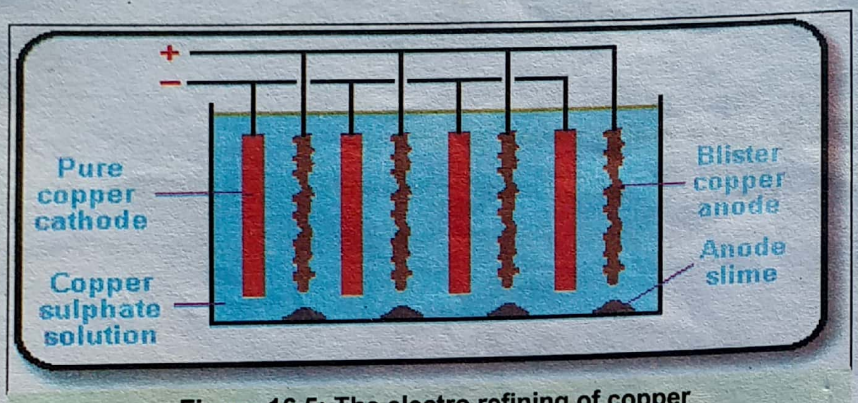



**Figure 16.5: The electro refining of copper**

An electrolytic cell is used in electro-refining, in which impure metal acts as the anode and a sample of pure metal acts as the cathode. For example, electrolytic refining of copper is carried out in an electrolytic tank containing acidified copper sulphate solution as electrolyte (Figure 16.5). Impure slabs of copper act as anode and pure copper sheets as cathode.

On passing electric current through the solution, impure copper dissolves forming $Cu^{+2}$ ions. These $Cu^{+2}$ ions gain electrons at cathode and form Cu atoms, which are deposited on the cathode. In this way pure copper is collected at cathode. The impurities like Au and Ag fall off the anode as anode mud.

**Anode Reaction:**

$$Cu_{(s)} \longrightarrow Cu^{+2}_{(aq)} + 2e^-$$

**Cathode Reaction:**

$$Cu^{+2}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$$

### ii) Distillation:

Metals with relatively low melting points, such. As and Hg are refined by distillation.

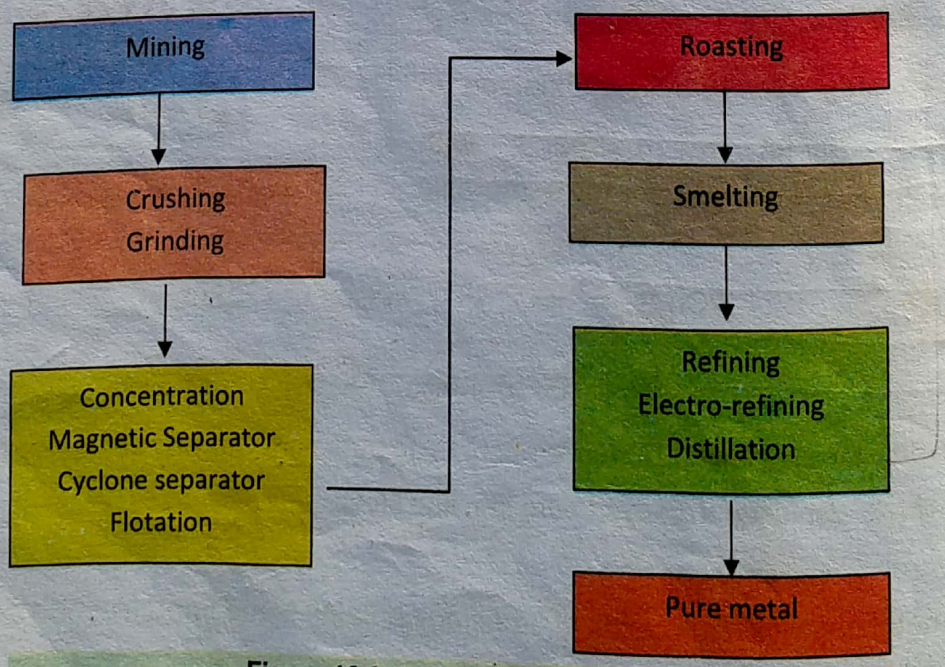



**Figure 16.6: Steps in metallurgy**

## Self-Assessment Exercise 16.1

1. List important ores of iron, copper, zinc and mercury.
2. List out basic metallurgical operations.
3. List main processes used to concentrate the ore.
4. Write names of methods used in the extraction of a metal from its concentrated ores.
5. List methods used to purify metals.

# 16.2 SOLVAY PROCESS

Sodium carbonate ($Na_2CO_3$) or soda ash is an important industrial chemical. It is used in the manufacturing of glass, soaps, detergents, paper and many other important chemicals. Sodium carbonate is manufactured in a continuous process known as the **Solvay process**.

## 16.2.1 Raw Materials

Commercially, sodium carbonate is manufactured in a continuous process that uses:

a) Ammonia
b) Brine (concentrated sodium chloride solution)
c) Lime stone as a source of carbon dioxide and slaked lime, $Ca(OH)_2$

## 16.2.2 Basic Reactions

Solvay process consist of following steps

**i) Preparation of ammonical brine:**
Ammonical brine is prepared by dissolving ammonia gas in brine. Ammonical brine is fed into the carbonating tower.

**ii) Carbonation**
In the carbonating tower, carbon dioxide is passed through ammonical brine. Following reaction takes place in it.

$$CO_{2(g)} + NH_{3(g)} + H_2O_{(l)} \longrightarrow NH_4HCO_{3(aq)}$$

$$NH_4HCO_{3(aq)} + NaCl_{(aq)} \xrightarrow{15^\circ C} NaHCO_{3(s)} + NH_4Cl_{(aq)}$$

In the lower compartments of carbonating tower, the temperature of the mixture is lowered to $15^0$C. At this temperature, $NaHCO_3$ precipitates out.

**iii) Filtration**
Precipitates of $NaHCO_3$ are separated from the milky solution by filtration. It is used as baking soda.

**iv) Calcinations**
Sodium hydrogen carbonate is heated to get sodium carbonate

$$2NaHCO_{3(s)} \xrightarrow{heat} Na_2CO_{3(s)} + CO_{2(g)} + H_2O_{(g)}$$

Carbon dioxide released is re-cycled in the process.

### v) Preparation of carbon dioxide and slaked lime.

Carbon dioxide is produced by heating limestone in a kiln.

$$CaCO_{3(l)} \xrightarrow{heat} CaO_{(s)} + CO_{2(g)}$$

Carbondioxide is fed into the carbonating tower from the top. Equal amounts of lime (CaO) and water are mixed to produce slaked lime, $Ca(OH)_2$

$$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_2$$

Slaked lime is pumped to the ammonia recovery tower.

### vi) Recovery of ammonia:

Solution containg ammonium chloride produced in the carbonation tower is heated with slaked lime.

$$2NH_4Cl_{(aq)} + Ca(OH)_{2(aq)} \xrightarrow{heat} 2NH_{3(g)} + CaCl_{2(aq)} + 2H_2O_{(l)}$$

Almost all the ammonia is recovered in this process. It is reused in the process.

### Advantages of Solvay Process

i) It is a cheap process. The raw materials are cheap and easily available.

ii) It is a pollution free process. No harmful products are produced.

iii) It consumes less fuel. This is because there is no solution to be evaporated.

iv) Carbon dioxide and ammonia are recovered and re-used in the process.

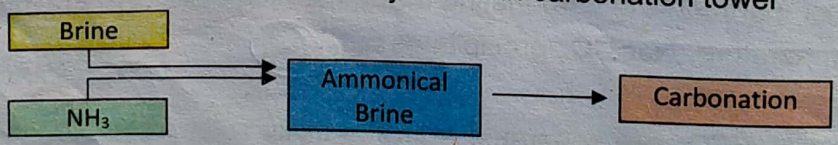
v) It produces pure $NaHCO_3$ and $Na_2CO_3$

### Activity 16.1

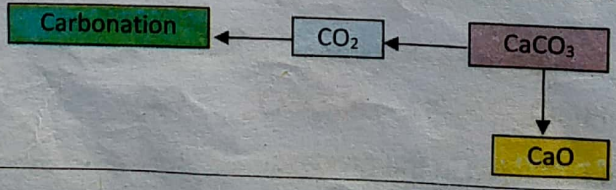
**Development of flow sheet diagram of Solvay process**

**Carry out the following**

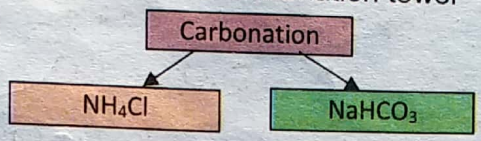
1. Represent each reactant, each product and each reaction chamber or container with one box.
2. Show formation of ammonical brine and join it with carbonation tower



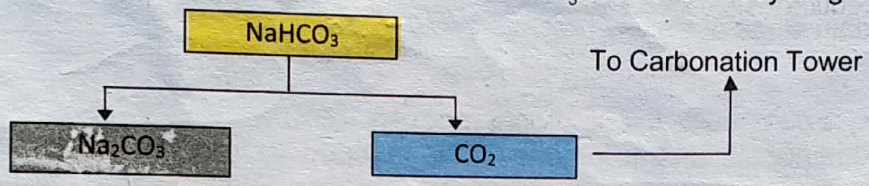

3. Show the formation of $CO_2$ with a box $CO_2$ and connect it with carbonation tower.



4. Show formation of two products from the carbonation tower

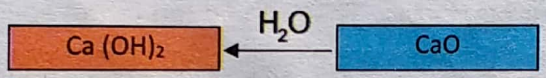



5. Show formation of $Na_2CO_3$ and $CO_2$ form $NaHCO_3$ and show recycling of $CO_2$.

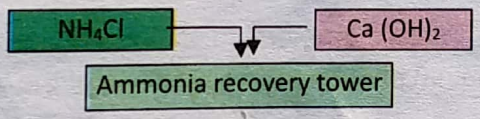



6. Show ammonia recovery:

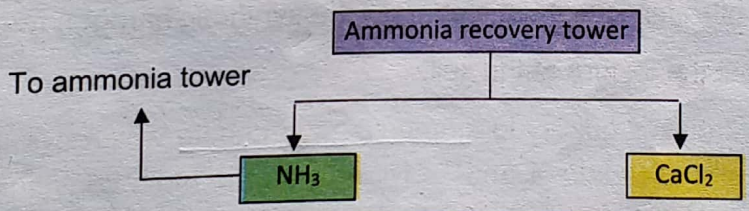
a) First show formation of $Ca(OH)_2$ from CaO and $H_2O$.




b) Connect $NH_4Cl$ and $Ca(OH)_2$ with ammonia recovery tower.




c) Show products of ammonia recovery tower, $NH_3$ and $CaCl_2$. Also show rec, cling of $NH_3$




**Solution**

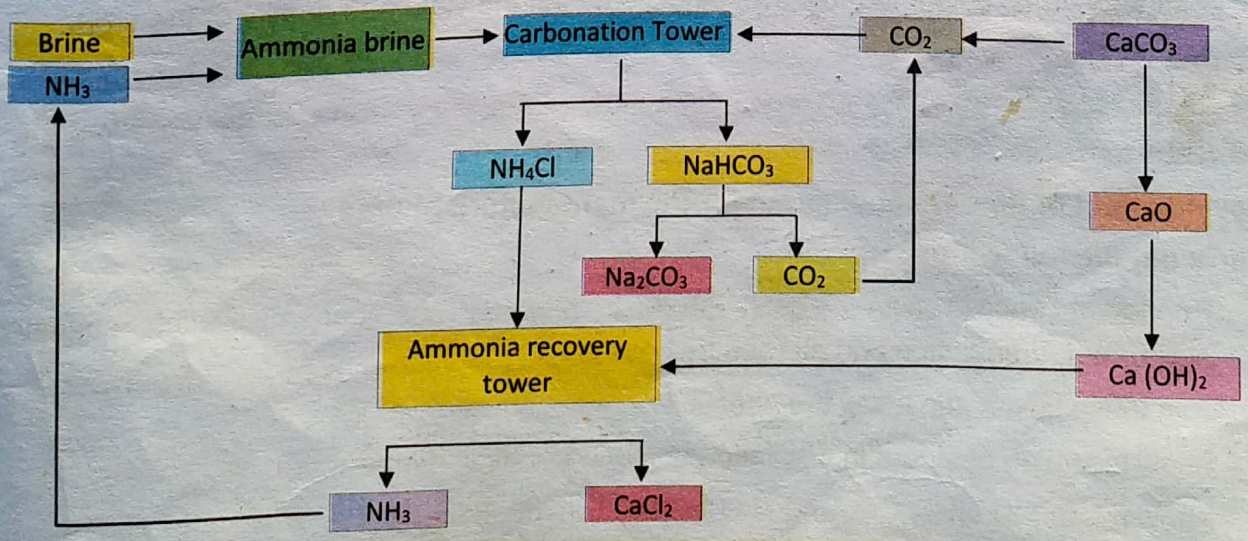



**Figure 16.7 Flow sheet diagram of Solvay process**

## Self-Assessment Exercise 16.2

1. Make a list of raw materials of Solvay process.
2. Outline the basic reactions of Solvay process.
3. List out main steps of Solvay process.

# 16.3. UREA

As the world population has increased, the demand for food has increased. The world population was 3.5 billion in 1965. By 2050, it will reach 10 billion. Many people today are hungry and many more are under-nourished. Crops take nutrients from the soil, and these must be replaced before the next crop is sown. Fertilizers are the compounds which are put in the soil to provide elements essential for plant's life. They are added to the soil to make up the deficiency caused by the previous crops. Fertilizers are classified into two categories:

1. Natural fertilizers or manures derived from animals and human wastes.
2. Synthetic fertilizers i.e. urea, ammonium sulphate, ammonium phosphate, super phosphate and di-ammonium phosphate. Urea is one of the widely used fertilizer because of the following qualities:

i) Percentage of nitrogen is highest among all the synthetic nitrogen fertilizers i.e. 46%.

ii) It does not affect the texture of the soil.

iii) In the soil it hydrolyses quickly to ammonium carbamate which eventually changes into $NH_3$ which decomposes into $N_2$ and $H_2$. Nitrogen is the main constituent of proteins; it is required by the stems and leaves during the early stages of the plant development. It imparts green colour to the leaves and increases the yield and quality of the crop.

## Activity 16.2

**Development of flow sheet diagram for the manufacture of urea.**

**Carry out the following:**

1. Represent each reactant, each product, reaction chamber, distillation chamber, evaporator, granulation and storage by boxes.
2. Join these boxes and show the direction of the changes or processes.
3. Show incoming of steam in distillation unit and hot air in evaporator.
4. Show release of $NH_3$, $CO_2$ and $H_2O$ from distillation unit.

**Solution:**

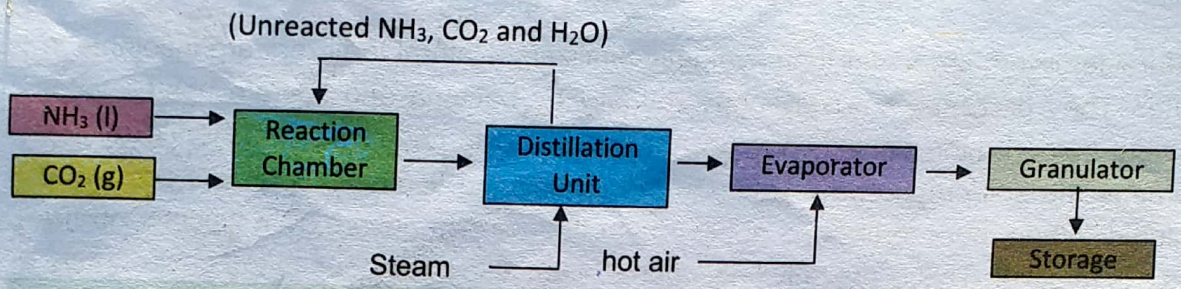



**Figure 16.8: Flow sheet for urea manufacturing**

## 16.3.2 Raw materials:

**The raw materials for the manufacture of urea are:**

i) Ammonia $(NH_3)$ ii) Carbon dioxide $(CO_2)$

Manufacturing of urea consists of following steps.

a) Reaction between $NH_3$ and $CO_2$ to form ammonium carbamate.

$$2NH_{3(l)} + CO_{2\,(l)} \longrightarrow NH_2COONH_4$$

b) Distillation of ammonium carbamate.

$$NH_2COONH_4 \longrightarrow NH_2-\overset{\overset{O}{\|}}{C}-NH_2 + H_2O$$

**Urea**

c) Evaporation of liquid urea and its granulation.

The urea solution is concentrated in vacuum evaporators, which is then rapidly cooled and sent to the prilling tower. Urea prills thus produced are packed and then marketed.

**Do you know**

% of nitrogen in various fertilizers

| Fertilizer | Formula | Molecular mass | % age of Nitrogen |
|---|---|---|---|
| Ammonium sulphate | $(NH_4)_2SO_4$ | 132 | 21.2 |
| Ammonium nitrate | $NH_4NO_3$ | 80 | 35.0 |
| Urea | $NH_2CONH_2$ | 60 | 46.6 |

## Self-Assessment Exercise 16.3

1. Calculate percentage of nitrogen in urea.
2. Outline the basic reactions that take place in the synthesis of urea.
3. What happens when ammonium carbamate is distilled with steam?

**Society, Technology and Science**

1. Natural fertilizers are better than synthetic fertilizers. Natural fertilizers are insoluble in water. They decompose slowly and gradually by bacteria and liberate useful water soluble nutrients for plants. They do not contain toxic chemicals and hence do not damage the soil crops and plants. On the other hand synthetic fertilizers are water soluble. When more fertilizer is applied than the soil can absorb, rain washes off the excess fertilizer. This is not only uneconomical but also hazardous to the environment. The dissolved nutrients flow into stream, lakes and rivers and contribute in the eutrophication of their waters. It results in over growth of water plants, algae and bad odour in these waters. A bloom of algae can spread across the surface, blocking light for other plant life in the water. When plants and algae die, bacteria multiply rapidly with so much food available. They remove the dissolved oxygen in the water. Without oxygen, fish die affecting the whole ecosystem. Nitrates in drinking water cause stomach cancer.
2. People have been preparing common chemical such as acids, alkalis, soaps, baking soda, soda ash, caustic soda etc. since centuries. But the use of technology has not only increased production of chemicals but improved quality as well. For instance, soda ash and baking soda are produced commercially by Solvay process, which is a continuous process. Soda is not handled until it is packed. Carbon dioxide and ammonia are recovered almost 100%. At the same time process is pollution free.

## 16.4 PETROLEUM INDUSTRY

### 16.4.1 Petroleum

Where the most of the energy used today come from?

Fossil fuels are energy-rich substances formed from remains of organisms. Coal, petroleum and natural gas are called fossil fuels because they were formed underground from the remains of once-living organisms. The name petroleum is derived from Latin words **petra** (rock) and **oleum** (oil). It is also called as crude oil. Petroleum or crude oil is thick dark liquid composed mostly of hydrocarbons. Natural gas, usually associated with petroleum deposits, consists mostly of methane. It also contains significant amounts of ethane, propane and butane.

### 16.4.2 Origin of Petroleum and Natural gas

It is believed that petroleum was formed from organisms that lived hundreds of millions of years ago. Plants and animals in the seas died. Their remains piled up. Layers of sand, rock and mud buried the dead organisms. Over time, in the absence of air, heat and pressure of sediments and bacterial effect changed the material into dark brownish viscous liquid called petroleum. It is also called crude oil. The gaseous products accumulated over the petroleum, is called as natural gas.

## 16.4.3 Mining of Petroleum

Petroleum is extracted by drilling holes into the earth crust where it is found. When drill is made through the rocks, natural gas comes out first with great pressure. After the gas pressure subsides, crude oil is extracted by pumps.

## 16.4.4 Important fractions of petroleum

The conversion of crude oil into useful products is called **refining.** These useful products are called fractions. Each fraction consists of a mixture of hydrocarbons which boil in a certain range of temperature. Petroleum is refined by fractional distillation in a tall fractionating tower. (See figure 16.9). The crude oil is heated up to 400°C under high pressure in a furnace. Then it is passed through the fractional distillation column. Its vapour rise through the column. As hot vapour move up, they condense according to their boiling points into various fractions. Compounds with highest boiling points condense first near the bottom. Compounds with lowest boiling point condense last near the top. Compounds which do not boil, collects at the bottom as residue. In this way vapour condense gradually at different levels according to their boiling points. Therefore, crude oil is separated into various fractions. Each fraction has its own specific boiling range and composition. How many fractions are obtained?

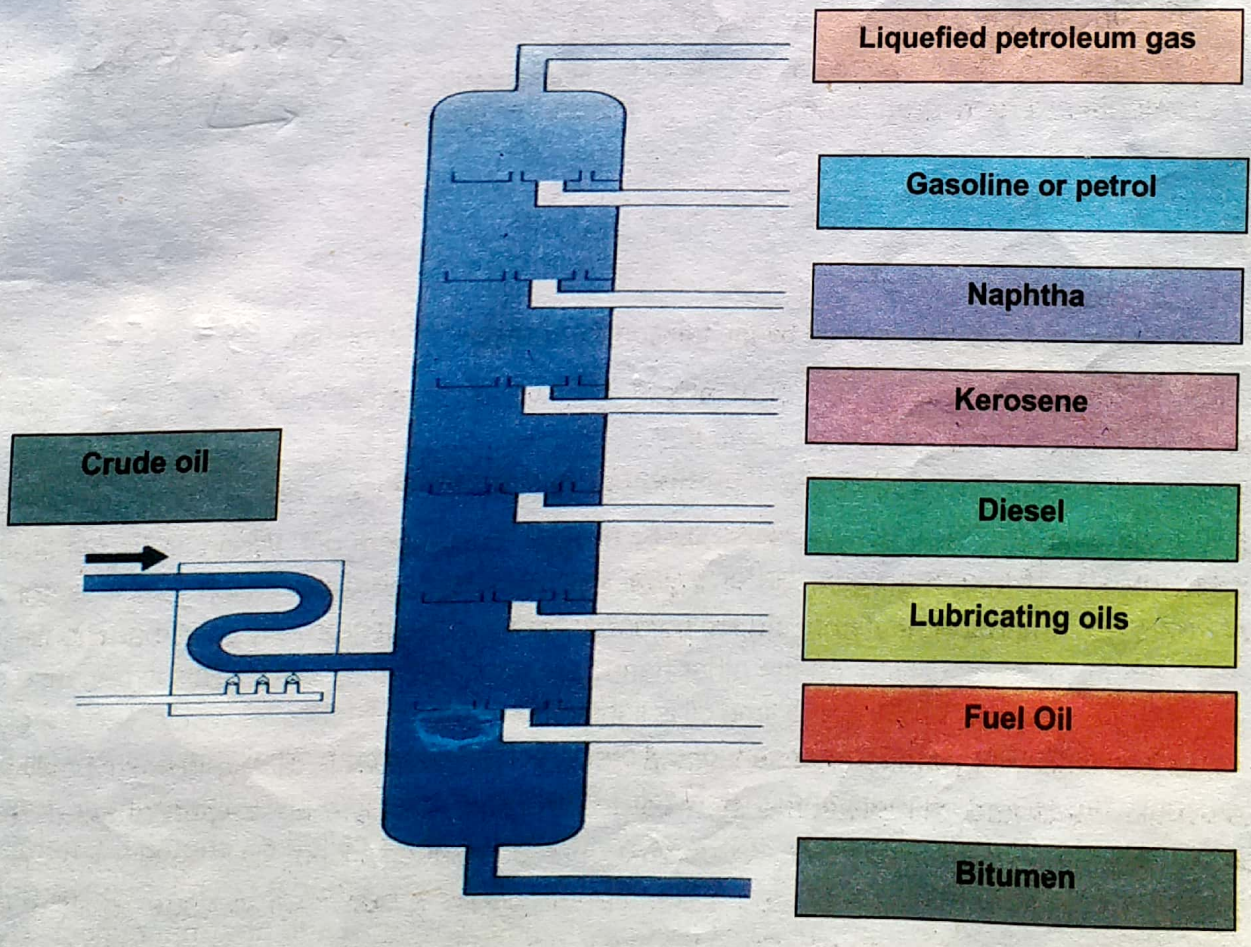



**Figure 16.9: Fractional distillation of petroleum**

The physical properties and uses of petroleum fractions are given in table 16.

**Table 16.2: Fractions of petroleum and their uses**

| Fraction | Number of carbon atoms per molecule | Boiling point °C | Important uses |
|---|---|---|---|
| Liquefied petroleum gas (LPG) | 1-4 | Below 20 | Cylinder gas for cooking |
| Petrol | 5-10 | 35-70 | Fuel for motor cars and vehicles |
| Naphtha | 8-12 | 70-120 | Chemical feedstock for making drugs, plastics and other chemicals |
| Kerosene | 10-16 | 170-250 | Fuel for jet planes, fuel for heating, lighting and cooking |
| Diesel | 14-20 | 270-340 | Fuel for buses, truck and trains. |
| Lubricating oil | 20-50 | 350-500 | Lubricants for machines and engines, waxes and polishes |
| Fuel oil | 50-70 | 500-600 | Fuel for power stations, factories and ships |
| Bitumen | More than 70 | More than 500 | Paving roads and making roofing materials |

## Self-Assessment Exercise 16.4

1. Define petroleum.
2. List names of fractions obtained by the fractional distillation of petroleum.
3. List one use of each petroleum fraction.
4. How is petroleum obtained?

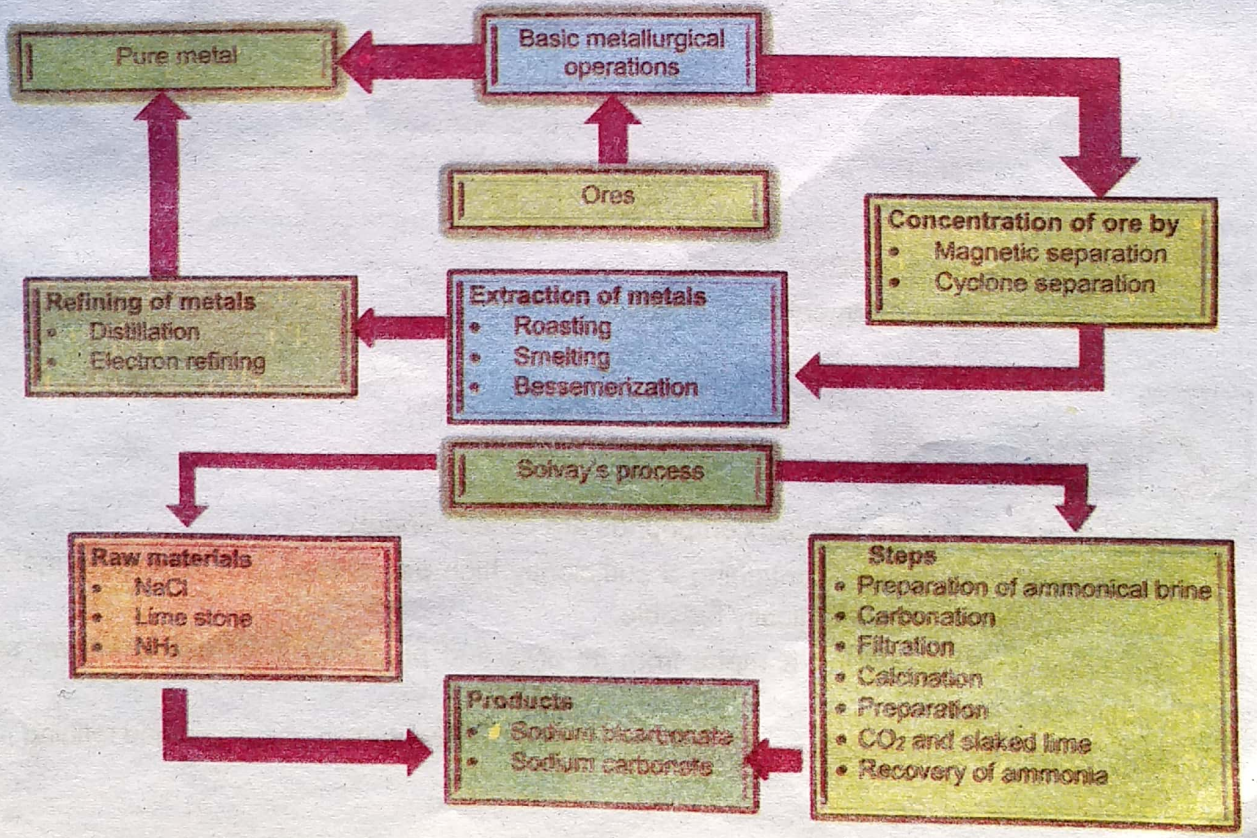
### Society, Technology and Science

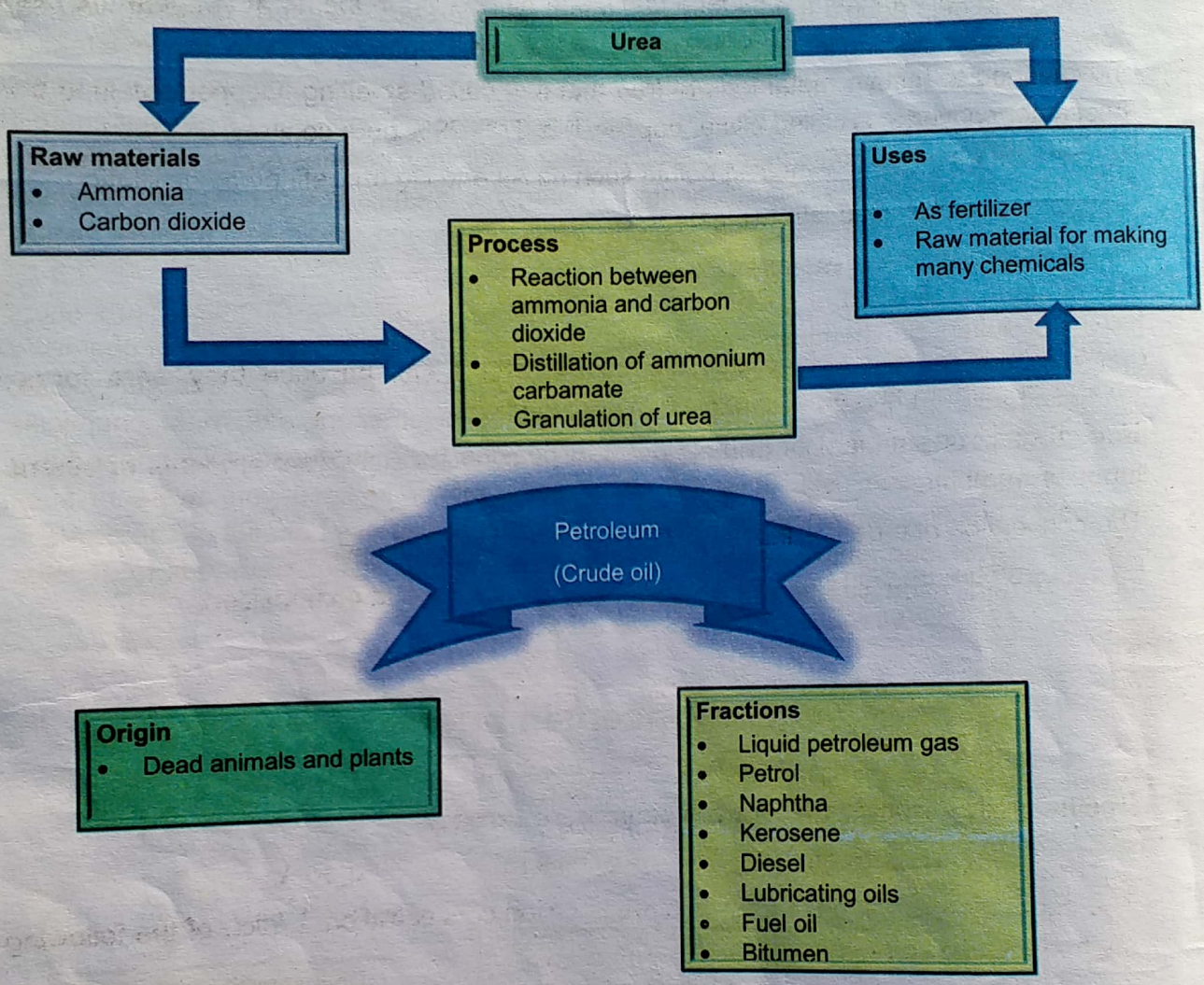
1. Wood, oil or electric fires required different techniques to put them out. Wood fire is generally extinguished by throwing water on it. Water has high heat of vaporization. So it absorbs considerable amount of heat from the fire before it vaporizes. So it gradually cools burning wood and extinguishes fire. Oil fire, on the other hand cannot be put off by water. This is because oil and water do not mix. At the same time oil is lighter than water. It floats over water. The fire also spreads with flowing water. Water cannot cut of contact between burning oil and oxygen. Oil fire is usually put off by throwing sand on it. Electric fires can only be put out by fire extinguishers.
2. A person who studies chemistry and works with chemicals is called as chemist. Chemists have opportunities in all the field of chemistry. For instance, organic chemists have good opportunities to work in industries like petroleum, petrochemical and pharmaceutical. They can research on new products, more effective medicines, new pesticides for better crops,

new ways to help people reduce environmental pollution etc. As a food chemist; you can work in food processing industry. You can discover new methods to store, improve texture and flavor of foods. In hospitals, chemists analyze blood, urine and stood samples to detect any disease, disease causing bacteria, virus, or other microorganisms. As nuclear chemist you can work in the development of new nuclear medicines besides giving chemotherapy and radiation therapy to cancer patients. As inorganic chemist you can work in chemical industries such as manufacturing cement, glass, soap and detergent, fertilizer, acids, alkalis, soda ash, dyes, explosives etc.

3. The modern application of chemical technology is a big business. Chemical firms spent billions of dollars on chemical research and development. The industrial use of chemistry brings us new medicines, lifesaving drugs, effective pesticides, germicides, fungicides, synthetic fertilizers, paints, cosmetics, artificial flavors, sweeteners, etc. These chemicals have raised our standard of living. However, besides benefits, these substances have some drawbacks and risks. It is the job of sales officer to keep you aware of such drawbacks besides explaining benefits. It is important to express benefits of chemicals in a way that everyone can understand. In order to share information he needs to develop good communication skills to promote chemical sales.

## Concept in brief






***References for additional information.***

- Longman Chemistry for IGCSE.
- David E. Goldberg, Fundamentals of chemistry.

## Key Points

- The naturally occurring metallic compounds are called minerals.
- An ore is a solid deposit containing a sufficiently high percentage of a mineral to make extraction of metals economically feasible.
- The process of separating a metal from its ores and preparing it for use is known as metallurgy.
- Basic metallurgical operations are crushing, grinding, concentration, extraction and refining.

- The process of converting a mineral into oxide by heating in the air at temperature below their melting point is called roasting.
- The method to reduce metal ions to free metal is called smelting. Copper obtained from bessemer converter is called blister copper. It is 97% 99% pure copper.
- Metals with relatively low melting points such as As and Hg are refined by distillation.
- Fertilizers are classified into two categories
  - Natural fertilizers or manures
  - Synthetic fertilizers
- Coal, petroleum and natural gas are called fossil fuels, because they were formed underground from the remains of once-living organisms.
- Natural gas consists mostly of methane. It also contains significant amounts of ethane, propane and butane.
- The conversion of crude oil into useful products in called refining.
- Each petroleum fraction has its own specific boiling range and composition.

## Review Questions

**1. Select the correct answer**

i) The naturally occurring metallic compounds are called as

a) ore b) gangue c) mineral d) rock

ii) The separation of minerals from gangue is called concentration. Which of the following methods is used for concentration?

a) smelting b) roasting c) refining d) flotation

iii) Which of the following steps is not used in the extraction process of metals

a) roasting b) smelting c) flotation d) bessemerization

iv) In electrolytic refining of copper, _____ is used as anode.

a) pure copper b) impure copper c) copper sulphate d) electrolytic tank

v) Which of the followings in not a raw material for the manufacture of soda ash.

a) ammonia b) carbon monoxide c) brine d) lime stone

vi) A mixture of $Cu_2S$ and FeS called matte is produced in one of the metallurgical operations in the extraction of copper. The name of this operation is.

a) smelting b) roasting c) bessemerization d) electro-refining

vii) Chemical formula of slaked lime is

a) $CaCO_3$ b) $CaO$ c) $Ca(OH)_2$ d) $CaCl_2$

viii) Calcination is the process in which sodium hydrogen carbonate is heated to get sodium carbonate. Which is not obtained in this process?

a) $CO_2$ b) CO c) $Na_2CO_3$ d) $H_2O$

ix) Percentage of nitrogen in urea is

a) 35 b) 21.2 c) 80 d) 46.6

x) What happens when ammonium carbamate is distilled with steam?

a) ammonia is produced

b) carbon dioxide is released

c) urea is produced

d) urea solution is produced

**2. Give short answers.**

i) How are urea prills produced?

ii) What is slaked lime? How is it produced?

iii) Write chemical reactions that take place during carbonation in Solvay process.

iv) Explain the process "Roasting" with two examples.

v) Write chemical reactions that take place during urea formation.

**3. Describe the following with an example**

a) roasting b) smelting c) flotation

**4. Make a list of metallurgical operations.**

**5. How was crude oil formed?**

**6. State five specific products made from crude oil.**

**7. Outline basic reactions of Solvay process.**

**8. Draw flow sheet diagram of Solvay process.**

**9. Describe composition of urea**

**10. Make a list of raw materials for Solvay process.**

**11 Describe the composition of petroleum**

**12 Relate the study of chemistry to careers in industry.**

**13. Draw flow sheet diagram for manufacture of urea.**

**14. Petroleum is a mixture of several compounds, which are separated in a refinery.**

a) What is the name of the apparatus used for this purpose?

b) What is the name of the process used in separating crude oil?

c) Write name of the fraction that represents gases.

d) Which fractions represent liquids with the lowest boiling points?

**15. Petroleum is a source of fuels. Name two fuels which are not obtained from petroleum.**

**16. What has to be done to crude oil before it is useful?**

## Think-Tank

17 **The table below lists some petroleum fractions with their approximate boiling points.**

| Fraction | Approximate Boiling Point/°C |
|---|---|
| P | Below 20 |
| Q | 35-70 |
| R | 170-250 |
| S | 350-500 |

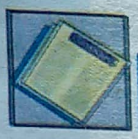
a) Name the process by which the fractions are obtained from petroleum?
b) Which fraction will contain the shortest chain molecules?
c) Which fraction will contain the longest chain molecules?
d) In what state will fraction P be at room temperature and pressure?

18 **Should fossil fuels be burned to provide energy, or should they be used to make useful products like drugs, plastics and chemicals? Analyze this statement.**

19 **Sketch flow sheet diagram of refining of petroleum.**

## KEY FOR MCQS

| | i | ii | iii | iv | v | vi | vii | viii | ix | x |
|---|---|---|---|---|---|---|---|---|---|---|
| **Chapter 9** | d | d | d | d | d | a | c | c | d | d |
| **Chapter 10** | c | c | d | d | a | c | d | b | c | c |
| **Chapter 11** | c | b | c | c | d | b | c | d | c | c |
| **Chapter 12** | b | c | a | b | c | d | c | d | d | a |
| **Chapter 13** | d | a | d | d | c | d | d | c | b | c |
| **Chapter 14** | c | b | c | b | b | b | d | d | b | d |
| **Chapter 15** | b | b | d | d | d | d | d | b | - | - |
| **Chapter 16** | c | d | c | b | b | b | c | b | d | d |



# Glossary

| | |
|---|---|
| **Acid** | is a substance that can donate a proton to a base. |
| **Alkenes** | The family of hydrocarbons which contain one carbon-carbon duble bond. |
| **Alkyl group** | a group of atoms that contains one less hydrogen atom than its parent alkane. |
| **Aqueous solutions** | are the mixtures in which substances are dissolved in water. |
| **Acid rain** | is formed when air pollutants dioxide are dissolved in rain water. |
| **Acid salts** | are formed by the incomplete neutralization of an acid. |
| **Alkanes** | the simplest hydrocarbons in which all carbon-carbon bonds are single. |
| **Alkynes** | unsaturated hydrocarbons with a carbon-carbon triple bond. |
| **Amino Acids** | organic compounds containing both amino and carboxyl groups. |
| **Arrhenius Acid** | a substance that produces $H^+$ ions in water. |
| **Arrhenious base** | a substance that produces $OH^-$ ions in water. |
| **Base** | a substance that can accept a proton from an acid. |
| **Bronsted lowry acid** | a substance that can donate a proton. |
| **Bronsted lowry base** | a substance that can accept a proton |
| **Carbohydrates** | -polyhyroxy aldehydes or ketones. |
| **Catenation** | -linking of carbon atoms with one another to form long chains or rings of carbon atoms. |
| **Cehmical equilibrium** | -a state of a chemical reaction at which rate of forward reaction equals the rate of reverse reaction. |
| **Concentration** | separation of mineral from the gangue. |
| **Crude oil** | a dark brownish viscous liquid. |
| **Carboxyl group** | the COOH functional group |

| | |
|---|---|
| **Destructive distillation** | heating a substance in the absence of air. |
| **Equilibrium constant** | is the ratio of the product of concentration of products to the product of concentration of reactants each raised to power equal to the co-efficient in a balanced chemical equation. |
| **Enhanced greenhouse effect** | an upset in the natural balance of the concentration of greenhouse gases in the atmosphere. |
| **Ethylene** | the industrial name for ethene. |
| **Fatty Acids** | are carboxylic acids which contain three or more carbon atoms in their chain. |
| **Functional groups** | are groups of atoms in an organic molecule which give particular properties. |
| **Fossil fuels** | fuels made from the remains of decayed animal and plant matter compressed over millions of years. |
| **Fraction** | a collection of hydrocarbons that have similar molecular masses and boil at similar- temperatures. |
| **Fractional distillation** | separating a mixture on the basis of differences in boiling points. |
| **Hard Water** | water containing dissolved calcium and magnesium salts which produce scum with soap. |
| **Hydrogenation** | is addition hydrogen in alkenes and alkynes. |
| **Hydrocarbons** | compounds containing only carbon and hydrogen. |
| **Indicators** | chemicals that change colour as pH of a solution changes. |
| **Isomer** | a compound having the same molecular formula but different structures. |
| **Law of mass action** | the rate at which a substance reacts is directly proportional to its active mass and the rate at which the reaction proceeds is directly proportional to the product of the active masses of the reactants. |
| **Lewis acid** | a substance that can accept a pair of electrons. |
| **Lewis base** | a substance that can donate a pair of electron. |

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| **Lipids** | any component of plant or animal tissue that is insoluble in water, but soluble in solvents of low polarity such as ether, hexane, benzene and carbon tetrachloride. |
| **Metallurgy** | is the art of extracting metals from their ores. |
| **Mineral** | a naturally occurring metallic compound. |
| **Monosaccharides** | the simple sugars that can not be hydrolyzed. |
| **Normal salts** | salt formed by the complete neutralization of an acid and a base. |
| **Oligosaccharides** | carbohydrates that on hydrolysis give 2 to 9 monsaccharide molecules. |
| **Ore** | a solid deposit containing a sufficiently high percentage of a mineral to make extraction of metal economically feasible. |
| **Ozone** | an allotropic form of oxygen that contains three oxygen atoms. |
| **Organic Compounds** | compounds containing carbon except carbon dioxide, carbon monoxide and carbonates. |
| **Permanent hardness** | in water is due to the presence of sulphates and chlorides of calcium and magnesium. |
| **Petroleum** | a dark brownish viscous liquid. |
| **pH** | is the negative logarithm of molar concentration of the hydrogen ions. |
| **Pollutants** | are substances that have adverse effect |
| **Polysaccharides** | carbohydrates that contain hundreds to thousands of monosaccharide units. |
| **Proteins** | organic compounds which on complete hydrolysis form amino acid units. |
| **pH Scale** | scale based on hydrogen ion concentration. |
| **Refining** | a process of separation of crude oil into useful fractions. |
| **Roasting** | the heating of concentrated ore in the presence of air. |
| **Salt** | an ionic compound made from the reaction of an acid and a base. |
| **Saturated hydrocarbons** | every carbon atom present in the hydrocarbon attached to four atoms. |
| **Side groups** | groups of atoms such as $CH_3$ group, which are attached to the main chain of carbon atoms in the molecule. |

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| **Structural formula** | shows the arrangements of atoms in a molecule. |
| **Smelting** | the heating of roasted ore in presence of a reducing agent. |
| **Soft water** | produces good lather with soap. |
| **Temporary hardness** | is due to the presence of hydrogen carbonates of calcium and magnesium. |
| **Unsaturated hydrocarbons** | molecules containing only carbon and hydrogen in which at least two carbon atoms form double or a triple bond. |
| **Universal indicator** | an indicator that changes colour at each pH value. |

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She obtained her Masters' degree in chemistry from Quaid-i-Azam University, Islamabad, and has over twenty eight years of teaching experience. She is serving Islamabad Model College Girls, F-10/2 Islamabad.

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His rich experience in teaching chemistry has enabled him to serve as member, National Review Committee from 2002-2006 for finalizing text-book manuscripts in the subject of chemistry for Secondary and Higher Secondary classes, developed by various Textbook Boards. He is Managing / Co-Author of several text books.

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