



ADSORPTION AND CATALYSIS

Surface of solids plays a crucial role in many physical and chemical phenomena. There are two main reasons for this special role. Firstly, the surface of a substance interacts first with its surroundings. Secondly, the surface molecules are in a different state as compared to the molecules in the interior of the solid. The surface molecules interact more readily with other substances which come close by and are responsible for many special properties. In this lesson we shall study about two such properties – adsorption and catalysis.



Objectives

After reading this lesson you will be able to :

- define adsorption;
- distinguish between physical adsorption and chemisorption;
- list and explain the various factors that affect adsorption;
- state Freundlich adsorption isotherm mathematically and explain it;
- explain Langmuir isotherm;
- define catalysis;
- distinguish between homogeneous and heterogeneous catalysis, and
- explain the role of activation energy in catalysis.

17.1 Adsorption

The surface of a solid attracts and retains molecules of a gas or a dissolved substance which comes in its contact. These molecules remain only at the surface and do not go deeper into the bulk Fig. 17.2(a).



Notes

The phenomenon of attracting and retaining the molecules of a gas or a dissolved substance by the surface of a solid, resulting in their higher concentration on the surface is called adsorption.

The substance which gets adsorbed is called the **adsorbate** and the solid substance which adsorbs is called the **adsorbent**.

A molecule in the interior of a solid is surrounded by other molecules in all directions (Fig. 17.1). However, a molecule at the surface is surrounded by other molecules within the solid phase but not from the outside. Therefore, these surface molecules have some unbalanced or residual forces.

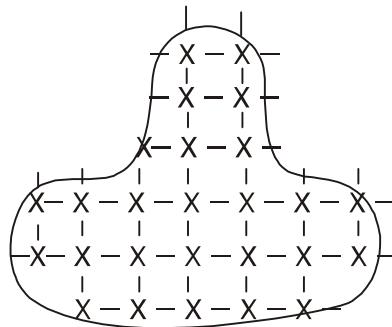


Fig. 17.1 : Molecules in the interior and at the surface of a solid

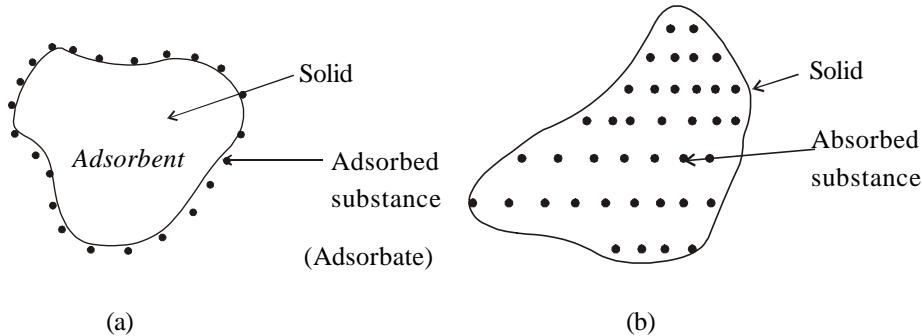


Fig. 17.2 : (a) Adsorption (b) Absorption

17.1.1 Adsorption and Absorption

The phenomenon of *adsorption* is different from that of *absorption*. The latter term implies that a substance is uniformly distributed throughout the body of a solid, Fig. 17.2(b). If we leave a small lump of calcium chloride in open, it absorbs water vapour (moisture) from air and after some time even starts dissolving in it. On the other hand if we keep a sample of silica gel in open, it adsorbs water vapour on its surface as shown in Fig. 17.2 (a).

17.1.2 Factors Affecting Adsorption

Adsorption occurs on the surface of almost all solids. However, the extent of adsorption of a gas on the surface of a solid depends upon the following factors :

- Nature and surface area of the adsorbent

Chemical Dynamics

Notes

- (ii) Nature of the adsorbed gas
- (iii) Temperature
- (iv) Pressure of the gas

Let us now discuss these factors briefly.

(i) Nature and Surface Area of the Adsorbent

Different solids would adsorb different amounts of the same gas even under similar conditions. Substances like charcoal and silica gel are excellent adsorbents. The substances that are porous in nature and have rough surfaces are better adsorbents.

The extent of adsorption also depends upon the surface area of the solid. Greater the surface area, more is the surface available for adsorption and greater is the adsorption. The surface area depends upon the particle size of the substance. A cube of each side equal to 1 cm has six faces. Each of them is a square with surface area of 1cm^2 . Thus, the total surface area of this cube is 6 cm^2 [Fig. 17.3 (a)]. If its each side is divided into two equal halves, $\frac{1}{2}\text{ cm}$ long, and the cube is divided into two equal halves, $\frac{1}{2}\text{ cm}$ long, and the cube is cut along the lines indicated in the Fig (b), the cube would be divided into 8 smaller cubes with each side 0.5 cm long [Fig. 17.3 (b)]. Surface area of each small cube would be $(6 \times 0.5 \times 0.5) = 1.5\text{ cm}^2$ and the total surface area of all the 8 smaller cubes would be 12 cm^2 which is double the surface area of the original cube. If it is subdivided into smaller cubes, each of side equal to $1 \times 10^{-6}\text{ cm}$ the surface area will increase to $6 \times 10^6\text{ cm}^2$ or 600 m^2 . The increase in surface area would result in greater adsorption.

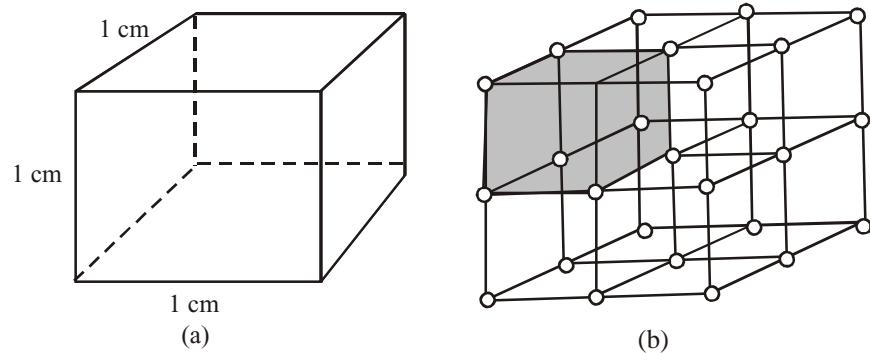


Fig. 17.3 : Subdivision of a cube

Now we can explain why the solids that are porous in nature and have rough surfaces are better adsorbents. It is so because each of these features increases the surface area.

(ii) The Nature of the Adsorbed Gas

The extent of adsorption also depends upon the nature of the gas. The gases which are more easily liquifiable or are more soluble in water are more readily adsorbed than others. For example, under similar conditions, the amount of SO_2 or NH_3 adsorbed by charcoal is much more than that of H_2 or O_2 gases. It is because the intermolecular forces are stronger in more easily liquifiable gases, therefore, they get adsorbed more strongly.

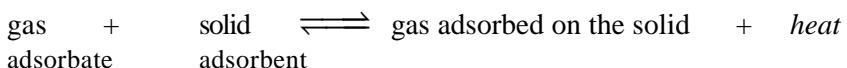


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(iii) Temperature

The extent of adsorption decreases with rise in temperature. For example, under one atmosphere pressure, one gram of charcoal adsorbs about 10 cm^3 of N_2 gas at 272 K, 20 cm^3 at 248 K and 45 cm^3 at 195 K.

Adsorption is an exothermic process. The change in enthalpy when one mole of a substance is adsorbed, is called enthalpy of adsorption. The adsorption process is similar to the condensation process. The reverse process is called **desorption** and is *endothermic* in nature. It is similar to the evaporation process. When a gas is kept in contact with a solid adsorbent in a closed container, a dynamic equilibrium is established in due course of time.



Since the forward process (adsorption) is exothermic in nature, according to the Le Chatelier's principle, it would be favoured at low temperature. Therefore, the extent of adsorption would increase on decreasing the temperature and would decrease on increasing the temperature.

(iv) Pressure of the gas

At a constant temperature the extent of adsorption increases with increase in the pressure of the gas (adsorbate). We shall study the relation between the two in detail a little later.

17.1.3 Physical and Chemical Adsorption

Adsorption can be divided into two main categories – physical and chemical adsorption.

(i) Physical Adsorption

It is the common type of adsorption. The basic feature of **physical adsorption** is that the adsorbate molecules are held at the surface of the adsorbent by weak van der Waals forces. These are the forces that exist between particles of all matter. Because of their universal nature, these forces would operate between any adsorbent and adsorbate pair. Therefore, the physical adsorption is observed on surface of any solid. Only, the extent of adsorption varies according to the nature of the adsorbent and adsorbate as discussed earlier.

Physical adsorption is characterized by low *enthalpy of adsorption*, that is about $10 - 40\text{ kJ mol}^{-1}$.

Another feature of the physical adsorption of a gas by a solid is that it is *reversible* in nature and an equilibrium is established between the adsorbent and the adsorbate as discussed earlier. Increase of pressure increases the adsorption and the release of pressure desorbs the gas. When temperature is increased, the physical adsorption decreases and when it is lowered, the adsorption increases. In physical adsorption, several layers of adsorbate are adsorbed one over the other.

(ii) Chemisorption or Chemical Adsorption

We have seen earlier that some unsaturated valancies exist on the surface of a solid. Whenever a chemical combination takes place between the adsorbent and the adsorbate the adsorption becomes very strong. This type of adsorption caused by forces similar to chemical bonds between the adsorbent and the adsorbate is called **chemisorption** or

Chemical Dynamics



Notes

chemical adsorption.

The enthalpy of chemisorption is as high as that of chemical bonds (bond enthalpies) and is in the range of $40 - 400 \text{ kJ mol}^{-1}$. Chemisorption is highly specific and is possible between a specific adsorbent – adsorbate pair. Like most of the chemical changes it is irreversible. Attempts to release the adsorbed gas gives the gas and some amount of a definite compound. For example, oxygen gas is chemisorbed on tungsten. It is released from the surface of tungsten as a mixture of oxygen and tungsten oxide. Unlike physical adsorption, chemisorption first increases and then decreases with rise in temperature [Fig. 17.4 (b)]. This shows that chemisorption has an energy of activation*. During chemisorption, only one layer of adsorbate molecules is adsorbed. The main distinctions between physical adsorption and chemisorption are summarized in Table 17.1.

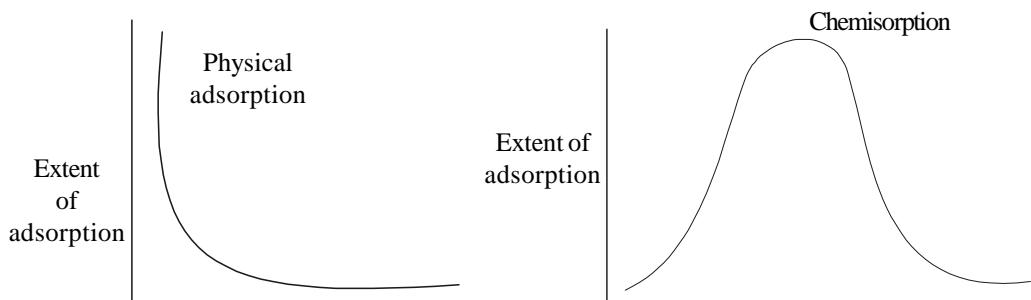


Fig. 17.4 : Effect of Temperature on (a) physical adsorption and (b) chemisorption.

(a) Table 17.1 : Physical Adsorption and Chemisorption

Physical Adsorption

1. The forces operating between adsorbate and adsorbent are the weak van der Waals forces.
2. The enthalpy of adsorption is low and ranges from 10 to 40 kJ mol^{-1} .
3. No activation energy is involved.
4. Adsorption occurs more readily at low temperature and high pressure.
5. It is not specific in nature. All gases are adsorbed on all solids and no compounds are formed.
6. It is reversible in nature. The gas is desorbed on increasing the temperature or decreasing the pressure.
7. Multilayer formation is common.

Chemisorption

1. The forces operating between adsorbate and adsorbent are strong and similar to chemical bonds.
2. The enthalpy of adsorption is high and ranges from 40 to 400 kJ mol^{-1} .
3. Significant activation energy is involved.
4. Chemisorption occurs at relatively high temperature and high pressure.
5. It is highly specific in nature and occurs between those adsorbents and adsorbates which have a possibility of compound formation between them.
6. It is irreversible in nature. Desorption also separates some amount of the compound formed.
7. Monolayer formation occurs.

17.1.4 Adsorption Isotherms

* You will learn more about energy of activation later in this lesson.

The extent of adsorption is measured in terms of the quantity $\frac{x}{m}$ where, x is the mass of

the gas (adsorbate) adsorbed at equilibrium on mass m of the adsorbent. $\frac{x}{m}$ is the mass of

the adsorbate adsorbed per unit mass of the adsorbent. The graph showing variation in $\frac{x}{m}$

with pressure(p) at a constant temperature is called **adsorption isotherm**. Let us see the variation in extent of adsorption in case of gases and of solutes from their solutions.

(i) Adsorption of Gases

The adsorption isotherm of a gas which is adsorbed on a solid is shown in Fig. 17.5. It shows that the extent of adsorption of a gas on a solid increases with the increase in the pressure of the gas, p at three different constant temperatures. The curves also show that the extent of adsorption, decreases at a fixed pressure as the temperature is increased (see the dotted line).

Freundlich Adsorption Isotherm

Freundlich gave an empirical mathematical relationship between the extent of adsorption

$\left(\frac{x}{m}\right)$ and the equilibrium pressure (p) of the gas as :

$$\frac{x}{m} = k p^{\frac{1}{n}} \text{ where } n > 1$$

In this relation k is a constant at a given temperature and depends upon the nature of the adsorbate and adsorbent. The value of n changes with pressure. It is 1 at low pressures and increases with pressure. The relationship is valid at a constant temperature. Therefore, it is called **Freundlich Adsorption Isotherm**. On taking logarithm of the above equation, we get

$$\log \frac{x}{m} = \log k + \frac{1}{n} \log p$$

This is an equation of a straight line and a plot of $\log \frac{x}{m}$ against $\log p$ should be a straight

line with slope $\frac{1}{n}$ as depicted in Fig. 17.6. In actual practice, a straight line is obtained provided the data at very low and very high pressures is neglected.



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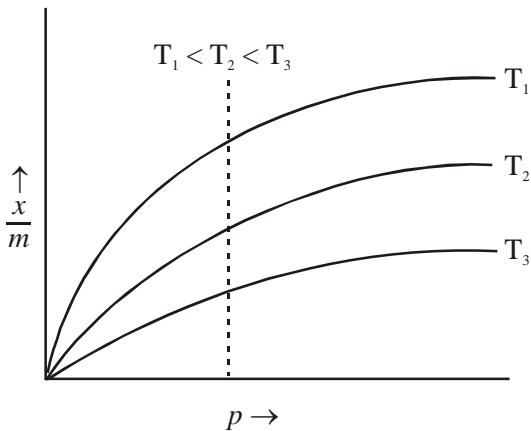


Fig. 17.5 : Adsorption isotherm of a gas

Chemical Dynamics



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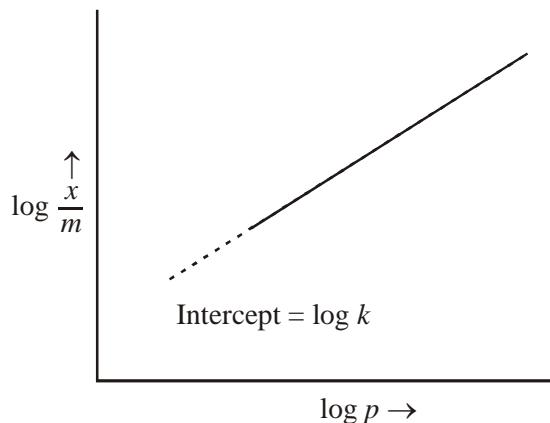


Fig. 17.6 : Plot of $\log \frac{x}{m}$ against $\log p$.

17.1.5 Langmuir Adsorption Isotherm

Adsorption Isotherm : One of the drawbacks of the Freundlich adsorption isotherm is that it fails at high pressure of the gas. Langmuir derived an adsorption isotherm on theoretical considerations based on kinetic theory of gases. This is named as the Langmuir adsorption isotherm. This isotherm is based on the assumption that every adsorption site is equivalent and that the ability of a particle to bind there is independent of whether or not nearby sites are occupied. In his derivation, Langmuir considered adsorption to consist of the following two opposing processes :

Asorption of the gas molecules on the surface of the solid.

Desorption of the adsorbed molecules from the surface of the solid.

Langmuir believed that eventually a dynamic equilibrium is established between the above two opposing processes. He also assumed that the layer of the adsorbed gas is only one molecule thick i.e., unimolecular. Since such type of adsorption is obtained in the case of **chemisorption**. Langmuir adsorption isotherm works particularly well for chemisorption.

The Langmuir adsorption isotherm is represented by the relation.

$$\frac{x}{m} = \frac{a p}{1 + b p} \quad \dots(17.1)$$

where a and b are two Langmuir parameters. At very high pressure, the above isotherm acquires the limiting form.

$$\frac{x}{m} = \frac{a}{b} \text{ (at very high pressure)} \quad \dots(17.2)$$

At very low pressure, Eq. (17.1) is reduced to $x/m = ap$ (at very low pressure)

$$\dots(17.3)$$

In order to determine the parameters a and b , Eq. (17.1) may be written in its inverse form:

$$\frac{m}{x} = \frac{1 + bp}{ap} = \frac{b}{a} + \frac{1}{ap} \quad \dots(17.4)$$



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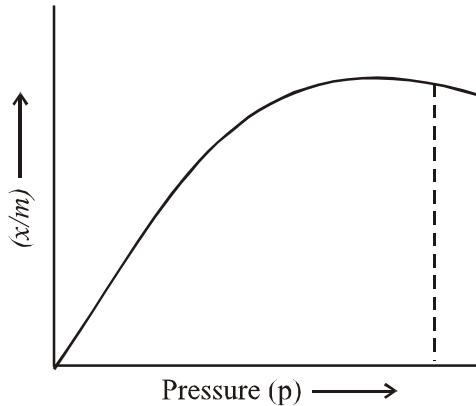


Fig. 17.7 : Langmuir Adsorption isotherm.

(ii) Adsorption from Solutions.

Adsorption occurs from solutions also. The solute gets adsorbed on the surface of a solid adsorbent. Charcoal, a good adsorbent, is often used to adsorb acetic acid, oxalic acid and organic dyestuffs from their aqueous solutions.

The extent of adsorption, $\frac{x}{m}$ depends upon the concentration c of the solute. Freundlich isotherm is applicable to adsorption from solutions when concentration is used in place of pressure as shown below.

$$\frac{x}{m} = k c^{\frac{1}{n}}$$

and in the logarithmic form as

$$\log \frac{x}{m} = \log k + \frac{1}{n} \log c$$

The plot of $\log \frac{x}{m}$ against c is also a straight line, provided very low and very high concentrations are avoided.

17.1.6 Applications of Adsorption

The phenomenon of adsorption finds many applications, some of which are given below:

1. Activated charcoal is used in gas masks in which toxic gases are adsorbed and air passes through it.

Chemical Dynamics

Notes

2. Silica gel packed in small cloth bags is used for adsorbing moisture in bottles of medicine and in small electronic instruments.
3. Animal charcoal is used for decolorizing many compounds during their manufacture.
4. In chromatography, the selective adsorption of different solutes on the surface of solid adsorbent helps in their separation.
5. Mordants are used during dyeing process with certain dyes. In such cases, the mordants fix the dye on the fabric by adsorption.

**Intext Questions 17.1**

1. Indicate which of the following statements are true or false. (T/F)
 - (i) More easily liquifiable gases are adsorbed more strongly.
 - (ii) Non-porous adsorbents would adsorb more quantity of a gas than porous adsorbents under similar conditions.
 - (iii) The extent of adsorption increases with rise in temperature.
 - (iv) Chemisorption is highly specific in nature.
 - (v) Adsorption can occur from solutions also.
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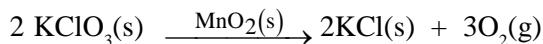
17.2 Catalysis

When hydrogen and oxygen gases are kept in contact with each other, no observable reaction occurs. If we add a small piece of platinum gauge in the mixture of these gases, the reaction occurs readily. Here platinum gauge speeds up the reaction and is called a **catalyst**.

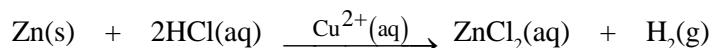
A catalyst is a substance which changes the rate of a reaction but remains chemically unchanged at the end of the reaction.

The phenomenon of change of reaction rate by addition of a substance which itself remains unchanged chemically is called **catalysis**. The following are some more examples of catalysis:

- (i) Decomposition of potassium chlorate occurs at high temperature. If a small amount of the manganese dioxide is added, the decomposition occurs at much lower temperature. Here, manganese dioxide acts as catalyst.



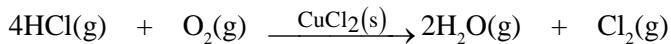
- (ii) The evolution of hydrogen by the reaction between zinc and hydrochloric acid is catalysed by $\text{Cu}^{2+}(\text{aq})$ ions.





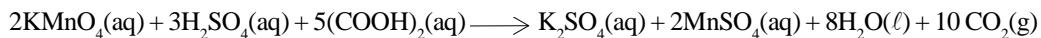
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- (iii) The oxidation of hydrogen chloride gas by oxygen occurs more quickly if the gases are passed over cupric chloride.



Auto-catalysis

In certain reactions, one of the products of the reaction acts as the catalyst. For example, the oxidation of oxalic acid by acidified potassium permanganate occurs as



At room temperature, the reaction is quite slow in the beginning. Gradually it becomes fast due to the catalytic action of Mn^{2+} ions which are one of the products as MnSO_4 in the reaction.

The phenomenon in which one of the products of a reaction acts as a catalyst is known as auto-catalysis.

Negative Catalysis

Some catalysts retard a reaction rather than speed it up. They are known as negative catalysts. For example :

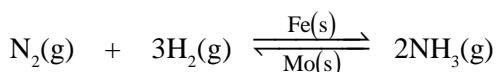
- (i) Glycerol retards the decomposition of hydrogen peroxide.
- (ii) Phenol retards the oxidation of sulphurous acid.

Promoters and Poisons

Certain substances increase or decrease the activity of the catalyst, although, by themselves they do not show any catalytic activity.

*The substances which increase the activity of a catalyst are called **promoters** and those which decrease the activity of a catalyst are called **poisons**.* For example :

- (i) In Haber's process for the manufacture of ammonia, the catalytic activity of iron is enhanced by molybdenum which acts as promoter.



- (ii) Copper promotes the catalytic activity of nickel during hydrogenation of oils.
- (iii) In Haber's process the catalyst iron is poisoned by hydrogen sulphide H_2S .
- (iv) In contact process for the manufacture of sulphuric acid, the catalyst platinum is poisoned by even the traces of arsenious oxide As_2O_3 .

17.2.1 General Characteristics of a Catalyst

The following are the general characteristics of a catalyst :

- (i) A catalyst remains unchanged at the end of the reaction.

Chemical Dynamics



Notes

The amount and the chemical composition of a catalyst remain unchanged in a catalytic reaction. However, the catalyst may undergo a physical change. For example, manganese dioxide, which is used as a catalyst in thermal decomposition of potassium chlorate becomes powder during the course of the reaction.

(ii) A small quantity of the catalyst is generally enough.

In most of the reactions, only a minute amount of catalyst is required. Only one gram of Cu^{2+} ions is sufficient to catalyse the oxidation of 10^9 litres of sodium sulphite solution. In some cases, the rate of reaction is directly proportional to the concentration of catalyst present. Catalysis by acids or bases is usually of this type.

(iii) A catalyst does not alter the position of equilibrium state of a reversible reaction.

A catalyst allows the equilibrium to be reached faster. However, it does not alter the equilibrium composition of the reaction mixture. It is because, a catalyst increases the rates of forward and backward reaction equally.

(iv) Catalysts are generally specific in their action.

Generally, one catalyst will change the rate of only one reaction. For example, manganese dioxide catalyses the decomposition of potassium chlorate but not of potassium perchlorate.

(v) A catalyst cannot initiate a reaction.

A catalyst can change the rate of a reaction which occurs even in the absence of catalyst.
It cannot start a reaction.

(vi) The activity of a catalyst can be increased by the presence of promoters and decreased by the presence of poisons.

Presence of a promoter increases the activity of a catalyst, while the presence of a poison decreases it.

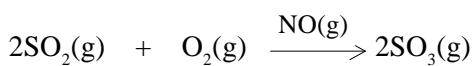
17.2.2 Homogeneous and Heterogeneous Catalysis

The phenomenon of catalysis can be divided into two main types – homogeneous and heterogeneous catalysis, on the bases of the number of phases present in the reaction mixture (A phase is a homogeneous part of a system).

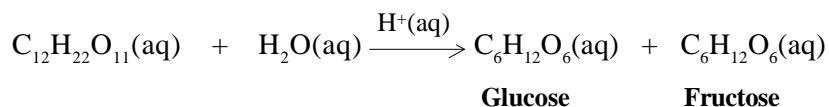
(a) *Homogeneous Catalysis*

When the catalyst is present in the same phase as the reactants, the phenomenon is called **homogeneous catalysis**. For example :

(i) Nitric oxide catalyses the oxidation of sulphur dioxide to sulphur trioxide in the lead chamber process.



(ii) Hydrogen ions catalyse the *inversion of cane sugar*



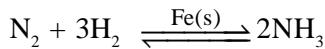


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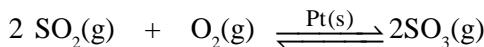
(b) Heterogeneous Catalysis

When the catalyst is present in a phase other than that of reactants the phenomenon is called **heterogeneous catalysis**. For example :

- (i) Iron (s) catalyses the formation of NH_3 gas.



- (ii) In contact process for the manufacture of sulphuric acid, platinized asbestos is used as the catalyst

**17.2.3 Catalysis and Activation Energy**

We have seen that a catalyst increases the rate of a reaction. We explain it by considering the Fig 17.8.

In this figure E_a is the activation energy of uncatalysed reaction and E'_a is the activation energy of the catalysed reaction. A catalyst lowers the activation energy as you can see in the figure ($E'_a < E_a$). The reduction in activation energy is achieved by providing an alternative pathway of lower energy for the reaction.

You can also see in this figure that the relative energies of reactants and products are not changed. The enthalpy change is the same for the catalysed and uncatalysed reactions.

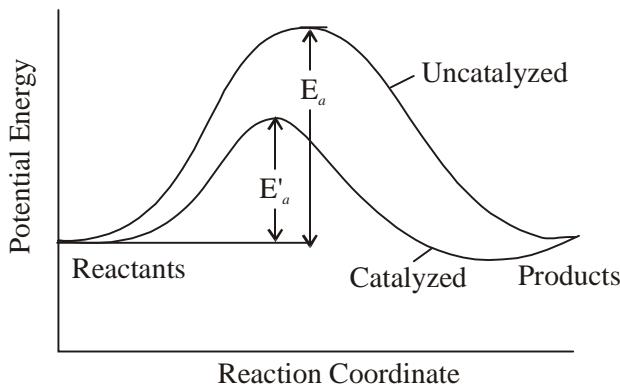


Fig. 17.8 : Graphical representation of the effect of catalyst on a reaction.

**Intext Questions 17.2**

1. List any two characteristics of a catalyst.

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Chemical Dynamics

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2. A small amount of alcohol when added to a solution of sodium sulphite slows down its oxidation to sodium sulphate. What type of catalyst is alcohol?
.....
 3. How would the activation energy be affected in the above reaction (given in Q.No.2) on adding the alcohol?
.....
 4. Addition of molybdenum enhances the catalytic activity of iron in the Haber's process for the manufacture of ammonia. What are the substances like molybdenum called?
.....
-

**What You Have Learnt**

- The phenomenon of attracting and retaining the molecules of a gas or of a dissolved substance on the surface of a solid is called adsorption.
- The substance which gets adsorbed is called the adsorbate and the solid substance which adsorbs is called the adsorbent.
- The substances that are porous in nature and have rough surfaces are better adsorbent.
- Easily liquifiable gases are more readily adsorbed.
- Extent of adsorption decreases with rise in temperature and increases with the increase in pressure of the gas.
- Physical adsorption is due to van der Waal forces and chemisorption is due to forces similar to chemical bonds.
- Pressure dependence of adsorption of a gas at a constant temperature is given by Freundlich Adsorption Isotherm

$$\frac{x}{m} = k p^{\frac{1}{n}}$$

- A catalyst is the substance which changes the rate of a reaction, but itself remains chemically unchanged during the reaction.
- The catalysts which increase the rate of a reaction are called the positive catalysts while those which decrease the rate are called the negative catalysts.
- Auto catalysed reactions are those in which one of the products acts as the catalyst.
- A promoter enhances the activity of a catalyst while a poison hampers it.
- A catalyst can't initiate a reaction, nor can it alter the position of equilibrium state of a reversible reaction.
- When the catalyst is present in the same phase as the reactants it is called a homogeneous catalyst.

- When the catalyst is present in a phase other than that of reactants it is called a heterogenous catalyst.
- A catalyst changes the rate of a reaction by changing its path and the activation energy.



Terminal Exercise

Notes

1. What is the difference between adsorption and absorption?
2. Distinguish between physical and chemical adsorption.
3. List the factors that affect adsorption.
4. What type of solids make better adsorbents?
5. Easily liquifiable gases are adsorbed more readily. Explain.
6. What is 'extent of adsorption'?
7. How does extent of adsorption vary with temperature in case of (i) physical adsorption and (ii) chemisorption? Depict graphically.
8. What is enthalpy of adsorption?
9. Explain the effect of temperature on extent of physical adsorption with the help of Le Chatelier's Principle.
10. What is an adsorption isotherm?
11. State mathematically Freundlich Adsorption Isotherm and depict it graphically. Under what conditions is it applicable.
12. Give the mathematical equation of Frundlich Isotherm for adsorption of solutes from solutions.
13. Give any three applications of adsorption.
14. What is a (i) catalyst and (ii) negative catalyst?
15. What are promoters and poisons? Give one example of each.
16. What is auto catalysis. Give one example.
17. Give any five characteristics of catalysis.
18. Distinguish between homogeneous and heterogeneous catalysis.
19. Give two examples each of homogeneous and heterogenous catalysis.
20. How does a catalyst change the rate of reaction. Explain with the help of appropriate example.

Chemical Dynamics

Notes

**Answers to the Intext Questions****17.1**

- (i) T, (ii) F, (iii) F, (iv) T, (v) T

17.2

1. See text section 17.2.1
2. Negative catalyst
3. Increase
4. Promoters

SENIOR SECONDARY COURSE

CHEMISTRY

Student's Assignment – 4

Maximum Marks: 50

Time : $1\frac{1}{2}$ Hours

INSTRUCTIONS

- Answer all the questions on a separate sheet of paper.
- Give the following information on your answer sheet:
 - Name
 - Enrolment Number
 - Subject
 - Assignment Number
 - Address
- Get your assignment checked by the subject teacher at your study centre so that you get positive feedback about your performance.

Do not send your assignment to NIOS

1. (a) Classify the following as electrolytes and non-electrolytes : sodium chloride, iodine, oxalic acid, alcohol.
(b) Give units of equivalent conductance.
(c) Identify anode and cathode in the following cell :
$$\text{Zn} | \text{Zn}^{2+} || \text{Cn}^{2+} | \text{Cu.}$$

(d) List the factors which affect the rate of a reaction.
(e) Give the relation between half-change period of a first order reaction and its rate constant.
(f) What is a buffer solution?
(g) What is the requirement for precipitating a sparingly soluble salt?
(h) What is overall order of a reaction?
(i) Name two characteristics of a catalyst.
(j) Define the term pH. $1 \times 10 = 10$
2. (a) How many electrons are required for discharging 0.5 mol of Al^{3+} ions.
(b) Draw a graph and label it showing the variation of equivalent conductance of sodium chloride and sodium bicarbonate.
(c) Predict the redox reaction between zinc and lead. Given
 E° of $\text{Zn}^{2+} | \text{Zn}$ is -0.763 V and that of $\text{Pb}^{2+} / \text{Pb}$ is -0.125 V

- (d) The Rate constant of a first order reaction is 0.024 hr^{-1} . What will be its initial rate if the initial concentration of the reactant is 0.3 mol L^{-1} ?
- (e) Draw and label a diagram showing energy changes during the course of an endothermic reaction.
- (f) Which of the following pairs is the weaker acid or weaker base :
- (i) CH_3COOH and HCN
 - (ii) H_2O and H_3O^+
 - (iii) F^- and NO_3^-
 - (iv) NH_3 and SO_4^{3-}
- (g) What is the hydrogen ion concentration in 10^{-4} NaOH solution?
- (h) Differentiate adsorption from absorption.
- (i) Define the laws of electrolysis.
- (j) Write an expression for the half life period of first order reaction. $(2 \times 10 = 20)$
3. (a) How many molecules of chlorine would be deposited from molten sodium chloride in five minutes by a current of 60 milliamperes?
- (b) The decomposition of Cl_2O_7 in gaseous phase into O_2 and Cl_2 is a first order reaction.
- (i) After 55 seconds the pressure of Cl_2O_7 falls from 0.62 to 0.44 atmosphere at 450 K.
Calculate the rate constant.
- (ii) Calculate the half change period of the reaction at 450 K.
- (c) What is the pH of a solution prepared by dissolving 5g NaOH in 500 mL water?
- (d) Calculate the Gib's free energy ΔG° for the reaction occurring in the cell
- $$\text{Zn(s)} + \text{Cu}^{2+}_{(\text{aq})} \rightleftharpoons \text{Zn}^{2+}_{(\text{aq})} + \text{Cu(s)} ; E^\circ_{\text{cell}} = 1.10\text{V} \quad (3 \times 4 = 12)$$
4. (a) At 300 K solubility of AgCl in water is $1.30 \times 10^{-3} \text{ mol L}^{-1}$.
- (i) Calculate its solubility product.
- (ii) What will be the solubility of AgCl in 0.1 M KCl at 300 K?
- (b) What would be the activation energy of a reaction whose rate becomes three times when the temperature is raised by 10°C from 27°C to 37°C ? $(4 \times 2 = 8)$

TERMS YOU SHOULD KNOW

Acceleration due to gravity: Acceleration with which a body would fall freely under the action of gravity in vacuum.

Amorphous solid: That solid in which particles have only short range order.

Ampere: SI unit of electric current. It is the current which, if maintained in two parallel conductors of infinite length, of negligible cross-section, and placed 1 metre apart in vacuum, would produce between the conductors a force equal 2×10^{-7} newtons per metre of length.

Atom: The smallest portion of an element that can take part in a chemical reaction.

Avogadro's constant: Number of atoms or molecules in a mole of a substance. It is equal to $6.022 \times 10^{23} \text{ mol}^{-1}$.

Boiling point: That temperature at which the vapour pressure of a liquid is equal to the atmospheric pressure is known as the boiling point of the liquid. Boiling point at one atmosphere; 760 torr, or 760 mm Hg is referred to as normal boiling point.

Candela: Fundamental SI unit of luminous intensity.

Condensation: The change of vapour into liquid.

Covalent solids: Those solids which have ordered arrangement of atoms held by continuous covalent bonds.

Critical temperature: The temperature above which a given gas cannot be liquified.

Crystalline solid: That solid which has repetitive well-ordered arrangement of particles.

Density: The mass of unit volume of a substance, usually expressed in kg./m³.

Diffusion: General transport of matter where by molecules or ions mix through normal thermal agitation.

Effusion: The passage of gases through small apertures under pressure.

Empirical Formula: Formula deduced from the results of analysis which is the simplest expression of the ratio of the atoms in substance.

Energy: The capacity of body for doing work.

Evaporation: The conversion of a liquid into vapour, at temperatures below the boiling point.

Frequency: Number of oscillations in unit time, usually one second. SI unit of frequency is hertz.

Gas: A state of matter in which the molecules move freely, thereby causing the matter to expand indefinitely, occupying the total volume of any vessel in which it is contained.

Ideal Gas: Gas with molecules of negligible size and exerting no intermolecular forces. Such a gas is a hypothetical gas which would obey the ideal gas law under all conditions.

Intermolecular forces: The forces binding one molecule to another.

Ion: Any atom or molecule which has a resultant electric charge due to loss or gain of valence electrons.

Kelvin: Thermodynamic scale of temperature.



Notes

Glossary



Notes

Liquid: A state of matter between a solid and a gas, in which the shape of a given mass depends on the containing vessel, the volume being independent.

Mass: Quantity of matter in a body.

Mole: The amount of substance that contains as many entities (atoms molecules, ions, electrons etc) as there are atoms in 12 g of ^{12}C .

Metallic solid: Those solids which have ordered arrangement of positive ions embedded in the valence electrons belonging to the crystal as a whole instead of any single atom.

Molecular solid: Those solids which have ordered arrangement of molecule or atoms held by weak van Waals forces.

Molecule: The smallest portion of substance capable of existing independently and retaining the properties of the original substance.

Vapour Pressure: The pressure exerted by the quantity of vapour above the liquid, when equilibrium is established is called the vapour pressure of the liquid.

Weight: gravitational force acting on a body at the earth's surface, Weight = mass \times acceleration due to gravity.

Alkali Metals : The chemical family headed by Lithium group 1 in the periodic table.

Alkaline Earth metals : the chemical family headed by beryllium; group 2 in the periodic table.

Bond angle : The angle between the two lines representing bonds joining the nuclei of these atoms.

Bond distance : The average distance between two nuclei in a chemical bond.

Bond energy : The energy required to break a chemical bond between two atoms into two neutral fragments.

Covalent bond : A Chemical bond formed by two atoms sharing a pair, or pairs, of electrons.

Deliquescent : A term used to describe compounds that remove enough water from their surroundings to dissolve themselves completely.

Double bond : A covalent bond that shares four electrons.

Electron-dot formula : A representation of atom, ion, or molecule using dots to symbolise the electrons.

Electronegativity : The ability of an atom in a covalent bond to attract the shared pair of electron to itself.

Glossary



Notes

Electrovalent bond	: A chemical bond formed by the attraction of a positive ion for negative ion.
Group	: A vertical column of elements in the periodic table.
Halogens	: The chemical family headed by flourine; group 17 in the periodic table.
Hydride	: Compounds of hydrogen where hydrogen has oxidation number -1.
Hydrogen bond	: A weak electrostatic attraction between a hydrogen nucleus bound to a highly electronegative atom (either oxygen, flourine or nitrogen) in one molecule and one of these highly electronegative atoms in a second molecule.
Hygroscopic	: Having a tendency to absorb moisture.
Ionization energy	: The energy required to remove an electron from an atom or ion.
Lewis acid	: A species that can accept a pair of electrons.
Lewis base	: An electron-rich species that has one unshared pair of electrons.
Lewis structures	: Electron-dot representations of the arrangement of atoms, ions, or molecules.
Metalloid	: An element that lies on the dividing line between metals and non-metals. It has some properties intermediate between each type.
Moderator	: A substance used in a nuclear reactor core to slow down neutrons.
Noble Gases	: A chemical family headed by helium. Krypton and xenon of this family are reactive to some extent, but the rest of the family appears to be chemically inert.
Octet rule	: Atoms in chemical changes (with few exceptions) tend to acquire noble gas configurations of $s^2 p^6$.
Oxidation number	: A positive or negative number that represents the charge that an atom appears to have when the bonding electrons are counted using some rather arbitrary rules.
Oxide	: A compound of oxygen.



Notes

Glossary

Period	:	A horizontal row of elements in the periodic table.
Periodic law	:	The properties of elements are periodic functions of their atomic numbers.
Periodic Table	:	A systematic arrangement of the known elements according to increasing atomic number.
Polar bond	:	A covalent bond that is shared unequally between two atoms. It has positive and negative side.
Triple bond	:	Two atoms sharing six electrons.
Valence electrons	:	The electrons located in the outer most principal energy level.

STUDENT FEEDBACK FORM

Senior Secondary Course

Name _____

Enrolment No. _____

Subject —

Book No. _____

Dear Learner,

We, at National Open School, are always trying to make our courses relevant to your needs. In order to get appropriate feedback from you so that we can improve the study material accordingly, we are enclosing this form. Please fill in the form and post it back to us at the following address:

Deputy Education Officer

National Open School

B-31, Kailash Colony,

New Delhi - 110 048.

1. Classify all the lessons of this book in the following table:

2. Which sections in this book you think need more explanation, examples or illustrations?

3. Indicate the Intext Question number and the question number (s) you found difficult to answer.

4. Could you answer the **Terminal Questions** of all the lessons?

5. Was any question difficult to answer?
if yes. indicate the lesson number and the question number?

6. Does the summary “**What you have learnt**” given at the end of each lesson help you to revise the lesson?

Yes/No

7. What format of “**What you have learnt**” do you like best?

- Point wise (as in Economics/Hindi)
- Flow chart (as in Home Science)
- Given in a paragraph (as in Political Science/Geography)

8. Did you find the **glossary** given in the lessons adequate

Yes/No

If no, please indicate the words that you want to be included.

9. Did you complete your student assignment of this book?

10. Did you face any difficulty in doing the assignment?

11. If yes, please specify your difficulties.

12. Did you get the assignment checked by your teacher at the AI?

13. Did you face any difficulty in getting them evaluated?

NATIONAL OPEN SCHOOL
Senior Secondary Curriculum in Chemistry

RATIONALE

According to present scheme of school education at Senior Secondary stage, chemistry emerges out as a separate discipline. It is this stage where major emphasis is to be laid on providing suitable conceptual foundation

The present chemistry course has been developed basically around the themes: Why do chemical reactions occur? What is the quantitative relationship among reacting constituents in a chemical reaction? How far and how fast will a chemical reaction proceed under a given set of conditions? Can we predict whether a chemical reaction will occur or not? What is the relation between the structure of a chemical substance and its functions/properties? In what way is a chemical reaction relevant for getting new types of substances and materials for daily life and chemical industries?

In the present course, there is no compartmentalisation like physical, inorganic and organic chemistry. However, basic chemical concepts considered necessary in the study of descriptive chemistry (inorganic and organic) are provided in the beginning of the course and an effort has been made to provide a disciplinary structure to chemistry and, therefore, a logical sequencing of concepts is provided. Applications of chemistry in daily life have been interwoven with the conceptual themes in such a way that learners can appreciate the importance of the study of chemistry relevant to daily life and in the economic development of the country. Some interdisciplinary aspects have also been provided to make the course more meaningful and functional.

OBJECTIVES OF THE COURSE

It is expected that a learner will be able to:

- *understand* the principles, theories and laws of chemistry responsible for various chemical processes/reactions,
- *realise* the role of chemistry in production of many elements (metals/non-metals) and compounds useful in industries and daily life,
- *appreciate* the chemical nature of inorganic and organic substances around him/her,
- *choose* various vocational, professional and applied courses of his/her choice based on knowledge of chemistry gained.

Apart from this, the present course also aims at developing the following capacity in the learner:

- *perform* chemical calculations to know about the chemical reactions and chemical compounds,
- *explain* chemical reactions, concepts and phenomenon,
- *develop* awareness about uses and abuses of chemical substances,
- *develop* skills arranging/setting up apparatus, handling apparatus and chemicals properly, and
- *analyse* and synthesise simple compounds.

SPECIAL FEATURES OF THE COURSE

The academic standard of the present chemistry course is comparable with the chemistry course of any State Education Board or Central Board of Secondary Education, New Delhi. Considering the nature of open learning system, it has not been found desirable to divide the course into class XI and class XII. The rationale behind the course is that every lesson has a role to play in understanding the holistic view of chemistry.

The course also provides optional modules ‘mostly of applied nature’ out of which a student can choose one module according to his/her choice of career. Thus, there are seven core modules and two optional modules. A student appearing for senior secondary examination is expected to offer all the seven core modules, one module out of two optional modules, and practicals. All the core and optional modules are listed below:

CORE MODULES

<i>S.No.</i>	<i>Module</i>	<i>Marks Alloted</i>	<i>Study Hours</i>
1.	Atom Molecule and Chemical Arithmatics	7	14
2.	Atomic Structure and Chemical Bonding	12	33
3.	States of Matter	12	18
4.	Chemical Energetics	8	23
5.	Chemical Dynamics	8	19
6.	Chemistry of Elements	10	48
7.	Chemistry of Organic Compounds	12	48

OPTIONAL MODULES

I.	Environmental Chemistry	15
II.	Chemistry and Industry	37
	Total	80

A detailed curriculum is given for your ready reference

Sr. Secondary Chemistry Curriculum

CORE MODULES

MODULE 1:ATOMS MOLECULES AND CHEMICAL ARITHMATICS

Lesson 1 Mole Concept

- A simple idea of basic SI units
- Counting and weighing of atoms and molecules
- Avogadro constant
- Molar quantities

Lesson 2 Chemical Arithmetic

- Chemical formula and percentage composition
- Empirical and molecular formulae
- Mole, Mass, Volume relationships in chemical reactions
- Limiting reagent concept and percentage yield

MODULE 2:ATOMS STRUCTURE AND CHEMICAL ARITHMATICS

Lesson 3 Chemical Arithmaties

- Fundamental particles of an atom (electron, Proton, Neutron)
- Rutherford's nuclear model
- Electromagnetic spectrum
- Line spectra of H-atom: Bohr model (no derivation)
- Wave-particle duality: Heisenberg's uncertainty principle
- The wave mechanical model-orbitals (probability picture may be emphasised),
- Quantum numbers
- Pauli's exclusion principle
- Aufbau Principle-electronic configuration of atoms
- Types of orbitals (s,p,d,f): shapes of s,p,d orbitals
- Hund's rule

Lesson 4 Periodic Table and Atomic Properties

- Long Form of periodic table and IUPAC nomenclature for elements with $Z > 110$ (brief mention)
- Variation in atomic properties (size, ionization energy, electron affinity, valency and electronegativity)

Lesson 5 Chemical Bonding

- Why do atoms combine? (potential-energy diagram)

- Types of bonds and their characteristics (Ionic, Covalent, Coordinate, Metallic)
- Shapes of molecules, Introduction to VSEPR theory (upto 6 electron pairs only)
- Hybridization of atomic orbitals
- Multiple covalent bonds (σ, π) e.g. $\text{C}_2\text{H}_4, \text{C}_2\text{H}_2$
- M.O. Theory, Homonuclear molecule ($\text{H}_2, \text{N}_2, \text{O}_2, \text{F}_2$), Bond Parameters
- Hydrogen Bonding

MODULE 3: STATES OF MATTER

Lesson 6 Gaseous State

- Properties
- Boyle's Law
- Charles law-Kelvin Temperature Scale
- Avogadro's Law
- Dalton's law of partial pressures
- Ideal gas equation
- The kinetic molecular theory of gases (no derivation)
- Graham's law of diffusion
- real gases-deviations from ideal gas behavior, Van der Waal equation Liquefaction of gases, critical Constants

Lesson 7 Liquid State

- Properties of liquids
- Vapour pressure
- Surface tension
- Viscosity

Lesson 8 Solid State

- Properties of solids
- Classification of solids
- Unit cell and their types
- Packing in crystals
- Structure of simple ionic compounds
- Imperfections in solids (Frenkel, Schottky defects)

Lesson 9 Solutions

- Solution, solute and solvent
- Concentration of solutions-molarity, molality, mole fraction, percentage and Strength
- Types of solutions
- Raoult's law
- Ideal and non-ideal solutions
- Colligative properties of solutions

- Van't Hoff factor

Lesson 10 Colloids

- The Colloidal Solution
- True solution, colloidal solution and suspension
- Classification of colloids
- Preparation and properties of colloidal solutions
- Applications of colloids

MODULE 4: CHEMICAL ENERGETICS

Lesson 11 Chemical Thermodynamics

- System : Isolated, closed and open systems
- Processes: cyclic, isothermal, adiabatic, reversible and irreversible
- Standard state of a substance
- Exothermic and endothermic reactions
- Thermochemical equations
- Concept of internal energy and enthalpy change, relationship between ΔH and ΔU ,
- Ist law of thermodynamics
- Standard enthalpy of reactions
- Enthalpy changes during a reaction: enthalpy of formation, enthalpy of combustion, enthalpy of neutralization
- Hess's law and its applications
- Bond enthalpy

Lesson 12 Spontaneity of Chemical Reactions

- Concept of entropy, entropy change and spontaneity
- IInd law of thermodynamics
- Concept of free energy, relationship between G_H and S
- Free energy change and spontaneity of a chemical reaction
- Standard free energy of formation
- Free energy change and chemical equilibrium
- IIIrd law of thermodynamics and its significance (illustrative)

MODULE 5: CHEMICAL DYNAMICS

Lesson 13 Chemical Equilibrium

- Dynamic nature of equilibrium; Factors affecting equilibrium
- Reversible and irreversible reactions
- Types of equilibrium system: Homogeneous and heterogeneous systems
- Laws of chemical equilibrium
- Relationship between K_c and K_p
- Le Chatelier's Principle and its applications

Lesson 14 Ionic Equilibria

- Acid-base equilibrium
- Ionisation constant of lead acids and bases
- Ionization of water
- pH value
- Common Ion effect
- Buffer solutions, Henderson equation
- Solubility equilibrium, solubility product and its applications
- Salt Hydrolysis
- Acid base titration

Lesson 15 Electrochemistry

- Oxidation and Reduction (Electron transfer concept)
- Oxidation number, balancing of Redox reaction by oxidation number method
- Types of cells: Electrolytic and electrochemical
- Electrolytic conduction (Conductance, conductivity molar conductivity, effect of dilution, Kohlrausch's law)
- Standard electrode potential
- Electrochemical series and its applications
- Effect of concentration of electrode potentials (Nernst equation)
- Relationship between emf and free energy change

Lesson 16 Chemical Kinetics

- Rate of Reaction: Average and Instantaneous
- Expressions for reaction rates
- Factors affecting rate of reaction
- Rate law
- Order of a reaction
- First order reaction
- Half change period
- Effect of temperature on reaction rate

Lesson 17 Adsorption and Catalysis

- Adsorption-Physical and Chemical
- Adsorption Isotherms (Freundlich and Langmuir)
- Catalysis-Homogenous and Heterogeneous
- Activation energy

MODULE 6 Chemistry of Elements

Lesson 18 Occurrence And Extraction of Metals

- Occurrence of metals
- Important ores of some common elements : Na, Al, Sn, Pb, Ti, Fe, Cu, Ag and Zn

- General principles involved in the isolation of metals from their ores (concentration of the ore, reduction and refining)

Lesson 19 Hydrogen and s-Block Elements

- Unique position of H₂ in Periodic
- Properties reactions and uses
- Isotopes of hydrogen
- Water structure and aggregation of water molecules, Heavy Water
- Hydrogen peroxide
- Alkali Metals and Alkaline earth metals- occurrence, electronic configuration trends in atomic and physical properties, reactivity electrode potential,
- Reaction with oxygen, hydrogen, halogens and water
- Solubility and thermal stability of their oxo salts.

Lesson 20 General characteristics of The p-block elements

- Occurrence in nature and electronic configuration, (physical and chemical properties)
- Inert pair effect
- Anomalous properties of first element

Lesson 21 p-Block elements and Their Compounds-I

- Boron family-borax, boric acid, boron hydrides, halides.
- Carbon family-allotropes (graphite, diamond, elementary idea of fullerenes)
- Oxides, carbides, halides
- Nitrogen family-Ammonia, Nitric acid, fertilizer (N,P) and fixation of nitrogen industrial and biological
- Nitrogenous and phosphatic fertilisers

Lesson 22 p-Block Elements and their compounds-II

- Oxygen family-oxides, acidic, basic and amphoteric, Ozone (Oxidizing Properties)
- Halogens- Hydrides, oxides and oxoacids of chlorine.
- Bleaching powder-preparation and properties, Interhalogen compounds.
- Noble gases-compounds of xenon: xenon fluorides, oxides (preparation, structure)

Lesson 23 d-Block and f-Block elements

- Electronic configuration
- General trends in the Chemistry of first row transition elements

- Properties-metallic character, oxidation state, ionic radii, catalytic properties, coloured ions, complex formation, magnetic properties, interstitial compounds alloy formation.

- Preparation, properties and applications some important compounds:
- KMnO₄, K₂Cr₂O₇
- f-Block elements-configuration, properties and lanthanide contraction

Lesson 24 Coordination Compounds

- Werner's theory
- Nomenclature
- Bonding-V.B. Approach
- Applications (qualitative analysis, extraction of metals and biological systems)

MODULE 7 CHEMISTRY OF ORGANIC COMPOUNDS

Lesson 25 Nomenclature and General Principles

- Rules of IUPAC Nomenclature
- Types of bond fission
- Types of reactions: substitution, addition, elimination, oxidation/reduction (electrophilic and nucleophilic)
- Electron displacement in a covalent bond: inductive effect, electromeric effect,
- resonance and hyperconjugation, steric effect
- Isomerism-Structural isomerism, stereoisomerism

Lesson 26 Hydrocarbons

- Definition and types of hydrocarbons (Alkane, Alkene, alkyne, Arene)
- IUPAC nomenclature
- Preparation and Properties of Hydrocarbons
- Physical properties of hydrocarbons
- Chemical properties of hydrocarbons (addition, substitution, elimination, oxidation)

Lesson 27 Compounds of Carbon Containing Halogens (Haloalkanes and Haloarenes)

- IUPAC Nomenclature of halogen compounds
- Preparation of haloalkanes and haloarenes
- Physical and chemical properties and uses

Lesson 28 Alcohol, Phenols and Ethers

- Classification
- IUPAC Nomenclature
- Methods of preparation

- Physical and Chemical properties

Lesson 29 Aldehydes, Ketones and Carboxylic acids.

- Carboxylic Acids and acid derivatives
- IUPAC Nomenclature
- Preparation and Properties
- Interconversion of acid derivations

Lesson 30 Compounds of Carbon Containing Nitrogen

- Nitro compounds, amines
- Classification of amines
- IUPAC nomenclature
- Preparation and properties

Lesson 31 Biomolecules

- Difference between DNA and RNA
- Biomolecules in biological systems.
- Structures of proteins and carbohydrates

OPTIONAL MODULES

MODULE 1: ENVIRONMENTAL CHEMISTRY

Lesson 32 Environment at concerns

- Idea of environment
- Threats to environment
- Pollutants

Lesson 33 Air Pollution

- Composition of air
- Respiration, photosynthesis and decay cycle
- Air pollutants
- Green house effect
- Global warming
- Depletion of ozone layer
- Acid rain

Lesson 34 Water Pollution

- Water resources
- Water pollutants
- Biological oxygen demand
- Prevention of water pollution

- Legislative measures for prevention of water pollution

Lesson 35 Heavy Metal Contamination

- Heavy metals
- Effects of heavy metal contamination
- Preventive measures

Lesson 36 Radioactive Pollution

- Radioactive sources
- III effects of radiation
- Preventive measures
- Regulation regarding safety

MODULE 2: CHEMISTRY AND INDUSTRY

Lesson 32 Petrochemicals

- Generations of petrochemicals
- Soaps and detergents
- Rocket propellants
- Pollutants and Indian Space Programs.

Lesson 33 Polymers

- Classification
- Teflax, polyester and nylons
- Biodegradable polymers
- Biopolymers

Lesson 34 Dyes. Paints and Pigments

- Composition
- Classification
- Process of dying
- Applications

Lesson 35 Drugs and Medicines

- Distinction between drugs and medicines
- Classification
- Analgesics and antipyretics
- Antibiotics and anaesthetics

Lesson 36 Building Materials

- Cement and its manufacture
- Mortar, Concrete and R.C.C
- Manufacture of glass
- Ceramics and day products

CURRICULUM FOR PRACTICAL WORK IN CHEMISTRY

Objectives of the present course in practical work are as follows:

1. To develop and inculcate laboratory skills and techniques
2. To enable the student to understand the basic chemical concepts.
3. To develop basic competence of analysing and synthesising chemical compounds and mixtures.

To meet these objectives three different types of laboratory experiments are provided in the present practical course.

1. Experiment for developing laboratory skills/techniques
2. Concept based experiments
3. Traditional experiments (for analysing and synthesizing chemicals)

List of Practicals

1. (i) General safety measures with special reference to safe handling of chemicals.
(ii) Aquaintance with chemistry laboratory and basic laboratory techniques (cutting, bending and boring of glass tubes, sealing of apparatus, filtration, distillation, crystallisation, preparation calibration, cleaning of glass apparatus and use of burner etc.)
(iii) Measurement of volume, length, mass and density and common errors therein.
2. Preparation, collection and study of some important physical and chemical properties of at least three gases, one each from the following groups.
 - (a) Hydrogen and oxygen
 - (b) Carbon dioxide and hydrogen sulphide
 - (d) Chlorine, hydrogen chloride, and sulphur dioxide
3. Preparation of dilute solutions of known concentration of sulphuric acid, hydrochloric acid and nitric acid. (Dilution should be carried out strictly under the supervision of a teacher).
4. Study of interaction of metals (any four) with salt solution and arranging them according to their activity (to form activity series). Metals and salts may be selected from the following
Mg, Zn, Fe, Sn, Pb, Cu and Al and their salts. (Checking the order of metals in series based on the electrode potential will be desirable).
5. (a) Determination of pH of following substances by using a universal indicator solution or pH papers.
 - (i) Salt solution
 - (ii) Acids and bases of different dilutions
 - (iii) Vegetable and fruit juices
(b) Study of pH change by common-ion effect in case of weak acids and weak bases by above

method (specific examples of CH_3COOH and CH_3COONa and NH_4OH and NH_4Cl may be taken).

6. Determination of melting point of a solid substance of low melting point (below 100°C) by glass capillary tube method (Paraffin oil may be used as bath).
7. Study of solubility of solid substances in water at different temperatures and plotting of a solubility curve.
8. Study of the shift in equilibrium between ferric ions and thiocyanate ions by increasing/decreasing the concentration of their ions.
9. Study of:
 - (a) the effect of concentration on the rate of reaction between sodium thio-sulphate and hydrochloric acid.
 - (b) the effect of temperature on the rate of reaction between sodium thiosulphate and hydrochloric acid.
10. Separation of coloured substances by paper chromatography, and comparison of their Rf values.
 - (a) a mixture of red and blue ink or a black ink.
 - (b) juice of a flower or grass.
11. Detection of nitrogen, sulphur and halogens in an organic compound (combinations of halogens to be avoided). Not more than two of the above elements should be present in the given organic compound.
12. Study of simple reactions of carbohydrates; fats and proteins. in pure form and detection of their presence in given food stuffs.
13. Preparation of soap by using different oils and its comparison with the market soap by determining the foaming capacity and cleaning effect.
14. Use of chemical balance to demonstrated.
 - (a) preparation of solution of oxalic acid and ferrous ammonium sulphate of known molarity by weighing (non-evaluative)
 - (b) A study of (i) acid-base and (ii) redox titrations (single titration only) (both the solutions to be provided).
 - (i) Oxalic acid
 - (ii) Ferrous ammonium sulphate and potassium permanganate.
15. Elementary qualitative analysis of a salt involving detection of one cationic and one anionic species from the following groups. (Salts insoluble in hydrochloric acid excluded).

Cations:

Pb^{2+} , Cu^{2+} , Fe^{3+} , Al^{3+} , Ni^{2+} , Zn^{2+}

Mn^{2+} , Ca^{2+} , NH^{4+}

Anions:

CO_3^{2-} , S^{2-} , Cl^- , Br^- , I^- , NO_2^- , NO_3^- , SO_4^{2-} , PO_4^{3-}

16. Functional groups in organic compounds
 - (i) Test of unsaturation
 - (ii) Test for Carboxylic, phenolic, aldehydic and ketonic groups.

PRACTICAL EXAMINATION

There will be a practical examination of 20 marks and 3 hours duration.

The distribution of marks is as follows.

	Marks
1. Salt Analysis (one cation + one anion)	4
2. Volumetric Analysis (i) write-up in which student may be asked to write brief method, indicator, equation, end point.	6
(ii) Set-up of experiment	2
(iii) Results	2
3. (i) Detection of elements in an organic compound (ii) Detection of functional group	2
OR	2
Setting up of one experiment from experiments at serial number 2 to 10, 12 and 13.	4
4. Viva-voce	3
5. Record book	3
Total	20