Chemical Reactions and Equations

1

NCERT SOLUTIONS

What's inside

– *In-Chapter Q's (solved)*

– *Textbook Exercise Q's (solved)*

IN-CHAPTER QUESTIONS

Test Yourself

1. Why should a magnesium ribbon be cleaned before burning in air?

Ans. Upon oxidation, magnesium is layered with magnesium oxide. Hence, it is cleaned using sandpaper, before use.

2. Write the balanced equation for the following chemical reactions :

(i) Hydrogen + Chlorine → Hydrogen chloride

(ii) Barium chloride + Aluminium sulphate → Barium sulphate + Aluminium chloride

(iii) Sodium + Water → Sodium hydroxide + Hydrogen

Ans. (i) $H_2 + Cl_2 \rightarrow 2HCl$

(ii) $3BaCl_2 + Al_2(SO_4)_3 \rightarrow 3BaSO_4 + 2AlCl_2$

(iii) $2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow$

3. Write a balanced chemical equation with state symbols for the following reactions:

(i) Solutions of barium chloride and sodium sulphate in water react to give insoluble barium sulphate and the solution of sodium chloride.

(ii) Sodium hydroxide solution (in water) reacts with a hydrochloric acid solution (in water) to produce sodium chloride solution and water.

Ans. (i) $BaCl_2\ (aq) + Na_2SO_4\ (aq) \rightarrow BaSO_4(s) + 2NaCl\ (aq)$

(ii) $NaOH\ (aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

Test Yourself

1. A solution of a substance 'X' is used for white washing.

(a) Name the substance 'X' and write its formula.

(b) Write the reaction of the substance 'X' named in (a) above with water.

Ans. (a) The substance whose solution in water is used for whitewashing is calcium oxide (or quicklime). Its formula is CaO.

(b) $\underset{\text{Calcium oxide (Quick lime)}}{CaO(s)} + H_2O(l) \longrightarrow \underset{\text{Calcium hydroxide (Slaked lime)}}{Ca(OH)_2(aq)}$

2. Why is the amount of gas collected in one of the test tubes in text book Activity 1.7 (*i.e.*, electrolysis of water) double of the amount collected in the other? Name this gas.

Ans. Since water is made up of two hydrogen atoms and one oxygen atom, the amount of gas collected in one test tube is twice that of the other. The name of the first gas

is hydrogen gas and the name of the second gas is oxygen gas.

A decomposition reaction is the exact opposite of a combination reaction. As hydrogen reacts with oxygen to form water and an electric current is passed through water, the electrolysis of water produces hydrogen and oxygen.

$2H_2\,(g) + O_2\,(g) \longrightarrow 2H_2O\,(l)$ (Combination)

$2H_2O(l) \xrightarrow[\text{decomposition}]{\text{Electrolysis}} 2H_2(g)O_2(g)$ (Decomposition)

Test Yourself

1. Why does the colour of copper sulphate solution change when an iron nail is dipped in it?

Ans. Because iron is a more reactive element than copper in this reaction. For this reason, they displace copper from its compound. Therefore, the color of the iron nail becomes brown and the color of the solution of copper sulphate becomes light blue.

$$\underset{\text{Copper Sulphate}}{Fe(s) + CuSO_4(aq)} \longrightarrow \underset{\text{Iron Sulphate}}{FeSO_4(aq)} + Cu(s)$$

2. Give an example of a double displacement reaction other than the one given in Activity 1.10 (NCERT).

Ans. When a solution of sodium chloride is added to a solution of silver nitrate, a white precipitate of silver chloride is formed.

$$NaCl + AgNO_3 \longrightarrow AgCl \uparrow + NaNO_3$$

3. Identify the substances that are oxidised and the substances which are reduced in the following reactions:

(i) $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

(ii) $CuO\,(s) + H_2(g) \rightarrow Cu\,(s) + H_2O(l)$

Ans. In reaction (i) Na is being changed from Na to Na_2O so sodium is oxidised to form Na_2O and oxygen is reduced.

In reaction (ii) CuO is oxidised to form Cu because oxygen is being lost from CuO. H_2 gets oxidised to H_2O because O_2 is increasing.

NCERT EXERCISES

1. Which statement is false regarding the reaction given below?

$2PbO(s) + C(s) \longrightarrow 2Pb(s) + CO_2(g)$

(a) Lead is reducing.

(b) Carbon dioxide is getting oxidised.

(c) Carbon is getting oxidised.

(d) Lead oxide is getting reduced.

(i) (a) and (b) **(ii) (a) and (c)**

(iii) (a), (b) and (c) **(iv) All**

Ans. (i) (a) and (b)

2. $Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$

What type of reaction is given above?

(a) Combination reaction

(b) Double displacement reaction.

(c) Decomposition reaction.

(d) Displacement reaction

Ans.(d) Displacement reaction

3. What happens when dilute hydrochloric acid is added to iron filings?

(a) Hydrogen gas and iron chloride are produced.

(b) Chlorine gas and iron hydroxide are produced.

(c) No reaction takes place.

(d) Iron salt and water are produced.

Ans.(a) Hydrogen gas and iron chloride are produced.

4. What is a balanced chemical equation? Why should chemical equations be balanced?

Ans. A chemical equation in which the number of atoms of different elements is equal on both sides is called a balanced chemical equation. It is necessary to balance it because it gives the correct information about the equation as well as the correct number of reactants and products.

5. Translate the following statements into chemical equations and then balance them.

(a) Hydrogen gas combines with nitrogen to form ammonia.

(b) Hydrogen sulfide gas burns in the air to give water and sulfur dioxide.

(c) Barium chloride reacts with aluminum sulphate to give aluminum chloride and a precipitate of barium sulphate.

(d) Potassium metal reacts with water to give potassium hydroxide and hydrogen gas.

Ans.(a) $N_2(g) + 3H_2(g) \rightarrow 2\ NH_3(g)$

(b) $2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(1) + 2SO_2(g)$

(c) $3BaCl_2(aq) + Al_2(SO_4)_3(aq) \rightarrow 2AlCl_3(aq) + 3BaSO_4\downarrow(s)$

(d) $2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

6.Balance the following chemical equations:

(a) $HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2 + H_2O$

(b) $NaOH + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$

(c) $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$

(d) $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + HCl$

Ans.(a) $2HNO_3 + Ca(OH)_2 \rightarrow Ca(NO_3)_2 + 2H_2O$

(b) $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

(c) $NaCl + AgNO_3(g) \rightarrow AgCl + NaNO_3$

(d) $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + 2HCl$

7. Write the balanced chemical equations for the following reactions:

(a) Calcium hydroxide + Carbon dioxide → Calcium carbonate + Water

(b) Zinc + Silver nitrate → Zinc nitrate + Silver

(c) Aluminium + Copper chloride → Aluminium chloride + Copper

(d) Barium chloride + Potassium sulphate → Barium sulphate + Potassium chloride

Ans.(a) $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

(b) $Zn + 2AgNO_3 \rightarrow Zn(NO_3)_2 + 2Ag$

(c) $2Al + 3\ CuCl_2 \rightarrow 2\ AlCl_3 + 3Cu$

(d) $BaCl_2 + K_2SO_4 \rightarrow BaSO_4 + 2KCl$

8. Write the balanced chemical equation for the following and identify the type of reaction in each case:

(a) Potassium bromide (aq) + Barium iodide (aq) → Potassium iodide (aq) + Barium

(b) Zinc carbonate(s) → Zinc oxide (s) + Carbon dioxide (g) bromide(s)

(c) Hydrogen (g) + Chloride (g) → Hydrogen chloride (g)

(d) Magnesium (s) + Hydrochloric acid (aq) → Magnesium chloride (aq) + Hydrogen (g)

Ans.(a) $2KBr\ (aq) + BaI_2(aq) \rightarrow 2Kl(aq) + BaBr_2(s)$

Type: Double displacement reaction

(b) $ZnCO_3\ (s) \rightarrow ZnO\ (s) + CO_2\ (g)$

Type: Decomposition reaction

(c) $H_2\ (g) + Cl_2\ (g) \rightarrow 2HCl(g)$

Type: Combination reaction

(d) $Mg\ (s) + 2HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2\ (g)$

Type: Displacement reaction

9. What is meant by exothermic and endothermic reaction? Give an example.

Ans. The reaction in which heat is produced is called an exothermic reaction. Such as the burning of natural gas.

$CaO\ (s) + H_2O\ (l) \longrightarrow Ca(OH)_2\ (aq) + Heat$

$C + O_2 \longrightarrow CO_2 + Heat + Light$

$CH4 + 2O_2 \longrightarrow CO_2 + 2H_2O + Heat + Light$

The reaction in which heat is absorbed is called endothermic reaction. For example :

$N_2 + O_2 \longrightarrow 2NO + Heat$

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

10. Why is respiration considered an exothermic reaction? Explain.

Ans. We need the energy to survive. This energy is obtained from food. When we breathe, the food item *i.e.*, food gets metabolized by oxygen. Energy is released in this process. Hence respiration is called an exothermic reaction.

$C_6H_{12}O_6(aq) + 6O_2(aq) \rightarrow 6CO_2(aq) + 6H_2O + Energy$

11. Why are decomposition reactions called the opposite of combination reactions? Write equations for these reactions.

Ans. A reaction in which a single reactant breaks down to give smaller products is called dissociation reaction.

$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$ ...(i)

The reactions in which two or more elements or compounds combine to form a single product are called combination reactions.

$CaO + CO_2 \rightarrow CaCO_3$ ...(ii)

Equations (i) and (ii) the reactions are the same but opposite. Eq. (i) is dissociation of $CaCO_3$ while Eq. (ii) is the combination (or formation) of $CaCO_3$.

12. Write one equation each for the decomposition reactions where energy is supplied in the form of heat, light or electricity.

Ans. (i) $CaCO_3 \xrightarrow{Heat} CaO + CO_2$

In this energy is being used in the form of heat.

(ii) $2AgCl\ (s) \xrightarrow{Light\ energy} 2Ag\ (s) + Cl_2\ (s)$

In this energy is being used as light energy.

(iii) $2H_2O \xrightarrow{Electricity} 2H_2 + O_2$

In this, energy is being used in the form of electricity.

13. What is the difference between displacement and double displacement reactions? Write equations for these reactions.

Ans. Refer Text

14. In the refining of silver, the recovery of silver from silver nitrate solution involved displacement by copper metal. Write down the reaction involved.

Ans. When copper is added to a solution of silver nitrate, it displaces silver because copper is more reactive than silver.

15. What do you understand by precipitation reaction? Explain with examples.

Ans. The reaction in which substances react to form insoluble salt is called a precipitation reaction and the formed substance is called a precipitate. The precipitate formed is indicated with an ↓ arrow. Example :

$Pb(NO_3)_2$	+	2KI	→	$2KNO_3\downarrow$	+	PbI_2	+	2NaCl(aq)
Lead Nitrate		Potassium Iodide		Potassium Nitrate (Precipitate)		Lead Iodide		Sodium Chloride

Na_2SO_4(aq)	+	$BaCl_2$(aq)	→	$BaSO_4$(s)↓	+	2NaCl(aq)
(Sodium sulphate)		(Barium chloride)		(Barium sulphate) (Precipitate)		(Sodium chloride)

16. Explain the following in terms of gain or loss of oxygen with two examples each:

(a) Oxidation

(b) Reduction

Ans.(a) Oxidation: The addition of oxygen to a substance is called oxidation.

$$Mg + O_2 \rightarrow MgO$$

$$2H_2 + 2O_2 \rightarrow 2\square_2O$$

(b) Reduction: The removal of oxygen from a substance is called reduction.

$$ZnO + C \rightarrow Zn + CO$$

$$CuO + H_2 \rightarrow Cu + H_2O$$

17. A shiny brown coloured element 'X' on heating in air becomes black in colour. Name the element 'X' and the black coloured compound formed.

Ans. The shiny brown colored element X is called copper which when heated in air forms copper oxide. It is of black colour.

$$\underset{\text{Copper (Brown)}}{2Cu} + \underset{\text{Oxygen}}{O_2} \longrightarrow \underset{\text{Copper oxide}}{2CuO}$$

18. Why do we apply paint on iron articles?

Ans. We apply paint on iron articles to prevent them from rusting. Paint breaks the contact

of the iron surface with moisture or air so that they do not rust

19.Oil and fat-containing food items are flushed with nitrogen. Why?

Ans. Because oils and fatty substances come in contact with the air, they become oxidized and give off a bad smell. Along with their smell, their taste also changes. For this reason, oily and fatty foods are flushed with nitrogen so that they do not spoil.

Nitrogen, being a non-reactive gas, prevents the unwanted oxidation of the food.

20. Explain the following terms with one example each

(a) Corrosion, (b) Rancidity.

Ans.(a) Corrosion: Corrosion is a chemical reaction in which metals react with air, moisture or acids to form undesirable substances.

Example: Rusting of iron

(b) Rancidity: The production of unpleasant smells and tastes in fatty and oily food due to the process of their natural oxidation is called rancidity.

Example: air is replaced by nitrogen gas inside the manufactured chips packets.

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ARIHANT KAPKOTI
(99.80%), CBSE Topper 2023

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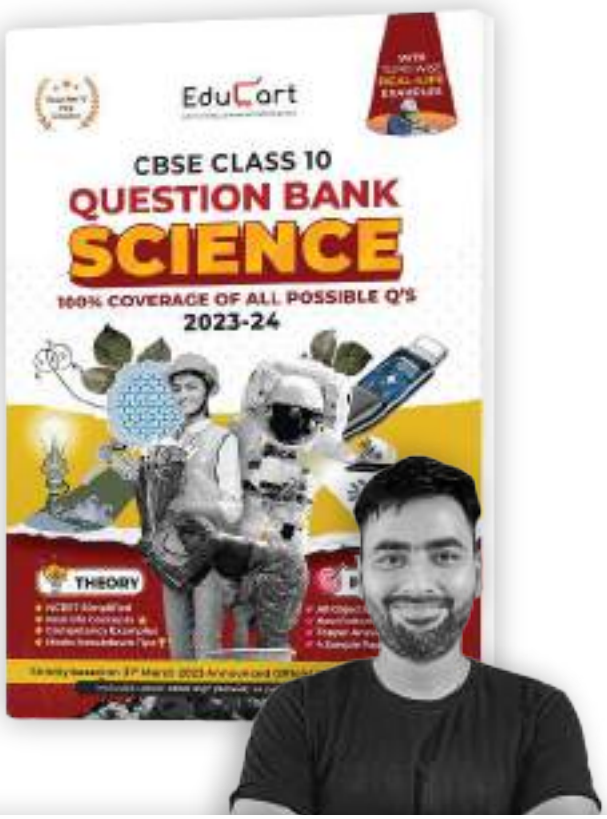

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Acids, Bases and Salts

2

NCERT SOLUTIONS

What's inside

– In-Chapter Q's (solved)

– Textbook Exercise Q's (solved)

IN-CHAPTER QUESTIONS

Test Yourself

1. You have been provided with three test tubes. One of them contains distilled water and the other two contain an acidic solution and a basic solution, respectively. If you are given only red litmus paper, how will you identify the contents of each test tube?

Ans. Red litmus paper is kept alternately in three test tubes. The solution which turns red litmus paper blue is an alkaline solution. Now put each end of blue litmus paper in the remaining two test tubes separately. The solution which turns blue litmus paper red is an acidic solution. If there is no effect on red and blue litmus paper, then the solution is distilled water.

Test Yourself

1. Why do HCl, HNO_3, etc., show acidic characters in aqueous solutions while solutions of compounds like alcohol and glucose do not show acidic character?

Ans. Since in aqueous solutions acids dissociate in water to form H^+ ions and get separated. This shows the acidic character of the compounds. Alcohol and glucose solution do not dissociate to form H^+ ions. Therefore, they do not show acidic character.

2. Why does an aqueous solution of an acid conduct electricity?

Ans. Acids dissolve in water to form ions (positive and negative), so aqueous solutions of acids conduct electricity.

$$HCl \longrightarrow H^+ + Cl^-$$
$$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$$
$$HNO_3 \longrightarrow H^+ + NO_3$$
$$CH_3COOH \longrightarrow H^+ + CH_3COO^-$$

3. Why does dry HCl gas not change the colour of the dry litmus paper?

Ans. Dry hydrochloric gas does not contain free hydrogen ions. Hence it does not show acidic character. Due to this it does not change the colour of litmus paper.

4. While diluting an acid, why is it recommended that the acid should be added to water and not water to the acid?

Ans. When acid is mixed with water, a lot of heat is generated. Thus, the acid should always be added to the water slowly and with continuous stirring. On adding water to the concentrated acid, the heat generated may cause the mixture to spill

and can burn the person. Therefore, utmost care should be taken while adding concentrated nitric acid or sulfuric acid to water.

5. How is the concentration of hydronium ions (H_3O^+) affected when a solution of an acid is diluted?

Ans. The concentration of hydronium ions (H_3O^+) decreases on diluting the acid.

6. How is the concentration of hydroxide ions (OH^-) affected when excess base is dissolved in a solution of sodium hydroxide?

Ans. The concentration of hydroxide ions (OH^-) increases.

Test Yourself

1. You have two solutions, A and B. The pH of solution A is 6 and pH of solution B is 8. Which solution has more hydrogen ion concentration? Which of this is acidic and which one is basic?

Ans. pH of solution A is 6, while pH of solution B is 8. Thus, the hydrogen ion concentration is more in solution A than B. Solution A is acidic and solution B is basic.

2. What effect does the concentration of H^+ (aq) ions have on the nature of the solution?

Ans. As the concentration of H^+ (aq) ions increases, acidic character increases and basic character decreases.

3. Do basic solutions also have H^+ (aq) ions? If yes, then why are these basic?

Ans. Yes, all basic solutions have H^+ ions. They are basic because the concentration of hydrogen ions is much less than that of hydroxide ions.

4. Under what soil condition do you think a farmer would treat the soil of his fields with quick lime (calcium oxide) or slaked lime (calcium hydroxide) or chalk (calcium carbonate)?

Ans. When the soil becomes acidic, farmers add the given bases to neutralise the soil.

Test Yourself

1. What is the common name of the compound $CaOCl_2$?

Ans. Bleaching powder.

2. Name the substance which on treatment with chlorine yields bleaching powder.

Ans. Slaked lime [$Ca(OH)_2$].

3. Name the sodium compound which is used for softening hard water.

Ans. Sodium carbonate (Na_2CO_3).

4. What will happen if a solution of sodium hydrogen carbonate is heated? Give the equation of the reaction involved.

Ans. On heating sodium hydrogen carbonate, sodium carbonate and water and carbon dioxide are formed. The chemical reactions is written as :

$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$$

Sodium bicarbonate Sodium carbonate

5. Write an equation to show the reaction between Plaster of Paris and water.

Ans. $CaSO_4.\frac{1}{2}H_2O + 1\frac{1}{2}H_2O \longrightarrow CaSO_4.2H_2O$

NCERT EXERCISES

1. A solution turns red litmus blue, its pH is likely to be :

(a) 1 **(b) 4**

(c) 5 **(d) 10**

Ans.(d) 10

2.A solution reacts with crushed egg-shells to give a gas that turns lime-water milky. The solution contains :

(a) NaCl **(b) HCl**

(c) LiCl **(d) KCl**

Ans.(b) HCl

3.10 mL of a solution of NaOH is found to be completely neutralised by 8 mL of a given solution of HCl. If we take 20 mL of the same solution of NaOH, the amount HCl solution (the same solution as before) required to neutralise it will be :

(a) 4 ml **(b) 8 ml**

(c) 12 ml **(d) 16 ml**

Ans.(b) 8 ml

4.Which one of the following types of medicines is used for treating indigestion?

(a) Antibiotic **(b) Analgesic**

(c) Antacid **(d) Antiseptic**

Ans. (c) Antacid

5.Write word equations and then balanced equations for the reaction taking place when :

(a) dilute sulphuric acid reacts with zinc granules.

(b) dilute hydrochloric acid reacts with magnesium ribbon.

(c) dilute sulphuric acid reacts with aluminium powder.

(d) dilute hydrochloric acid reacts with iron filings.

Ans. (a)Dil. Sulphuric acid + Zinc → Zinc sulphate + hydrogen gas

$$H_2SO_4(aq) + Zn \longrightarrow ZnSO_4(aq) + H_2(g)$$

(b) Dil. hydrochloric acid + Magnesium → Magnesium chloride + hydrogen gas

$$2HCl(aq) + Mg \longrightarrow MgCl_2(aq) + 3H_2(g)$$

(c) Dil. Sulphuric acid + aluminium → Aluminium sulphate + hydrogen gas

$$3H_2SO_4(aq) + 2Al(s) \longrightarrow Al_2(SO_4)_3(aq) + H_2(g)$$

(d) Dil. hydrochloric acid + Iron → Ferrous chloride + hydrogen gas

$$6HCl(aq) + 3Fe(s) \longrightarrow 3FeCl_3(aq) + 3H_2(g)$$

6. Compounds such as alcohols and glucose also contain hydrogen but are not categorised as acids. Describe an Activity to prove it.

Ans. Insert two nails on the wooden or rubber cork and place them on a beaker as shown in figure. Connect iron nail to a bulb, 6-volt battery and a wire connected to switch. Pour some alcohol or glucose so as to dip the nails in glucose or alcohol. Turn the switch on and we will observe that the bulb does not glow. Now empty the beaker and add HCL or H_2SO_4 solution. This time bulb glows. This proves acid can conduct electricity but alcohol and glucose does not conduct electricity.

7. Why does distilled water not conduct electricity, whereas rain water does?

Ans. Distilled water is a pure form of water which does not contain any solute (ions salts) in it therefore it cannot conduct electricity while rain water contains dissolved salts and acids which dissociates in ions and conducts electricity.

Acids do not dissociate in the presence of water. Therefore it does not show acidic properties.

8. Why do acids not show acidic behaviour in the absence of water?

Ans. The acidic behaviour of acid is due to the presence of hydrogen ions H^+. In the absence of water, an acid will not show its acidic behaviour because acids do not dissociate to produce H^+ (aq) ions. Water, a polar solvent assists in the dissociation of acids into their respective ions.

9. Five solutions A, B, C, D and E when tested with universal indicator showed pH as 4,1,11,7 and 9, respectively. Which solution is :

(a) Neutral? (b)Strongly alkaline?

(c) Strongly acidic? (d)Weakly acidic?

(e) Weakly alkaline?

Arrange the pH in increasing order of hydrogen-ion concentration.

Ans. (a) – D, (b) –C, (c) – B, (d) – A, (e) – E

Increasing order of hydrogen-ion concentration :

C < E < D < A < B

10. Equal lengths of magnesium ribbons are taken in test tubes A and B. Hydrochloric acid (HCl) is added to test tube A, while acetic acid (CH_3COOH) is added to test tube B. Amount and concentration taken for both the acids are same. In which test tube will the fizzing occur more vigorously and why?

Ans. Magnesium metal when reacts with an acid gives off hydrogen gas in the reaction. In test tube A fizzing occurs more vigorously because HCl is stronger acid than acetic acid. Hence, HCl liberates hydrogen gas more vigorously, which causes fizzing more vigorously.

11. Fresh milk has a pH of 6. How do you think the pH will change as it turns into curd? Explain your answer.

Ans. The pH value of fresh milk is 6. When it turns into curd, it becomes sour due to formation of lactic acid and hence its pH decreases below 6.

12.A milkman adds a very small amount of baking soda to fresh milk.

(a) Why does he shift the pH of the fresh milk from 6 to slightly alkaline?

(b) Why does this milk take a long time to set as curd?

Ans.(a) The milkman shifts the pH of the fresh milk from 6 to slight alkalinity because in the alkaline condition the milk will not become sour or curdle due to the formation of lactic acid.

(b) The milk takes time to set as curd because the addition of baking soda has made the milk basic and the acids produced will take a longer time to neutralize the base

13. Plaster of Paris should be stored in a moisture-proof container. Explain why?

Ans. The plaster of Paris absorbs water to form hard gypsum. For this reason, Plaster of Paris is kept in a moisture-proof container so that it does not harden and is saved from spoilage.

14.What is a neutralisation reaction? Give two examples.

Ans. A reaction in which an acid and a base react to form a salt and water is a neutralization reaction.

$2KOH + H_2SO_4 \longrightarrow K_2SO_4 + 2H_2O$

$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$

15. Give two important uses of washing soda and baking soda.

Ans.Use of washing soda :

(i) It is used in homes for cleaning cotton clothes.

(ii)It is used in glass, soap and paper industries.

Use of baking soda :

(i) It is used in making soda acid and in fire extinguishing.

(ii) It is used for making bread, cake, spongy etc.

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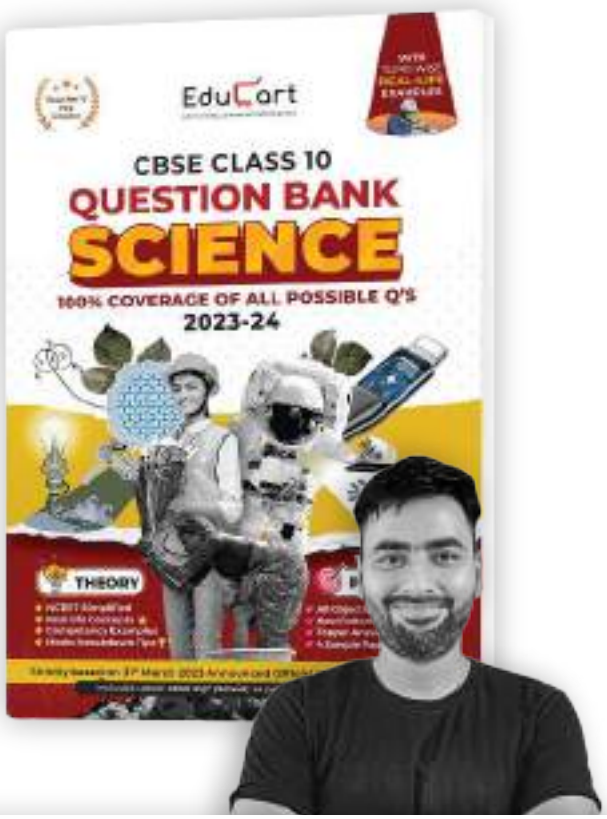

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Metals and Non-Metals 3

NCERT SOLUTIONS

What's inside

IN-CHAPTER QUESTIONS

Test Yourself

1. Give an example of a metal which.

(i) is a liquid at room temperature.

(ii)can be easily cut with a knife.

(iii) is the best conductor of heat.

(iv) is a poor conductor of heat.

Ans.(i) Mercury, (ii) Sodium, (iii) Silver, (iv) Lead.

2. Explain the meanings of malleable and ductile.

Ans. The property of metals due to which they can be converted into sheets by beating them with a hammer is called malleability. Example - gold, silver, aluminium, copper etc.

The property of metals due to which they can be drawn into wire is called ductility. Example - gold, silver, aluminium, copper.

Test Yourself

1. Why is sodium kept immersed in kerosene oil?

Ans. Since sodium reacts rapidly with water and oxygen at room temperature, but it does not react with kerosene. Thus, sodium is kept immersed in kerosene oil.

2. Write equations for the reactions of :

(i) iron with steam

(ii) calcium and potassium with water

Ans.(i) $2Fe + 3H_2 \longrightarrow Fe_2O_3 + 3H_2$

(ii)$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2$

(iii)$2K + 2H_2O \longrightarrow 2KOH + H_2 + \Delta$

3. Samples of four metals A, B, C and D were taken and added to the following solution one by one. The results obtained have been tabulated as follows.

Metal	Iron(II) sulphate	Copper(II) sulphate	Zinc sulphate	Silver nitrate
A	No reaction	Displacement	No reaction	Displacement
B	Displacement	No reaction	No eaction	No reaction
C	No reaction	No reaction	No reaction	
D	No reaction			

Use the Table above to answer the following questions about metals A, B, C and D :

(i) Which is the most reactive metal?

(ii) What would you observe if B is added to a solution of Copper (II) sulphate?

(iii) Arrange the metals A, B, C and D in the order of decreasing reactivity.

Ans.(i) Metal B is most reactive.

(ii) When metal B is added to copper (II) sulphate solution, displacement reaction occurs.

$$Cu + H_2SO_4 \longrightarrow CuSO_4 + H_2$$

(iii) Metal B > Metal A > Metal C > Metal D

4. Which gas is produced when dilute hydrochloric acid is added to a reactive metal? Write the chemical reaction when iron reacts with dilute H_2SO_4.

Ans. Hydrogen gas is released, along with the formation of metal salt solution.

$$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2$$

5. What would you observe when zinc is added to a solution of iron (II) sulphate? Write the chemical reaction that takes place.

Ans. When zinc is added to a solution of iron (II) sulphate, iron is displaced from iron (II) sulphate because Zn is more reactive than Fe.

$$Zn + FeSO_4 \longrightarrow ZnSO_4 + Fe$$

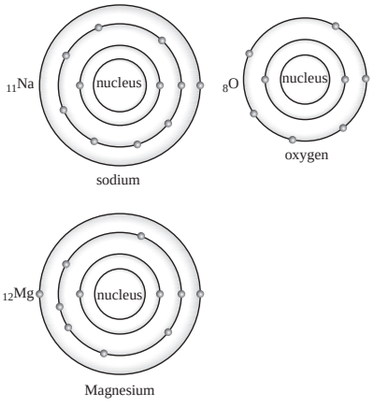
Test Yourself

1.(i) Write the electron-dot structures for sodium, oxygen and magnesium.

(ii) Show the formation of Na_2O and MgO by the transfer of electrons.

(iii) What are the ions present in these compounds?

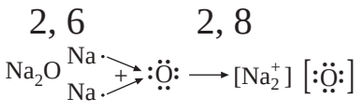
Ans. (i)



(ii) $Na \longrightarrow Na^+ + e$

2, 8, 1 2, 8

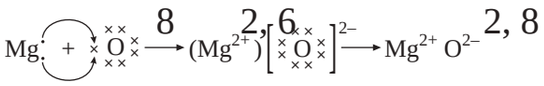
$O + 2e \longrightarrow O^{2-}$



$$MgO \quad Mg \longrightarrow Mg \longrightarrow Mg^{2+} + 2e^-$$

12 2,8,1, 2, 8

$$O \quad O + 2e^- \longrightarrow O^{-2}$$



(iii)In Na_2O, Na^+ and O^{2-} ions are present.

In MgO, Mg^{2+} and O^{2-} ions are present.

2.Why do ionic compounds have high melting points?

Ans. The structure of ionic compounds is solid and hard. In this state the force of attraction between the ions is very strong. To overcome (break) such strong forces, a high amount of energy is required. Thus, ionic compounds have high melting points.

Test Yourself

1.Define the following terms.

(i)Mineral (ii) Ore (iii) Gangue

Ans.(i) Minerals : The elements or compounds found naturally in the earth's crust are called minerals.

(ii) Ore : At some places, a particular metal is found in abundance in minerals, from which metals are obtained at low cost and easily. Such minerals are called ores.

(iii) Gangue : The minerals or ores are mixed with many impurities such as clay and sand called gangue.

2.Name two metals which are found in nature in the free state.

Ans. Gold and platinum.

3.What chemical process is used for obtaining a metal from its oxide?

Ans. Carbon reduction method.

Test Yourself

1. Metallic oxides of zinc, magnesium and copper were heated with the following metals :

Metal	Zinc	Magnesium	Copper
Zinc oxide			
Magnesium oxide			
Copper oxide			

In which cases will you find displacement reactions taking place?

Ans.

Metal	Zinc	Magnesium	Copper
Zinc oxide	No	Yes	No
Magnesium oxide	No	No	No
Copper oxide	Yes	No	Yes

2. Which metals do not corrode easily?

Ans. Gold and silver metals do not corrode easily because they are least reactive in nature.

3.What are alloys?

Ans. A homogenous mixture of two or more metals or a metal and non-metal is called an alloy. An alloy of copper and zinc is brass, an alloy of tin and copper is bronze. Their alloys have lower electrical conductivity and melting points than pure metals.

IN-CHAPTER QUESTIONS

1. Which of the following pairs will give displacement reactions?

(a) NaCl solution and copper metal

(b) $MgCl_2$ solution and aluminium metal

(c) $FeSO_4$ solution and silver metal

(d) $AgNO_3$ solution and copper metal.

2. Which of the following methods is suitable for preventing an iron frying pan from rusting?

(a) Applying grease

(b) Applying paint

(c) Applying a coating of zinc

(d) All of the above.

3. An element reacts with oxygen to give a compound with a high melting point. This compound is also soluble in water. The element is likely to be

(a) calcium

(b) carbon

(c) silicon

(d) iron.

4. Food cans are coated with tin and not with zinc because

(a) zinc is costlier than tin.

(b) zinc has a higher melting point than tin.

(c) zinc is more reactive than tin.

(d) zinc is less reactive than tin.

5. You are given a hammer, a battery, a bulb, wires and a switch.

   (a) How could you use them to distinguish between samples of metals and non-metals?

   (b) Assess the usefulness of these tests in distinguishing between metals and non-metals.

6. What are amphoteric oxides? Give two examples of amphoteric oxides.

7. Name two metals which will displace hydrogen from dilute acids, and two metals which will not.

8. In the electrolytic refining of a metal M, what would you take as the anode, the cathode and the electrolyte?

9. Pratyush took sulphur powder on a spatula and heated it. He collected the gas evolved by inverting a test tube over it, as shown in figure below.

   (a) What will be the action of gas on

   (i) dry litmus paper?

   (ii) moist litmus paper?

   (b) Write a balanced chemical equation for the reaction taking place.

10. State two ways to prevent the rusting of iron.

11. What type of oxides are formed when non-metals combine with oxygen?

12. Give reasons

   (a) Platinum, gold and silver are used to make jewellery.

   (b) Sodium, potassium and lithium are stored under oil.

   (c) Aluminium is a highly reactive metal, yet it is used to make utensils for cooking.

   (d) Carbonate and sulphide oresare usually converted into oxides during the process of extraction.

13. You must have seen tarnished copper vessels being cleaned with lemon or tamarind juice. Explain why these sour substances are effective in cleaning the vessels.

14. Differentiate between metal and non-metal on the basis of their chemical properties.

15. A man went door to door posing as a goldsmith. He promised to bring back the glitter of old and dull gold ornaments. An unsuspecting lady gave a set of gold bangles to him which he dipped in a particular solution. The bangles

sparkled like new but their weight was reduced drastically. The lady was upset but after a futile argument the man beat a hasty retreat. Can you play the detective to find out the nature of the solution he had used?

16. Give reasons why copper is used to make hot water tanks and not steel (an alloy of iron).

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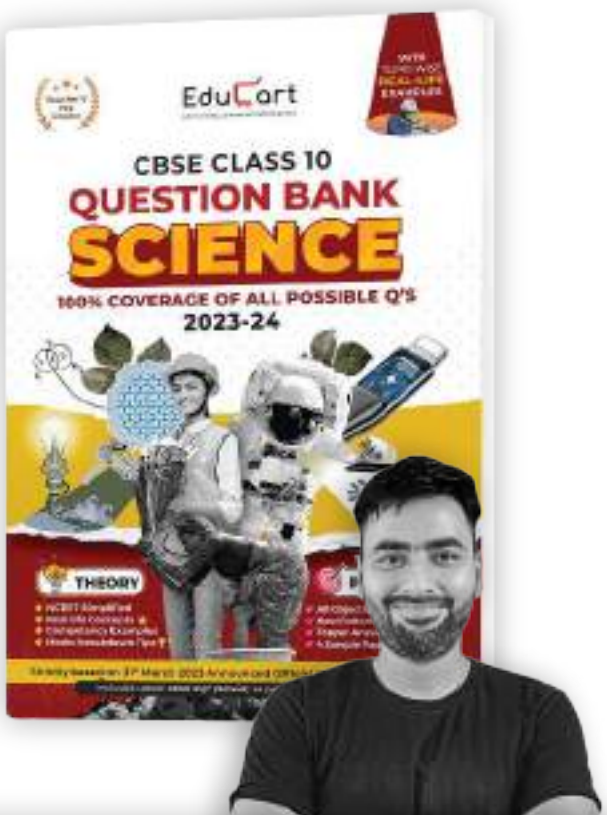

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CBSE 2022-23

Carbon and its Compounds

4

NCERT SOLUTIONS

What's inside

– In-Chapter Q's (solved)

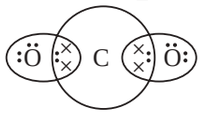
– Textbook Exercise Q's (solved)

IN-CHAPTER QUESTIONS

Test Yourself

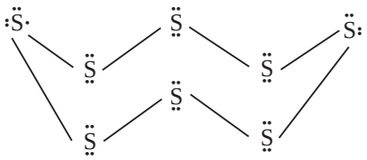
1. What would be the electron dot structure of carbon dioxide which has the formula CO_2?

Ans.



2. What would be the electron dot structure of a molecule of sulphur which is made up of eight atoms of sulphur? (Hint : The eight atoms of sulphur are joined together in the form of a ring.)

Ans.

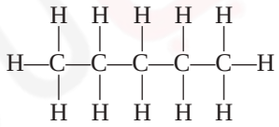


Test Yourself

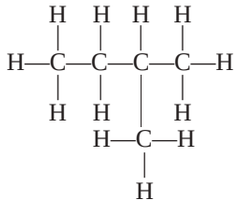
1. How many structural isomers can you draw for pentane?

Ans. 3 isomers can be drawn for pentane :

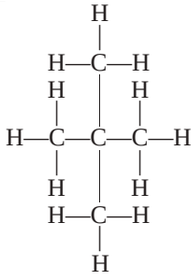
(a) normal pentane



(b) Isopentane or 2-methylpentane



(c) Neopentane or 2,2 dimethylpropane



2. What are the two properties of carbon which lead to the huge number of carbon compounds we see around us?

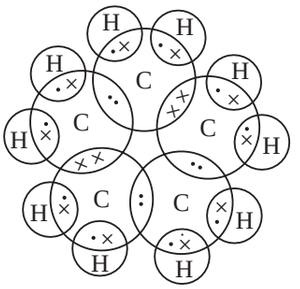
Ans.(i) Catenation property and valency of carbon is 4.

(ii) Due to these properties, carbon forms straight, branched and cyclic chains. Due to valency 4, they form single, double and triple bonds.

Using these properties, carbon forms a large number of compounds. Hence, we can see carbon compounds in large numbers around us.

3. What will be the formula and electron dot structure of cyclopentane?

Ans. C_5H_{10}



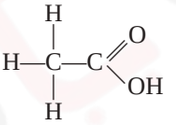
4. Draw the structures for the following compounds :

(i)Ethanoic acid (ii)Bromopentane*

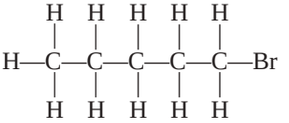
(iii) Butanone (iv) Hexanal.

*Are structural isomers possible for bromopentane.

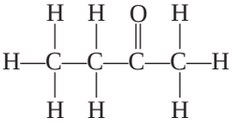
Ans.(i) Ethanoic acid (CH_3COOH)



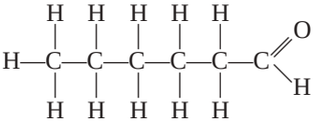
(ii) Bromopentane ($C_5H_{11}Br$)



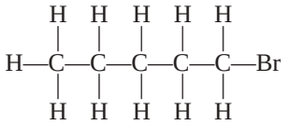
(iii) Butanone ($C_2H_5COCH_3$)



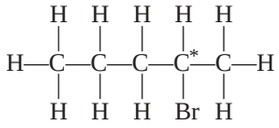
(iv) Hexanal (C_5H_9CHO)



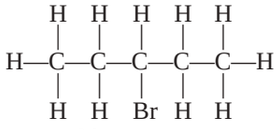
Yes structural Isomers are possible for Bromopentane :



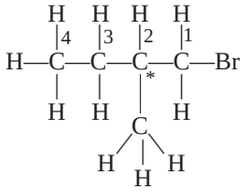
1-bromopentane



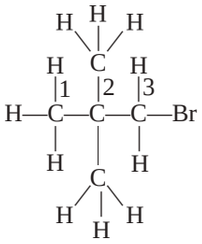
2-bromopentane



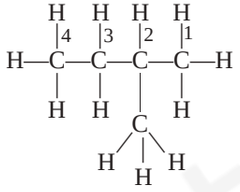
3-bromopentane



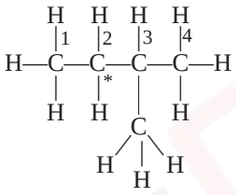
1-bromo-2-methylbutane



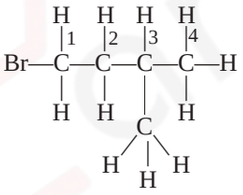
1-bromo-2, 2-dimethylpropane



2-bromo-2-methylbutane



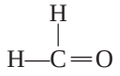
2-bromo-2-methylbutane

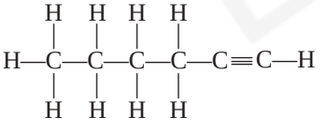


1-bromo-3-methylbutane

5. How would you name the following compounds?

(i) $CH_3—CH_2—Br$

(ii) 

(iii) 

Ans.(i) Bromoethane

(ii)Methanal (iii) Hexene

Test Yourself

1. Write two properties of covalent compounds.

Ans. Properties : (i) They have high boiling and melting points.

(ii) They are bad conductors of electricity.

2. A mixture of oxygen and ethyne is burnt for welding. Can you tell why a mixture of ethyne and air is not used?

Ans. When ethyne is burnt in air, it gives a sooty flame due to incomplete combustion

in limited supply of air. But, if ethyne is burnt with oxygen only, a clean flame with temperature above 3000°C is obtained because of complete combustion. Such flame is used for welding. It is impossible to attain such a high temperature without mixing oxygen. This is the reason why a mixture of ethyne and air is not used.

Test Yourself

1. How would you distinguish experimentally between an alcohol and a carboxylic acid?

Ans.(i) Alcohol has no effect on litmus acid whereas carboxylic acid turns blue litmus paper red.

(ii) Alcohol does not react with Na_2CO_3, while carboxylic acid reacts with Na_2CO_3 to form CO_2 gas.

2. What are oxidising agents?

Ans. An oxidising agent is a chemical substance that decomposes itself to oxidise another.

Test Yourself

1. Would you be able to check if water is hard by using a detergent?

Ans. No, since detergent gives forms lather with both hard and soft water. So using it, we cannot tell whether water is hard or not. But we can check whether water is hard or not using soap. Soap gives lather with soft water, but forms scum with hard water.

2. What are functional groups?

Ans. The heterogeneous atoms or their groups, which replace one or more hydrogen atoms in a hydrocarbon chain to form a new compound. are called functional groups.

NCERT EXERCISES

1. Ethane, with the molecular formula C2H6 has

(a) 6 covalent bonds.

(b) 7 covalent bonds.

(c) 8 covalent bonds.

(d) 9 covalent bonds.

Ans.(b) 7 covalent bonds.

2. Butanone is a four-carbon compound with the functional group :

(a) carboxylic acid (b) aldehyde

(c) ketone **(d) alcohol**

Ans.(c) ketone

3. While cooking, if the bottom of the vessel is getting blackened on the outside, it means that

(a) the food is not cooked completely.

(b) the fuel is not burning completely.

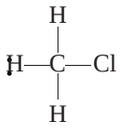
(c) the fuel is wet.

(d) the fuel is burning completely.

Ans.(b) the fuel is not burning completely.

4. Explain the nature of the covalent bond using the bond formation in CH_3Cl.

Ans. Covalent bond formation in CH_3Cl



In this structure three hydrogen atoms are linked to carbon by covalent bond and there is also covalent bond between carbon and chlorine, but chlorine is more negative than carbon so it forms a polar covalent bond.

$$CH_3Cl \longrightarrow CH_3^+ + Cl^-$$

5. Draw the electron dot structures for :

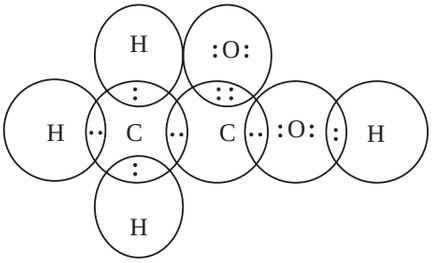
(a) ethanoic acid

(b) H_2S

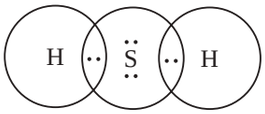
(c) propanone

(d) F_2

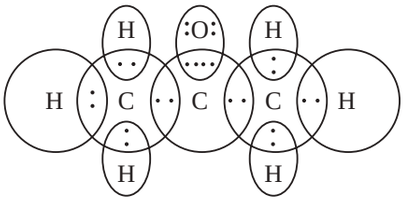
Ans. (a) CH_3COOH (Ethanoic acid)



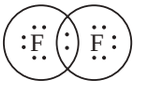
(b) H_2S (Hydrogen sulphide)



(c) CH_3COCH_3 (Propanone)



(d) F_2 (Fluorine)



6. What is homologous series? Explain with an example.

Ans. A group of compounds having the same general formula and functional group is called a homologous series. Example :

(i)

Methane CH_4

Ethane C_2H_6 (CH_4 + CH_2)

Propane C_3H_8 (C_2H_6 + CH_2)

(ii)

Methanol CH_3OH

Ethanol CH_3CH_2OH

Propanol $CH_3CH_2CH_2OH$

7. How can ethanol and ethanoic acid be differentiated on the basis of their physical and chemical properties?

Ans.Difference in physical properties :

Ethanol		Ethanoic acid	
(i)	It has specific smell.	(i)	It smells like vinegar.
(ii)	Its boiling point is 351 K.	(ii)	Its boiling point is 391 K.
(iii)	Its melting point is 150K.	(iii)	Its melting point is 290 K.

Difference in chemical properties :

Ethanol		Ethanoic acid	
(i)	It does not react with sodium carbonate.	(i)	It reacts with sodium carbonate and form sodium salt and CO_2 gas.
(ii)	In presence of basic $KMnO_4$, it forms ethanoic acid, due to which $KMnO_4$ becomes colourless. $C_2H_5OH \xrightarrow{KMnO_4} CH_3COOH$	(ii)	It does not react in presence of basic $KMnO_4$, Due to which $KMnO_4$ retains its original colour.

8. Why does micelle formation take place when soap is added to water? Will a micelle be formed in other solvents such as ethanol also?

Ans. Soap molecule has two parts - one which is soluble in water is called hydrophilic and the other which is soluble in hydrocarbon is called hydrophobic. When soap

is on the surface of water, its molecules arrange themselves in such a way that its ionic end is inside the water. In contrast, the hydrocarbon tail is outside the water. There is a special arrangement of these molecules inside water, due to which its hydrocarbon end is protudes out of water. This happens due to the formation of a large clusters of molecules in which the hydrophobic tail is on the inner side, while its ionic end is on the surface. Such arrangement are called called micelles. Ethanol is a non-polar solvent. Therefore, it also does not have attracts to the hydrophilic part, hence micelles are not form when soap is dissolved in ethanol.

9. Why are carbon and its compounds used as fuels for most applications?

Ans. Carbon compounds are used as fuel because they burn with a clean flame and no smoke is produced. Carbon compounds have high calorific values, maximum ignition temperature and their combustion can be controlled. Hence, carbon and its compounds are a great source of fuel.

10. Explain the formation of scum when hard water is treated with soap.

Ans. Since hard water contains soluble salts of Ca and Mg, which react with soap to form an insoluble salt called scum.

$$Ca^{++} + 2R - COONa \rightarrow (R - COO)_2\ Ca + 2\ Na^{+}$$

Soluble salts scum

$$Mg^{++} + 2R - COONa \rightarrow (R - COO)_2\ Mg + 2Na^{+}$$

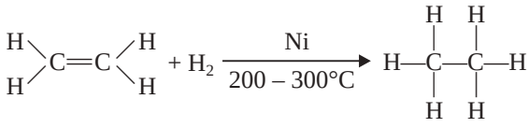
Soluble salts scum

11. What change will you observe if you test soap with litmus paper (red and blue)?

Ans. Soap turns red litmus blue. Therefore, it is alkaline.

12. What is Hydrogenation? What is its industrial application?

Ans. The process of addition of hydrogen to an unsaturated hydrocarbon chain is called hydrogenation.



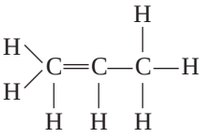
Ethylene Ethane

Hydrogenation is used to convert fat into saturated fat.

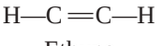
Edible oil (unsaturated) → saturated fat (ghee)

13. Which of the following hydrocarbons undergo addition reactions:
C_2H_6, C_3H_8, C_3H_6, C_2H_2 and CH_4

Ans. C_2H_2 and C_3H_6 shows addition reactions, because they have triple and double bonds respectively.



Propyne



Ethyne

14. Give a test that can be used to differentiate between saturated and unsaturated hydrocarbons

Ans.

Saturated hydrocarbon	Unsaturated hydrocarbon
When butter is heated and some bromine water is added to it, its colour does not fade. This shows that butter is a saturated compound.	When some bromine water is added to edible oil, after a short time the colour of the bromine water becomes colourless. This suggests that the edible oil is an unsaturated compound.

15. Explain the mechanism of the cleaning action of soaps.

Ans. A soap molecule consists of two parts - one part is long chain of hydrocarbon and the other part is of –COONa group. Hydrocarbons are hydrophobic. The scum sticks to the hydrocarbon part of the soap molecule. The –COONa part sticks to the water and removes the dirt from the surface of the cloth. This cleanses the cloth.

sWhen soap is dissolved in water, it forms micelles, in which the soap molecules are arranged in a cluster form. The hydrocarbon part of the soap towards the center and the hydrophilic part faces outward. These micelles are formed around the particles of scum present on the surface of the soap-soaked cloth.

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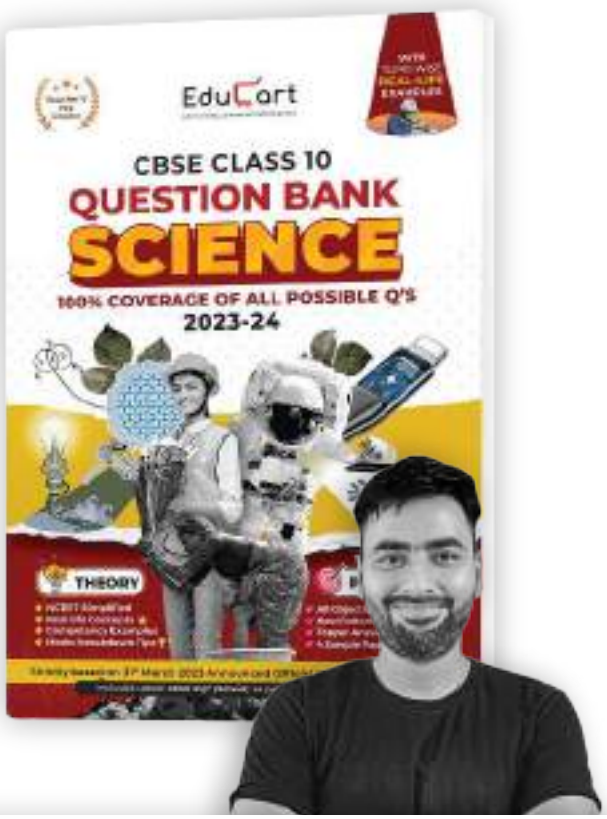

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Regional Topper
CBSE 2022-23

Life Processes 5

NCERT SOLUTIONS

What's inside

IN-CHAPTER QUESTIONS

Test Yourself

1. Why is diffusion insufficient to meet the oxygen requirement in multicellular organisms like us?

Ans. Multicellular organisms such as humans possess complex body designs. They have specialised cells and tissues for performing various necessary functions of the body such as intake of food and oxygen. Unlike unicellular organisms, multicellular cells are not in direct contact with the outside environment. Therefore, diffusion cannot meet their oxygen requirements.

2. What criterion would we use to determine if an object is alive?

Ans. Common proofs of being alive are breathing, growth, movement etc.

3. What raw materials are used by an organism?

Ans. Oxygen, water and food are used by an organism as a raw material.

Food : Used by organisms as energy and sources of substances.

Oxygen: Organisms get energy from the breakdown of substances like food, for this they have to undergo respiration.

Water: Water is essential for the digestion of food and biological processes.

4. What processes would you consider essential for the maintenance of life?

Ans. All those processes which together do the work of maintenance are called biological processes. In this, nutrition, respiration, transport, excretion are essential processes.

Test Yourself

1. What is the difference between autotrophic nutrition and heterotrophic nutrition?

Ans.

Autotrophic nutrition	Heterotrophic nutrition
1. Green plants make their own food in the presence of sunlight and chlorophyll to make carbohydrates using CO_2 and water, they prepare their own food.	Heterozygous organisms are unable to prepare their own food, they depend on the food prepared by others.
2. They do not depend on anyone else	Heterotrophs depend on plants such as humans and fungi.

2. Where does the plant get the raw material needed for photosynthesis?

Ans. Plants get the raw materials needed for photosynthesis from different sources :

(1)Chlorophyll : From chloroplast of leaf.

(2)Carbon dioxide: from the atmosphere.

(3) Water: From the soil.

3. What is the role of acid in our stomach?

Ans. Role of acid in our stomach :

(1) The enzymes found in the stomach digest food in an acidic medium. The acid in the stomach makes the food acidic so that the enzymes found in the gastric juice can digest it.

(2) Many germs also come with food, which are destroyed by the effect of acid.

4. What is the function of digestive enzymes?

Ans. Enzymes break down complex components of food into simpler parts by catalytic action, so that they become soluble and are absorbed in the body.

5. How is the small intestine designed to absorb digested food?

Ans. The small intestine has millions of tiny finger-like projections called villi. These villi increase the surface area for efficient food absorption. Within these villi, many blood vessels are present that absorb the digested food and carry it to the bloodstream. The absorbed food from the bloodstream is delivered to every cell of the body.

Test Yourself

1. How is a terrestrial organism advantageous over an aquatic organism in obtaining oxygen for respiration?

Ans. Organisms that live in water use oxygen dissolved in water because the amount of dissolved oxygen in water is very less, so the respiration rate of organisms is faster than that of terrestrial organisms. Terrestrial organisms use oxygen in the atmosphere for respiration. In different organisms, this oxygen is absorbed by different organs. All organs have a composition that increases the surface area. Terrestrial organisms are exposed to oxygen rich atmosphere.

2. What are the different ways in which glucose is oxidised to provide energy in various organisms?

Ans. There are several pathways for obtaining energy in organisms other than the oxidation of glucose:

Glycogenolysis : This is the breakdown of glycogen, a storage form of glucose, into glucose molecules. This process can occur in liver and muscle cells and provides a source of glucose for energy production.

Lipolysis : This is the breakdown of stored fats into fatty acids and glycerol. The fatty acids can then be used for energy production via beta-oxidation, a process that occurs in the mitochondria of cells.

Proteolysis : This is the breakdown of proteins into amino acids, which can then

be used for energy production via gluconeogenesis, a process that converts amino acids into glucose.

3. How is oxygen and carbon dioxide transported in humans?

Ans.(i) Transport of oxygen: Haemoglobin is found in red blood cells that carry oxygen from the air in the lungs to the tissues where there is a lack of oxygen.

(ii) Transport of carbon dioxide: Carbon dioxide is more soluble in water, so it is transported in a soluble state in our blood, it goes out through the nostrils.

4. How is the maximum area in the human lung envisaged for exchange of gases ?

Ans. There are innumerable alveoli in the human lung, if we calculate their combined area, then it will be equal to about 80 square metres, so it is the design of these alveoli that the area of our lungs becomes maximum.

Test Yourself

1. What are the components of the transport system in humans? What are the functions of these components?

Ans. The following are the components of the transport system in human :

(a) Heart

(b) Blood

(c) Blood vessels

(a) Work of heart : Heart is a muscular organ that is the size of our fist. It carries blood in the body, it receives deoxygenated blood from different parts of the body and on the other hand, oxygenated blood is pumped throughout the body.

(b) Blood : Blood is a fluid connective organ in which 1. Plasma 2. Red blood cells 3. white blood cells and platelets.

1. Plasma transports food, carbon dioxide and nitrogen containing excretory substances.
2. Red blood cells transport respiratory gases and hormones.
3. White blood cells protect the body from infections.
4. Platelets form a blood clot at the site of bleeding and block the passage in which the flow of blood stops.

(c) Blood vessels : Blood vessels carry blood from the heart to the different parts of the body, their walls are thick and flexible.

2. Why is it necessary to separate oxygenated and deoxygenated blood in mammals and birds ?

Ans. Separation of oxygenated and deoxygenated blood in mammals and birds is necessary because birds and mammals have high energy requirements. This is also

beneficial because they need constant energy to maintain their body temperature, hence they need oxygen continuously to get energy.

3. What are the components of the transport system in highly organized plants?

Ans. The transport system in highly organised plants has two components. 1. Xylem and 2. Phloem

1. **Xylem :** In the xylem tissue, the ducts and vessels of the roots, stems and leaves join together to form a continuous network of water conduction vessels. These are attached to all parts of the plant. Xylem transports water and salts from the soil to the leaves.
2. **Phloem :** Phloem consists of sieve and companion cells that transport food from leaves to different parts of plants.

4. How are water and minerals transported in plants?

Ans. In plants, water and minerals are transferred from the soil to the leaves by the xylem cells. Root cells obtain salts from the soil, this creates a difference in the concentration of soil and root salts, due to which there is a constant movement of water in the xylem. Due to transpiration, there is a continuous loss of water and there is suction, due to which the constant movement of water is maintained, thus water and minerals are transported.

5. How does food transfer in a plant?

Ans. The transport of food in plants starts from the leaves and takes place through the phloem ducts throughout the plant body. The flow of food from high concentration to low concentration through the sieve plate in the sieve tube of phloem vessels.

Test Yourself

1. Describe the structure and functioning of nephrons

Ans. Structure of nephron : Nephron is the constructive and functional unit of excretion, its main parts are

1. **Bowman capsule :** The tip of the nephron is cup-like.
2. **Cell bundle :** A clump of blood cells formed by the repeated division of the renal artery and renal vein.
3. **Renal vein :** Blood vessel carrying impure blood to the kidney.
4. **Renal artery :** Blood vessel carrying pure blood from Bowman's capsule.
5. **Tubular part of nephron :** The end of the nephron in front of the Hanel's loop coils up to form this part. It has a network of blood cells on its surface.
6. **Collecting duct :** The end of the nephron meets a tube that leads to the bladder.

Mechanism of action of the nephron :

1. Due to the high blood pressure in the cell clusters of Bowman Capsule, excretory substances are filtered out of the blood. These substances go along with the water into the collecting canal and reach the bladder.
2. Due to the high blood pressure of the cell cluster, some important substances such as glucose, amino acids etc. are also filtered out, which are reabsorbed in the hanel's loop and tubule car part. This is called reabsorption.

2. What methods do plants use to get rid of excretory products?

Ans. Plants use the following methods to get rid of excretory products:

1. They can get rid of the excess water by transpiration.
2. Many tissues in plants are made of dead cells, they get rid of by decaying leaves.
3. Some excreted products are stored in the dormant xylem as gum.
4. The excretory substances tannins, resins, gums are stored in the bark which are destroyed by the removal of the bark.

3. How is the amount of urine produced regulated ?

Ans. The amount of urine depends on the water intake by the body. The amount of water absorbed by the nephron tubule depends on the following factors.

1. How much water is there in the body, how much water is to be excreted so that there is no shortage of water in the body tissues
2. How much of the soluble excretory like urea and uric acid and salt etc. is to be excreted from the body. When there is more excretion in the body, more water is required. In this situation more urine is produced.

NCERT EXERCISES

1. The kidneys in human beings are a part of the system for

(a) nutrition. **(c) excretion.**

(b) respiration. **(d) transportation.**

Ans.(c)Excretion

2. Xylem in plant is responsible for :

(a) transport of water

(b) transport of food

(c) carrying amino acids

(d) carrying oxygen.

Ans.(a) transport of water

3. For autotrophic nutrition _____ is necessary.

(a) carbon dioxide and water

(b) chlorophyll

(c) sunlight

(d) all of the above.

Ans.(d) all of the above.

4. By fission of pyruvate, it gives carbon dioxide, water and energy and this reaction takes place in :

(a) cytoplasm (b) mitochondria

(c) chloroplast (d) Nucleus.

Ans.(b) mitochondria

5. How does the digestion of fat take place in our body ? Where does this process take place ?

Ans. Fat digestion takes place in the small intestine. The alkaline secretion of the liver, bile is carried to the small intestine by the bile duct. The process starts with emulsification (breakdown) of large fat globules by the salt of bile into smaller micelles to facilitate further enzymatic reaction and digestion process. The fat-digesting lipase enzyme in pancreatic juice and intestinal juices digest the fat in micelles into triacylglycerol and then fatty acids and glycerol. These fat digestion products are then absorbed by the intestinal mucosa and are carried to tissues by the lymphatic system and blood where they either serve as energy fuel or are stored after re-esterification.

6. What is the role of saliva in digestion of food?

Ans. The juice released from the salivary gland is called saliva. It makes the food very soft. When we break the food into small pieces by chewing with the teeth, then saliva enzyme gets mixed in it. This makes it easier to swallow food. This is called salivary amylase. It also digests the food.

7. What are the conditions necessary for autotrophic nutrition and what are its by products ?

Ans. The following are the conditions necessary for autotrophic nutrition:

- Absorption of light energy by chlorophyll Conversion of light energy into chemical form and hydrolysis water molecules into H_2 and O_2.
- Reduction of carbon dioxide into carbohydrates.

The main products of nutrition are as follows :

- Sugar

- Water
- Oxygen and its by-product

8. What is the difference between aerobic and anaerobic respiration? Name some organisms which have anaerobic respiration.

Ans.

	Aerobic Respiration	Anaerobic Respiration
1.	In the presence of oxygen	In the absence of oxygen
2.	CO_2 and water	Ethanol or lactic acid
3.	Mainly plants and animals	Anaerobic bacteria, yeast, airborne muscles
4.	Energy produced in high amount	Energy produced in low amount

9. How are alveoli designed for maximum exchange of gases?

Ans. The tubules have a balloon-like structure in which the oxygen gas is transferred, it has a surface in which the exchange of gases takes place. In the wall of the alveoli there is a very wide network of blood vessels. The CO_2 brought from the body through the blood gives to the alveoli. The blood of the alveolar blood vessel carries oxygen from the air to all the cells of the body.

10. What can be the consequences of the deficiency of hemoglobin in our body?

Ans. If the amount of hemoglobin in our body is less, then the carrying capacity of oxygen decreases, so diseases caused by lack of oxygen start to suffer. Breathlessness occurs especially due to lack of hemoglobin.

11. Describe the double circulation in human beings. Why is it necessary?

Ans. Blood has to pass through the human heart twice to reach once in the body, hence it is called double circulation. There are two circulations under this :

(i) Systemic circulation

(ii) Pulmonary circulation

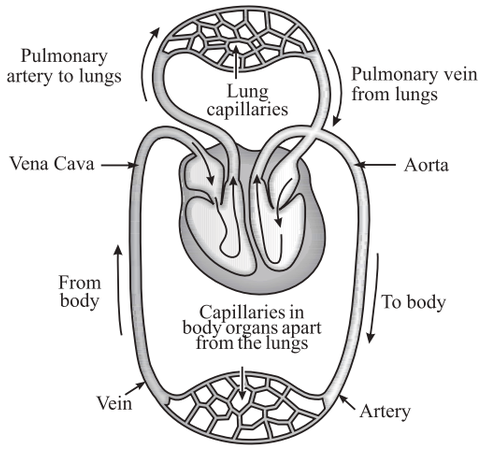

Fig. 5.23 : Double Circulation

(i) Systemic circulation : Systemic circulation transfers oxygenated blood from the left ventricles to capillaries in the tissue. The oxygen-rich blood is passed to the aorta for distribution into various body parts. The veins and vessels later absorb the deoxygenated blood, rich in carbon dioxide from different parts of the body. The deoxygenated blood is transferred back to the superior vena cava, then on to the right atrium. The right atrium transports blood to the right ventricle for pulmonary circulation after receiving the deoxygenated blood.

(ii)Pulmonary circulation : The pulmonary artery receives the blood from the right ventricle and carries it to the lungs for oxygenation. When the oxygenated blood is pumped back to the left atrium via the pulmonary vein that is brought to the left ventricles after the purification process. The left ventricles pump the oxygenated blood to the aorta for systemic circulation.

The need for double circulation : The right and left sides of the human heart do not allow oxygenated and deoxygenated blood to mix. Due to the separation of oxygenated and deoxygenated blood, oxygen reaches the body effectively. It keeps on giving energy to regulate the temperature of the body.

12. What is the difference between transport of materials in xylem and phloem?

Ans. The following is the difference between the transport of materials by xylem and phloem :

Transport by Xylem	Transport by Phloem
1. Xylem carries water and soluble salts to the trunk, branches and leaves of the tree.	The food substances are transported from the leaves to other parts of the plant in a dissolved state.
2.The rise of water and dissolved salts is due to the pull caused by evaporation.	This increases the osmotic pressure, which transports substances from the phloem to the tissues, and the pressure decreases.
3.It does not consume energy.	It requires energy because it is an active process.

13. Compare the structure and mechanism of alveoli in the lung and nephron in the kidney.

Ans.

	Alveoli	Nephron
1.	The alveoli are thin, fine, with a delicate surface. It has a similar structure to a balloon	It is a thin cup-shaped structure.

2.	It increases the surface area for the exchange of gases in the lungs.	In this, the tubular parts carry urine to the collecting duct.
3.	There is a long and wide network of blood cells for the exchange of gases.	Its function is to filter. Due to this there is re-absorption of beneficial substances and water.
4.	In this, there is diffusion of carbon dioxide from blood to air and oxygen from air to blood.	Its surface area also increases for filtering blood and for reabsorption of water. Urine remains as the end product

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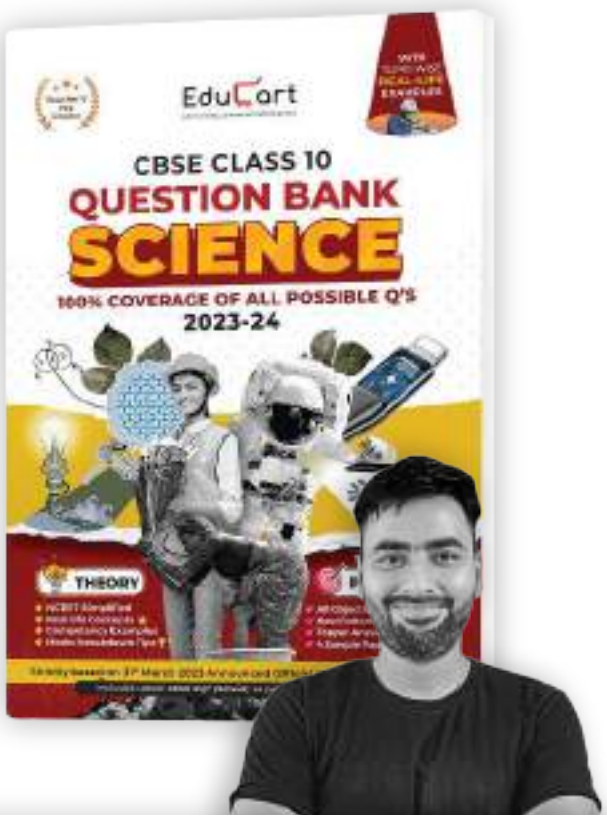

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CBSE 2022-23

Control and Coordination

6

NCERT SOLUTIONS

What's inside

– *In-Chapter Q's (solved)*

– *Textbook Exercise Q's (solved)*

IN-CHAPTER QUESTIONS

Test Yourself

1. What is the difference between reflex action and walking ?

Ans.

Reflex action	Walking
It is controlled and coordinated by the spinal cord	It is acquired through learning
This action takes place in the state of the subconscious mind	This action takes place under the control of the brain
It cannot be changed.	It can be changed.

2. What happens at the synapse between two neurons ?

Ans. The synapse is the small empty space between the two nerve cells. At the synapse, a chemical substance is produced at the end of the axon of one of the neurons that reaches to the other neurons with the help of dendrite. Therefore, the information signal is transmitted through one neuron to other neurons by synapse.

3. Which part of the brain maintains posture and equilibrium of the body ?

Ans. Cerebellum controls and maintains the posture and equilibrium of the body.

4. How do we detect the smell of an agarbatti (incense stick) ?

Ans. It is detected by the olfactory receptor of the nose. The sensory nerves of the forebrain send this information to the olfactory lobe and respond to the information signal.

5. What is the role of the brain in reflex action ?

Ans. The nerves of the whole body join in the form of a bundle on the way to the brain through the spinal cord, which is called reflex arc. The response to a sensation is informed by this reflex arc to the brain. It is reconsidered by the brain.

Test Yourself

1. What is Plant Hormone?

Ans. The chemical substances that co-ordinate the biological activities of plants are called plant hormones or phytohormones.

2. How is the movement of leaves of the sensitive plant different from the movement of a shoot towards light?

Ans. The speed of a mimosa plant is different from the speed affected by the speed of stimulation of light. The speed of mimosa is called contractile speed, while the speed of shoots towards light is affected by the direction of stimulation of light. The plant appears to bend in the same direction from where light is received.

3. Give an example of a plant hormone that promotes growth.

Ans. ● Auxins are responsible for the cell elongation in shoots and also regulate growth.
● Gibberellin is responsible for stem elongation and germination.

4. How do auxins promote the growth of a tendril around a support?

Ans. The tendrils are sensitive to touch. As the tendril comes in contact with a base, the auxin diffuses out and moves to that side. Due to this the cells elongate and the tendril is twisted and wrapped around the base.

5. Design an experiment to demonstrate hydrotropism.

Ans. Hydrotropism is the directional growth of plant roots towards or away from water. For the germination of seeds, moist soil on one side and dry land on the other is used. The seedling first moves downwards due to positive gravity. Later it starts turning towards the wet ground.

Test Yourself

1. How does chemical co-ordination take place in animals?

Ans. In animals, chemical coordination takes place through the hormones secreted by the endocrine gland. It can also be done by the nervous system, which is called the endocrine system. Endocrine glands secrete hormones directly into the bloodstream that directly reaches the specific cells. These cells act according to the information that particular hormones carry.

2. Why is the use of iodised salt advisable?

Ans. Iodine is essential for synthesis of the hormone thyroxine in the thyroid gland. Thyroxine controls basal metabolic rate, carbohydrate, protein and fat metabolism. Deficiency of thyroxine causing disorders of goitre Therefore, it is always advisable to take iodised salt.

3. How does our body respond when adrenaline is secreted into the blood?

Ans. The rate of heartbeat becomes faster when adrenaline is secreted into the blood so that the supply of oxygen to our muscles is more. The amount of blood to the digestive system and skin is reduced because of the small arteries around the muscles of these organs contract.

4. Why are some patients of diabetes treated by giving injections of insulin?

Ans. Insulin hormone regulates the level of sugars in the blood. If it is not adequately secreted, then the sugar level rises in our blood, causing many harmful effects. So, that is why diabetic patients are treated by giving injections of insulin.

NCERT EXERCISES

1. Which of the following is a plant hormone?

(a) Insulin **(b) Thyroxine**

(c) Estrogen **(d) Cytokinin**

Ans.(d) Cytokinin

2. The gap between two neurons is called a :

(a) Dendrite. **(b) Synapse.**

(c) Axon. **(d) Impulse.**

Ans.(b) Synapse.

3. The brain is responsible for :

(a) Thinking.

(b) Regulating the heartbeat.

(c) Balancing the body.

(d) All of the above.

Ans.(b) Regulating the heartbeat

4. What is the function of receptors in our body? Think of situations where receptors do not work properly. What problems are likely to arise?

Ans. Receptors collect the information about changes that happen around us and send the signal to information to the brain which renders the effector mechanism against the change. When receptors do not work properly, the environmental stimuli are not able to create nerve impulses and the body does not respond.

5. Draw the structure of a neuron and explain its function.

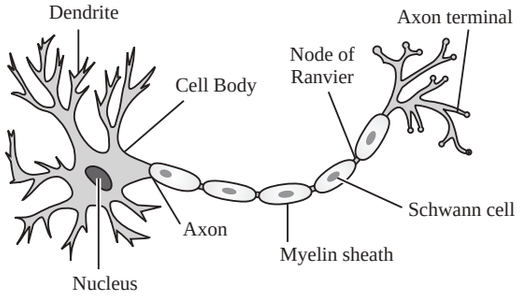
Ans. Nerve cell or neuron is the functional and structural unit of the nervous system. A nerve cell has three parts **:**

(i) cell body

(ii) dendrite

(iii) axon

Structure of a Typical Neuron :



The function of nerve cells is to carry information in the form of electrical signals which are called nerve impulses. Cells receive stimulus to send it to the spinal cord and brain and carry the message from the brain to the target organ.

6. How does phototropism occur in plants?

Ans. Phototropism in a plant takes place under the influence of the stimulus of light towards the light. In light tracking, the plant turns towards the light while the root turns in the opposite direction to the ground.

7. Which signals will get disrupted in case of a spinal cord injury?

Ans. In case of a spinal cord injury, signals coming from the nerves as well as the signals coming to the receptors will be disrupted. Both these signals meet in a bundle in the spinal cord. Hence, both these signals get disrupted.

8. How does chemical co-ordination take place in plants?

Ans. Some chemical substances are secreted by the cells in plants. They are called plant hormones. Plant hormones co-ordinate with the growth and development of plants. These plant hormones work by being secreted somewhere away from the site of action and reaching that place by diffusion.

9. What is the need for a system of control and co-ordination in an organism?

Ans. Every environmental change has an effect on the response of the organism. Like we talk slowly in an office, do not talk loudly. Our activities are done in such a way that the work gets completed. There should not be any interference in it. Control and co-ordination mechanism is absolutely needed in working according to the environment and occasion, due to which the person remains controlled and related.

10. How are involuntary actions and reflex actions different from each other?

Ans.

Involuntary actions	Reflex actions
1. Those actions which occur immediately without any thinking are called **involuntary actions.**	**1.** Reflex action is an immediate response to an event which does not require any processing by the brain.
2. Involuntary actions are controlled by the mid and hind brain. **Example:** Breathing, beating of heart, etc.	**2.** Reflex actions are controlled by the spinal cord. **Example:** Sneezing, coughing, etc.

11. Compare and contrast the neural and hormone mechanisms of action for control and co-ordination in animals.

Ans. Sensory nerves receive information. Actions in animals are controlled by the nerves of the nervous system. It is regulated by all the hormones on the blood sugar level, metabolism, growth and development. Therefore, control and co-ordination in human beings are done by the nervous system and the hormonal system together.

12. What is the difference between the movement in the mimosa plant and the mode of movement in our leg?

Ans. The information of touch is transmitted in the mimosa plant. Plants use electrochemical means to transmit this information from one cell to another. The leaves of the plants bend down. This is due to the reduced osmotic pressure in the base cells. When the time of stimulation is over, the leaves return to their normal state.

Movement of leg : Information operates in the form of electrochemical signals. By reaching the muscles, they are converted into signals, due to which there is movement in the foot. This movement is due to the contraction and expansion of muscles which are controlled by the brain. Leg muscles are connected with nerves.

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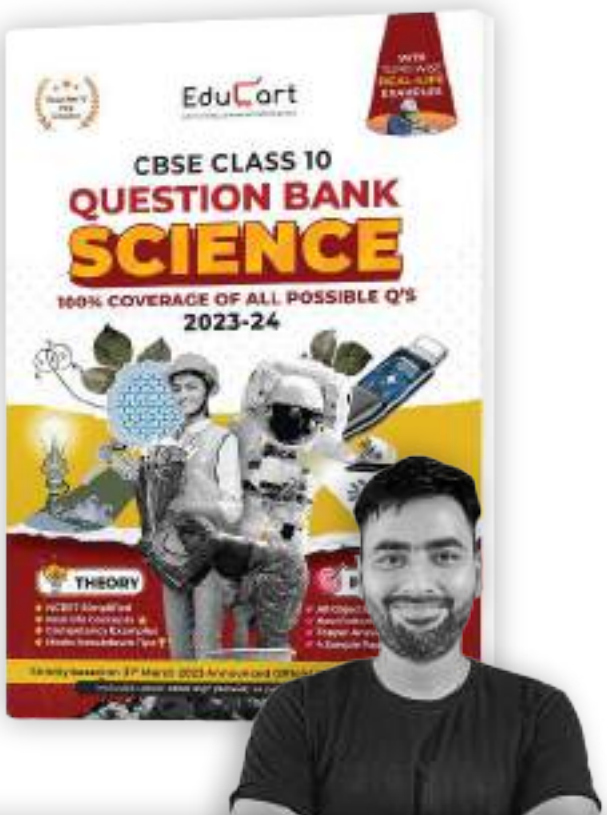

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Arun Sharma
Regional Topper
CBSE 2022-23

How do Organisms Reproduce?

7

NCERT SOLUTIONS

What's inside

IN-CHAPTER QUESTIONS

Test Yourself

1. What is the importance of DNA copying in reproduction?

Ans.
- DNA copying, also known as DNA replication, is a critical process in reproduction because it ensures that the genetic information of the parent organism is accurately passed on to its offspring.
- During reproduction, genetic information is transmitted from one generation to the next, and this information is stored in the DNA of the parent cells.

2. Why is variation beneficial to the species but not necessarily for the individual?

Ans. The various populations of organisms interact with many types of ecological niches. This is important for them to survive in given conditions. In case of any damage caused to the ecological conditions of the population, the population gets adversely affected. The organisms which are able to survive may reproduce to develop a population which is adapted or suited to the varied conditions. Hence variation is beneficial to species, but not to the individuals.

Test Yourself

1. How does binary fission differ from multiple fission?

Ans.

Binary Fission	Multiple Fission
In unicellular organisms, new organisms are produced by cell division. In this, the cell divides into two equal parts like- Amoeba.	In multicellular organisms, new organisms are produced by cell division. In this the cell divides into many daughter cells. E.g. Malaria, Parasites, Plasmodium.

2. How will an organism be benefited if it reproduces through spores?

Ans. An organism is benefited by reproducing through the spores because spores are surrounded by a thick layer which protects them in adverse conditions. When the favourable conditions occur, these spores start to grow again. In this way they successfully live in unfavourable conditions.

3. Can you think of reasons why more complex organisms cannot give rise to new individuals through regeneration?

Ans.
- In complex multicellular organisms, specialised cells make up tissues, tissue make up organs, organs make up organ systems and finally organ systems make up organisms.
- Since complex multicellular organisms have a very high degree of organisation in their body, they cannot be reproduced from their cut body parts by the process of regeneration.

- For example, a dog is a complex multicellular organism which cannot be regenerated from its cut body part say, a cut tail. This is because the cells present in the cut tail of a dog cannot produce dog's organs like heart brain, lungs, stomach, intestines and limbs, etc. needed for the making of a complete dog.

4. Why is vegetative propagation practised for growing some types of plants?

Ans. Vegetative propagation is practiced for growing such plants which usually do not produce seeds or produce non-viable seeds.

Test Yourself

1. How is the process of pollination different from fertilisation?

Ans. Pollination is the process of transfer of pollens from anther to stigma. It occurs with the help of certain pollinators such as air, water, birds, or some insects. Fertilization,on the other hand, is the fusion of the male and female gametes. It occurs inside the ovule and leads to the formation of zygote.

2. What is the role of the seminal vesicles and the prostate gland?

Ans. The prostate and sperms put their secretions in the vas deferens, due to which the sperms come in a liquid medium. Due to this, its transfer is easily done, as well as this discharge also provides nutrition to them. Sperm are microscopic structures.

3. What are the changes seen in girls at the time of puberty?

Ans. The following changes are seen in girls at the time of puberty :

- The production of reproductive hormones starts and the skin becomes oily.
- Breasts and buttocks begin to grow.
- Darkening of the nipple skin that is present at the tip of the breast.
- Beginning of menstruation.

4. How does the embryo get nourishment inside the mother's body?

Ans. The blood flow is good so as to nourish the growing embryo. Placenta is a special tissue which is embedded in the uterine wall and helps the embryo get the nourishment from the mother's tissue. Placenta has villi on the embryo side and blood space on the mother's side. This spacing provides a large area between the mother and the embryo and also for waste removal.

5. If a woman is using a copper-T, will it help in protecting her from sexually transmitted diseases?

Ans. No, a Copper-T (intrauterine device) is a form of contraception that is inserted into the uterus to prevent pregnancy. It does not protect against sexually transmitted infections (STIs). While using a Copper-T may help prevent unwanted pregnancy, it is still important to use condoms or practice other safe sex methods to protect against STIs.

NCERT EXERCISES

1. Asexual reproduction takes place through budding in :

(a) Amoeba **(b) Yeast**

(c) Plasmodium **(d) Leishmania**

Ans.(b) Yeast

2. Which of the following is not a part of the female reproductive system in human beings?

(a) Ovary **(b) Uterus**

(c) Vas deferens **(d) Fallopian tube**

Ans.(c) Vas deferens

3. The anther contains :

(a) sepals **(b) ovules**

(c) pistil **(d) pollen grains**

Ans.(d) pollen grains

4. What are the advantages of sexual reproduction over asexual reproduction?

Ans. Advantages of sexual reproduction :

(a)In sexual reproduction, more variations are produced. Thus, it ensures survival of species in a population.

(b) The new formed individual has characteristics of both the parents. Variations are more viable in sexual mode than in asexual one. This is because in asexual reproduction, DNA has to function inside the inherited cellular apparatus.

5. What are the functions performed by the testis in human beings?

Ans. The testes are the male reproductive organs that are located outside the abdominal cavity within a pouch called scrotum.

Functions of testes :

(a)Produce sperms

(b)Produce a hormone called testosterone, which brings about secondary sexual characters in boys.

6. Why does menstruation occur?

Ans. If there is no fertilization of the ovum, it lives for about a day because each ovary releases a new egg. Therefore, the uterus also prepares every month to receive the fertilized egg. Its end wall becomes fleshy and conjoined. It is necessary for the nutrition of the egg at the time of fertilization. But in the absence of fertilization, even this layer is not needed. Therefore, this layer gradually breaks down and is expelled from the vaginal tract in the form of blood and mucus. This cycle takes about 1 month and it is called the menstrual cycle. Its duration is about 2 to 8 days.

7. Draw a labelled diagram of the longitudinal section of a flower.

Ans.

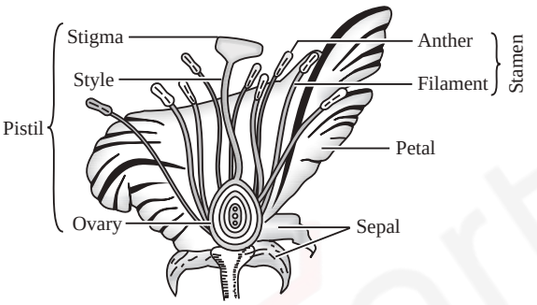

Fig. 7.19 : Longitudinal section of flower

8. What are the different methods of contraception?

Ans. Following are the different methods of contraception :

(i) Physical devices such as condoms, diaphragms and cervical caps are used.

(ii) This method involves tablets or drugs which have to be taken orally. These contain small doses of hormones that prevent the discharge of eggs and thus fertilization cannot occur.

(iii) Contraceptive devices such as loop or Copper-T are placed within the uterus to prevent pregnancy.

(iv) In surgical method, the fallopian tubes are blocked in females to stop flow of eggs and vas deferens is blocked in men to stop the flow of sperms.

(v) Self-Control is also a solution.

9. How are the modes for reproduction different in unicellular and multicellular organisms ?

Ans.

Unicellular Organisms	Multicellular Organisms
Reproductive Cell. The same cell which functions as the body of the organism also gets transformed into reproductive cell.	Specific cells take part in reproduction.

Asexual Reproduction occurs through fission, budding and spore formation.	It occurs by several methods like fragmentation regeneration, budding, spore formation, vegetative reproduction, etc.
No special sex cell or sex organ is present.	special sex cell or sex organ is present.

10. How does it help in the stability of the population of an organism?

Ans. Reproduction ensures the continuity of various species on the Earth and the absence of reproduction; the species will not be able to exist for a long time and may soon get extinct. It is not necessary for an organism to reproduce to stay alive. But for the continuity of life on earth, reproduction is inevitable.

11. What could be the reasons for adopting contraceptive methods?

Ans. The increasing population is a matter of concern for humans because the organism increases its population only through reproduction. Therefore, due to the increasing population, to improve the standard of living

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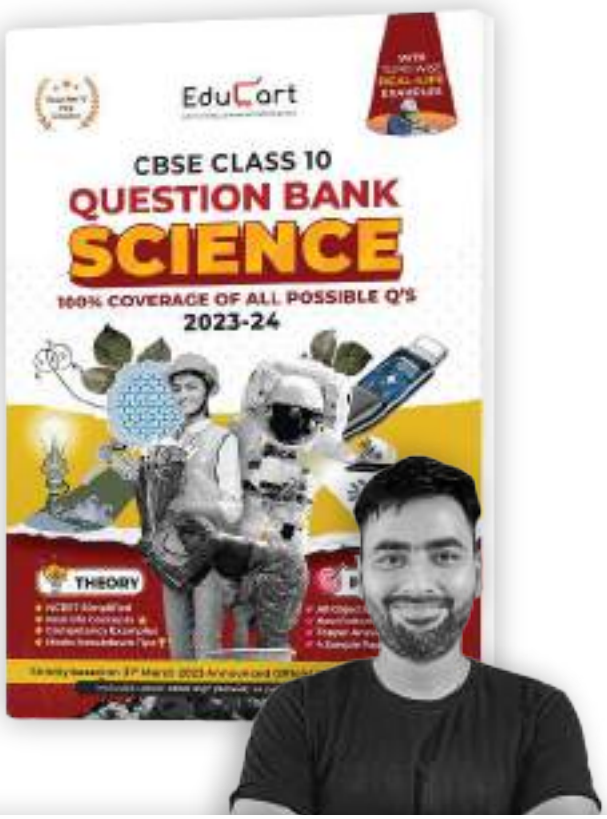

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CBSE 2022-23

Heredity and Evolution 8

NCERT SOLUTIONS

What's inside

IN-CHAPTER QUESTIONS

Test Yourself

1. If a trait A exists in 10% of a population of an asexually reproducing species and a trait B exists in 60% of the same population, which trait is likely to have arisen earlier?

Ans. In the given question we will see that trait B will be seen earlier. This happens because, in the case of an asexually reproducing population, the organisms will be the exact copy of their parents. Now if there is a mutation just in the case of trait A as we see, it will take time to appear in the population. Trait B being the majority will appear first.

2. How does the creation of variations in a species promote survival?

Ans. Variation promotes the survival of species in the following ways:

- Variation improves the survival rate of species as it helps the individual organisms adapt based on altering environmental conditions.
- Variants formed due to environmental concerns form the basis for evolution.

Test Yourself

1. How do Mendel's experiments show that traits may be dominant or recessive?

Ans. Mendel selected true breeding tall (TT) and dwarf (tt) pea plants.When a tall pea plant is crossed with a short (dwarf) pea plant, all the F1 hybrids are tall. (i.e., in this case, the gene causing tallness is dominant while the gene causing dwarfism is recessive.).The trait expressing itself in the hybrid is the dominant one. Mendel's first law of inheritance states that when a pair of contrasting factors is brought in a hybrid, one factor inhibits the appearance of the other. The one which inhibits is the dominant one and which is inhibited is recessive.

2. How do Mendel's experiments show that traits are inherited independently?

Ans. During dihybrid cross by Mendel, it was observed that when two pairs of traits were considered; each trait expressed independently of the other. Thus, Mendel was able to propose the Law of Independent Assortment which says about the independent inheritance of traits.

3. A man with blood group A marries a woman with blood group O and B their daughter has blood group O. Is this information enough to tell you which of the traits – blood group A or O – is dominant? Why or why not?

Ans. The given information is not sufficient to tell which blood group is dominant B

or O. For a daughter to have blood group O her mother should be homozygous OO and father should be heterozygous AO.

4. How is the sex of the child determined in human beings?

Ans. Prediction of whether a child will be male or female before the birth is called sex determination. The child who gets the X chromosome from the father is a girl and the child who gets the Y chromosome from the father is a boy. Father has XY but mother has only XX chromosomes. Thus the Y chromosome determines the sex of the child.

NCERT EXERCISES

1. In one of Mendel's experiments, tall pea plants with purple flowers were crossed with dwarf plants with white flowers. The flowers of all the plants of his praise were purple in color. But about half of them were dwarfs. From this it can be said that the genetic composition of tall parent plants was :

(a) TTWW (b) TTww

(c) Tt WW (d) Tt Ww

Ans. (c) TtWW

2. One study showed that the parents of children with light colored eyes also have light colored eyes. On the basis of this, can we say whether the symptom of light colored eyes is effective or ineffective? Explain your answer.

Ans. On the basis of the above description we cannot say whether the light colored eye trait is dominant or recessive, as both the parents have light colored eyes. It may be that both the gene variants are recessive in the parent, so whether there is a second choice of eye color or not, the offspring was found to have light colored eyes. Considering the second assumption, it is shown that the light-colored eye symptom is dominant. Some children at this stage may have dark eyes, as the recessive symptom should be expressed in 1 in 4 children.

3. Make a project to find the effective color of dog skin.

Ans. First a pure black skin dog (BB) and a pure white skinned bitch (WW) are selected. They are hybridized on time. If all the pups produced in them are black-skinned then the black-skinned trait is said to be dominant.

Dog	×	bitch
Black skinned (BB)	↓	white skinned (WW)
F_1 progeny	previous BW	all black skinned

4. How is equal share of genetic contribution by male and female parents in the progeny ensured?

Ans. If tall pea plants with round seeds are crossed with dwarf plants with wrinkled seeds, then in the F_2 generation, the tall or dwarf trait and the rounded wrinkled trait are inherited independently.

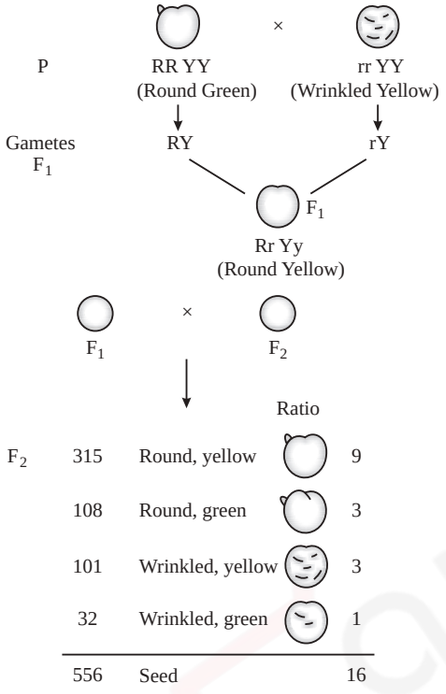

Fig. 8.8

If a complete set of whole organisms is obtained from the parent plant of the offspring plant, then the experiment given in the figure 8.8 cannot be successful, because the 2 traits R and Y will be attached to each other in the set and cannot be drawn independently. In fact, gene sets do not exist as a single DNA chain, but as separate independent atoms of DNA. Each of these chromosomes has two replicates. In which they get one from the male and the other from the female parent. Only 1 chromosome of each pair of chromosomes from each generative cell goes to a generative cell. When the fusion of two gametes takes place, the number of chromosomes in the zygote formed from them becomes normal again.

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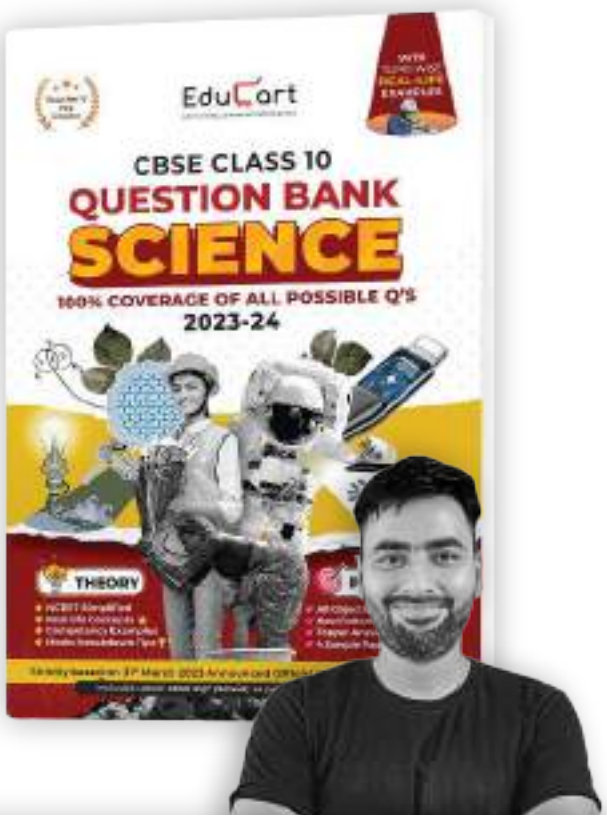

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Light : Reflection and Refraction

9

NCERT SOLUTIONS

What's inside

– In-Chapter Q's (solved)

– Textbook Exercise Q's (solved)

IN-CHAPTER QUESTIONS

Test Yourself

1. Define the principal focus of a concave mirror.

Ans. The principal focus of a concave mirror is the point on its principal axis where rays parallel to the principal axis meet after reflection from the mirror.

2. The radius of curvature of a spherical mirror is 20 cm. What is its focal length?

Ans. $f = \frac{R}{2}$

$= \frac{20}{2} = 10$ cm

3. Name a mirror that can give an erect and enlarged image of an object.

Ans. Concave mirror.

4. Why do we prefer a convex mirror as a rear-view mirror in vehicles?

Ans. Virtual and erect images are always formed in a convex mirror and have a wide field of vision, due to which the driver is able to see a very large area behind him. Thus, convex mirrors are preferred as rear-view in vehicles.

Test Yourself

1. Find the focal length of a convex mirror whose radius of curvature is 32 cm.

Ans. f = +16 cm.

2. A concave mirror produces a three times magnified (enlarged) real image of an object placed at 10 cm in front of it. Where is the image located?

Ans. m = 3, u = –10 cm, v = ?

From $m = -\frac{v}{u}$.

$v = -(3)(-10) = 30$ cm

So, the image is located 30 cm away behind the mirror.

Test Yourself

1. Define 1 dioptre of power of a lens.

Ans. 1 dioptre is the power of the lens whose focal length is 1 m.

2. A convex lens forms a real and inverted image of a needle at a distance of 50 cm from it. Where is the needle placed in front of the convex lens if the image is equal to the size of the object? Also, find the power of the lens.

Ans. $m = -1$, $v = +50$, $u = ?$

$$m = \frac{v}{u} = \frac{50}{u}$$

$$u = \frac{v}{m} = \frac{50}{-1}$$

$$u = -50$$

Using lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$= \frac{1}{50} - \frac{1}{-50} = \frac{2}{50}$$

$$f = 25 \text{ cm}$$

Power of lens, $P = \frac{1}{f} = \frac{100}{25}$ m^{-1} = +4 D

3. Find the power of a concave lens of focal length 2 m.

Ans. –0.5 D.

NCERT EXERCISES

1. Which of the following materials cannot be used to make lenses?

(a) Water (b) Glass

(c) Plastic (d) Soil

Ans.(d) Soil

2. The image formed by a concave mirror of an object is found to be virtual, erect and larger than the object. The position of the object will be :

(a) Between the principal focus and the center of curvature

(b) At the center of curvature

(c) Beyond the center of curvature

(d) Between the pole and the principal focus of the mirror **[UP Board 2019 (824 - BN)]**

Ans.(d) Between the pole and the principal focus of the mirror

3. Where do you place the object in front of a convex lens to get a real and equal size image of an object?

(a) At the principal focus of the lens,

(b) At twice the focal length

(c) At infinity

(d) Between the optical centre of the lens and the principal focus

Ans.(c) At infinity

4. The focal length of a spherical mirror is : 15 cm. The mirror is probably :

(a) concave (b) convex

(c) plane mirror (d) none of these

Ans.(a) concave

5. No matter how far you stand from a mirror, your image always appears straight. The mirror probably is :

(a) plane

(b) only concave

(c) only convex

(d) either plane or convex

Ans.(d) either plane or convex

6. Which of the following lenses would you prefer while reading small letters in a dictionary?

(a) A convex lens with focal length of 50 cm

(b) A concave lens with focal length of 50 cm

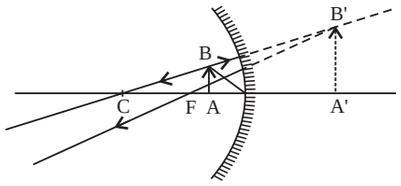
(c) A convex lens with focal length of 5 cm

(d) A concave lens with focal length of 5 cm

Ans.(c) A convex lens with focal length of 5 cm

7. Using a concave mirror of focal length 15 cm, we want to form an erect image of an object. What should be the range of distance of the object from the mirror? What is the nature of the image? Is the image bigger or smaller than the object? Draw a ray diagram of the image formation for this case.

Ans.



Place the object 15 cm away from the mirror.

Nature of image is virtual and erect. Size of image is larger than the object.

8. Name the mirror used for the following situations :

(a) Headlight of a car

(b) Side mirror/ rear mirror of a vehicle

(c) Solar furnace

Explain your answers.

Ans.(a) A concave mirror is used in the headlight of a car. The reason is that it is a good reflector and produce parallel beam of light.

(b) A convex mirror is used for side/rear view in a vehicle because it helps the driver to view large areas of the traffic behind him and he can easily detect the vehicle coming or running behind him.

(c) A concave mirror is used in the solar furnace, because it focuses the rays of the sun and puts it on the furnace, due to which the furnace receives more heat.

9. Cover the half of a convex lens with black paper. Will this lens be able to form a complete image of an object? Check your answer with the help of an experiment. Explain your observations.

Ans. Yes, this lens will be able to form a complete image of an object.

Observation : When half of a convex lens is covered with black paper and the object is placed near it, it is observed that its full image is formed on the screen.

10. An object 5 cm long is placed at a distance of 25 cm from a converging lens of focal length 10 cm. Find the position, size and nature of the image formed along with the ray diagram.

Ans. Here, h = 5cm = Height of image, h' = Height of image = ?, $u = -25$ cm, $f = +25$ cm, v = ?

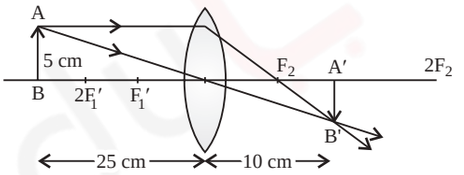


Fig. 9.65

Using Lens formula :

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} + \frac{1}{-25}$$

$$= \frac{1}{10} - \frac{1}{25} = \frac{5-2}{50}$$

$$\frac{1}{v} = \frac{3}{50}$$

$$v = \frac{50}{3}$$

$\therefore$ $v = 16.6$ cm

v = positive. This implies that the image formed at a distance of 16.6 cm behind the mirror is real and inverted.

Power of lens $m = \frac{h'}{h} = \frac{v}{u}$

$\Rightarrow \quad h' = \frac{v}{u} \times h = \frac{50}{3} \times \frac{1}{-25} \times 5$

$= -3.33$ cm

h' = negative. Thus, the image formed is inverted.

11. An object is placed at a distance of 15 cm from a convex lens of focal length 10 cm. Write the nature and magnification of the image.

[**Ans.** The image will be real and inverted. $m = 2$]

Ans. $\mu = -15$ cm; $f = +10$ cm ; v = ?

Using lens formula

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{v}$$

$$= \frac{1}{10} + \left(\frac{1}{-15}\right)$$

$$\frac{1}{v} = \frac{5}{150}$$

$$v = +30 \text{ cm}$$

Magnification $m = \frac{v}{\mu} = +\left(\frac{30}{-15}\right) = -2$

The image formed will be real and inverted and twice the size of the object.

12. An object is placed at a distance of 10 cm from a convex mirror of focal length 15 cm. Find the position and image of the image.

Ans. $u = -10$ cm, v =?, $f = 15$ cm

Using the formula :

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{15} - \frac{1}{-10}$$

$$= \frac{1}{15} + \frac{1}{10} = \frac{5}{30}$$

$$= \frac{1}{6}$$

$\square \qquad v = 6$ cm

Image is formed 6 cm behind the mirror and is virtual and erect in nature.

13. The magnification of an image formed by plane mirror is +1. What does this mean?

Ans. The image formed by plane mirror has $m = +1$. Plus (+) sign represent that the image is virtual and erect. In this mirror, the size of an image is equal to that of an object.

14. An object of length 0.5 cm is placed at a distance of 20 cm in front of a convex mirror of radius of curvature 30 cm. Find the position, nature and size of the image.

Ans. Here, $h = 5$ cm = height of an object

R = Radius of curvature = 30 cm

$\therefore \quad f = \frac{R}{2} = \frac{30}{2} = 15$ cm

$v = -20$ cm

$v = ?, h' = ?$

Using mirror formula,

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\therefore \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{15} + \frac{1}{20} = \frac{7}{60}$$

$$\Rightarrow \quad v = \frac{60}{7} = 8.57 \text{ cm}$$

The distance of image is 8.57 cm behind the mirror.

Magnification $m = \frac{h'}{h} = -\frac{v}{u}$

$$\therefore \quad h' = -\frac{v}{u} \times h = -\frac{60}{7} \times \frac{1}{-20} \times 5$$

$$= \frac{15}{7} = 2.17$$

$$= 2.2 \text{ cm}$$

Image formed is small, virtual and erect in nature.

15. An object of size 7.0 cm is placed at a distance of 27 cm in front of a concave mirror of focal length 18 cm. At what distance from the mirror should a screen be placed so that a clear focused image of the object is formed? Find the size and nature of an object.

Ans. Height of an object $h_1 = 5$ cm

Object distance $u = -27$ cm

Focal length $= -18$ cm

Height of an image $h_1 = ?$

Image distance $u = ?$

From the formula :

$$\Rightarrow \quad \frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\Rightarrow \quad \frac{1}{-27} + \frac{1}{v} = \frac{1}{-18}$$

$$\Rightarrow \quad \frac{1}{v} = -\frac{1}{18} + \frac{1}{27} = -\frac{3+2}{54} = -\frac{1}{54}$$

$\Rightarrow \quad v = -54$ cm

Therefore, screen should be placed at a distance of 54 cm from the screen.

$$m = \frac{h_2}{h_1} = -\frac{v}{u}$$

$$\Rightarrow \quad \frac{h_2}{7} = \frac{-54}{-27}$$

$$\Rightarrow \quad \frac{h_2}{7} = 2 \Rightarrow h_2 = 14 \text{ cm}$$

Thus, the height of the image formed is 14 cm and is real and inverted in nature.

16. Find the focal length of the lens whose power is – 2.0 D. What is the type of lens?

Ans. Here $P = -2.0$ D

Power of lens P $= \frac{100}{f}$ (in cm)

$$f = \frac{100}{P} = \frac{-100}{2} = -50 \text{ cm}$$

f = negative. Thus, it is a concave lens.

17. A doctor prescribes a rectifier lens of power +1.5 D. Find the focal length of the lens. Is the lens converging or diverging?

Ans. Here P = 1.5 D

Power of lens P $= \frac{1}{f}$ (m)

$$f = \frac{1}{P} = \frac{1}{1.5}$$

$$= \frac{10}{15} = \frac{2}{3} \text{m}$$

f = positive. Thus, it is a converging (convex) lens.

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ARIHANT KAPKOTI
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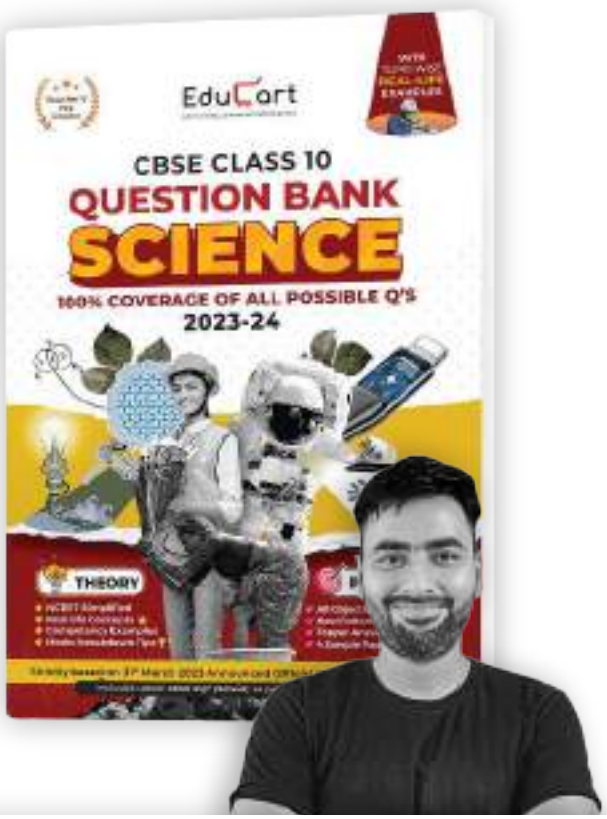

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★★★★★

Arun Sharma
Regional Topper
CBSE 2022-23

The Human Eye and the Colourful World

10

NCERT SOLUTIONS

What's inside

– *In-Chapter Q's (solved)*

– *Textbook Exercise Q's (solved)*

IN-CHAPTER QUESTIONS

Test Yourself

1. What is meant by power of accommodation of the eye?

Ans. Power of accommodation is the ability of the eye to change the focal length of the eye-lens and form a clear image of a distant object or a near object on the retina.

2. A person with a myopic eye cannot see objects beyond 1.2 m distinctly. What should be the type of the corrective lens used to restore proper vision?

Ans. Concave lens.

Power of lens $P = \frac{1}{f}$

$P = \frac{1}{-1.2}$

$= -\frac{10}{12}$ (for concave lens)

$\therefore \quad P = -0.83$ D

3. What is the far point and near point of the human eye with normal vision?

Ans. Near point is the shortest distance of the eye at which the placed object is clearly visible is called near point. For a normal eye it is 25 cm.

Far Point is the farthest distance of the eye at which the placed object is clearly visible is called the far point. For the normal eye, the far point is infinity.

4. A student has difficulty reading the blackboard while sitting in the last row. What could be the defect the child is suffering from? How can it be corrected?

Ans. The student is suffering from myopia. It can be corrected with a concave lens.

NCERT EXERCISES

1. The human eye can focus on objects at different distances by adjusting the focal length of the eye lens. This is due to :

(a) presbyopia (b) accommodation
(c) near-sightedness (d) far-sightedness

Ans.(b) accommodation.

2. The human eye forms the image of an object at its :

(a) cornea (b) iris
(c) pupil (d) retina

Ans.(d) retina.

3. The least distance of distinct vision for a young adult with normal vision is about

(a) 25 m (b) 2.5 cm

(c) 25 cm (d) 2.5 m

Ans.(c) 25 cm

4. The change in focal length of an eye lens is caused by the action of the :

(a) pupil (b) retina.

(c) ciliary muscles. (d) iris.

Ans.(c) ciliary muscles

5. A person needs a lens of power –5.5 dioptres for correcting his distant vision. For correcting his near vision, he needs a lens of power +1.5 dioptre. What is the focal length of the lens required for correcting :

(i) distant vision, and (ii) near vision?

Ans.(i) for far sight :

$$P = -5.5 \text{ D}$$

$$\text{Power of lens} = \frac{1}{f} \text{ (in m)}$$

$$\therefore \quad f = \frac{1}{P} = \frac{1}{-5.5}$$

$$= \frac{-10}{15} = -0.182 = -0.18 \text{ m}$$

(ii) for near sight

$$P = +1.5$$

$$\therefore \quad P = \frac{1}{f} \text{ (m)}$$

$$\therefore \quad f = \frac{1}{P} = \frac{1}{1.5}$$

$$= \frac{10}{15} = \frac{2}{3}$$

$$= 0.66 \text{ cm} = 0.67 \text{ cm}$$

6. The far point of a myopic person is 80 cm in front of the eye. What is the nature and power of the lens required to correct the problem?

Ans.

$$P = \frac{1}{f}$$

$$f = -80 \text{ cm}$$

$$P = \frac{1}{f} = -\frac{100}{80}$$

$$= -\frac{5}{4} = -1.25 \text{ D}$$

For correction of the defect, the lens should be concave, because power is negative.

7. Make a diagram to show how hypermetropia is corrected. The near point of a hypermetropic eye is 1 m. What is the power of the lens required to correct this defect? Assume that the near point of the normal eye is 25 cm.

Ans. Refer Fig. 10.5

Here $u = -25\text{cm}$, $v = -1\text{m} = -100$ cm

Lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{-f}$

$$\frac{1}{-100} - \frac{1}{-25} = \frac{1}{f}$$

$$\Rightarrow \quad \frac{1}{f} = \frac{-1+4}{100}$$

$$\Rightarrow \quad f = \frac{100}{3}\text{cm}$$

$$= \frac{100}{3} \times \frac{1}{100}$$

$$= \frac{1}{3}\text{cm}$$

Power of lens $P = \frac{1}{f} = \frac{1}{\frac{1}{3}} = +3\text{D}$

So, convex lens is used to correct this defect.

8. Why are normal eyes not able to see clearly objects placed closer than 25 cm?

Ans. A normal eye can see object kept at different distances clearly due to ability of ciliary muscles to increase or decrease its focal length of the eye lens. However, we cannot see objects placed closer than 25 cm because ciliary muscles can contract to a certain limit. Thus, the object placed closer than 25 cm appears blurred as the light rays coming from the object meet beyond retina.

9. What happens to the image distance in the eye when we increase the distance of an object from the eye?

10. Why do stars twinkle?

Ans. Refer Twinking of Stars on page no. 248 of Textbook.

11. Why do planets not twinkle?

Ans. Planets do not twinkle as they are closer to the Earth than those distant stars, so planets appear larger in comparison. Due to the planets' closeness to Earth, the light coming from them does not bend much due to Earth's atmosphere. Therefore, the light coming from our solar system's planets does not appear to twinkle.

12. Why does the sky appear dark instead of blue to an astronaut?

Ans. The sky appears black than blue to an astronaut because at a high altitude (space) there is lack of atmosphere. So, there is no scattering of light. Due to this, the sky appears dark to the astronaut when travelling in space.

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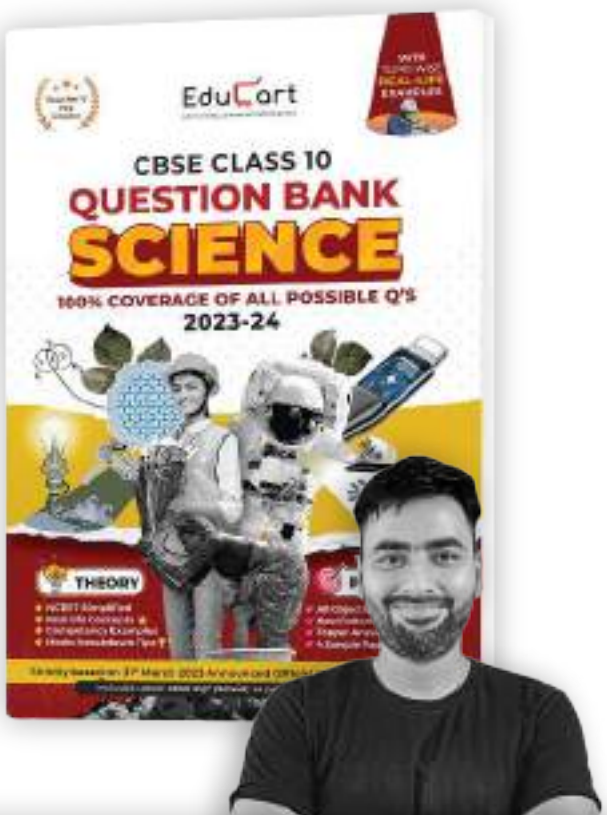

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Arun Sharma
Regional Topper
CBSE 2022-23

Electricity 11

NCERT SOLUTIONS

What's inside

– In-Chapter Q's (solved)

– Textbook Exercise Q's (solved)

IN-CHAPTER QUESTIONS

Test Yourself

1. What does an electric circuit mean?

Ans. The arrangement in which electric current flows is called an electric circuit. It consists of batteries, conductors, resistors, switches and many other devices.

2. Define the unit of current.

Ans. When 1 coulomb of current flows through a conductor for 1 second, then the amount of electric current used is called 1 ampere.

3. Calculate the number of electrons constituting one coulomb of charge.

Ans. Since, charge of electron = 1.6×10^{-19} C

No. of electrons = n

According to the question,

$n \times 1.6 \times 10^{-19} = 1$ C

$$n = \frac{1}{1.6 \times 10^{-19}}$$

$$= \frac{10^9}{1.6} \times \frac{100}{16} \times 10^{18}$$

$$= 6.25 \times 10^{18}$$

$$1 \text{ C} = 6.25 \times 10^{18} \text{ electrons}$$

Test Yourself

1. Name a device that helps to maintain a potential difference across a conductor.

Ans. Cell or Battery

2. What is meant by saying that the potential difference between two points is 1 V?

Ans. The potential difference between two points is 1 V means to move a charge of 1 C, 1 joule work is done.

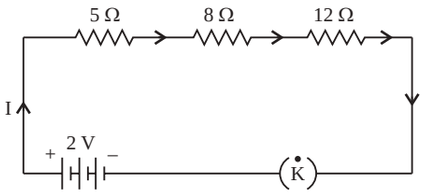
3. How much energy is given to each coulomb of charge passing through a 6 V battery?

Ans. Using formula—W = V Q = 6 V × 1C = 6 J

Test Yourself

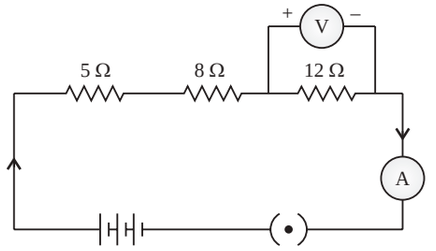
1. Draw a schematic diagram of a circuit consisting of a battery of three cells of 2 V each, a 5 Ω resistor, an 8 Ω resistor, and a 12 Ω resistor, and a plug key, all connected in series.

Ans.



2. Redraw the circuit of Question 1, putting in an ammeter to measure the current through the resistors and a voltmeter to measure the potential difference across the 12 Ω resistor. What would be the readings in the ammeter and the voltmeter?

Ans.



Resistance of circuit,

$$= R_1 + R_2 + R_3$$
$$= 5 + 8 + 12 = 25\ \Omega$$

Using Ohm's law

$$I = \frac{V}{R} = \frac{2 \times 3}{25} = \frac{6}{25} = 0.24\ \Omega$$

The potential difference between 12 Ω resistor is

$$V = IR = 0.24 \times 12 = 2.88\ V$$

The reading of the ammeter is 0.24 A and the voltmeter is 2.88 V.

Test Yourself

1. Judge the equivalent resistance when the following are connected in parallel : (a) 1 Ω and 10^6 Ω, (b) 1 Ω and 10^3 Ω and 10^6 Ω.

Ans.(a) When resistance is arranged in parallel,

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{1} + \frac{1}{10^6}$$

$$= \frac{10^6 + 1}{10^6} = \frac{1000001}{1000000}$$

$$R_P = \frac{1000001}{1000000} = 0.9\Omega$$

(b) Similarly,

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{1} + \frac{1}{10^3} + \frac{1}{10^6}$$

$$= \frac{10^6 + 10^3 + 1}{10^6}$$

$$R_P = \frac{10^6}{1000000 + 1000 + 1}$$

$$= \frac{1000000}{1001001} = 0.9\ \Omega$$

2. An electric lamp of 100 Ω, a toaster of resistance 50 Ω, and a water filter of resistance 500 Ω are connected in parallel to a 220 V source. What is the resistance of an electric iron connected to the same source that takes as much current as all three appliances, and what is the current through it?

Ans. Here, $R_1 = 100$, $R_2 = 50$, $R_3 = 500$

When they are connected in parallel, then

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{100} + \frac{1}{50} + \frac{1}{500}$$

$$= \frac{5 + 10 + 1}{500} = \frac{16}{500}$$

$$R_P = \frac{500}{16} = 31.25\ \Omega$$

Equivalent resistance = 31.25 W

Current flowing

$$I = \frac{V}{R}$$

3. What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series?

Ans. Instead of connecting in series, connecting electrical devices in parallel has the following advantages:

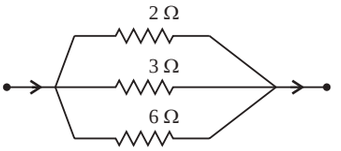
(i) The value of equivalent resistance in parallel is less than in series.

(ii)The value of current becomes high in parallel resistors.

(iii)Lesser resistance in the parallel leads to less energy loss.

4. How can three resistors of resistances 2 Ω, 3 Ω and 6 Ω be connected to give a total resistance of (a) 4 Ω, (b) 1 Ω?

Ans.(a) To get 4 Ω equivalent resistance, 3 Ω and 6 Ω resistors are connected in parallel and 2 Ω in series.



When 3 Ω and 6 Ω are added in parallel.

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{3} + \frac{1}{6}$$

$$= \frac{2+1}{6} = \frac{1}{2} \Rightarrow R_P = 2\ \Omega$$

When its equivalent resistance is connected in series with a resistor of 2 Ω, then

$$R_S = R_1 + R_2 = 2 + 2 = 4\ \Omega$$

When all three resistors are connected, the equivalent resistance is 1 Ω.

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{3+2+1}{6} = \frac{6}{6} = 1$$

$$R_P = 1\ \Omega$$

5. What is (a) the highest, (b) the lowest total resistance that can be secured by combinations of four coils of resistance 4 Ω, 8 Ω, 12 Ω, 24 Ω?

Ans.(a) To obtain the highest resistance, connect the coils in series,

$$R_S = R_1 + R_2 + R_3 + R_4$$
$$= 4 + 8 + 12 + 24 = 48\ \Omega$$

(b) To obtain the lowest resistance, connect the coils in parallel,

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{4} + \frac{1}{8} + \frac{1}{12} + \frac{1}{24}$$

$$= \frac{6+3+2+1}{24} = \frac{12}{24} = \frac{1}{2}$$

$$R_P = 2\ \Omega$$

Test Yourself

1. Why does the cord of an electric heater not glow while the heating element does?

Ans. By Joule's law of heating, $H \propto R$

Therefore, the resistance of the heating element is much higher than that of the heater cord. This gives more heat and makes this component better, whereas the cord of an electric heater does not.

2. Compute the heat generated while transferring 96000 Coulomb of charge in one hour through a potential difference of 50 V.

Ans. Here,

t = 1h = 1 × 60 × 60 second

= 3600 seconds

From formula W = H = VQ = 50 × 96000

= 4800000 J

3. An electric iron of resistance 20 Ω takes a current of 5 A. Calculate the heat developed in 30 s.

Ans. Here, I = 5 A, R = 20 Ω, t = 30 s

From formula H = I^2Rt

= 5 × 5 × 20 × 30

= 15000 J

= 15 KJ

Heat = 15 KJ

Test Yourself

1. What determines the rate at which energy is delivered by a current?

Ans. The rate of energy provided by an electric current is determined by the work done per second.

$$\text{Amount of heat} = \frac{\text{Work done}}{\text{time required}}$$

2. An electric motor takes 5 A from a 220 V line. Determine the power of the motor and the energy consumed in 2 h.

Ans. Here, I = 5 A, V = 220 V, t = 2 h = 2 × 3600 s

From the formula, P = VI

= 5 × 220 = 1100 W

Heat = Power × time

= 1100 × 2 × 3600

= 7920000 J = 7.92 × 103 KJ

NCERT EXERCISES

1. A piece of wire of resistance *R* is cut into five equal parts. These parts are then connected in parallel. If the equivalent resistance of this combination is *R'*, then the ratio *R/R'* is :

(a) 1/25 (b) 1/5

(c) 5 **(d) 25**

Ans. (d)Resistance of piece $-\frac{R}{5}$

Explanation : For parallel combination of five pieces:

$$\frac{1}{R'} = \frac{1}{R/5} + \frac{1}{R/5} + \frac{1}{R/5} + \frac{1}{R/5} + \frac{1}{R/5}$$

$$\frac{1}{R'} = \frac{5}{R} + \frac{5}{R} + \frac{5}{R} + \frac{5}{R} + \frac{5}{R} = \frac{25}{R}$$

$$\Rightarrow \quad \frac{R}{R'} = 25$$

2. Which of the following terms does not represent electrical power in a circuit?

(a) I^2R **(b) IR^2**

(c) VI **(d) V^2/R [NCERT]**

Ans.(b) IR^2

Explanation : Electric Power = VI = IR (R) = I^2R

$$= V\left[\frac{V}{R}\right] = \frac{V^2}{R}$$

Only IR^2 does not represent electrical power in a circuit.

3. An electric bulb is rated 220 V and 100 W. When it is operated on 110 V, the power consumed will be :

(a) 100 W **(b) 75 W**

(c) 50 W **(d) 25 W**

Ans.(d) 25 W

Explanation: Resistance of bulb

$$R = \frac{V^2}{P} = \frac{220 \times 220}{100} = 484\Omega$$

Power used by 10 V bulb

$$P' = \frac{V^2}{R} = \frac{110 \times 110}{484} = 25 \text{ W.}$$

4. Two conducting wires of the same material and equal lengths and equal diameters are first connected in series and then parallel in a circuit across the same potential difference. The ratio of heat produced in series and parallel combinations would be :

(a) 1 : 2 **(b) 2 : 1**

(c) 1 : 4 **(d) 4 : 1**

Ans.(c) 1 : 4

Explanation : The wire is made of the same conducting material, having equal

length and width, thus each wire has the same resistance = R

For series combination :

$$R_S = R + R = 2R$$

For parallel combination : $\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R}$

Electric Power $P = \frac{V^2}{R}$

For series combination, the heat released : $P_s = \frac{V^2}{R_s}$

For parallel combination, the heat released :

$$P_p = \frac{V^2}{R_p}$$

$$\Rightarrow \quad \frac{P_s}{P_p} = \frac{V^2/R_s}{V^2/R_p} = \frac{1}{4}$$

$$\therefore \quad P_s : P_4 = 1 : 4.$$

5. How is a voltmeter connected in the circuit to measure the potential difference between two points?

Ans. To measure the potential difference between two points, a voltmeter is connected in parallel between the two points.

6. A copper wire has a diameter of 0.5 mm and resistivity of 1.6×10^{-8} Ω m. What will be the length of this wire to make its resistance 10 Ω? How much does the resistance change if the diameter is doubled?

Ans. d = diameter = 0.5 mm, $e = 1.6 \times 10^{-8}$ Ω m, R = 10 Ω

$$r = \frac{d}{2} = \frac{0.5 \quad 10^{-3}}{2}$$

$$m = \frac{5}{20} \times 10^{-3} m$$

$$R = \rho \frac{l}{A}$$

$$l = \frac{R \quad A}{\rho}$$

$$= \frac{10 \quad 3.14 \quad \left(\frac{5}{20} \times 10^{-3}\right)^2}{1.6 \quad 10^{-8}}$$

$$= \frac{3.14 \times 10}{1.6 \times 10^{-8}} \times \frac{5}{20} \times \frac{5}{20} \times 10^{-3} \times 10^{-3}$$

$$= \frac{78.50 \times 10}{1.6 \times 4}$$

$$= \frac{7850}{69} = 122.65 = 122.7\text{m}$$

$\therefore$ Length of wire = 122.7 m

If $d = 2 \times 0.5 = 1.0$ mm, $r = \frac{1}{2} \times 10^{-3}$ m

$$R = \rho \frac{l}{A}$$

$$l = \frac{10 \times 3.14 \times \left(\frac{1}{2} \times 10^{-3}\right)^2}{1.6 \quad 10^{-8}}$$

$$l = \frac{3.14 \times 10 \times 10^{-6}}{1.6 \times 4 \times 10^{-8}}$$

$$= \frac{31400}{64} = 490.5$$

Thus, we can say,

Since $R \propto \frac{1}{d^2}$

So, if d is doubled, then R becomes $1/4^{th}$ time.

7. The values of current *I* flowing in a given resistor for the corresponding values of potential difference *V* across the resistor are given below :

***I* (amperes)**	**0.5**	**1.0**	**2.0**	**3.0**	**4.0**
***V* (volts)**	**1.6**	**3.4**	**6.7**	**10.2**	**13.2**

Plot a graph between *V* and *I* and calculate the resistance of that resistor.

Ans.

Resistance = $\frac{V_2 - V_1}{I_2 - I_1}$

$$R_1 = \frac{3.4 - 1.6}{1.0 - 0.5} = \frac{1.8}{0.5} = 3.5\Omega$$

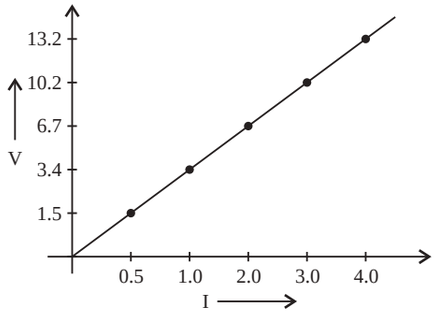
$$R_2 = \frac{6.7 - 3.4}{2.0 - 1.0} = 3.3\Omega$$

$$R_3 = \frac{10.2 - 3.4}{3.0 - 2.0} = 6.8\ \Omega$$

$$R_4 = \frac{13.2 - 10.2}{4.0 - 3.0} = 3.0\ \Omega$$

$$R = \frac{R_1 + R_2 + R_3 + R_4}{4} = \frac{16.7}{4}\ 4.2\ \Omega$$

Resistance = 4.2 Ω



8. When a 12 V battery is connected across an unknown resistor, there is a current of 2.5 mA in the circuit. Find the value of the resistance of the resistor.

Ans. Here, V = 12 V, I = 2.5 mA = 2.5×10^{-3} A

Using Ohm's Law,

$$R = \frac{V}{I} = \frac{12}{2.5 \times 10^{-3}}$$

$$= \frac{12 \times 10^3}{2.5} = \frac{120}{25} \times 10^3 = 4.8 \times 10^3 \Omega$$

The resistance of a resistor is $4.8x \times 10^{-3}\ \Omega$.

9. A battery of 9 V is connected in series with resistors of 0.2 Ω, 0.3 Ω, 0.4 Ω, 0.5 Ω and 12 Ω, respectively. How much current would flow through the 12 Ω resistor?

Ans. The resistance is connected in series

$$R_s = 0.2\Omega + 0.3\Omega + 0.4\Omega + 0.5\Omega + 12\Omega$$

$$= 13.4\Omega$$

$$\text{Current} = I = \frac{V}{R_s} = \frac{9\ V}{13.4\ \Omega} = 0.67A$$

So, the current flowing through 12 Ω resistor = 0.67 A.

10. How many 176 Ω resistors (in parallel) are required to carry 5 A on a 220 V line?

Ans. Here, V = 220 V, I = 5 A

Let the number of resistors be *n*

Resistance of circuit $R = \frac{V}{I} = \frac{220V}{5A} = 44\ \Omega$

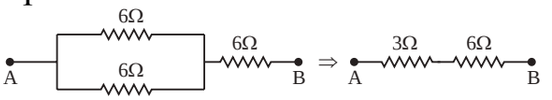
Resistance of each resistor $r = 176\ \Omega$

For *n* resistors, if the resistance of each is *r* is connected in parallel, the resultant resistance R is :

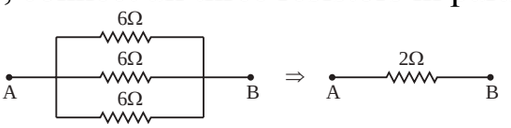
$$R = \frac{r}{n} \Rightarrow 44 = \frac{176}{n} \Rightarrow n = \frac{176}{44} = 4$$

11. Show how you would connect three resistors, each of resistance 6 Ω so that the combination has a resistance of (i) 9 Ω, (ii) 4 Ω.

Ans.(i) To get a resistance of 9 Ω from three resistors of 6 Ω, connect two resistors in parallel and the other in series.



(ii) To get 2 Ω resistivity, connect all three resistors in parallel.



12. Several electric bulbs designed to be used on a 220 V electric supply line, are rated 10 W. How many lamps can be connected in parallel with each other across the two wires of a 220 V line if the maximum allowable current is 5 A?

Ans. Resistance of each bulb

$$r = \frac{V^2}{P} = \frac{220 \times 220}{10} = 4840\,\Omega$$

Total resistance

$$R = \frac{220V}{5V} = 44\Omega$$

Let the number of bulbs be n and for resistance R :

$$R = \frac{r}{n} \Rightarrow n = \frac{r}{R} = \frac{4840}{44}\Omega = 110\Omega.$$

13. A hot plate of an electric oven connected to a 220 V line has two resistance coils A and B, each of 24 Ω resistance, which may be used separately, in series, or parallel. What are the currents in the three cases?

Ans.(i)Potential difference = 220 V, resistance of each coil = 24 Ω

(ii)When Coil A and B are connected in series :

$$R_s = r + r = 2r = 48\Omega$$

Current flowing :

$$I_s = \frac{V}{R_s} = \frac{220}{48} = 4.58A$$

(iii)When Coil A and B are connected in parallel :

$$R_p = \frac{r}{2} = \frac{24}{2} = 12\ \Omega$$

Current flowing :

$$I_p = \frac{V}{R_p} = \frac{220V}{12\Omega} = 18.3\ \Omega$$

14. Compare the power used in the 2 Ω resistor in each of the following circuits:

(i) A 6 V battery in series with 1 Ω and 2 Ω resistors.

(ii) A 4 V battery in parallel with 12 Ω and 2 Ω resistors.

Ans.(i) When resistors are arranged in series

$$R = R_1 + R_2 = 1 + 2 = 3\Omega$$

From Ohm's law

$$I = \frac{V}{R} = \frac{6}{3} = 2A$$

Power $P_1 = VI = 6 \times 2 = 12$ W

(ii) When resistors are arranged in parallel

$$R = \frac{R_1R_2}{R_1+R_2} = \frac{12\times 2}{12+2} = \frac{24}{14}$$

$$I = \frac{V}{R} = \frac{4}{\frac{24}{14}} = \frac{14}{6} = \frac{7}{3}A$$

$$P = V.\ I.$$

$$P_2 = 4\times\frac{7}{3} = \frac{28}{3} = 9.33W$$

$$\frac{P_1}{P_2} = \frac{12}{9.33} \Rightarrow P_1 = P_2\frac{12}{93}$$

$$= P_2\times\frac{120}{93} = P_2\times\frac{40}{31}.$$

15. Two lamps, one rated 100 W at 220 V, and the other 60 W at 220 V, are connected in parallel to the electric mains supply. What current is drawn from the line if the supply voltage is 220 V?

Ans. Let, Resistance for the first lamp = R_1

Resistance for the second lamp = R_2

$P_1 = 100$ W, $P_2 = 60$W, V = 220 V

From Formula :

$$R_1 = \frac{V^2}{P_1} = \frac{220\times 220}{100} = 484\Omega$$

$$R_2 = \frac{V^2}{P_2} = \frac{220\times 220}{60} = \frac{2420}{3}\Omega$$

Connecting R_1 and R_2 in parallel series

$$R = \frac{R_1\times R_2}{R_1+R_2} = \frac{484\times\frac{2420}{3}}{484+\frac{2420}{3}} = \frac{2420}{8} = \frac{605}{2}\Omega$$

$$I = \frac{V}{R} = \frac{220}{\frac{605}{2}} = 220 \times \frac{2}{605} = \frac{8}{11} = 0.72 \text{ A}$$

So, the current drawn from mains is 0.72 A.

16. Which uses more energy, a 250 W TV set in 1 hr, or a 1200 W toaster in 10 minutes?

Ans. In the T.V. set, P = 250 W

Time t = 1 hr = 60 × 60 seconds = 36000 sec

Electrical energy $E_1 = P \times t = 250 \times 3600 = 900000$ J

$E_1 = 9 \times 10^5$ J

In heater, P = 120 W

Time t = 10 min = 100 × 60 seconds = 600 sec

Electrical energy $E_2 = P \times t = 120 \times 600 = 72000$ J

$E_2 = 7.2 \times 10^4$ J

Since, $E_1 > E_2$

So, T.V. uses more energy.

17. An electric heater of resistance 8 W draws 15 A from the service mains for 2 hours. Calculate the rate at which heat is developed in the heater.

Ans. I = 15 A, R = 8Ω

$\therefore$ Power $P = \frac{E}{t} = \frac{I^2Rt}{t}$

$\therefore$ $P = I^2R = 15 \times 15 \times 8 = 1800$W

Amount of Heat = 1800 W.

18. Explain the following :

(a) Why is tungsten used almost exclusively for filament of electric lamps?

(b) Why are the conductors of electric heating devices, such as bread-toasters and electric irons, made of an alloy rather than a pure metal?

(c) Why is the series arrangement not used for domestic circuits?

(d) How does the resistance of a wire vary with its area of cross-section?

(e) Why are copper and aluminium wires usually employed for electricity transmission?

Ans. (a) Tungsten is used in the manufacture of filaments for electric lamps because tungsten has both a high melting point and high resistance. Due to the high resistance, the production of heat is also high in it. Therefore, the filaments shine very brightly after heating.

(b) Alloys are used in making bread toasters and electric irons because alloys have

higher melting points and high resistivity than other pure metals. Therefore, they produce a large amount of heat.

(c) Since the resistance is very high in the series and, when the filament of one bulb is broken, the flow of current stops in all the connected bulbs, and thus all are extinguished simultaneously. Due to this, the amount of current flowing in the circuit becomes very less. But, when connected in parallel, the value of resistance is very less, due to which the value of current increases greatly. Therefore, in domestic electric circuits, the parallel is used instead of using the series connection.

(d) Since the resistance of a wire is inversely proportional to the area of the cross-section. When the area of cross-section (increased) is increased, the value of resistance decreases, *i.e.,*

$$R \propto \frac{1}{A}$$

(e) Since copper and aluminium are the best conductors of electricity and they are also cheap. This is why copper and aluminium are used for power transmission.

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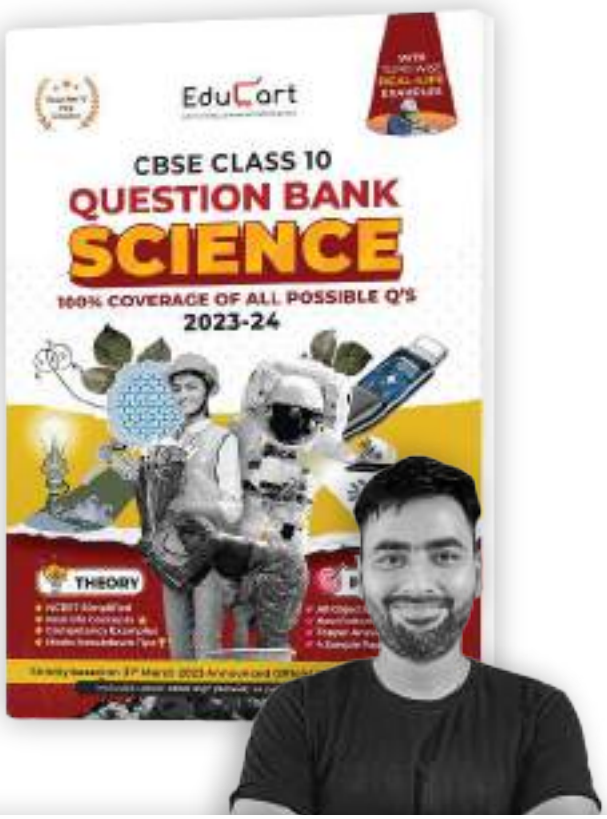

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Magnetic Effects of Electric Current 12

NCERT SOLUTIONS

What's inside

IN-CHAPTER QUESTIONS

Test Yourself

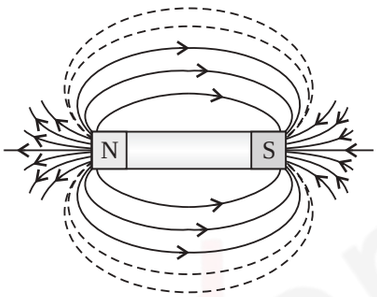
1. Why does a compass needle get deflected when brought near a bar magnet?

Ans. Because a magnetic field is generated around the magnet and this field exerts a magnetic force on the magnetic needle, due to which the needle is deflected.

Test Yourself

1. Draw magnetic field lines around a bar magnet.

Ans.



2. List the properties of magnetic field lines.

Ans. Magnetic field lines show the following properties :

(i) Magnetic field lines originate from the north pole of the magnet and end at the south pole.

(ii) These lines do not intersect each other.

(iii) The direction of the tangent drawn at a point shows the direction of the magnetic field.

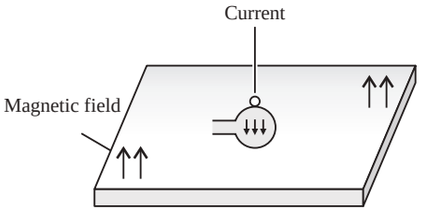
3. Why don't two magnetic field lines intersect each other?

Ans. Magnetic field lines have one direction in particular. If two magnetic field lines intersect, then there will be two directions of the magnetic field at the point of intersection which is impossible. Therefore, these lines do not intersect.

Test Yourself

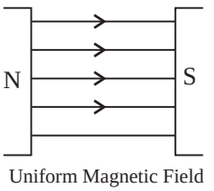
1. Consider a circular loop of wire lying in the plane of the table. Let the current pass through the loop clockwise. Apply the right-hand rule to find out the direction of the magnetic field inside and outside the loop.

Ans. Using the right hand thumb rule, the direction of the magnetic field inside the loop is downward and outside the loop is upwards as shown in the figure.



2. The magnetic field in a given region is uniform. Draw a diagram to represent it.

Ans.



3. Choose the correct option.

The magnetic field inside a long straight solenoid-carrying current :

(a) is zero.
(b) decreases as we move towards its end.
(c) increases as we move towards its end.
(d) is the same at all points.

Ans.(d) is the same at all points.

Test Yourself

1. Which one of the following properties of a proton changes while moving freely in a magnetic field?

(a) Mass (b) Speed
(c) Velocity (d) Impulse

Ans.(c) Velocity

2. In Activity 13.9, how do we think the displacement of rod AB will be affected if (i) the current in rod AB is increased; (ii) a stronger horse-shoe magnet is used, and (iii) the length of the rod AB is increased?

Ans. We know that if an electric current (I) is passed through a conductor of length l placed in a magnetic field (B), then the force acting :

$$F = BIl \quad \ldots (1)$$

(i) If the current is increased, then from eq. (1), $F \propto I$ i.e., Rod AB is more displaced.

(ii) If a stronger horse-shoe magnet is used then from eq. (1), $F \propto B$, i.e., Rod AB is more displaced.

(iii) If the length of rod AB is increased, then from eq. (1), $F \propto l$, i.e., Rod AB is more displaced.

3. A positively-charged particle (alpha-particle) projected towards the west is deflected towards the north by a magnetic field. The direction of magnetic field is :

(a) towards south (b) towards east

(c) downward (d) upward

Ans.(d) upward

Test Yourself

1. Name two safety measures commonly used in electric circuits and appliances.

Ans. (i) Fuse, (ii) Earth wire.

2. An electric oven with 2 kW power rating is operated in a domestic electric circuit (220 V) that has a current rating of 5 A. What result do you expect? Explain.

Ans. Here 1 = ?, R = ?, P = 2W = 2×10^3 W, V = 220 V

Using formula, $P = \frac{V^2}{R}$

$$\Rightarrow \quad R = \frac{V^2}{P} = \frac{220 \times 220}{2 \times 10^3} = \frac{220 \times 5}{2 \times 10^3}$$

$$= \frac{11 \times 22}{10} = \frac{11 \times 11}{5}$$

Using formula $V = IR$

$$\Rightarrow \quad I = \frac{V}{R}$$

$$= \frac{220 \times 5}{11 \times 11}$$

$$= 9.99 \text{ A}$$

The current (9.1 A) exceeds the fuse rating (5 A) of the given circuit. Due to this, the fuse is broken due to the high flow of current through the circuit.

3. What precautions should be taken to avoid the overloading of domestic electric circuits?

Ans. In household electrical circuits, more than one socket should not be connected to electrical equipment, as there is a fear of overloading. To protect against this, the fuse is replaced.

NCERT EXERCISES

1. Which of the following correctly describes the magnetic field near a long straight wire?

(a) The field consists of straight lines perpendicular to the wire.

(b) The field consists of straight lines parallel to the wire.

(c) The field consists of radial lines originating from the wire.

(d) The field consists of concentric circles centred on the wire.

Ans.(d) The field consists of concentric circles centred on the wire.

2. At the time of the short circuit, the current in circuit :

(a) reduces substantially (b) does not change

(c) increases heavily (d) vary continuously

Ans.(c) increases heavily.

3. State whether the following statements are true or false :

(a) The field at the center of a long circular coil carrying current will be parallel straight lines.

(b) A wire with green insulation is usually the live wire of an electric supply

Ans.(a) True, (b) False

4. List two methods of producing magnetic fields.

Ans. The methods of producing magnetic fields are :

(i) around a current carrying a straight conductor.

(ii) around a current carrying solenoid.

(iii) around a natural magnet.

5. When is the force experienced by a current–carrying conductor placed in a magnetic field largest?

Ans. The force exerted on a current-carrying conductor placed in a magnetic field is greatest when the direction of the current is perpendicular to the direction of the magnetic field.

6. Imagine that you are sitting in a chamber with your back to one wall. An electron beam, moving horizontally from the back wall towards the front wall, is deflected by a strong magnetic field to your right side. What is the direction of the magnetic field?

Ans. The direction of current flowing is from the front wall towards the back wall as it is in the opposite direction to the flow of electrons. If the direction of force applied

is towards the right side, then using Fleming's left-hand rule, the magnetic field is applied in a downward direction.

7. State the rules for finding the direction, when :

(a) A magnetic field produced around a straight conductor carrying current,

(b)The force experienced by a current carrying a straight conductor placed in a magnetic field placed perpendicular to it.

(c) current induced in a coil due to its rotation in a magnetic field.

Ans.(a) The direction of the magnetic field produced around a straight current carrying conductor is given by the right-hand thumb rule.

(b) The direction of the force experienced by a current-carrying straight conductor placed in a magnetic field perpendicular to it is given by Fleming's left-hand rule.

(For an explanation on page no. 290 and 293 of Textbook respectively.

8. When does an electric short circuit occur?

Ans. When the live wire and neutral wire come in contact, a short circuit occurs.

9. What is the function of an earth wire? Why is it necessary to earth metallic appliances?

Ans. The wire which is in contact with the earth from the metallic part of an electrical device is called an earth contact wire. It is color is green. In a faulty situation, if an electric current start flowing in the metallic part of the equipment, then there is a possibility of an accident. If there is earth contact, then the current is transferred to the earth. This does not cause electric shock and prevents accidents.

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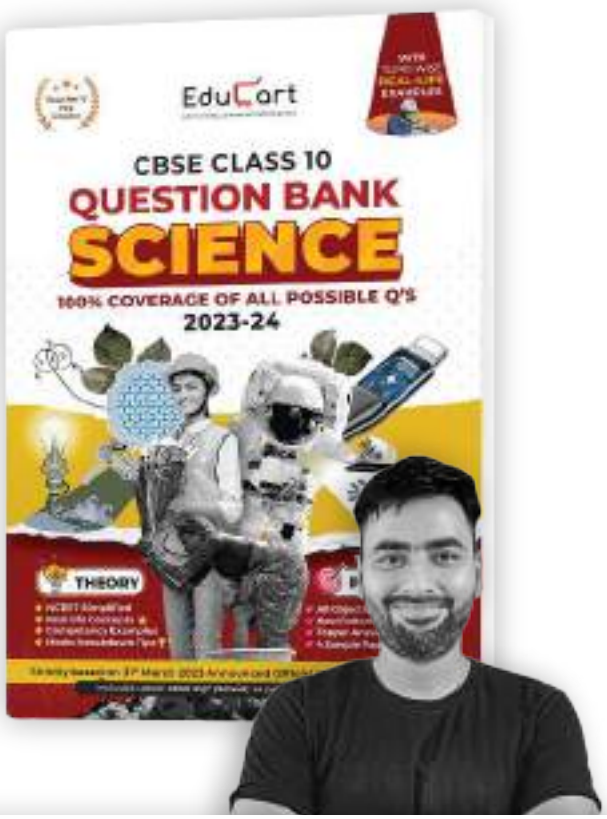

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Our Environment 13

NCERT SOLUTIONS

What's inside

IN-CHAPTER QUESTIONS

Test Yourself

1. What are trophic levels? Give an example of a food chain and state the different trophic levels in it.

Ans. The different steps in a food chain are called trophic levels.

For example: Grass → Deer → Lion (Tiger).

There are different trophic levels in this food chain.

(i) The first trophic level is the grass which is called producer.

(ii) The second trophic level is deer, it is a herbivore.

(iii) The third trophic level is the lion, it is a carnivore.

2. What is the role of decomposers in the ecosystem?

Ans. Decomposers break apart dead organisms into simpler inorganic materials, making nutrients available to primary producers. Thus they maintain the flow of energy through an ecosystem.

Test Yourself

1. Why are some biodegradable substances and some non-biodegradable?

Ans. The substances which can be broken down by biological processes are biodegradable. In our environment, such substances are broken down by decomposers (bacteria and fungi). However, there are other substances which cannot break down and are known as non-biodegradable substances. Since these substances are not degraded by bacteria and fungi, they persist for a long time. Such substances are acted upon by physical processes like heat and pressure.

2. Give any two ways in which biodegradable substances would affect the environment.

Ans. Biodegradable substances affect the environment in two ways.

(i) These substances decompose to form toxic substances, which increases air pollution.

(ii) Biodegradable substances can be used as humus after composting, which enhance the soil fertility.

(iii) They may produce a foul smell during the decomposition process.

3. Give any two ways in which non-biodegradable substances would affect the environment.

Ans. (i) Non-biodegradable substances, due to their non-degradable nature, create disposal problems and pollute the landscape.

(ii) These substances often emit very harmful gaseous pollutants which are very dangerous for health.

Test Yourself

1.What is ozone and how does it affect any ecosystem?

Ans. Ozone is a poisonous gas made of three atoms of oxygen, present in the stratosphere. It protects the environment from the damaging effects of UV radiation which causes skin cancer and cataract and impairs our immune system.

$$O_2 \xrightarrow{u.v.} O + O$$

$$O + O_2 \longrightarrow O_3$$

2. How can you help in reducing the problem of waste disposal? Give any two methods.

Ans.(i) We should use more and more biodegradable materials, because it can be converted into manure by simple methods.

(ii) The waste of non-biodegradable materials should be sent to the factory for recycling.

NCERT EXERCISES

1. Which of the following groups contains only biodegradable items?

(a) Grass, flowers and leather

(b) Grass, wood and plastic

(c) Fruit-peels, cake and lime-juice

(d)Cake, wood and grass

Ans.(c) Fruit-peels, cake and lime-juice

2. Which of the following make up the food chain?

(a) Grass, Wheat and Mango

(b) Grass, Goat and Human

(c) Goat, Cow and Elephant

(d) Grass, Fish and Goat

Ans.(b) Grass, Goat and Human

3. Which of the following are environment-friendly practices?

(a) Carrying cloth-bags to put purchases in while shopping

(b) Switching off unnecessary lights and fans

(c) Walking to school instead of getting your mother to drop you on her scooter

(d) All of the above

Ans.(d) All of the above

4. What will happen if we kill all the organisms in one trophic level?

Ans. The organisms at all trophic levels in the food chain depend on each other for food. If all organisms at a trophic level are killed, the food chain will be destroyed, all the living beings at higher trophic level will be affect by the lack of food. They will start resorting to other sources. On the other hand, organisms at lower trophic level will face sudden increase in the population which will lead to a risk of deterioration of the unbalanced ecosystem.

For example, if we kill all the deer (second trophic level), then lion, tiger and other carnivores will face difficulty with the lack of food while the plants in that region will grow at unlimited rate.

5. Will the impact of removing all the organisms in a trophic level be different for different trophic levels? Can the organisms of any trophic level be removed without causing any damage to the ecosystem?

Ans. Yes, the impact of removing all the organisms in a trophic level will be different for different trophic levels. The removal of producers will affect herbivores due to absence of food. They will die. Similarly, the carnivores would also die in absence of herbivores and producers are also affected and may die due to competition for space and nutrients. Therefore, it is not possible to remove any trophic level organisms without affecting the ecosystem as they are all interlinked. This will create an imbalance in the ecosystem.

6. What is biological magnification? Will the levels of this magnification be different at different levels of the ecosystem?

Ans. Biological magnification is the phenomenon in which harmful chemicals enter in the food chain and its concentration increases at each tropic level. The levels of biological magnification is different at different levels of the ecosystem. It will be increases with each successive level. It is maximum at highest tropic levels and minimum at lowest tropic levels. For example, it is highest in humans and lowest in plants.

D. D. T. $\longrightarrow$ Water $\longrightarrow$ Algae $\longrightarrow$ Fish $\longrightarrow$ Birds

0.02 ppm 5 ppm 140 ppm 1600 ppm

7. What are the problems caused by the non-biodegradable wastes that we generate?

Ans. Non-biodegradable wastes do not get destroyed due to which many problems arise

like :

(i) They pollute the water which becomes unfit for drinking.

(ii)They stop the flow of water in drains.

(iii)They make the atmosphere poisonous.

(iv)They pollute the soil due to which the land becomes unsuitable.

(v)They cause to diseases.

8. If all the waste we generate is biodegradable, will this have no impact on the environment?

Ans. Biodegradable waste materials do not exist in nature for long. Some are affected by the environment but they get decomposed in a short time. The decomposed matter can be converted into manure which will be beneficial for the plants. However, it may still pollute the environment if they are not decomposed within a particular period of time or else the accumulation of the waste will lead again to pollution. It will become a breeding ground for flies causing the spread of diseases.

9. Why is damage to the ozone layer a cause for concern? What steps are being taken to limit this damage?

Ans. The damage to the ozone layer a cause for concern because :

- It causes skin darkening, skin cancer, ageing, and corneal cataracts in human beings.
- It can result in the death of many phytoplankton that leads to increased global warming.

To limit the damage to the ozone layer the release of CFCs into the atmosphere must be reduced CFCs used as refrigerants and in fire extinguishers should be replaced with environmentally-safe alternatives Also the release of CFCs through industrial activities should be controlled.

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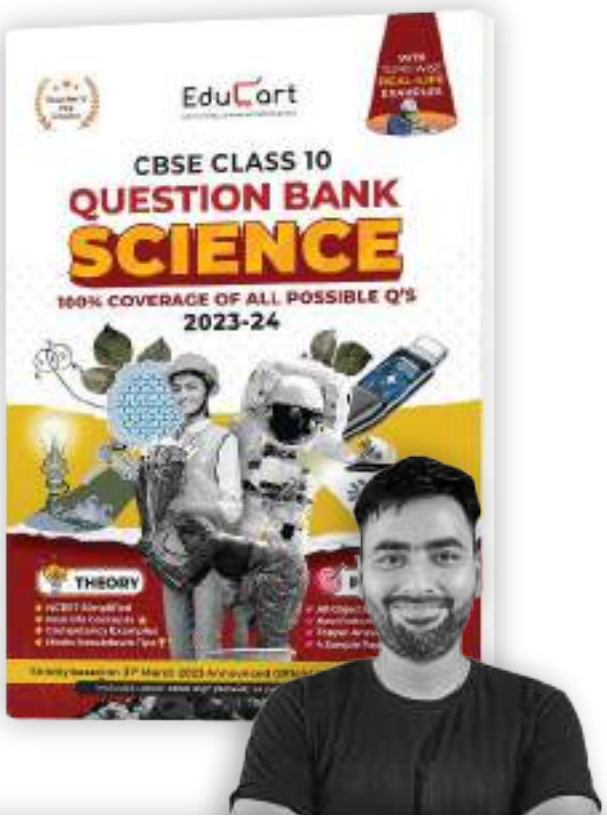

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12085CH02

Unit 1

Solutions

Objectives

After studying this Unit, you will be able to

- describe the formation of different types of solutions;
- express concentration of solution in different units;
- state and explain Henry's law and Raoult's law;
- distinguish between ideal and non-ideal solutions;
- explain deviations of real solutions from Raoult's law;
- describe colligative properties of solutions and correlate these with molar masses of the solutes;
- explain abnormal colligative properties exhibited by some solutes in solutions.

Almost all processes in body occur in some kind of liquid solutions.

In normal life we rarely come across pure substances. Most of these are mixtures containing two or more pure substances. Their utility or importance in life depends on their composition. For example, the properties of brass (mixture of copper and zinc) are quite different from those of German silver (mixture of copper, zinc and nickel) or bronze (mixture of copper and tin); 1 part per million (ppm) of fluoride ions in water prevents tooth decay, while 1.5 ppm causes the tooth to become mottled and high concentrations of fluoride ions can be poisonous (for example, sodium fluoride is used in rat poison); intravenous injections are always dissolved in water containing salts at particular ionic concentrations that match with blood plasma concentrations and so on.

In this Unit, we will consider mostly liquid solutions and their formation. This will be followed by studying the properties of the solutions, like vapour pressure and colligative properties. We will begin with types of solutions and then various alternatives in which concentrations of a solute can be expressed in liquid solution.

1.1 Types of Solutions

Solutions are **homogeneous** mixtures of two or more than two components. By homogenous mixture we mean that its composition and properties are uniform throughout the mixture. Generally, the component that is present in the largest quantity is known as **solvent**. Solvent determines the physical state in which solution exists. One or more components present in the solution other than solvent are called **solutes.** In this Unit we shall consider only **binary solutions** (i.e.,

consisting of two components). Here each component may be solid, liquid or in gaseous state and are summarised in Table 1.1.

Table 1.1: Types of Solutions

Type of Solution	Solute	Solvent	Common Examples
Gaseous Solutions	Gas	Gas	Mixture of oxygen and nitrogen gases
	Liquid	Gas	Chloroform mixed with nitrogen gas
	Solid	Gas	Camphor in nitrogen gas
Liquid Solutions	Gas	Liquid	Oxygen dissolved in water
	Liquid	Liquid	Ethanol dissolved in water
	Solid	Liquid	Glucose dissolved in water
Solid Solutions	Gas	Solid	Solution of hydrogen in palladium
	Liquid	Solid	Amalgam of mercury with sodium
	Solid	Solid	Copper dissolved in gold

1.2 Expressing Concentration of Solutions

Composition of a solution can be described by expressing its concentration. The latter can be expressed either qualitatively or quantitatively. For example, qualitatively we can say that the solution is dilute (i.e., relatively very small quantity of solute) or it is concentrated (i.e., relatively very large quantity of solute). But in real life these kinds of description can add to lot of confusion and thus the need for a quantitative description of the solution.

There are several ways by which we can describe the concentration of the solution quantitatively.

(i) *Mass percentage* (w/w): The mass percentage of a component of a solution is defined as:

Mass % of a component

$$= \frac{\text{Mass of the component in the solution}}{\text{Total mass of the solution}} \times 100 \qquad (1.1)$$

For example, if a solution is described by 10% glucose in water by mass, it means that 10 g of glucose is dissolved in 90 g of water resulting in a 100 g solution. Concentration described by mass percentage is commonly used in industrial chemical applications. For example, commercial bleaching solution contains 3.62 mass percentage of sodium hypochlorite in water.

(ii) *Volume percentage (V/V)*: The volume percentage is defined as:

$$\text{Volume \% of a component} = \frac{\text{Volume of the component}}{\text{Total volume of solution}} \times 100 \qquad (1.2)$$

For example, 10% ethanol solution in water means that 10 mL of ethanol is dissolved in water such that the total volume of the solution is 100 mL. Solutions containing liquids are commonly expressed in this unit. For example, a 35% (*v*/*v*) solution of ethylene glycol, an antifreeze, is used in cars for cooling the engine. At this concentration the antifreeze lowers the freezing point of water to 255.4K (–17.6°C).

(iii) *Mass by volume percentage (*w/*V)*: Another unit which is commonly used in medicine and pharmacy is mass by volume percentage. It is the mass of solute dissolved in 100 mL of the solution.

(iv) *Parts per million*: When a solute is present in **trace** quantities, it is convenient to express concentration in **parts per million (ppm)** and is defined as:

Parts per million =

$$\frac{\text{Number of parts of the component}}{\text{Total number of parts of all components of the solution}} \times 10^6 \quad (1.3)$$

As in the case of percentage, concentration in parts per million can also be expressed as mass to mass, volume to volume and mass to volume. A litre of sea water (which weighs 1030 g) contains about 6×10^{-3} g of dissolved oxygen (O_2). Such a small concentration is also expressed as 5.8 g per 10^6 g (5.8 ppm) of sea water. The concentration of pollutants in water or atmosphere is often expressed in terms of μg mL^{-1} or ppm.

(v) *Mole fraction*: Commonly used symbol for mole fraction is *x* and subscript used on the right hand side of *x* denotes the component. It is defined as:

Mole fraction of a component =

$$\frac{\text{Number of moles of the component}}{\text{Total number of moles of all the components}} \quad (1.4)$$

For example, in a binary mixture, if the number of moles of A and B are n_A and n_B respectively, the mole fraction of A will be

$$x_A = \frac{n_A}{n_A + n_B} \quad (1.5)$$

For a solution containing i number of components, we have:

$$x_i = \frac{n_i}{n_1 + n_2 + \ldots\ldots + n_i} = \frac{n_i}{\sum n_i} \quad (1.6)$$

It can be shown that in a given solution sum of all the mole fractions is unity, i.e.

$$x_1 + x_2 + \ldots\ldots\ldots\ldots\ldots + x_i = 1 \quad (1.7)$$

Mole fraction unit is very useful in relating some physical properties of solutions, say vapour pressure with the concentration of the solution and quite useful in describing the calculations involving gas mixtures.

Example 1.1 Calculate the mole fraction of ethylene glycol ($C_2H_6O_2$) in a solution containing 20% of $C_2H_6O_2$ by mass.

Solution Assume that we have 100 g of solution (one can start with any amount of solution because the results obtained will be the same). Solution will contain 20 g of ethylene glycol and 80 g of water.

Molar mass of $C_2H_6O_2 = 12 \times 2 + 1 \times 6 + 16 \times 2 = 62\ g\ mol^{-1}$.

$$\text{Moles of } C_2H_6O_2 = \frac{20\ g}{62\ g\ mol^{-1}} = 0.322\ mol$$

$$\text{Moles of water} = \frac{80\ g}{18\ g\ mol^{-1}} = 4.444\ mol$$

$$x_{glycol} = \frac{\text{moles of } C_2H_6O_2}{\text{moles of } C_2H_6O_2 + \text{moles of } H_2O}$$

$$= \frac{0.322\ mol}{0.322\ mol + 4.444\ mol} = 0.068$$

$$\text{Similarly, } x_{water} = \frac{4.444\ mol}{0.322\ mol + 4.444\ mol} = 0.932$$

Mole fraction of water can also be calculated as: 1 – 0.068 = 0.932

(vi) *Molarity*: Molarity (*M*) is defined as number of moles of solute dissolved in one litre (or one cubic decimetre) of solution,

$$\text{Molarity} = \frac{\text{Moles of solute}}{\text{Volume of solution in litre}} \quad (1.8)$$

For example, 0.25 mol L^{-1} (or 0.25 M) solution of NaOH means that 0.25 mol of NaOH has been dissolved in one litre (or one cubic decimetre).

Example 1.2 Calculate the molarity of a solution containing 5 g of NaOH in 450 mL solution.

Solution $$\text{Moles of NaOH} = \frac{5\ g}{40\ g\ mol^{-1}} = 0.125\ mol$$

Volume of the solution in litres = 450 mL / 1000 mL L^{-1}

Using equation (2.8),

$$\text{Molarity} = \frac{0.125\ mol \times 1000\ mL\ L^{-1}}{450\ mL} = 0.278\ M$$

$$= 0.278\ mol\ L^{-1}$$

$$= 0.278\ mol\ dm^{-3}$$

(vii) *Molality*: Molality (*m*) is defined as the number of moles of the solute per kilogram (kg) of the solvent and is expressed as:

$$\text{Molality (m)} = \frac{\text{Moles of solute}}{\text{Mass of solvent in kg}} \qquad (1.9)$$

For example, 1.00 mol kg^{-1} (or 1.00 m) solution of KCl means that 1 mol (74.5 g) of KCl is dissolved in 1 kg of water.

Each method of expressing concentration of the solutions has its own merits and demerits. Mass %, ppm, mole fraction and molality are independent of temperature, whereas molarity is a function of temperature. This is because volume depends on temperature and the mass does not.

Example 1.3

Calculate molality of 2.5 g of ethanoic acid (CH_3COOH) in 75 g of benzene.

Solution

Molar mass of $C_2H_4O_2$: $12 \times 2 + 1 \times 4 + 16 \times 2 = 60$ g mol^{-1}

$$\text{Moles of } C_2H_4O_2 = \frac{2.5 \text{ g}}{60 \text{ g mol}^{-1}} = 0.0417 \text{ mol}$$

Mass of benzene in kg = 75 g/1000 g kg^{-1} = 75 × 10^{-3} kg

$$\text{Molality of } C_2H_4O_2 = \frac{\text{Moles of } C_2H_4O_2}{\text{kg of benzene}} = \frac{0.0417 \text{ mol} \times 1000 \text{ g kg}^{-1}}{75 \text{ g}}$$

$$= 0.556 \text{ mol kg}^{-1}$$

Intext Questions

1.1 Calculate the mass percentage of benzene (C_6H_6) and carbon tetrachloride (CCl_4) if 22 g of benzene is dissolved in 122 g of carbon tetrachloride.

1.2 Calculate the mole fraction of benzene in solution containing 30% by mass in carbon tetrachloride.

1.3 Calculate the molarity of each of the following solutions: (a) 30 g of $Co(NO_3)_2$. $6H_2O$ in 4.3 L of solution (b) 30 mL of 0.5 M H_2SO_4 diluted to 500 mL.

1.4 Calculate the mass of urea (NH_2CONH_2) required in making 2.5 kg of 0.25 molal aqueous solution.

1.5 Calculate (a) molality (b) molarity and (c) mole fraction of KI if the density of 20% (mass/mass) aqueous KI is 1.202 g mL^{-1}.

1.3 Solubility

Solubility of a substance is its maximum amount that can be dissolved in a specified amount of solvent at a specified temperature. It depends upon the nature of solute and solvent as well as temperature and pressure. Let us consider the effect of these factors in solution of a solid or a gas in a liquid.

1.3.1 Solubility of a Solid in a Liquid

Every solid does not dissolve in a given liquid. While sodium chloride and sugar dissolve readily in water, naphthalene and anthracene do not. On the other hand, naphthalene and anthracene dissolve readily in benzene but sodium chloride and sugar do not. It is observed that polar solutes dissolve in polar solvents and non polar solutes in non-polar solvents. In general, a solute dissolves in a solvent if the intermolecular interactions are similar in the two or we may say **like dissolves like**.

When a solid solute is added to the solvent, some solute dissolves and its concentration increases in solution. This process is known as dissolution. Some solute particles in solution collide with the solid solute particles and get separated out of solution. This process is known as crystallisation**.** A stage is reached when the two processes occur at the same rate. Under such conditions, number of solute particles going into solution will be equal to the solute particles separating out and a state of dynamic equilibrium is reached.

$$\text{Solute} + \text{Solvent} \rightleftharpoons \text{Solution} \qquad (1.10)$$

At this stage the concentration of solute in solution will remain constant under the given conditions, i.e., temperature and pressure. Similar process is followed when gases are dissolved in liquid solvents. Such a solution in which no more solute can be dissolved at the same temperature and pressure is called a **saturated solution**. An *unsaturated solution* is one in which more solute can be dissolved at the same temperature. The solution which is in dynamic equilibrium with undissolved solute is the saturated solution and contains the maximum amount of solute dissolved in a given amount of solvent. Thus, the concentration of solute in such a solution is its solubility.

Earlier we have observed that solubility of one substance into another depends on the nature of the substances. In addition to these variables, two other parameters, i.e., temperature and pressure also control this phenomenon.

Effect of temperature

The solubility of a solid in a liquid is significantly affected by temperature changes. Consider the equilibrium represented by equation 1.10. This, being dynamic equilibrium, must follow **Le Chateliers Principle.** In general, if in a *nearly saturated solution,* the dissolution process is endothermic (Δ_{sol} H > 0), the solubility should increase with rise in temperature and if it is exothermic (Δ_{sol} H < 0) the solubility should decrease. These trends are also observed experimentally.

Effect of pressure

Pressure does not have any significant effect on solubility of solids in liquids. It is so because solids and liquids are highly incompressible and practically remain unaffected by changes in pressure.

1.3.2 Solubility of a Gas in a Liquid

Many gases dissolve in water. Oxygen dissolves only to a small extent in water. It is this dissolved oxygen which sustains all aquatic life. On the other hand, hydrogen chloride gas (HCl) is highly soluble in water. Solubility of gases in liquids is greatly affected by pressure and

temperature. The solubility of gases increase with increase of pressure. For solution of gases in a solvent, consider a system as shown in Fig. 1.1 (a). The lower part is solution and the upper part is gaseous system at pressure *p* and temperature *T*. Assume this system to be in a state of dynamic equilibrium, i.e., under these conditions rate of gaseous particles entering and leaving the solution phase is the same. Now increase the pressure over the solution phase by compressing the gas to a smaller volume [Fig. 1.1 (b)]. This will increase the number of gaseous particles per unit volume over the solution and also the rate at which the gaseous particles are striking the surface of solution to enter it. The solubility of the gas will increase until a new equilibrium is reached resulting in an increase in the pressure of a gas above the solution and thus its solubility increases.

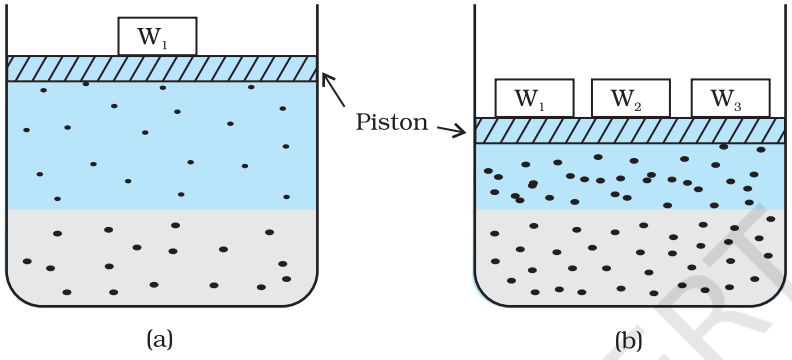


Fig. 1.1: *Effect of pressure on the solubility of a gas. The concentration of dissolved gas is proportional to the pressure on the gas above the solution.*

Henry was the first to give a quantitative relation between pressure and solubility of a gas in a solvent which is known as **Henry's law**. The law states that at a constant temperature, **the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas present above the surface of liquid or solution.** Dalton, a contemporary of Henry, also concluded independently that the solubility of a gas in a liquid solution is a function of partial pressure of the gas. If we use the mole fraction of a gas in the solution as a measure of its solubility, then it can be said that the **mole fraction of gas in the solution is proportional to the partial pressure of the gas over the solution.** The most commonly used form of Henry's law states that "**the partial pressure of the gas in vapour phase (*p*) is proportional to the mole fraction of the gas (*x*) in the solution**" and is expressed as:

$$p = K_H\, x \qquad (1.11)$$

Here K_H is the Henry's law constant. If we draw a graph between partial pressure of the gas versus mole fraction of the gas in solution, then we should get a plot of the type as shown in Fig. 1.2.

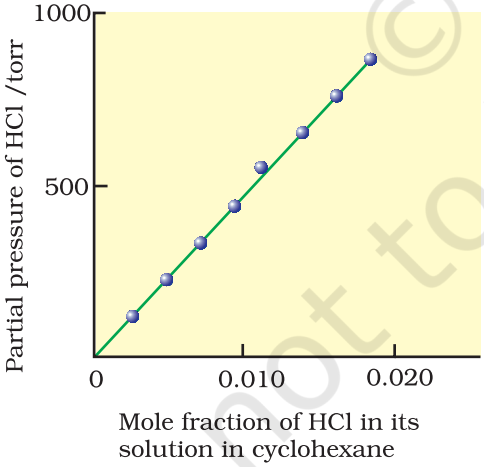


Fig. 1.2: *Experimental results for the solubility of HCl gas in cyclohexane at 293 K. The slope of the line is the Henry's Law constant, K_H.*

Different gases have different K_H values at the same temperature (Table 1.2). This suggests that K_H is a function of the nature of the gas.

It is obvious from equation (1.11) that higher the value of K_H at a given pressure, the lower is the solubility of the gas in the liquid. It can be seen from Table 1.2 that K_H values for both N_2 and O_2 increase with increase of temperature indicating that the solubility of gases

Table 1.2: Values of Henry's Law Constant for Some Selected Gases in Water

Gas	Temperature/K	K_H /kbar	Gas	Temperature/K	K_H/kbar
He	293	144.97	Argon	298	40.3
H_2	293	69.16	CO_2	298	1.67
N_2	293	76.48	Formaldehyde	298	1.83×10^{-5}
N_2	303	88.84	Methane	298	0.413
O_2	293	34.86	Vinyl chloride	298	0.611
O_2	303	46.82			

increases with decrease of temperature. It is due to this reason that aquatic species are more comfortable in cold waters rather than in warm waters.

Example 1.4 If N_2 gas is bubbled through water at 293 K, how many millimoles of N_2 gas would dissolve in 1 litre of water? Assume that N_2 exerts a partial pressure of 0.987 bar. Given that Henry's law constant for N_2 at 293 K is 76.48 *k*bar.

Solution The solubility of gas is related to the mole fraction in aqueous solution. The mole fraction of the gas in the solution is calculated by applying Henry's law. Thus:

$$x\,(\text{Nitrogen}) = \frac{p\,(\text{nitrogen})}{K_H} = \frac{0.987\text{bar}}{76{,}480\ \text{bar}} = 1.29 \times 10^{-5}$$

As 1 litre of water contains 55.5 mol of it, therefore if n represents number of moles of N_2 in solution,

$$x\,(\text{Nitrogen}) = \frac{n\ \text{mol}}{n\ \text{mol} + 55.5\ \text{mol}} = \frac{n}{55.5} = 1.29 \times 10^{-5}$$

(n in denominator is neglected as it is $<<55.5$)

Thus $n = 1.29 \times 10^{-5} \times 55.5\ \text{mol} = 7.16 \times 10^{-4}\ \text{mol}$

$$= \frac{7.16\times10^{-4}\ \text{mol} \times 1000\ \text{mmol}}{1\ \text{mol}} = 0.716\ \text{mmol}$$

Henry's law finds several applications in industry and explains some biological phenomena. Notable among these are:

- To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.
- Scuba divers must cope with high concentrations of dissolved gases while breathing air at high pressure underwater. Increased pressure increases the solubility of atmospheric gases in blood. When the divers come towards surface, the pressure gradually decreases. This releases the dissolved gases and leads to the formation of bubbles of nitrogen in the blood. This blocks capillaries and creates a medical condition known as *bends*, which are painful and dangerous to life.

To avoid bends, as well as, the toxic effects of high concentrations of nitrogen in the blood, the tanks used by scuba divers are filled with air diluted with helium (11.7% helium, 56.2% nitrogen and 32.1% oxygen).

- At high altitudes the partial pressure of oxygen is less than that at the ground level. This leads to low concentrations of oxygen in the blood and tissues of people living at high altitudes or climbers. Low blood oxygen causes climbers to become weak and unable to think clearly, symptoms of a condition known as *anoxia*.

Effect of Temperature

Solubility of gases in liquids decreases with rise in temperature. When dissolved, the gas molecules are present in liquid phase and the process of dissolution can be considered similar to condensation and heat is evolved in this process. We have learnt in the last Section that dissolution process involves dynamic equilibrium and thus must follow **Le Chatelier's Principle**. As dissolution is an exothermic process, the solubility should decrease with increase of temperature.

Intext Questions

1.6 H_2S, a toxic gas with rotten egg like smell, is used for the qualitative analysis. If the solubility of H_2S in water at STP is 0.195 m, calculate Henry's law constant.

1.7 Henry's law constant for CO_2 in water is 1.67×10^8 Pa at 298 K. Calculate the quantity of CO_2 in 500 mL of soda water when packed under 2.5 atm CO_2 pressure at 298 K.

1.4 Vapour Pressure of Liquid Solutions

Liquid solutions are formed when solvent is a liquid. The solute can be a gas, a liquid or a solid. Solutions of gases in liquids have already been discussed in Section 1.3.2. In this Section, we shall discuss the solutions of liquids and solids in a liquid. Such solutions may contain one or more volatile components. Generally, the liquid solvent is volatile. The solute may or may not be volatile. We shall discuss the properties of only binary solutions, that is, the solutions containing two components, namely, the solutions of (i) liquids in liquids and (ii) solids in liquids.

1.4.1 Vapour Pressure of Liquid-Liquid Solutions

Let us consider a binary solution of two volatile liquids and denote the two components as 1 and 2. When taken in a closed vessel, both the components would evaporate and eventually an equilibrium would be established between vapour phase and the liquid phase. Let the total vapour pressure at this stage be p_{total} and p_1 and p_2 be the partial vapour pressures of the two components 1 and 2 respectively. These partial pressures are related to the mole fractions x_1 and x_2 of the two components 1 and 2 respectively.

The French chemist, Francois Marte Raoult (1886) gave the quantitative relationship between them. The relationship is known as the **Raoult's law** which states that **for a solution of volatile liquids,**

the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution.

Thus, for component 1

$$p_1 \propto x_1$$

and $$p_1 = p_1^0 x_1 \quad (1.12)$$

where p_1^0 is the vapour pressure of pure component 1 at the same temperature.

Similarly, for component 2

$$p_2 = p_2^0 x_2 \quad (1.13)$$

where p_2^0 represents the vapour pressure of the pure component 2.

According to **Dalton's law of partial pressures**, the total pressure (p_{total}) over the solution phase in the container will be the sum of the partial pressures of the components of the solution and is given as:

$$p_{total} = p_1 + p_2 \quad (1.14)$$

Substituting the values of p_1 and p_2, we get

$$p_{total} = x_1 p_1^0 + x_2 p_2^0$$

$$= (1 - x_2) p_1^0 + x_2 p_2^0 \quad (1.15)$$

$$= p_1^0 + (p_2^0 - p_1^0) x_2 \quad (1.16)$$

Following conclusions can be drawn from equation (1.16).

(i) Total vapour pressure over the solution can be related to the mole fraction of any one component.

(ii) Total vapour pressure over the solution varies linearly with the mole fraction of component 2.

(iii) Depending on the vapour pressures of the pure components 1 and 2, total vapour pressure over the solution decreases or increases with the increase of the mole fraction of component 1.

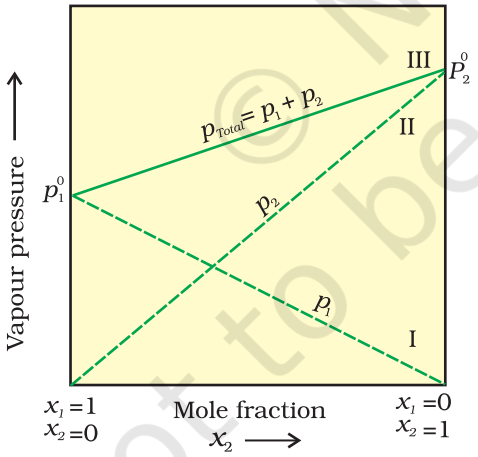


Fig. 1.3: *The plot of vapour pressure and mole fraction of an ideal solution at constant temperature. The dashed lines I and II represent the partial pressure of the components. (It can be seen from the plot that p_1 and p_2 are directly proportional to x_1 and x_2, respectively). The total vapour pressure is given by line marked III in the figure.*

A plot of p_1 or p_2 versus the mole fractions x_1 and x_2 for a solution gives a linear plot as shown in Fig. 1.3. These lines (I and II) pass through the points for which x_1 and x_2 are equal to unity. Similarly the plot (line III) of p_{total} versus x_2 is also linear (Fig. 1.3). The minimum value of p_{total} is p_1^0 and the maximum value is p_2^0, assuming that component 1 is less volatile than component 2, i.e., $p_1^0 < p_2^0$.

The composition of vapour phase in equilibrium with the solution is determined by the partial pressures of the components. If y_1 and y_2 are the mole fractions of the

components 1 and 2 respectively in the vapour phase then, using Dalton's law of partial pressures:

$$p_1 = y_1\ p_{total} \quad (1.17)$$

$$p_2 = y_2\ p_{total} \quad (1.18)$$

In general

$$p_i = y_i\ p_{total} \quad (1.19)$$

Example 1.5

Vapour pressure of chloroform ($CHCl_3$) and dichloromethane (CH_2Cl_2) at 298 K are 200 mm Hg and 415 mm Hg respectively. (i) Calculate the vapour pressure of the solution prepared by mixing 25.5 g of $CHCl_3$ and 40 g of CH_2Cl_2 at 298 K and, (ii) mole fractions of each component in vapour phase.

Solution

(i) Molar mass of $CH_2Cl_2 = 12 \times 1 + 1 \times 2 + 35.5 \times 2 = 85\ g\ mol^{-1}$

Molar mass of $CHCl_3 = 12 \times 1 + 1 \times 1 + 35.5 \times 3 = 119.5\ g\ mol^{-1}$

$$\text{Moles of } CH_2Cl_2 = \frac{40\ g}{85\ g\ mol^{-1}} = 0.47\ mol$$

$$\text{Moles of } CHCl_3 = \frac{25.5\ g}{119.5\ g\ mol^{-1}} = 0.213\ mol$$

Total number of moles = 0.47 + 0.213 = 0.683 mol

$$x_{CH_2Cl_2} = \frac{0.47\ mol}{0.683\ mol} = 0.688$$

$$x_{CHCl_3} = 1.00 - 0.688 = 0.312$$

Using equation (2.16),

$$p_{total} = p_1^0 + (p_2^0 - p_1^0)\ x_2 = 200 + (415 - 200) \times 0.688$$

$$= 200 + 147.9 = 347.9\ mm\ Hg$$

(ii) Using the relation (2.19), $y_i = p_i/p_{total}$, we can calculate the mole fraction of the components in gas phase (y_i).

$$p_{CH_2Cl_2} = 0.688 \times 415\ mm\ Hg = 285.5\ mm\ Hg$$

$$p_{CHCl_3} = 0.312 \times 200\ mm\ Hg = 62.4\ mm\ Hg$$

$$y_{CH_2Cl_2} = 285.5\ mm\ Hg/347.9\ mm\ Hg = 0.82$$

$$y_{CHCl_3} = 62.4\ mm\ Hg/347.9\ mm\ Hg = 0.18$$

Note: Since, CH_2Cl_2 is a more volatile component than $CHCl_3$, [$p^0_{CH_2Cl_2}$ = 415 mm Hg and $p^0_{CHCl_3}$ = 200 mm Hg] and the vapour phase is also richer in CH_2Cl_2 [$y_{CH_2Cl_2}$ = 0.82 and y_{CHCl_3} = 0.18], it may thus be concluded that **at equilibrium, vapour phase will be always rich in the component which is more volatile.**

1.4.2 Raoult's Law as a special case of Henry's Law

According to Raoult's law, the vapour pressure of a volatile component in a given solution is given by $p_i = x_i\, p_i^0$. In the solution of a gas in a liquid, one of the components is so volatile that it exists as a gas and we have already seen that its solubility is given by Henry's law which states that

$$p = K_H\, x.$$

If we compare the equations for Raoult's law and Henry's law, it can be seen that the partial pressure of the volatile component or gas is directly proportional to its mole fraction in solution. Only the proportionality constant K_H differs from p_1^0. Thus, Raoult's law becomes a special case of Henry's law in which K_H becomes equal to p_1^0.

1.4.3 Vapour Pressure of Solutions of Solids in Liquids

Another important class of solutions consists of solids dissolved in liquid, for example, sodium chloride, glucose, urea and cane sugar in water and iodine and sulphur dissolved in carbon disulphide. Some physical properties of these solutions are quite different from those of pure solvents. For example, vapour pressure. Liquids at a given temperature vapourise and under equilibrium conditions the pressure exerted by the vapours of the liquid over the liquid phase is called vapour pressure [Fig. 1.4 (a)]. In a pure liquid the entire surface is occupied by the molecules of the liquid. If a non-volatile solute is added to a solvent to give a solution [Fig. 1.4.(b)], the vapour pressure of the solution is solely from the solvent alone. This vapour pressure of the solution at a given temperature is found to be lower than the vapour pressure of the pure solvent at the same temperature. In the solution, the surface has both solute and solvent molecules; thereby the fraction of the surface covered by the solvent molecules gets reduced. Consequently, the number of solvent molecules escaping from the surface is correspondingly reduced, thus, the vapour pressure is also reduced.

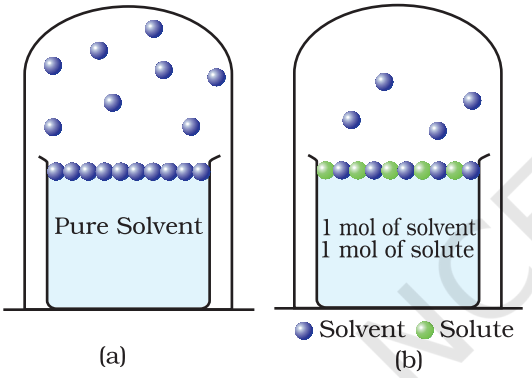


Fig. 1.4: *Decrease in the vapour pressure of the solvent on account of the presence of solute in the solvent (a) evaporation of the molecules of the solvent from its surface is denoted by ●, (b) in a solution, solute particles have been denoted by ● and they also occupy part of the surface area.*

The decrease in the vapour pressure of solvent depends on the quantity of non-volatile solute present in the solution, irrespective of its nature. For example, decrease in the vapour pressure of water by adding 1.0 mol of sucrose to one kg of water is nearly similar to that produced by adding 1.0 mol of urea to the same quantity of water at the same temperature.

Raoult's law in its general form can be stated as, **for any solution the partial vapour pressure of each volatile component in the solution is directly proportional to its mole fraction**.

In a binary solution, let us denote the solvent by 1 and solute by 2. When the solute is non-volatile, only the solvent molecules are present in vapour phase and contribute to vapour pressure. Let p_1 be

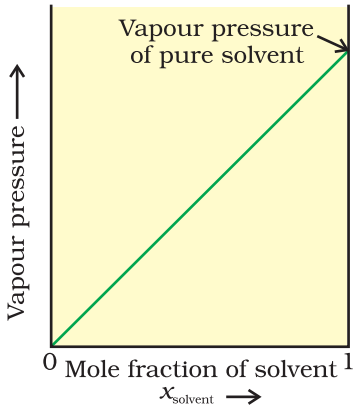


Fig. 1.5 *If a solution obeys Raoult's law for all concentrations, its vapour pressure would vary linearly from zero to the vapour pressure of the pure solvent.*

the vapour pressure of the solvent, x_1 be its mole fraction, p_1^0 be its vapour pressure in the pure state. Then according to Raoult's law

$$p_1 \propto x_1$$

$$\text{and} \quad p_1 = x_1 \, p_1^0 \qquad (1.20)$$

The proportionality constant is equal to the vapour pressure of pure solvent, p_1^0. A plot between the vapour pressure and the mole fraction of the solvent is linear (Fig. 1.5).

1.5 Ideal and Non-ideal Solutions

Liquid-liquid solutions can be classified into ideal and non-ideal solutions on the basis of Raoult's law.

1.5.1 Ideal Solutions

The solutions which obey Raoult's law over the entire range of concentration are known as *ideal solutions*. The ideal solutions have two other important properties. The enthalpy of mixing of the pure components to form the solution is zero and the volume of mixing is also zero, i.e.,

$$\Delta_{mix}H = 0, \qquad \Delta_{mix}V = 0 \qquad (1.21)$$

It means that no heat is absorbed or evolved when the components are mixed. Also, the volume of solution would be equal to the sum of volumes of the two components. At molecular level, ideal behaviour of the solutions can be explained by considering two components A and B. In pure components, the intermolecular attractive interactions will be of types A-A and B-B, whereas in the binary solutions in addition to these two interactions, A-B type of interactions will also be present. If the intermolecular attractive forces between the A-A and B-B are nearly equal to those between A-B, this leads to the formation of ideal solution. A perfectly ideal solution is rare but some solutions are nearly ideal in behaviour. Solution of n-hexane and n-heptane, bromoethane and chloroethane, benzene and toluene, etc. fall into this category.

1.5.2 Non-ideal Solutions

When a solution does not obey Raoult's law over the entire range of concentration, then it is called *non-ideal solution*. The vapour pressure of such a solution is either higher or lower than that predicted by Raoult's law (equation 1.16). If it is higher, the solution exhibits **positive deviation** and if it is lower, it exhibits **negative deviation** from Raoult's law. The plots of vapour pressure as a function of mole fractions for such solutions are shown in Fig. 1.6.

The cause for these deviations lie in the nature of interactions at the molecular level. In case of positive deviation from Raoult's law, A-B interactions are weaker than those between A-A or B-B, i.e., in this case the intermolecular attractive forces between the solute-solvent molecules are weaker than those between the solute-solute and solvent-solvent molecules. This means that in such solutions, molecules of A (or B) will find it easier to escape than in pure state. This will increase the vapour

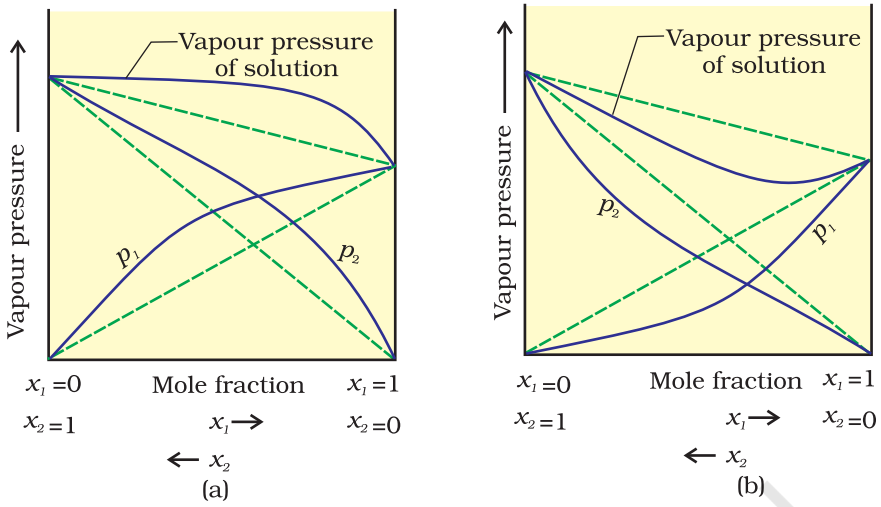
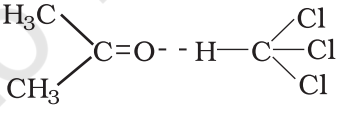


Fig.1.6 *The vapour pressures of two component systems as a function of composition (a) a solution that shows positive deviation from Raoult's law and (b) a solution that shows negative deviation from Raoult's law.*

pressure and result in positive deviation. Mixtures of ethanol and acetone behave in this manner. In pure ethanol, molecules are hydrogen bonded. On adding acetone, its molecules get in between the host molecules and break some of the hydrogen bonds between them. Due to weakening of interactions, the solution shows positive deviation from Raoult's law [Fig. 1.6 (a)]. In a solution formed by adding carbon disulphide to acetone, the dipolar interactions between solute-solvent molecules are weaker than the respective interactions among the solute-solute and solvent-solvent molecules. This solution also shows positive deviation.

In case of negative deviations from Raoult's law, the intermolecular attractive forces between A-A and B-B are weaker than those between A-B and leads to decrease in vapour pressure resulting in negative deviations. An example of this type is a mixture of phenol and aniline. In this case the intermolecular hydrogen bonding between phenolic proton and lone pair on nitrogen atom of aniline is stronger than the respective intermolecular hydrogen bonding between similar molecules. Similarly, a mixture of chloroform and acetone forms a solution with negative deviation from Raoult's law. This is because chloroform molecule is able to form hydrogen bond with acetone molecule as shown.



This decreases the escaping tendency of molecules for each component and consequently the vapour pressure decreases resulting in negative deviation from Raoult's law [Fig. 1.6. (b)].

Some liquids on mixing, form **azeotropes** which are binary mixtures having the same composition in liquid and vapour phase and boil at a constant temperature. In such cases, it is not possible to separate the components by fractional distillation. There are two types of azeotropes called **minimum boiling azeotrope and maximum boiling azeotrope**. The solutions which show a large positive deviation from Raoult's law form minimum boiling azeotrope at a specific composition.

For example, ethanol-water mixture (obtained by fermentation of sugars) on fractional distillation gives a solution containing approximately 95% by volume of ethanol. Once this composition, known as azeotrope composition, has been achieved, the liquid and vapour have the same composition, and no further separation occurs.

The solutions that show large negative deviation from Raoult's law form maximum boiling azeotrope at a specific composition. Nitric acid and water is an example of this class of azeotrope. This azeotrope has the approximate composition, 68% nitric acid and 32% water by mass, with a boiling point of 393.5 K.

Intext Question

1.8 The vapour pressure of pure liquids A and B are 450 and 700 mm Hg respectively, at 350 K . Find out the composition of the liquid mixture if total vapour pressure is 600 mm Hg. Also find the composition of the vapour phase.

1.6 Colligative Properties and Determination of Molar Mass

We have learnt in Section 1.4.3 that the vapour pressure of solution decreases when a non-volatile solute is added to a volatile solvent. There are many properties of solutions which are connected with this decrease of vapour pressure. These are: (1) relative lowering of vapour pressure of the solvent (2) depression of freezing point of the solvent (3) elevation of boiling point of the solvent and (4) osmotic pressure of the solution. **All these properties depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution. Such properties are called *colligative properties*** (colligative: from Latin: co means together, ligare means to bind). In the following Sections we will discuss these properties one by one.

1.6.1 Relative Lowering of Vapour Pressure

We have learnt in Section 1.4.3 that the vapour pressure of a solvent in solution is less than that of the pure solvent. Raoult established that the lowering of vapour pressure depends only on the concentration of the solute particles and it is independent of their identity. The equation (1.20) given in Section 1.4.3 establishes a relation between vapour pressure of the solution, mole fraction and vapour pressure of the solvent, i.e.,

$$p_1 = x_1 \, p_1^0 \qquad (1.22)$$

The reduction in the vapour pressure of solvent (Δp_1) is given as:

$$\Delta p_1 = p_1^0 - p_1 = p_1^0 - p_1^0 \, x_1$$
$$= p_1^0 \, (1 - x_1) \qquad (1.23)$$

Knowing that $x_2 = 1 - x_1$, equation (1.23) reduces to

$$\Delta p_1 = x_2 \, p_1^0 \qquad (1.24)$$

In a solution containing several non-volatile solutes, the lowering of the vapour pressure depends on the sum of the mole fraction of different solutes.

Equation (1.24) can be written as

$$\frac{\Delta p_1}{p_1^0} = \frac{p_1^0 - p_1}{p_1^0} = x_2 \qquad (1.25)$$

The expression on the left hand side of the equation as mentioned earlier is called **relative lowering of vapour pressure and is equal to the mole fraction of the solute**. The above equation can be written as:

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{n_2}{n_1 + n_2} \quad \left(\text{since } x_2 = \frac{n_2}{n_1 + n_2}\right) \tag{1.26}$$

Here n_1 and n_2 are the number of moles of solvent and solute respectively present in the solution. For dilute solutions $n_2 << n_1$, hence neglecting n_2 in the denominator we have

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{n_2}{n_1} \tag{1.27}$$

$$\text{or} \quad \frac{p_1^0 - p_1}{p_1^0} = \frac{w_2 \times M_1}{M_2 \times w_1} \tag{1.28}$$

Here w_1 and w_2 are the masses and M_1 and M_2 are the molar masses of the solvent and solute respectively.

From this equation (1.28), knowing all other quantities, the molar mass of solute (M_2) can be calculated.

Example 1.6 The vapour pressure of pure benzene at a certain temperature is 0.850 bar. A non-volatile, non-electrolyte solid weighing 0.5 g when added to 39.0 g of benzene (molar mass 78 g mol^{-1}). Vapour pressure of the solution, then, is 0.845 bar. What is the molar mass of the solid substance?

Solution The various quantities known to us are as follows:

$p_1^0 = 0.850$ bar; $p = 0.845$ bar; $M_1 = 78$ g mol^{-1}; $w_2 = 0.5$ g; $w_1 = 39$ g

Substituting these values in equation (2.28), we get

$$\frac{0.850 \text{ bar} - 0.845 \text{ bar}}{0.850 \text{ bar}} = \frac{0.5 \text{ g} \times 78 \text{ g mol}^{-1}}{M_2 \times 39 \text{ g}}$$

Therefore, $M_2 = 170$ g mol^{-1}

1.6.2 Elevation of Boiling Point

The vapour pressure of a liquid increases with increase of temperature. It boils at the temperature at which its vapour pressure is equal to the atmospheric pressure. For example, water boils at 373.15 K (100° C) because at this temperature the vapour pressure of water is 1.013 bar (1 atmosphere). We have also learnt in the last section that vapour pressure of the solvent decreases in the presence of non-volatile solute. Fig. 1.7 depicts the variation of vapour pressure of the pure solvent and solution as a function of temperature. For example, the vapour pressure of an aqueous solution of sucrose is less than 1.013 bar at 373.15 K. In order to make this solution boil, its vapour pressure must be increased to 1.013 bar by raising the temperature above the boiling temperature of the pure solvent (water). Thus, the boiling point of a solution is

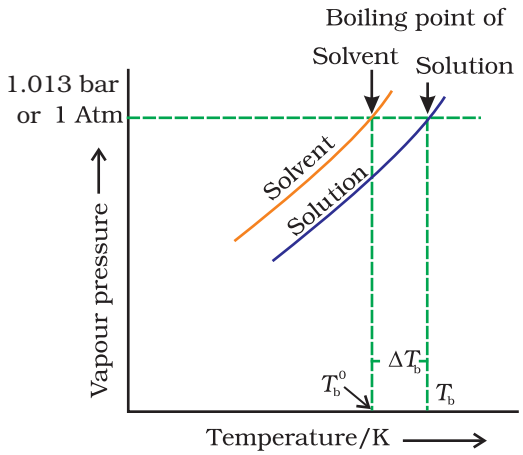


Fig. 1.7: *The vapour pressure curve for solution lies below the curve for pure water. The diagram shows that ΔT_b denotes the elevation of boiling point of a solvent in solution.*

always higher than that of the boiling point of the pure solvent in which the solution is prepared as shown in Fig. 1.7. Similar to lowering of vapour pressure, the elevation of boiling point also depends on the number of solute molecules rather than their nature. A solution of 1 mol of sucrose in 1000 g of water boils at 373.52 K at one atmospheric pressure.

Let T_b^0 be the boiling point of pure solvent and T_b be the boiling point of solution. The increase in the boiling point $\Delta T_b = T_b - T_b^0$ is known as **elevation of boiling point**.

Experiments have shown that for **dilute solutions** the elevation of boiling point (ΔT_b) is directly proportional to the molal concentration of the solute in a solution. Thus

$$\Delta T_b \propto m \qquad (1.29)$$

$$\text{or} \quad \Delta T_b = K_b\, m \qquad (1.30)$$

Here *m* (molality) is the number of moles of solute dissolved in 1 kg of solvent and the constant of proportionality, K_b is called **Boiling Point Elevation Constant or Molal Elevation Constant (Ebullioscopic Constant)**. The unit of K_b is K kg mol^{-1}. Values of K_b for some common solvents are given in Table 1.3. If w_2 gram of solute of molar mass M_2 is dissolved in w_1 gram of solvent, then molality, m of the solution is given by the expression:

$$m = \frac{w_2/M_2}{w_1/1000} = \frac{1000 \times w_2}{M_2 \times w_1} \qquad (1.31)$$

Substituting the value of molality in equation (1.30) we get

$$\Delta T_b = \frac{K_b \times 1000 \times w_2}{M_2 \times w_1} \qquad (1.32)$$

$$M_2 = \frac{1000 \times w_2 \times K_b}{\Delta T_b \times w_1} \qquad (1.33)$$

Thus, in order to determine M_2, molar mass of the solute, known mass of solute in a known mass of the solvent is taken and ΔT_b is determined experimentally for a known solvent whose K_b value is known.

Example 1.7

18 g of glucose, $C_6H_{12}O_6$, is dissolved in 1 kg of water in a saucepan. At what temperature will water boil at 1.013 bar? K_b for water is 0.52 K kg mol^{-1}.

Solution

Moles of glucose = 18 g/ 180 g mol^{-1} = 0.1 mol
Number of kilograms of solvent = 1 kg
Thus molality of glucose solution = 0.1 mol kg^{-1}
For water, change in boiling point

$\Delta T_b = K_b \times m = 0.52$ K kg mol^{-1} $\times$ 0.1 mol kg^{-1} = 0.052 K

Since water boils at 373.15 K at 1.013 bar pressure, therefore, the boiling point of solution will be 373.15 + 0.052 = 373.202 K.

Example 1.8 The boiling point of benzene is 353.23 K. When 1.80 g of a non-volatile solute was dissolved in 90 g of benzene, the boiling point is raised to 354.11 K. Calculate the molar mass of the solute. K_b for benzene is 2.53 K kg mol^{-1}

Solution The elevation (ΔT_b) in the boiling point = 354.11 K – 353. 23 K = 0.88 K

Substituting these values in expression (2.33) we get

$$M_2 = \frac{2.53 \text{ K kg mol}^{-1} \times 1.8 \text{ g} \times 1000 \text{ g kg}^{-1}}{0.88 \text{ K} \times 90 \text{ g}} = 58 \text{ g mol}^{-1}$$

Therefore, molar mass of the solute, M_2 = 58 g mol^{-1}

1.6.3 Depression of Freezing Point

The lowering of vapour pressure of a solution causes a lowering of the freezing point compared to that of the pure solvent (Fig. 1.8). We know that at the freezing point of a substance, the solid phase is in dynamic equilibrium with the liquid phase. Thus, the freezing point of a substance may be defined as the temperature at which the vapour pressure of the substance in its liquid phase is equal to its vapour pressure in the solid phase. A solution will freeze when its vapour pressure equals the vapour pressure of the pure solid solvent as is clear from Fig. 1.8. According to Raoult's law, when a non-volatile solid is added to the solvent its vapour pressure decreases and now it would become equal to that of solid solvent at lower temperature. Thus, the freezing point of the solvent decreases.

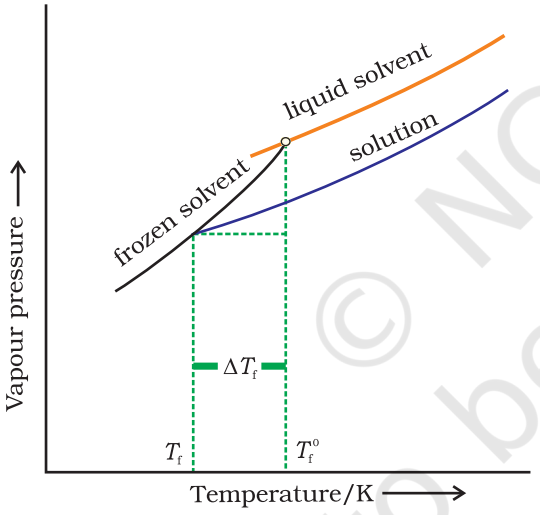


Fig. 1.8: *Diagram showing ΔT_f, depression of the freezing point of a solvent in a solution.*

Let T_f^0 be the freezing point of pure solvent and T_f be its freezing point when non-volatile solute is dissolved in it. The decrease in freezing point.

$\Delta T_f = T_f^0 - T_f$ is known as depression in freezing point.

Similar to elevation of boiling point, depression of freezing point (ΔT_f) for **dilute solution** (ideal solution) is directly proportional to molality, m of the solution. Thus,

$$\Delta T_f \propto m$$

or $$\Delta T_f = K_f \, m \qquad (1.34)$$

The proportionality constant, K_f, which depends on the nature of the solvent is known as **Freezing Point Depression Constant or Molal**

Depression Constant or Cryoscopic Constant. The unit of K_f is K kg mol^{-1}. Values of K_f for some common solvents are listed in Table 1.3.

If w_2 gram of the solute having molar mass as M_2, present in w_1 gram of solvent, produces the depression in freezing point ΔT_f of the solvent then molality of the solute is given by the equation (1.31).

$$m = \frac{w_2 / M_2}{w_1/1000} \tag{1.31}$$

Substituting this value of molality in equation (1.34) we get:

$$\Delta T_f = \frac{K_f \times w_2 / M_2}{w_1 / 1000}$$

$$\Delta T_f = \frac{K_f \times w_2 \times 1000}{M_2 \times w_1} \tag{1.35}$$

$$M_2 = \frac{K_f \times w_2 \times 1000}{\Delta T_f \times w_1} \tag{1.36}$$

Thus for determining the molar mass of the solute we should know the quantities w_1, w_2, ΔT_f, along with the molal freezing point depression constant.

The values of K_f and K_b, which depend upon the nature of the solvent, can be ascertained from the following relations.

$$K_f = \frac{R \times M_1 \times T_f^2}{1000 \times \Delta_{fus}H} \tag{1.37}$$

$$K_b = \frac{R \times M_1 \times T_b^2}{1000 \times \Delta_{vap}H} \tag{1.38}$$

Here the symbols R and M_1 stand for the gas constant and molar mass of the solvent, respectively and T_f and T_b denote the freezing point and the boiling point of the pure solvent respectively in kelvin. Further, $\Delta_{fus}H$ and $\Delta_{vap}H$ represent the enthalpies for the fusion and vapourisation of the solvent, respectively.

Table 1.3: Molal Boiling Point Elevation and Freezing Point Depression Constants for Some Solvents

Solvent	b. p./K	K_b/K kg mol^{-1}	f. p./K	K_f/K kg mol^{-1}
Water	373.15	0.52	273.0	1.86
Ethanol	351.5	1.20	155.7	1.99
Cyclohexane	353.74	2.79	279.55	20.00
Benzene	353.3	2.53	278.6	5.12
Chloroform	334.4	3.63	209.6	4.79
Carbon tetrachloride	350.0	5.03	250.5	31.8
Carbon disulphide	319.4	2.34	164.2	3.83
Diethyl ether	307.8	2.02	156.9	1.79
Acetic acid	391.1	2.93	290.0	3.90

Example 1.9 45 g of ethylene glycol ($C_2H_6O_2$) is mixed with 600 g of water. Calculate (a) the freezing point depression and (b) the freezing point of the solution.

Solution

Depression in freezing point is related to the molality, therefore, the molality of the solution with respect to ethylene glycol = $\frac{\text{moles of ethylene glycol}}{\text{mass of water in kilogram}}$

Moles of ethylene glycol = $\frac{45\ \text{g}}{62\ \text{g mol}^{-1}} = 0.73\ \text{mol}$

Mass of water in kg = $\frac{600\text{g}}{1000\text{g kg}^{-1}} = 0.6\ \text{kg}$

Hence molality of ethylene glycol = $\frac{0.73\ \text{mol}}{0.60\ \text{kg}} = 1.2\ \text{mol kg}^{-1}$

Therefore freezing point depression,

$\Delta T_f = 1.86\ \text{K kg mol}^{-1} \times 1.2\ \text{mol kg}^{-1} = 2.2\ \text{K}$

Freezing point of the aqueous solution = 273.15 K – 2.2 K = 270.95 K

Example 1.10 1.00 g of a non-electrolyte solute dissolved in 50 g of benzene lowered the freezing point of benzene by 0.40 K. The freezing point depression constant of benzene is 5.12 K kg mol^{-1}. Find the molar mass of the solute.

Solution

Substituting the values of various terms involved in equation (1.36) we get,

$M_2 = \frac{5.12\ \text{K kg mol}^{-1} \times 1.00\ \text{g} \times 1000\ \text{g kg}^{-1}}{0.40 \times 50\ \text{g}} = 256\ \text{g mol}^{-1}$

Thus, molar mass of the solute = 256 g mol^{-1}

1.6.4 Osmosis and Osmotic Pressure

There are many phenomena which we observe in nature or at home. For example, raw mangoes shrivel when pickled in brine (salt water); wilted flowers revive when placed in fresh water, blood cells collapse when suspended in saline water, etc. If we look into these processes we find one thing common in all, that is, all these substances are bound by membranes. These membranes can be of animal or vegetable origin and these occur naturally such as pig's bladder or parchment or can be synthetic such as cellophane. These membranes appear to be continuous sheets or films, yet they contain a network of submicroscopic holes or pores. Small solvent

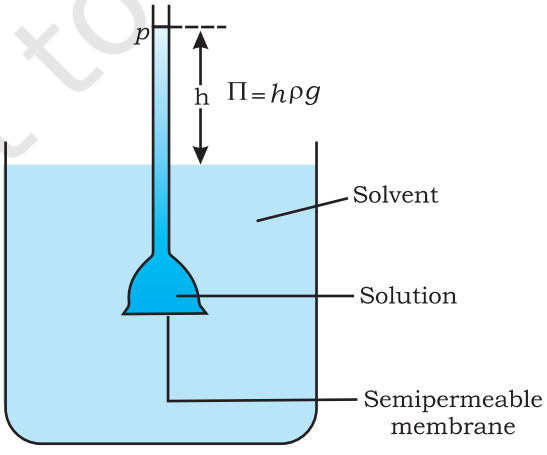


Fig. 1.9 *Level of solution rises in the thistle funnel due to osmosis of solvent.*

molecules, like water, can pass through these holes but the passage of bigger molecules like solute is hindered. Membranes having this kind of properties are known as *semipermeable membranes* (SPM).

Assume that only solvent molecules can pass through these semi-permeable membranes. If this membrane is placed between the solvent and solution as shown in Fig. 1.9, the solvent molecules will flow through the membrane from pure solvent to the solution. **This process of flow of the solvent is called *osmosis*.**

The flow will continue till the equilibrium is attained. The flow of the solvent from its side to solution side across a semipermeable membrane can be stopped if some extra pressure is applied on the solution. **This pressure that just stops the flow of solvent is called *osmotic pressure* of the solution.** The flow of solvent from dilute solution to the concentrated solution across a semipermeable membrane is due to osmosis. The important point to be kept in mind is that solvent molecules always flow from lower concentration to higher concentration of solution. The osmotic pressure has been found to depend on the concentration of the solution.

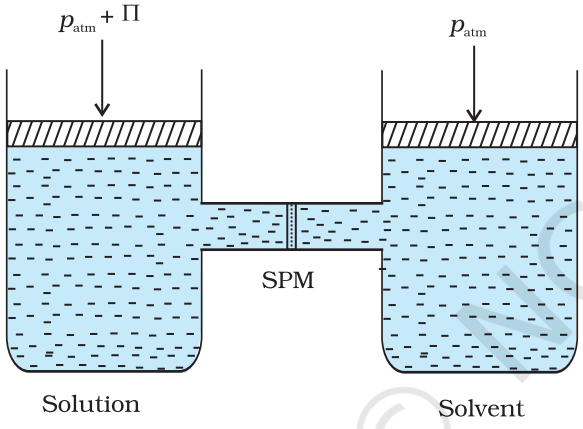


Fig. 1.10: *The excess pressure equal to the osmotic pressure must be applied on the solution side to prevent osmosis.*

The osmotic pressure of a solution is the excess pressure that must be applied to a solution to prevent osmosis, i.e., to stop the passage of solvent molecules through a semipermeable membrane into the solution. This is illustrated in Fig. 1.10. Osmotic pressure is a colligative property as it depends on the number of solute molecules and not on their identity. For dilute solutions, it has been found experimentally that **osmotic pressure is proportional to the molarity, *C* of the solution at a given temperature *T***. Thus:

$$\Pi = C\,R\,T \qquad (1.39)$$

Here Π is the osmotic pressure and R is the gas constant.

$$\Pi = (n_2 / V)\,R\,T \qquad (1.40)$$

Here V is volume of a solution in litres containing n_2 moles of solute. If w_2 grams of solute, of molar mass, M_2 is present in the solution, then $n_2 = w_2 / M_2$ and we can write,

$$\Pi\,V = \frac{w_2\,R\,T}{M_2} \qquad (1.41)$$

$$\text{or}\quad M_2 = \frac{w_2\,R\,T}{\Pi\,V} \qquad (1.42)$$

Thus, knowing the quantities w_2, T, Π and V we can calculate the molar mass of the solute.

Measurement of osmotic pressure provides another method of determining molar masses of solutes. This method is widely used to determine molar masses of proteins, polymers and other

macromolecules. The osmotic pressure method has the advantage over other methods as pressure measurement is around the room temperature and the molarity of the solution is used instead of molality. As compared to other colligative properties, its magnitude is large even for very dilute solutions. The technique of osmotic pressure for determination of molar mass of solutes is particularly useful for biomolecules as they are generally not stable at higher temperatures and polymers have poor solubility.

Two solutions having same osmotic pressure at a given temperature are called isotonic solutions. When such solutions are separated by semipermeable membrane no osmosis occurs between them. For example, the osmotic pressure associated with the fluid inside the blood cell is equivalent to that of 0.9% (mass/volume) sodium chloride solution, called normal saline solution and it is safe to inject intravenously. On the other hand, if we place the cells in a solution containing more than 0.9% (mass/volume) sodium chloride, water will flow out of the cells and they would shrink. Such a solution is called **hypertonic**. If the salt concentration is less than 0.9% (mass/volume), the solution is said to be **hypotonic**. In this case, water will flow into the cells if placed in this solution and they would swell.

Example 1.11

200 cm^3 of an aqueous solution of a protein contains 1.26 g of the protein. The osmotic pressure of such a solution at 300 K is found to be 2.57×10^{-3} bar. Calculate the molar mass of the protein.

Solution

The various quantities known to us are as follows: $\Pi = 2.57 \times 10^{-3}$ bar,

$V = 200\ cm^3 = 0.200$ litre

$T = 300$ K

$R = 0.083$ L bar mol^{-1} K^{-1}

Substituting these values in equation (2.42) we get

$$M_2 = \frac{1.26\ g \times 0.083\ L\ bar\ K^{-1}\ mol^{-1} \times 300\ K}{2.57 \times 10^{-3} bar \times 0.200\ L} = 61{,}022\ g\ mol^{-1}$$

The phenomena mentioned in the beginning of this section can be explained on the basis of osmosis. A raw mango placed in concentrated salt solution loses water via osmosis and shrivel into pickle. Wilted flowers revive when placed in fresh water. A carrot that has become limp because of water loss into the atmosphere can be placed into the water making it firm once again. Water will move into its cells through osmosis. When placed in water containing less than 0.9% (mass/volume) salt, blood cells swell due to flow of water in them by osmosis. People taking a lot of salt or salty food experience water retention in tissue cells and intercellular spaces because of osmosis. The resulting

puffiness or swelling is called **edema**. Water movement from soil into plant roots and subsequently into upper portion of the plant is partly due to osmosis. The preservation of meat by salting and of fruits by adding sugar protects against bacterial action. Through the process of osmosis, a bacterium on salted meat or candid fruit loses water, shrivels and dies.

1.6.5 Reverse Osmosis and Water Purification

The direction of osmosis can be reversed if a pressure larger than the osmotic pressure is applied to the solution side. That is, now the pure solvent flows out of the solution through the semi permeable membrane. This phenomenon is called **reverse osmosis** and is of great practical utility. Reverse osmosis is used in desalination of sea water. A schematic set up for the process is shown in Fig. 1.11. When pressure more than osmotic pressure is applied, pure water is squeezed out of the sea water through the membrane. A variety of polymer membranes are available for this purpose.

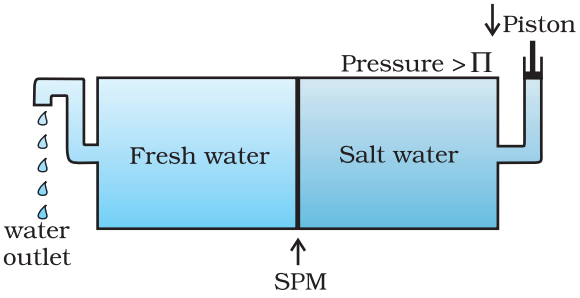


Fig. 1.11: *Reverse osmosis occurs when a pressure larger than the osmotic pressure is applied to the solution.*

The pressure required for the reverse osmosis is quite high. A workable porous membrane is a film of cellulose acetate placed over a suitable support. Cellulose acetate is permeable to water but impermeable to impurities and ions present in sea water. These days many countries use desalination plants to meet their potable water requirements.

Intext Questions

1.9 Vapour pressure of pure water at 298 K is 23.8 mm Hg. 50 g of urea (NH_2CONH_2) is dissolved in 850 g of water. Calculate the vapour pressure of water for this solution and its relative lowering.

1.10 Boiling point of water at 750 mm Hg is 99.63°C. How much sucrose is to be added to 500 g of water such that it boils at 100°C.

1.11 Calculate the mass of ascorbic acid (Vitamin C, $C_6H_8O_6$) to be dissolved in 75 g of acetic acid to lower its melting point by 1.5°C. $K_f = 3.9$ K kg mol^{-1}.

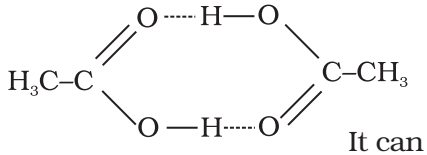
1.12 Calculate the osmotic pressure in pascals exerted by a solution prepared by dissolving 1.0 g of polymer of molar mass 185,000 in 450 mL of water at 37°C.

1.7 Abnormal Molar Masses

We know that ionic compounds when dissolved in water dissociate into cations and anions. For example, if we dissolve one mole of KCl (74.5 g) in water, we expect one mole each of K^+ and Cl^- ions to be released in the solution. If this happens, there would be two moles of particles in the solution. If we ignore interionic attractions, one mole of KCl in one kg of water would be expected to increase the boiling point by 2 × 0.52 K = 1.04 K. Now if we did not know about the degree of

dissociation, we could be led to conclude that the mass of 2 mol particles is 74.5 g and the mass of one mole of KCl would be 37.25 g. This brings into light the rule that, when there is dissociation of solute into ions, the experimentally determined molar mass is always lower than the true value.

$$2\ CH_3COOH \rightleftharpoons (CH_3COOH)_2$$



Molecules of ethanoic acid (acetic acid) dimerise in benzene due to hydrogen bonding. This normally happens in solvents of low dielectric constant. In this case the number of particles is reduced due to dimerisation. Association of molecules is depicted as follows:

It can be undoubtedly stated here that if all the molecules of ethanoic acid associate in benzene, then ΔT_b or ΔT_f for ethanoic acid will be half of the normal value. The molar mass calculated on the basis of this ΔT_b or ΔT_f will, therefore, be twice the expected value. Such a molar mass that is either lower or higher than the expected or normal value is called as **abnormal molar mass.**

In 1880 van't Hoff introduced a factor *i*, known as the van't Hoff factor, to account for the extent of dissociation or association. This factor *i* is defined as:

$$i = \frac{\text{Normal molar mass}}{\text{Abnormal molar mass}}$$

$$= \frac{\text{Observed colligative property}}{\text{Calculated colligative property}}$$

$$i = \frac{\text{Total number of moles of particles after association/dissociation}}{\text{Number of moles of particles before association/dissociation}}$$

Here abnormal molar mass is the experimentally determined molar mass and calculated **colligative properties** are obtained by assuming that the non-volatile solute is neither associated nor dissociated. In case of association, value of *i* is less than unity while for dissociation it is greater than unity. For example, the value of *i* for aqueous KCl solution is close to 2, while the value for ethanoic acid in benzene is nearly 0.5.

Inclusion of van't Hoff factor modifies the equations for colligative properties as follows:

Relative lowering of vapour pressure of solvent,

$$\frac{p_1^\circ - p_1}{p_1^\circ} = i.\frac{n_2}{n_1}$$

Elevation of Boiling point, $\Delta T_b = i\ K_b\ m$

Depression of Freezing point, $\Delta T_f = i\ K_f\ m$

Osmotic pressure of solution, $\Pi = i\ n_2\ R\ T\ /\ V$

Table 1.4 depicts values of the factor, i for several strong electrolytes. For KCl, NaCl and $MgSO_4$, i values approach 2 as the solution becomes very dilute. As expected, the value of i gets close to 3 for K_2SO_4.

Table 1.4: Values of van't Hoff factor, i, at Various Concentrations for NaCl, KCl, $MgSO_4$ and K_2SO_4.

Salt	*Values of i			van't Hoff Factor i for complete dissociation of solute
	0.1 m	0.01 m	0.001 m	
NaCl	1.87	1.94	1.97	2.00
KCl	1.85	1.94	1.98	2.00
$MgSO_4$	1.21	1.53	1.82	2.00
K_2SO_4	2.32	2.70	2.84	3.00

* *represent* i *values for incomplete dissociation.*

Example 1.12

2 g of benzoic acid (C_6H_5COOH) dissolved in 25 g of benzene shows a depression in freezing point equal to 1.62 K. Molal depression constant for benzene is 4.9 K kg mol^{-1}. What is the percentage association of acid if it forms dimer in solution?

Solution

The given quantities are: $w_2 = 2$ g; $K_f = 4.9$ K kg mol^{-1}; $w_1 = 25$ g,

$\Delta T_f = 1.62$ K

Substituting these values in equation (1.36) we get:

$$M_2 = \frac{4.9 \text{ K kg mol}^{-1} \times 2 \text{ g} \times 1000 \text{ g kg}^{-1}}{25 \text{ g} \times 1.62 \text{ K}} = 241.98 \text{ g mol}^{-1}$$

Thus, experimental molar mass of benzoic acid in benzene is

$= 241.98$ g mol^{-1}

Now consider the following equilibrium for the acid:

$$2\ C_6H_5COOH \rightleftharpoons (C_6H_5COOH)_2$$

If x represents the degree of association of the solute then we would have $(1 - x)$ mol of benzoic acid left in unassociated form and correspondingly $\frac{x}{2}$ as associated moles of benzoic acid at equilibrium. Therefore, total number of moles of particles at equilibrium is:

$$1 - x + \frac{x}{2} = 1 - \frac{x}{2}$$

Thus, total number of moles of particles at equilibrium equals van't Hoff factor i.

$$\text{But } i = \frac{\text{Normal molar mass}}{\text{Abnormal molar mass}}$$

$$= \frac{122\ g\ mol^{-1}}{241.98\ g\ mol^{-1}}$$

or $\frac{x}{2} = 1 - \frac{122}{241.98} = 1 - 0.504 = 0.496$

or $x = 2 \times 0.496 = 0.992$

Therefore, degree of association of benzoic acid in benzene is 99.2 %.

Example 1.13 0.6 mL of acetic acid (CH_3COOH), having density 1.06 g mL^{-1}, is dissolved in 1 litre of water. The depression in freezing point observed for this strength of acid was 0.0205°C. Calculate the van't Hoff factor and the dissociation constant of acid.

Solution

Number of moles of acetic acid $= \frac{0.6\ mL \times 1.06\ g\ mL^{-1}}{60\ g\ mol^{-1}}$

$= 0.0106\ mol = n$

Molality $= \frac{0.0106\ mol}{1000\ mL \times 1\ g\ mL^{-1}} = 0.0106\ mol\ kg^{-1}$

Using equation (1.35)

$\Delta T_f = 1.86\ K\ kg\ mol^{-1} \times 0.0106\ mol\ kg^{-1} = 0.0197\ K$

van't Hoff Factor (i) $= \frac{\text{Observed freezing point}}{\text{Calculated freezing point}} = \frac{0.0205\ K}{0.0197\ K} = 1.041$

Acetic acid is a weak electrolyte and will dissociate into two ions: acetate and hydrogen ions per molecule of acetic acid. If x is the degree of dissociation of acetic acid, then we would have $n(1 - x)$ moles of undissociated acetic acid, nx moles of CH_3COO^- and nx moles of H^+ ions,

$CH_3COOH \rightleftharpoons$	H^+ +	CH_3COO^-
n mol	0	0
$n(1-x)$	nx mol	nx mol

Thus total moles of particles are: $n(1 - x + x + x) = n(1 + x)$

$$i = \frac{n(1+x)}{n} = 1 + x = 1.041$$

Thus degree of dissociation of acetic acid = $x = 1.041 - 1.000 = 0.041$

Then $[CH_3COOH] = n(1 - x) = 0.0106\ (1 - 0.041)$,

$[CH_3COO^-] = nx = 0.0106 \times 0.041$, $[H^+] = nx = 0.0106 \times 0.041$.

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]} = \frac{0.0106 \times 0.041 \times 0.0106 \times 0.041}{0.0106\ (1.00 - 0.041)}$$

$= 1.86 \times 10^{-5}$

Summary

A solution is a homogeneous mixture of two or more substances. Solutions are classified as solid, liquid and gaseous solutions. The concentration of a solution is expressed in terms of mole fraction, molarity, molality and in percentages. The dissolution of a gas in a liquid is governed by **Henry's law**, according to which, at a given temperature, the **solubility of a gas in a liquid is directly proportional to the partial pressure of the gas**. The vapour pressure of the solvent is lowered by the presence of a non-volatile solute in the solution and this lowering of vapour pressure of the solvent is governed by Raoult's law, according to which the **relative lowering of vapour pressure of the solvent over a solution is equal to the mole fraction of a non-volatile solute present in the solution**. However, in a binary liquid solution, if both the components of the solution are volatile then another form of Raoult's law is used. Mathematically, this form of the Raoult's law is stated as: $p_{\text{total}} = p_1^0 x_1 + p_2^0 x_2$. **Solutions which obey Raoult's law over the entire range of concentration are called ideal solutions**. Two types of deviations from Raoult's law, called positive and negative deviations are observed. Azeotropes arise due to very large deviations from Raoult's law.

The properties of solutions which depend on the number of solute particles and are independent of their chemical identity are called colligative properties. These are lowering of vapour pressure, elevation of boiling point, depression of freezing point and osmotic pressure. The process of osmosis can be reversed if a pressure higher than the osmotic pressure is applied to the solution. Colligative properties have been used to determine the molar mass of solutes. Solutes which dissociate in solution exhibit molar mass lower than the actual molar mass and those which associate show higher molar mass than their actual values.

Quantitatively, the extent to which a solute is dissociated or associated can be expressed by van't Hoff factor *i*. This factor has been defined as ratio of normal molar mass to experimentally determined molar mass or as the ratio of observed colligative property to the calculated colligative property.

Exercises

1.1 Define the term solution. How many types of solutions are formed? Write briefly about each type with an example.

1.2 Give an example of a solid solution in which the solute is a gas.

1.3 Define the following terms:
(i) Mole fraction (ii) Molality (iii) Molarity (iv) Mass percentage.

1.4 Concentrated nitric acid used in laboratory work is 68% nitric acid by mass in aqueous solution. What should be the molarity of such a sample of the acid if the density of the solution is 1.504 g mL^{-1}?

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1.5 A solution of glucose in water is labelled as 10% w/w, what would be the molality and mole fraction of each component in the solution? If the density of solution is 1.2 g mL^{-1}, then what shall be the molarity of the solution?

1.6 How many mL of 0.1 M HCl are required to react completely with 1 g mixture of Na_2CO_3 and $NaHCO_3$ containing equimolar amounts of both?

1.7 A solution is obtained by mixing 300 g of 25% solution and 400 g of 40% solution by mass. Calculate the mass percentage of the resulting solution.

1.8 An antifreeze solution is prepared from 222.6 g of ethylene glycol ($C_2H_6O_2$) and 200 g of water. Calculate the molality of the solution. If the density of the solution is 1.072 g mL^{-1}, then what shall be the molarity of the solution?

1.9 A sample of drinking water was found to be severely contaminated with chloroform ($CHCl_3$) supposed to be a carcinogen. The level of contamination was 15 ppm (by mass):

(i) express this in percent by mass

(ii) determine the molality of chloroform in the water sample.

1.10 What role does the molecular interaction play in a solution of alcohol and water?

1.11 Why do gases always tend to be less soluble in liquids as the temperature is raised?

1.12 State Henry's law and mention some important applications.

1.13 The partial pressure of ethane over a solution containing 6.56×10^{-3} g of ethane is 1 bar. If the solution contains 5.00×10^{-2} g of ethane, then what shall be the partial pressure of the gas?

1.14 What is meant by positive and negative deviations from Raoult's law and how is the sign of $\Delta_{mix}H$ related to positive and negative deviations from Raoult's law?

1.15 An aqueous solution of 2% non-volatile solute exerts a pressure of 1.004 bar at the normal boiling point of the solvent. What is the molar mass of the solute?

1.16 Heptane and octane form an ideal solution. At 373 *K*, the vapour pressures of the two liquid components are 105.2 kPa and 46.8 kPa respectively. What will be the vapour pressure of a mixture of 26.0 g of heptane and 35 g of octane?

1.17 The vapour pressure of water is 12.3 kPa at 300 *K*. Calculate vapour pressure of 1 molal solution of a non-volatile solute in it.

1.18 Calculate the mass of a non-volatile solute (molar mass 40 g mol^{-1}) which should be dissolved in 114 g octane to reduce its vapour pressure to 80%.

1.19 A solution containing 30 g of non-volatile solute exactly in 90 g of water has a vapour pressure of 2.8 kPa at 298 *K*. Further, 18 g of water is then added to the solution and the new vapour pressure becomes 2.9 kPa at 298 *K*. Calculate:

(i) molar mass of the solute (ii) vapour pressure of water at 298 *K*.

1.20 A 5% solution (by mass) of cane sugar in water has freezing point of 271*K*. Calculate the freezing point of 5% glucose in water if freezing point of pure water is 273.15 *K*.

1.21 Two elements A and B form compounds having formula AB_2 and AB_4. When dissolved in 20 g of benzene (C_6H_6), 1 g of AB_2 lowers the freezing point by 2.3 *K* whereas 1.0 g of AB_4 lowers it by 1.3 *K*. The molar depression constant for benzene is 5.1 *K* kg mol^{-1}. Calculate atomic masses of A and B.

1.22 At 300 K, 36 g of glucose present in a litre of its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of the solution is 1.52 bars at the same temperature, what would be its concentration?

1.23 Suggest the most important type of intermolecular attractive interaction in the following pairs.

(i) n-hexane and n-octane
(ii) I_2 and CCl_4
(iii) $NaClO_4$ and water
(iv) methanol and acetone
(v) acetonitrile (CH_3CN) and acetone (C_3H_6O).

1.24 Based on solute-solvent interactions, arrange the following in order of increasing solubility in n-octane and explain. Cyclohexane, KCl, CH_3OH, CH_3CN.

1.25 Amongst the following compounds, identify which are insoluble, partially soluble and highly soluble in water?

(i) phenol (ii) toluene (iii) formic acid
(iv) ethylene glycol (v) chloroform (vi) pentanol.

1.26 If the density of some lake water is 1.25g mL^{-1} and contains 92 g of Na^+ ions per kg of water, calculate the molarity of Na^+ ions in the lake.

1.27 If the solubility product of CuS is 6×10^{-16}, calculate the maximum molarity of CuS in aqueous solution.

1.28 Calculate the mass percentage of aspirin ($C_9H_8O_4$) in acetonitrile (CH_3CN) when 6.5 g of $C_9H_8O_4$ is dissolved in 450 g of CH_3CN.

1.29 Nalorphene ($C_{19}H_{21}NO_3$), similar to morphine, is used to combat withdrawal symptoms in narcotic users. Dose of nalorphene generally given is 1.5 mg. Calculate the mass of 1.5×10^{-3} m aqueous solution required for the above dose.

1.30 Calculate the amount of benzoic acid (C_6H_5COOH) required for preparing 250 mL of 0.15 M solution in methanol.

1.31 The depression in freezing point of water observed for the same amount of acetic acid, trichloroacetic acid and trifluoroacetic acid increases in the order given above. Explain briefly.

1.32 Calculate the depression in the freezing point of water when 10 g of $CH_3CH_2CHClCOOH$ is added to 250 g of water. $K_a = 1.4 \times 10^{-3}$, $K_f = 1.86$ K kg mol^{-1}.

1.33 19.5 g of CH_2FCOOH is dissolved in 500 g of water. The depression in the freezing point of water observed is 1.0^0 C. Calculate the van't Hoff factor and dissociation constant of fluoroacetic acid.

1.34 Vapour pressure of water at 293 *K* is 17.535 mm Hg. Calculate the vapour pressure of water at 293 *K* when 25 g of glucose is dissolved in 450 g of water.

1.35 Henry's law constant for the molality of methane in benzene at 298 *K* is 4.27×10^5 mm Hg. Calculate the solubility of methane in benzene at 298 *K* under 760 mm Hg.

1.36 100 g of liquid A (molar mass 140 g mol^{-1}) was dissolved in 1000 g of liquid B (molar mass 180 g mol^{-1}). The vapour pressure of pure liquid B was found to be 500 torr. Calculate the vapour pressure of pure liquid A and its vapour pressure in the solution if the total vapour pressure of the solution is 475 Torr.

1.37 Vapour pressures of pure acetone and chloroform at 328 *K* are 741.8 mm Hg and 632.8 mm Hg respectively. Assuming that they form ideal solution over the entire range of composition, plot p_{total}, $p_{chloroform}$, and $p_{acetone}$ as a function of $x_{acetone}$. The experimental data observed for different compositions of mixture is:

$100 \times x_{acetone}$	0	11.8	23.4	36.0	50.8	58.2	64.5	72.1
$p_{acetone}$ /mm Hg	0	54.9	110.1	202.4	322.7	405.9	454.1	521.1
$p_{chloroform}$ /mm Hg	632.8	548.1	469.4	359.7	257.7	193.6	161.2	120.7

Plot this data also on the same graph paper. Indicate whether it has positive deviation or negative deviation from the ideal solution.

1.38 Benzene and toluene form ideal solution over the entire range of composition. The vapour pressure of pure benzene and toluene at 300 *K* are 50.71 mm Hg and 32.06 mm Hg respectively. Calculate the mole fraction of benzene in vapour phase if 80 g of benzene is mixed with 100 g of toluene.

1.39 The air is a mixture of a number of gases. The major components are oxygen and nitrogen with approximate proportion of 20% is to 79% by volume at 298 *K*. The water is in equilibrium with air at a pressure of 10 atm. At 298 *K* if the Henry's law constants for oxygen and nitrogen at 298 *K* are 3.30×10^7 mm and 6.51×10^7 mm respectively, calculate the composition of these gases in water.

1.40 Determine the amount of $CaCl_2$ (i = 2.47) dissolved in 2.5 litre of water such that its osmotic pressure is 0.75 atm at 27° C.

1.41 Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 litre of water at 25° C, assuming that it is completely dissociated.

Answers to Some Intext Questions

1.1 C_6H_6 = 15.28%, CCl_4 = 84.72%

1.2 0.459, 0.541

1.3 0.024 M, 0.03 M

1.4 36.946 g

1.5 1.5 mol kg^{-1} , 1.45 mol L^{-1} 0.0263

1.9 23.4 mm Hg

1.10 121.67 g

1.11 5.077 g

1.12 30.96 Pa

PHYSICS

PART – I

TEXTBOOK FOR CLASS XII

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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FOREWORD

The National Curriculum Framework (NCF), 2005 recommends that children's life at school must be linked to their life outside the school. This principle marks a departure from the legacy of bookish learning which continues to shape our system and causes a gap between the school, home and community. The syllabi and textbooks developed on the basis of NCF signify an attempt to implement this basic idea. They also attempt to discourage rote learning and the maintenance of sharp boundaries between different subject areas. We hope these measures will take us significantly further in the direction of a child-centred system of education outlined in the National Policy on Education (NPE), 1986.

The success of this effort depends on the steps that school principals and teachers will take to encourage children to reflect on their own learning and to pursue imaginative activities and questions. We must recognise that, given space, time and freedom, children generate new knowledge by engaging with the information passed on to them by adults. Treating the prescribed textbook as the sole basis of examination is one of the key reasons why other resources and sites of learning are ignored. Inculcating creativity and initiative is possible if we perceive and treat children as participants in learning, not as receivers of a fixed body of knowledge.

These aims imply considerable change in school routines and mode of functioning. Flexibility in the daily time-table is as necessary as rigour in implementing the annual calendar so that the required number of teaching days are actually devoted to teaching. The methods used for teaching and evaluation will also determine how effective this textbook proves for making children's life at school a happy experience, rather than a source of stress or boredom. Syllabus designers have tried to address the problem of curricular burden by restructuring and reorienting knowledge at different stages with greater consideration for child psychology and the time available for teaching. The textbook attempts to enhance this endeavour by giving higher priority and space to opportunities for contemplation and wondering, discussion in small groups, and activities requiring hands-on experience.

The National Council of Educational Research and Training (NCERT) appreciates the hard work done by the textbook development committee responsible for this book. We wish to thank the Chairperson of the advisory group in science and mathematics, Professor J.V. Narlikar and the Chief Advisor for this book, Professor A.W. Joshi for guiding the work of this committee. Several teachers contributed to the development of this textbook; we are grateful to their principals for making this possible. We are indebted to the institutions and organisations which have generously permitted us to draw upon their resources, material and personnel. We are especially grateful to the members of the National Monitoring Committee, appointed by the Department of Secondary and Higher Education, Ministry of Human Resource Development under the Chairpersonship of Professor Mrinal Miri and Professor G.P. Deshpande, for their valuable time and contribution. As an organisation committed to systemic reform and continuous improvement in the quality of its products, NCERT welcomes comments and suggestions which will enable us to undertake further revision and refinement.

Director
National Council of Educational
Research and Training

New Delhi
20 December 2006

Rationalisation of Content in the Textbooks

In view of the COVID-19 pandemic, it is imperative to reduce content load on students. The National Education Policy 2020, also emphasises reducing the content load and providing opportunities for experiential learning with creative mindset. In this background, the NCERT has undertaken the exercise to rationalise the textbooks across all classes. Learning Outcomes already developed by the NCERT across classes have been taken into consideration in this exercise.

Contents of the textbooks have been rationalised in view of the following:

- Overlapping with similar content included in other subject areas in the same class
- Similar content included in the lower or higher class in the same subject
- Difficulty level
- Content, which is easily accessible to students without much interventions from teachers and can be learned by children through self-learning or peer-learning
- Content, which is irrelevant in the present context

This present edition, is a reformatted version after carrying out the changes given above.

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a [1]**[SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC]** and to secure to all its citizens :

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the [2][unity and integrity of the Nation];

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949 do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

---

1. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Sovereign Democratic Republic" (w.e.f. 3.1.1977)
2. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Unity of the Nation" (w.e.f. 3.1.1977)

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Constitution of India

Part IV A (Article 51 A)

Fundamental Duties

It shall be the duty of every citizen of India —

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forests, lakes, rivers, wildlife and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement;

*(k) who is a parent or guardian, to provide opportunities for education to his child or, as the case may be, ward between the age of six and fourteen years.

Note: The Article 51A containing Fundamental Duties was inserted by the Constitution (42nd Amendment) Act, 1976 (with effect from 3 January 1977).

*(k) was inserted by the Constitution (86th Amendment) Act, 2002 (with effect from 1 April 2010).

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CONSTITUTION OF INDIA

Part III (Articles 12 – 35)
(Subject to certain conditions, some exceptions and reasonable restrictions)

guarantees these

Fundamental Rights

Right to Equality

- before law and equal protection of laws;
- irrespective of religion, race, caste, sex or place of birth;
- of opportunity in public employment;
- by abolition of untouchability and titles.

Right to Freedom

- of expression, assembly, association, movement, residence and profession;
- of certain protections in respect of conviction for offences;
- of protection of life and personal liberty;
- of free and compulsory education for children between the age of six and fourteen years;
- of protection against arrest and detention in certain cases.

Right against Exploitation

- for prohibition of traffic in human beings and forced labour;
- for prohibition of employment of children in hazardous jobs.

Right to Freedom of Religion

- freedom of conscience and free profession, practice and propagation of religion;
- freedom to manage religious affairs;
- freedom as to payment of taxes for promotion of any particular religion;
- freedom as to attendance at religious instruction or religious worship in educational institutions wholly maintained by the State.

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- for protection of interests of minorities to conserve their language, script and culture;
- for minorities to establish and administer educational institutions of their choice.

Right to Constitutional Remedies

- by issuance of directions or orders or writs by the Supreme Court and High Courts for enforcement of these Fundamental Rights.

Preface

It gives me pleasure to place this book in the hands of the students, teachers and the public at large (whose role cannot be overlooked). It is a natural sequel to the Class XI textbook which was brought out in 2006. This book is also a trimmed version of the textbooks which existed so far. The chapter on thermal and chemical effects of current has been cut out. This topic has also been dropped from the CBSE syllabus. Similarly, the chapter on communications has been substantially curtailed. It has been rewritten in an easily comprehensible form.

Although most other chapters have been based on the earlier versions, several parts and sections in them have been rewritten. The Development Team has been guided by the feedback received from innumerable teachers across the country.

In producing these books, Class XI as well as Class XII, there has been a basic change of emphasis. Both the books present physics to students without assuming that they would pursue this subject beyond the higher secondary level. This new view has been prompted by the various observations and suggestions made in the National Curriculum Framework (NCF), 2005. Similarly, in today's educational scenario where students can opt for various combinations of subjects, we cannot assume that a physics student is also studying mathematics. Therefore, physics has to be presented, so to say, in a standalone form.

As in Class XI textbook, some interesting box items have been inserted in many chapters. They are not meant for teaching or examinations. Their purpose is to catch the attention of the reader, to show some applications in daily life or in other areas of science and technology, to suggest a simple experiment, to show connection of concepts in different areas of physics, and in general, to break the monotony and enliven the book.

Features like Summary, Points to Ponder, Exercises and Additional Exercises at the end of each chapter, and Examples have been retained. Several concept-based Exercises have been transferred from end-of-chapter Exercises to Examples with Solutions in the text. It is hoped that this will make the concepts discussed in the chapter more comprehensible. Several new examples and exercises have been added. Students wishing to pursue physics further would find Points to Ponder and Additional Exercises very useful and thoughtful. To provide *resources beyond the textbook* and to encourage *eLearning*, each chapter has been provided with some relevant website addresses under the title *ePhysics*. These sites provide additional material on specific topics and also provide learners with opportunites for interactive demonstrations/experiments.

The intricate concepts of physics must be understood, comprehended and appreciated. Students must learn to ask questions like 'why', 'how', 'how do we know it'. They will find almost always that the question 'why' has no answer within the domain of physics and science in general. But that itself is a learning experience, is it not? On the other hand, the question 'how' has been reasonably well answered by physicists in the case of most natural phenomena. In fact, with the understanding of how things happen, it has been possible to make use of many phenomena to create technological applications for the use of humans.

For example, consider statements in a book, like 'A negatively charged electron is attracted by the positively charged plate', or 'In this experiment, light (or electron) behaves like a wave'. You will realise that it is not possible to answer 'why'. This question belongs to the domain of philosophy or metaphysics. But we can answer 'how', we can find the force acting, we can find

the wavelength of the photon (or electron), we can determine how things behave under different conditions, and we can develop instruments which will use these phenomena to our advantage.

It has been a pleasure to work for these books at the higher secondary level, along with a team of members. The Textbook Development Team, Review Team and Editing Teams involved college and university teachers, teachers from Indian Institutes of Technology, scientists from national institutes and laboratories, as well as, higher secondary teachers. The feedback and critical look provided by higher secondary teachers in the various teams are highly laudable. Most box items were generated by members of one or the other team, but three of them were generated by friends and well-wishers not part of any team. We are thankful to Dr P.N. Sen of Pune, Professor Roopmanjari Ghosh of Delhi and Dr Rajesh B Khaparde of Mumbai for allowing us to use their box items, respectively, in Chapters 3, 4 (Part I) and 9 (Part II). We are thankful to the members of the review and editing workshops to discuss and refine the first draft of the textbook. We also express our gratitude to Prof. Krishna Kumar, *Director*, NCERT, for entrusting us with the task of presenting this textbook as a part of the national effort for improving science education. I also thank Prof. G. Ravindra, *Joint Director*, NCERT, for his help from time-to-time. Prof. Hukum Singh, *Head*, Department of Education in Science and Mathematics, NCERT, was always willing to help us in our endeavour in every possible way.

We welcome suggestions and comments from our valued users, especially students and teachers. We wish our young readers a happy journey into the exciting realm of physics.

A. W. JOSHI
Chief Advisor
Textbook Development Committee

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CHAPTER THREE
CURRENT ELECTRICITY

CHAPTER FOUR
MOVING CHARGES AND MAGNETISM

CHAPTER FIVE
MAGNETISM AND MATTER

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Cover design

(Adapted from http://nobelprize.org and
the Nobel Prize in Physics 2006)

Different stages in the evolution of
the universe.

Back Cover

(Adapted from http://www.iter.org and
http://www.dae.gov.in)

Cut away view of *International Thermonuclear Experimental Reactor* (ITER) device. The man in the bottom shows the scale.

ITER is a joint international research and development project that aims to demonstrate the scientific and technical feasibility of fusion power.

India is one of the seven full partners in the project, the others being the European Union (represented by EURATOM), Japan, the People's Republic of China, the Republic of Korea, the Russian Federation and the USA. ITER will be constructed in Europe, at Cadarache in the South of France and will provide 500 MW of fusion power.

Fusion is the energy source of the sun and the stars. On earth, fusion research is aimed at demonstrating that this energy source can be used to produce electricity in a safe and environmentally benign way, with abundant fuel resources, to meet the needs of a growing world population.

For details of India's role, see *Nuclear India*, Vol. 39, Nov. 11-12/ May-June 2006, issue available at Department of Atomic Energy (DAE) website mentioned above.

BIOLOGY

TEXTBOOK FOR CLASS XII

12083

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FOREWORD

The National Curriculum Framework (NCF) 2005, recommends that children's life at school must be linked to their life outside the school. This principle marks a departure from the legacy of bookish learning which continues to shape our system and causes a gap between the school, home and community. The syllabi and textbooks developed on the basis of NCF signify an attempt to implement this basic idea. They also attempt to discourage rote learning and the maintenance of sharp boundaries between different subject areas. We hope these measures will take us significantly further in the direction of a child-centred system of education outlined in the National Policy on Education (1986).

The success of this effort depends on the steps that school principals and teachers will take to encourage children to reflect on their own learning and to pursue imaginative activities and questions. We must recognise that, given space, time and freedom, children generate new knowledge by engaging with the information passed on to them by adults. Treating the prescribed textbook as the sole basis of examination is one of the key reasons why other resources and sites of learning are ignored. Inculcating creativity and initiative is possible if we perceive and treat children as participants in learning, not as receivers of a fixed body of knowledge.

These aims imply considerable change in school routines and mode of functioning. Flexibility in the daily time-table is as necessary as rigour in implementing the annual calendar so that the required number of teaching days are actually devoted to teaching. The methods used for teaching and evaluation will also determine how effective this textbook proves for making children's life at school a happy experience, rather than a source of stress or boredom. Syllabus designers have tried to address the problem of curricular burden by restructuring and reorienting knowledge at different stages with greater consideration for child psychology and the time available for teaching. The textbook attempts to enhance this endeavour by giving higher priority and space to opportunities for contemplation and wondering, discussion in small groups, and activities requiring hands-on experience.

The National Council of Educational Research and Training (NCERT) appreciates the hard work done by the textbook development committee responsible for this book. We wish to thank the Chairperson of the advisory group in science and mathematics, Professor J.V. Narlikar and the Chief Advisor for this book, Professor K. Muralidhar, Department of Zoology, University of Delhi, Delhi for guiding the work of this committee. Several teachers contributed to the development of this textbook. We are grateful to their principals for making this possible. We are indebted to the institutions and organisations which have generously permitted us to draw upon their resources, material and personnel. We are especially grateful to the members of the National Monitoring Committee, appointed

by the Department of Secondary and Higher Education, Ministry of Human Resource Development under the Chairmanship of Professor Mrinal Miri and Professor G.P. Deshpande, for their valuable time and contribution.

As an organisation committed to systemic reform and continuous improvement in the quality of its products, NCERT welcomes comments and suggestions which will enable us to undertake further revision and refinement.

Director
National Council of Educational
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RATIONALISATION OF CONTENT IN THE TEXTBOOK

In view of the COVID-19 pandemic, it is imperative to reduce content load on students. The National Education Policy 2020, also emphasises reducing the content load and providing opportunities for experiential learning with creative mindset. In this background, the NCERT has undertaken the exercise to rationalise the textbooks across all classes. Learning Outcomes already developed by the NCERT across classes have been taken into consideration in this exercise.

Contents of the textbooks have been rationalised in view of the following:

- Overlapping with similar content included in other subject areas in the same class
- Similar content included in the lower or higher class in the same subject
- Difficulty level
- Content, which is easily accessible to students without much interventions from teachers and can be learned by children through self-learning or peer-learning
- Content, which is irrelevant in the present context

This present edition, is a reformatted version after carrying out the changes given above.

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a [1]**[SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC]** and to secure to all its citizens :

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the [2][unity and integrity of the Nation];

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949 do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

---

1. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Sovereign Democratic Republic" (w.e.f. 3.1.1977)
2. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Unity of the Nation" (w.e.f. 3.1.1977)

PREFACE

Biology is the study of life in its entirety. The growth of biology as a natural science during the last 1000 years is interesting from many points of view. One feature of this growth is changing emphasis. Initially it was description of life forms. Identification, nomenclature, classification of all recorded living forms enjoyed the attention of scientists for a long time. Description of their habitats and (in the case of animals) their behaviour was included in this study. In later years, the focus was physiology and internal morphology or anatomy. Darwinian ideas of evolution by natural selection changed the perception completely. Classical descriptive and clueless biology found a theoretical framework in the evolutionary theory of Darwin.

In the nineteenth and twentieth centuries, Physics and Chemistry were applied to Biology and the new science of Biochemistry soon became the dominant face of biology. On one hand Biochemistry was integrating with Physiology, becoming almost synonymous with it. On the other hand it gave rise to Structural Biology (structure of biomacromolecules), originally called Molecular Biology. The work of Bernal, Pauling, Watson and Crick, Hodgkins, Perutz and Kendrew, Delbruck, Luria, Monod, Beadle and Tatum, Lederberg, Brenner, Benzer, Nirenberg, Khorana, Mclintock, Sanger, Cohen, Boyer, Kornbergs (father and son), Leder, Chambon and scores of others brought in and established a modern version of Molecular Biology dealing with life processes at molecular level.

Physics and Chemistry dominated public perception of science for a long time. Daytoday life of man was influenced by developments in Physics, Chemistry and their respective manufacturing industries. Slowly and steadily, Biology, not to be left behind, demonstrated its utility for human welfare. Medical practice, especially diagnostics, green revolution and the newly emerging biotechnology and its success stories made the presence of biology felt by the common man. Patent laws brought biology into political domain and commercial value of biology became obvious.

For more than a century, classical and so-called reductionist biology fought artifical battles. The fact is both are important. Ecology brought in synthesis of both approaches and emphasised integrated understanding of biology. Form and process are both equally important. Systems biology, using mathematical tools, is bringing about a modern synthesis of both the aspects of Biology.

The Class XI and XII textbooks in biology essentially were to reflect these threads of biological thought. While the Class XI book dealt with morphology, taxonomy, molecular and cellular aspects of physiology, the Class XII book deals with the physiological process of reproduction in flowering plants and humans, the principles of inheritance, the nature of genetic material and its function, the contributions of biology to human welfare, basic principles of biotechnological processes and their applications and achievements. The Class XII book also relates genes to evolution on one hand and presents ecological interactions, behaviour of populations and ecosystems on the other. Most important, the guidelines under NCF-2005 have been followed in letter and spirit. The total learning load has been reduced

considerably and themes like environmental issues, adolescent problems and reproductive health have been dealt with in some detail. Studied together, the class XI and class XII textbooks in Biology would enable the student to —

(i) become familiar with the diversity of biological material.
(ii) appreciate and believe in the Darwinian evolutionary process exhibited by the living world.
(iii) understand the dynamic state of constituents of living bodies, i.e., metabolic basis of all physiological processes in plants, animals and microbes.
(iv) realise the structure and function of genetic material in directing the inherited phenotype pattern as well as a mediator of evolutionary process.
(v) appreciate the profound contributions of biology to human welfare.
(vi) reflect on the physico-chemical basis of living processes and at the same time realise the limitation of reductionism in understanding behaviour of organisms.
(vii) experience the humbling effect of this realisation that all living organisms are related to each other by virtue of shared genetic material.
(viii) realise that biology is the story of the struggle of living organisms for existence and survival.

One may notice a perceptible change in the writing style. Most of the chapters are written in an easy dialogue style engaging the student constantly while some chapters are in the form of critical comments on the subject matter. A number of questions have been provided at the end of each chapter though answers to some may not be found in the text. Students have to read supplementary material, upon advise from the teacher, to answer such questions.

I am thankful to Professor Krishna Kumar, Director NCERT; Professor G. Ravindra, Joint Director, NCERT and Professor Hukum Singh, Head, DESM, NCERT for constant support. I must place on record my deep appreciation for Dr B.K. Tripathi, *Reader,* DESM, NCERT for his relentless efforts as coordinator in bringing out the Biology textbook for both the Class XI and XII. All the members of the development team, the experts and reviewers, and the school teachers have contributed enormously in the preparation of this book. I thank them all. I am indeed highly thankful to the members of monitoring committee constituted by Ministry of Human Resource Development for their valuable observation that helped in the improvement of the book at the final stage. The book is prepared keeping in mind the guidelines of the NCF-2005 especially the emphasis on reducing the learning load. We hope that the book would meet the expectations of all the stakeholders. All suggestions for further improvement are always welcome.

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Chief Advisor
Biology Textbook for Class XII

Department of Zoology
University of Delhi

TEXTBOOK DEVELOPMENT COMMITTEE

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CONTENTS

UNIT X

UNIT VI
REPRODUCTION

Biology in essence is the story of life on earth. While individual organisms die without fail, species continue to live through millions of years unless threatened by natural or anthropogenic extinction. Reproduction becomes a vital process without which species cannot survive for long. Each individual leaves its progeny by asexual or sexual means. Sexual mode of reproduction enables creation of new variants, so that survival advantage is enhanced. This unit explains the details of reproductive processes in flowering plants and humans as easy to relate representative examples. A related perspective on human reproductive health and how reproductive ill health can be avoided is also presented to complete our understanding of biology of reproduction.

PANCHANAN MAHESHWARI
(1904-1966)

Born in November 1904 in Jaipur (Rajasthan) Panchanan Maheshwari rose to become one of the most distinguished botanists not only of India but of the entire world. He moved to Allahabad for higher education where he obtained his D.Sc. During his college days, he was inspired by Dr W. Dudgeon, an American missionary teacher, to develop interest in Botany and especially morphology. His teacher once expressed that if his student progresses ahead of him, it will give him a great satisfaction. These words encouraged Panchanan to enquire what he could do for his teacher in return.

He worked on embryological aspects and popularised the use of embryological characters in taxonomy. He established the Department of Botany, University of Delhi as an important centre of research in embryology and tissue culture. He also emphasised the need for initiation of work on artificial culture of immature embryos. These days, tissue culture has become a landmark in science. His work on test tube fertilisation and intra-ovarian pollination won worldwide acclaim.

He was honoured with fellowship of Royal Society of London (FRS), Indian National Science Academy and several other institutions of excellence. He encouraged general education and made a significant contribution to school education by his leadership in bringing out the very first textbooks of Biology for Higher Secondary Schools published by NCERT in 1964.

CHAPTER 1

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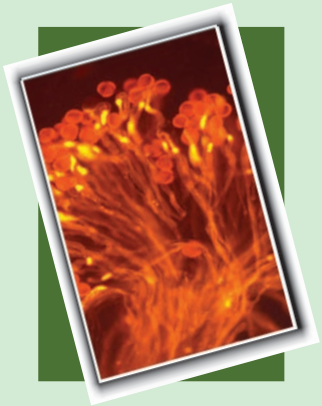


SEXUAL REPRODUCTION IN FLOWERING PLANTS

Are we not lucky that plants reproduce sexually? The myriads of flowers that we enjoy gazing at, the scents and the perfumes that we swoon over, the rich colours that attract us, are all there as an aid to sexual reproduction. Flowers do not exist only for us to be used for our own selfishness. All flowering plants show sexual reproduction. A look at the diversity of structures of the inflorescences, flowers and floral parts, shows an amazing range of adaptations to ensure formation of the end products of sexual reproduction, the fruits and seeds. In this chapter, let us understand the morphology, structure and the processes of sexual reproduction in flowering plants (angiosperms).

1.1 Flower – A Fascinating Organ of Angiosperms

Human beings have had an intimate relationship with flowers since time immemorial. Flowers are objects of aesthetic, ornamental, social, religious and cultural value – they have always been used as symbols for conveying important human feelings such as love, affection, happiness, grief, mourning, etc. *List at least five flowers of ornamental value that are commonly cultivated at*

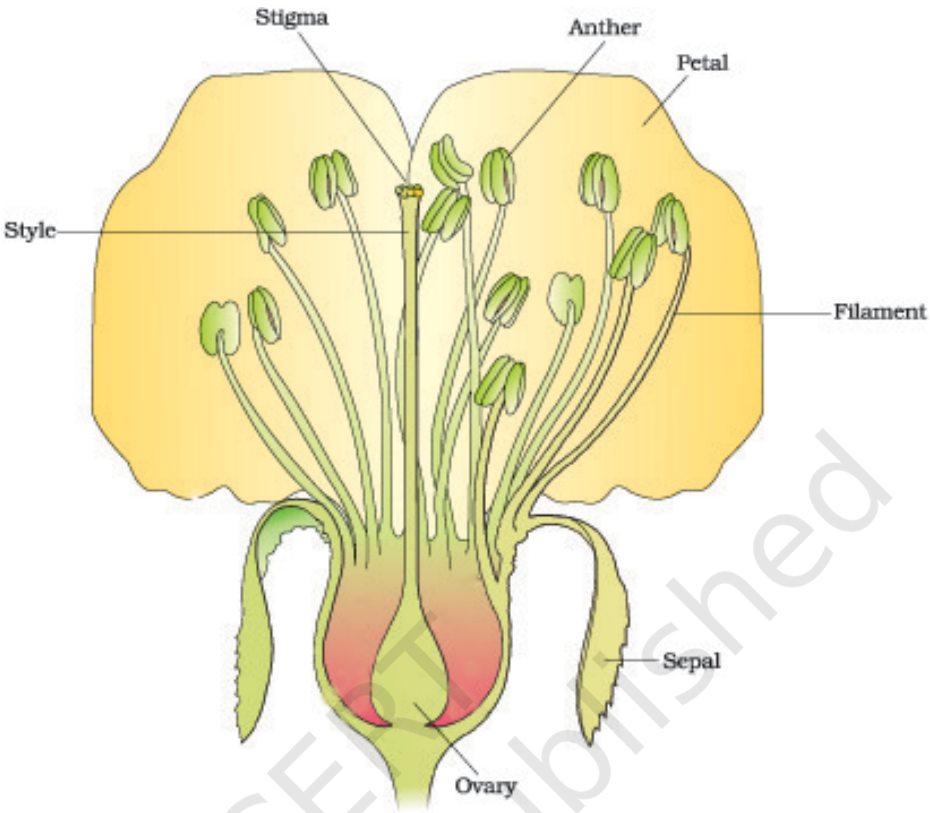


Figure 1.1 A diagrammatic representation of L.S. of a flower

homes and in gardens. Find out the names of five more flowers that are used in social and cultural celebrations in your family. Have you heard of floriculture – what does it refer to?

To a biologist, flowers are morphological and embryological marvels and the sites of sexual reproduction. In earlier classes, you have read the various parts of a flower. Figure 1.1 will help you recall the parts of a typical flower. Can you name the two parts in a flower in which the two most important units of sexual reproduction develop?

1.2 Pre-fertilisation: Structures and Events

Much before the actual flower is seen on a plant, the decision that the plant is going to flower has taken place. Several hormonal and structural changes are initiated which lead to the differentiation and further development of the floral primordium. Inflorescences are formed which bear the floral buds and then the flowers. In the flower the male and female reproductive structures, the androecium and the gynoecium differentiate and develop. You would recollect that the androecium consists of a whorl of stamens representing the male reproductive organ and the gynoecium represents the female reproductive organ.

1.2.1 Stamen, Microsporangium and Pollen Grain

Figure 1.2a shows the two parts of a typical **stamen –** the long and slender stalk called the **filament,** and the terminal generally bilobed structure called the **anther.** The proximal end of the filament is attached to the thalamus or the petal of the flower. The number and length of stamens are variable in flowers of different species. If you were to collect a stamen each from ten flowers (each from different species) and arrange them on a slide, you would be able to appreciate the large variation in size seen in nature. Careful observation of each stamen under a dissecting microscope and making neat diagrams would elucidate the range in shape and attachment of anthers in different flowers.

A typical angiosperm anther is **bilobed** with each lobe having two theca, i.e., they are **dithecous** (Figure 1.2b). Often a longitudinal groove runs lengthwise separating the theca. Let us understand the various types of tissues and their organisation in the transverse section of an anther (Figure 1.3a). The bilobed nature of an anther is very distinct in the transverse section of the anther. The anther is a four-sided (tetragonal) structure consisting of four **microsporangia** located at the corners, two in each lobe.

The microsporangia develop further and become **pollen sacs.** They extend longitudinally all through the length of an anther and are packed with pollen grains.

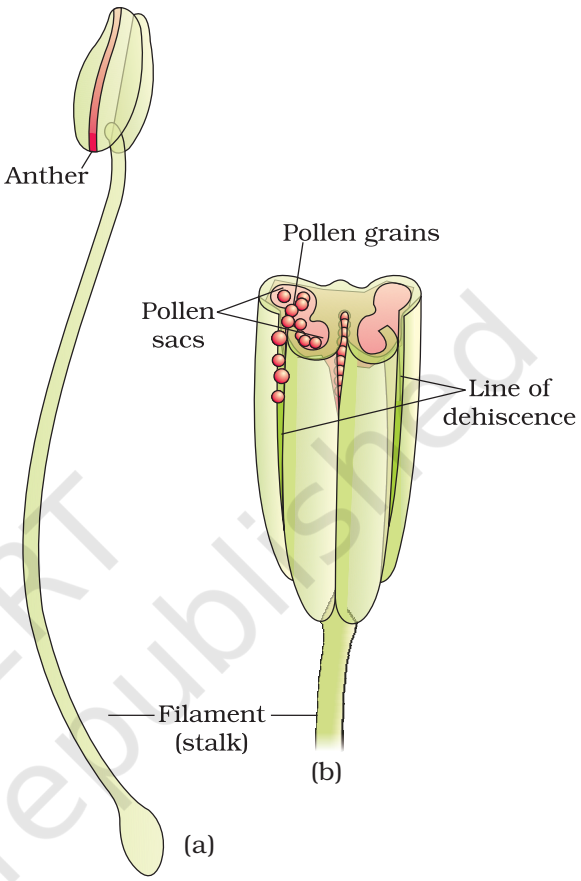


Figure 1.2 (a) A typical stamen; (b) three–dimensional cut section of an anther

Structure of microsporangium: In a transverse section, a typical microsporangium appears near circular in outline. It is generally surrounded by four wall layers (Figure 1.3b)– the epidermis, endothecium, middle layers and the tapetum. The outer three wall layers perform the function of protection and help in dehiscence of anther to release the pollen. The innermost wall layer is the **tapetum.** It nourishes the developing pollen grains. Cells of the tapetum possess dense cytoplasm and generally have more than one nucleus. *Can you think of how tapetal cells could become bi-nucleate?*

When the anther is young, a group of compactly arranged homogenous cells called the **sporogenous tissue** occupies the centre of each microsporangium.

Microsporogenesis : As the anther develops, the cells of the sporogenous tissue undergo meiotic divisions to form microspore tetrads. *What would be the ploidy of the cells of the tetrad?*

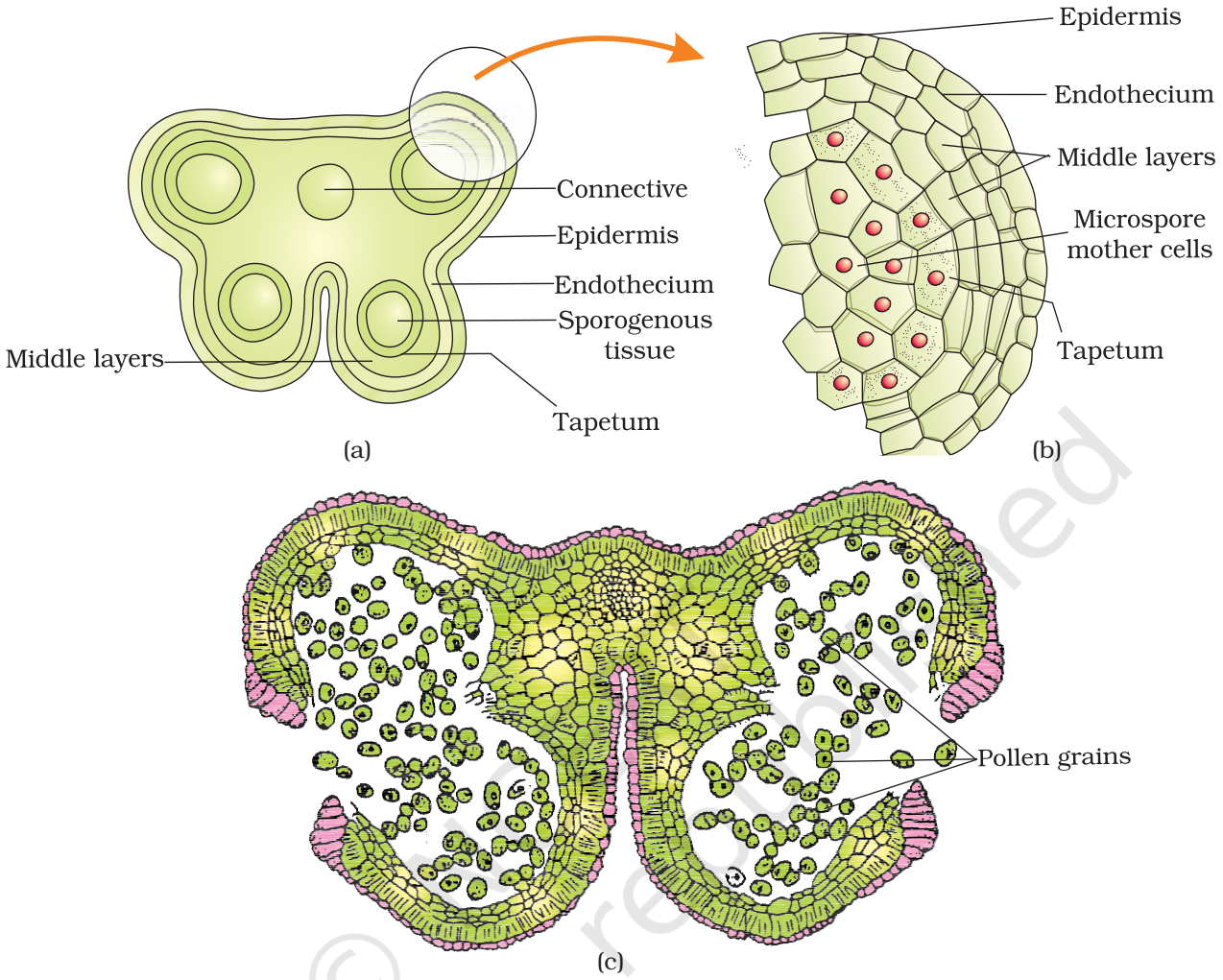


Figure 1.3 (a) Transverse section of a young anther; (b) Enlarged view of one microsporangium showing wall layers; (c) A mature dehisced anther

As each cell of the sporogenous tissue is capable of giving rise to a microspore tetrad. Each one is a potential pollen or microspore mother cell. The process of formation of microspores from a pollen mother cell (PMC) through meiosis is called **microsporogenesis.** The microspores, as they are formed, are arranged in a cluster of four cells–the **microspore tetrad** (Figure 1.3a). As the anthers mature and dehydrate, the microspores dissociate from each other and develop into **pollen grains** (Figure 1.3 b)**.** Inside each microsporangium several thousands of microspores or pollen grains are formed that are released with the dehiscence of anther (Figure 1.3c).

Pollen grain: The pollen grains represent the male gametophytes. If you touch the opened anthers of *Hibiscus* or any other flower you would find deposition of yellowish powdery pollen grains on your fingers. Sprinkle these grains on a drop of water taken on a glass slide and observe under

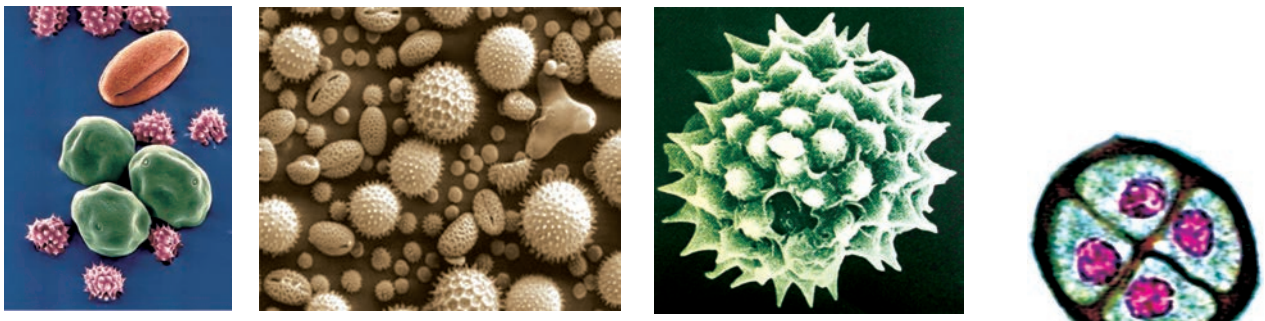


Figure 1.4 Scanning electron micrographs of a few pollen grains

a microscope. You will really be amazed at the variety of architecture – sizes, shapes, colours, designs – seen on the pollen grains from different species (Figure 1.4).

Pollen grains are generally spherical measuring about 25-50 micrometers in diameter. It has a prominent two-layered wall. The hard outer layer called the **exine** is made up of sporopollenin which is one of the most resistant organic material known. It can withstand high temperatures and strong acids and alkali. No enzyme that degrades sporopollenin is so far known. Pollen grain exine has prominent apertures called **germ pores** where sporopollenin is absent. Pollen grains are well-preserved as fossils because of the presence of sporopollenin. The exine exhibits a fascinating array of patterns and designs. *Why do you think the exine should be hard? What is the function of germ pore?* The inner wall of the pollen grain is called the **intine.** It is a thin and continuous layer made up of cellulose and pectin. The cytoplasm of pollen grain is surrounded by a plasma membrane. When the pollen grain is mature it contains two cells, the **vegetative cell** and **generative cell** (Figure 1.5b)**.** The vegetative cell is bigger, has abundant food reserve and a large irregularly shaped nucleus. The **generative cell** is small and floats in the cytoplasm of the vegetative cell. It is spindle shaped with dense cytoplasm and a nucleus. In over 60 per cent of angiosperms, pollen grains are shed at this 2-celled stage. In the remaining species, the generative cell divides mitotically to give rise to the two male gametes before pollen grains are shed (3-celled stage).

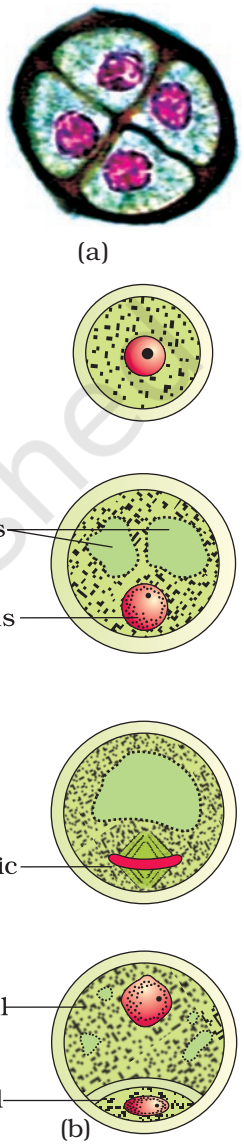


Figure 1.5 (a) Enlarged view of a pollen grain tetrad; (b) stages of a microspore maturing into a pollen grain

Pollen grains of many species cause severe allergies and bronchial afflictions in some people often leading to chronic respiratory disorders– asthma, bronchitis, etc. It may be mentioned that *Parthenium* or carrot grass that came into India as a contaminant with imported wheat, has become ubiquitous in occurrence and causes pollen allergy.

Pollen grains are rich in nutrients. It has become a fashion in recent years to use pollen tablets as food supplements. In western countries, a large number of pollen products in the form of tablets and syrups are available in the market. Pollen consumption has been claimed to increase the performance of athletes and race horses (Figure 1.6).

Figure 1.6 Pollen products

When once they are shed, pollen grains have to land on the stigma before they lose viability if they have to bring about fertilisation. How long do you think the pollen grains retain viability? The period for which pollen grains remain viable is highly variable and to some extent depends on the prevailing temperature and humidity. In some cereals such as rice and wheat, pollen grains lose viability within 30 minutes of their release, and in some members of Rosaceae, Leguminoseae and Solanaceae, they maintain viability for months. You may have heard of storing semen/ sperms of many animals including humans for artificial insemination. It is possible to store pollen grains of a large number of species for years in liquid nitrogen (-196^{0}C). Such stored pollen can be used as pollen banks, similar to seed banks, in crop breeding programmes.

1.2.2 The Pistil, Megasporangium (ovule) and Embryo sac

The gynoecium represents the female reproductive part of the flower. The gynoecium may consist of a single pistil (**monocarpellary**) or may have more than one pistil (**multicarpellary**). When there are more than one, the pistils may be fused together (**syncarpous**) (Figure 1.7b) or may be free (**apocarpous**) (Figure 1.7c). Each pistil has three parts (Figure 1.7a), **the stigma, style and ovary**. The **stigma** serves as a landing platform for pollen grains. The style is the elongated slender part beneath the stigma. The basal bulged part of the pistil is the **ovary.** Inside the ovary is the **ovarian cavity (locule)**. **The placenta** is located inside the ovarian cavity. Recall the definition and types of placentation that you studied in

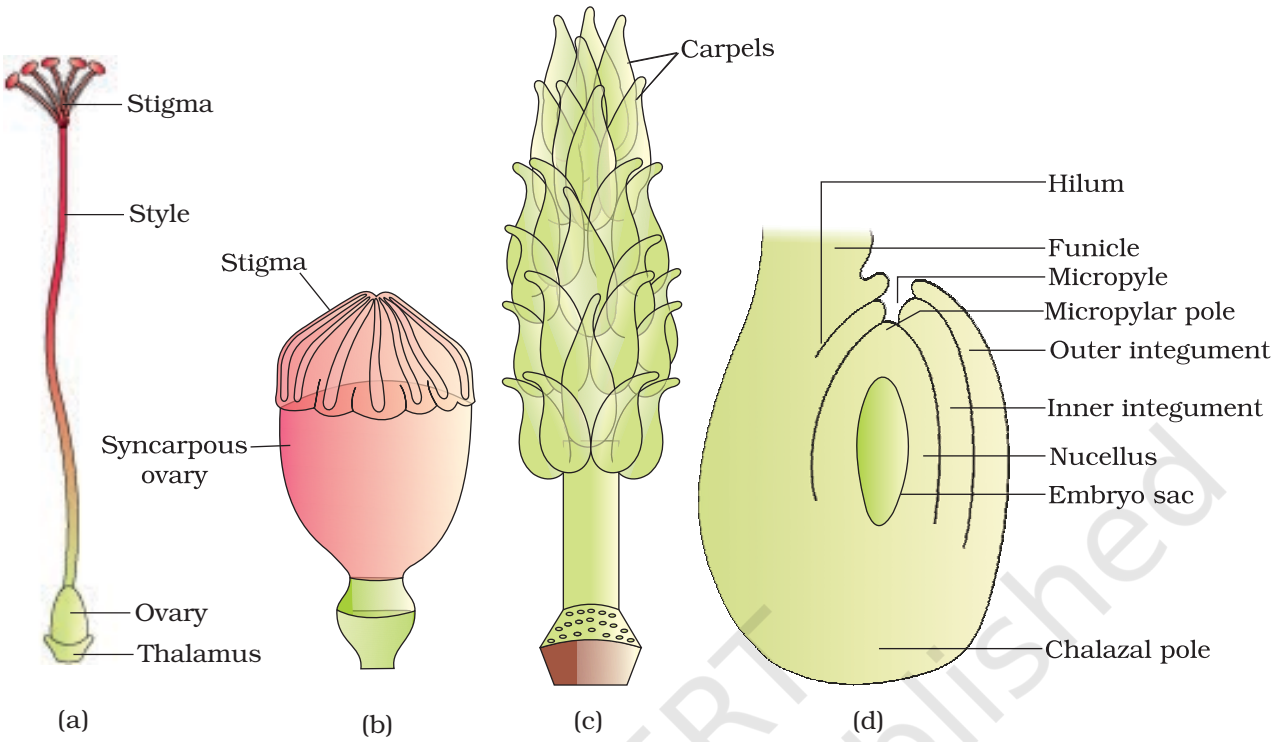


Figure 1.7 (a) A dissected flower of *Hibiscus* showing pistil (other floral parts have been removed); (b) Multicarpellary, syncarpous pistil of *Papaver*; (c) A multicarpellary, apocarpous gynoecium of *Michelia*; (d) A diagrammatic view of a typical anatropous ovule

Class XI. Arising from the placenta are the **megasporangia,** commonly called **ovules.** The number of ovules in an ovary may be one (wheat, paddy, mango) to many (papaya, water melon, orchids).

The Megasporangium (Ovule) : Let us familiarise ourselves with the structure of a typical angiosperm ovule (Figure 1.7d). The ovule is a small structure attached to the placenta by means of a stalk called **funicle**. The body of the ovule fuses with funicle in the region called **hilum.** Thus, hilum represents the junction between ovule and funicle. Each ovule has one or two protective envelopes called **integuments.** Integuments encircle the nucellus except at the tip where a small opening called the **micropyle** is organised. Opposite the micropylar end, is the **chalaza**, representing the basal part of the ovule.

Enclosed within the integuments is a mass of cells called the **nucellus**. Cells of the nucellus have abundant reserve food materials. Located in the nucellus is the **embryo sac** or **female gametophyte**. An ovule generally has a single embryo sac formed from a megaspore.

Megasporogenesis : The process of formation of megaspores from the **megaspore mother cell** is called **megasporogenesis**. Ovules generally differentiate a single megaspore mother cell (MMC) in the micropylar region

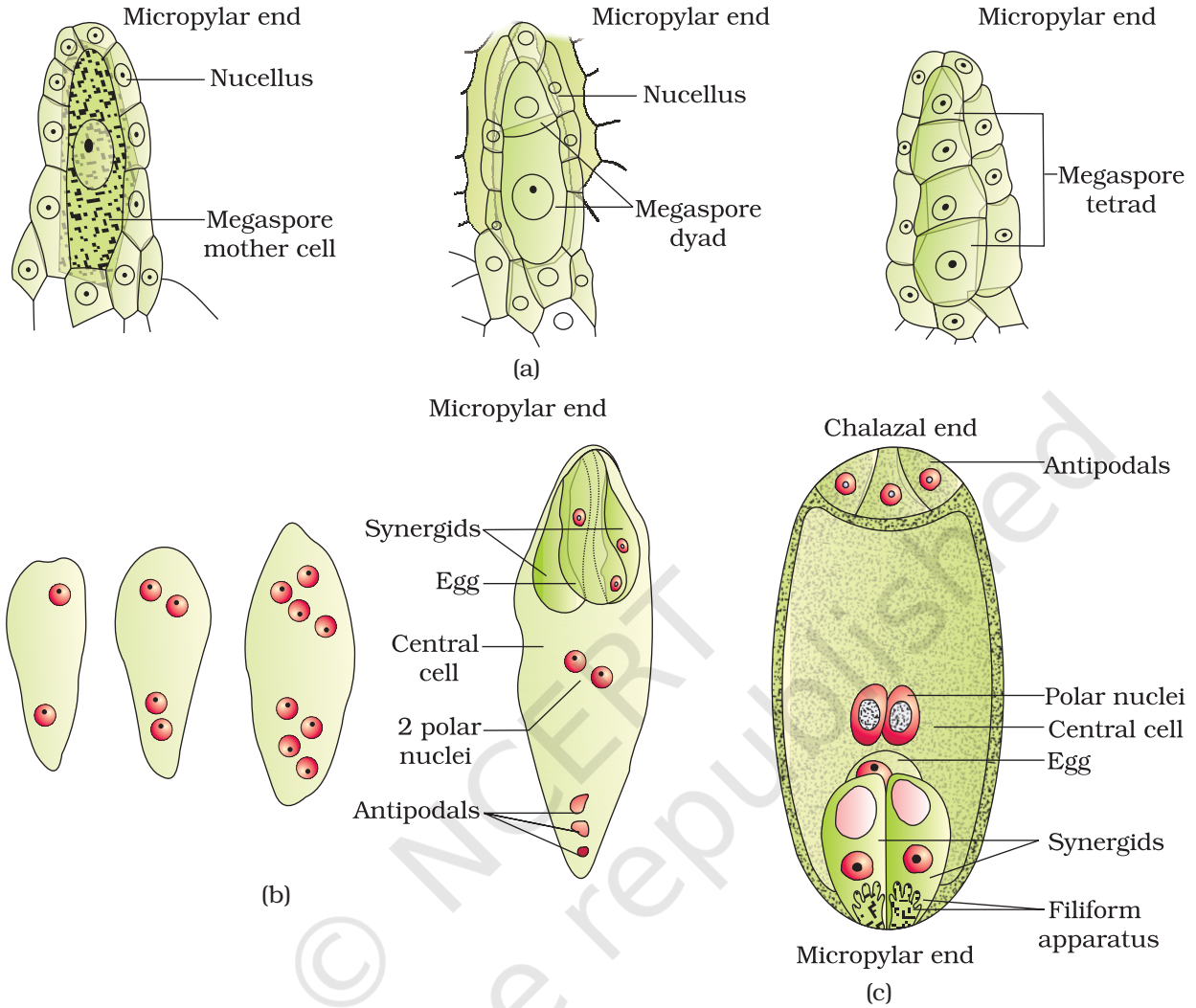


Figure 1.8 (a) Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores; (b) 2, 4, and 8-nucleate stages of embryo sac and a mature embryo sac; (c) A diagrammatic representation of the mature embryo sac.

of the nucellus. It is a large cell containing dense cytoplasm and a prominent nucleus. The MMC undergoes meiotic division. *What is the importance of the MMC undergoing meiosis?* Meiosis results in the production of four **megaspores** (Figure 1.8a).

Female gametophyte : In a majority of flowering plants, one of the megaspores is **functional** while the other three degenerate. Only the **functional megaspore** develops into the **female gametophyte** (**embryo sac).** This method of embryo sac formation from a single megaspore is termed **monosporic** development. *What will be the ploidy of the cells of the nucellus, MMC, the functional megaspore and female gametophyte?*

Let us study about the formation of the embryo sac in detail. (Figure 1.8b). The nucleus of the functional megaspore divides mitotically to form two nuclei which move to the opposite poles, forming the **2-nucleate** embryo sac. Two more sequential mitotic nuclear divisions result in the formation of the **4-nucleate** and later the **8-nucleate** stages of the embryo sac. It is of interest to note that these mitotic divisions are strictly free nuclear, that is, nuclear divisions are not followed immediately by cell wall formation. After the 8-nucleate stage, cell walls are laid down leading to the organisation of the typical **female gametophyte** or **embryo sac**. Observe the distribution of cells inside the embryo sac (Figure 1.8b, c). Six of the eight nuclei are surrounded by cell walls and organised into cells; the remaining two nuclei, called polar nuclei are situated below the egg apparatus in the large **central cell.**

There is a characteristic distribution of the cells within the embryo sac. Three cells are grouped together at the micropylar end and constitute the **egg apparatus**. The egg apparatus, in turn, consists of two **synergids** and one **egg cell**. The synergids have special cellular thickenings at the micropylar tip called filiform apparatus, which play an important role in guiding the pollen tubes into the synergid. Three cells are at the chalazal end and are called the **antipodals**. The large central cell, as mentioned earlier, has two polar nuclei. Thus, a typical angiosperm embryo sac, at maturity, though **8-nucleate** is **7-celled**.

1.2.3 Pollination

In the preceding sections you have learnt that the male and female gametes in flowering plants are produced in the pollen grain and embryo sac, respectively. As both types of gametes are non-motile, they have to be brought together for fertilisation to occur. How is this achieved?

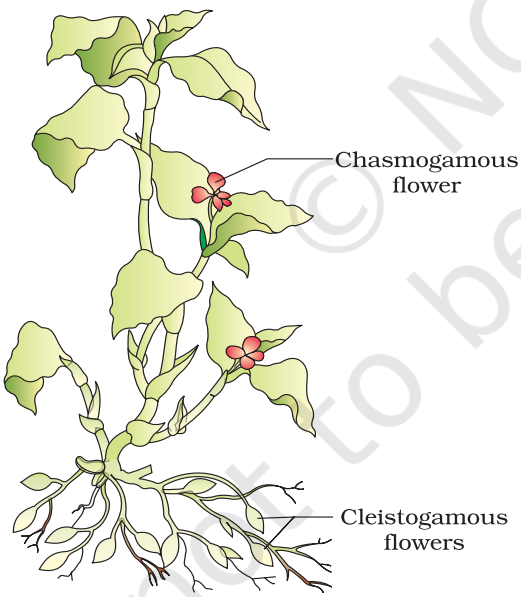
Pollination is the mechanism to achieve this objective. Transfer of pollen grains (shed from the anther) to the stigma of a pistil is termed **pollination**. Flowering plants have evolved an amazing array of adaptations to achieve pollination. They make use of external agents to achieve pollination. *Can you list the possible external agents?*

Kinds of Pollination : Depending on the source of pollen, pollination can be divided into three types.

(i) ***Autogamy* :** In this type, pollination is achieved within the same flower. Transfer of pollen grains from the anther to the stigma of the same flower (Figure 1.9a). In a normal flower which opens and exposes the anthers and the stigma, complete autogamy is rather rare. Autogamy in such flowers requires synchrony in pollen release and stigma receptivity and also, the anthers and the stigma should

(a)

(b)



(c)

Figure 1.9 (a) Self-pollinated flowers; (b) Cross pollinated flowers; (c) Cleistogamous flowers

lie close to each other so that self-pollination can occur. Some plants such as *Viola* (common pansy), *Oxalis*, and *Commelina* produce two types of flowers – **chasmogamous** flowers which are similar to flowers of other species with exposed anthers and stigma, and **cleistogamous** flowers which do not open at all (Figure 1.9c). In such flowers, the anthers and stigma lie close to each other. When anthers dehisce in the flower buds, pollen grains come in contact with the stigma to effect pollination. Thus, cleistogamous flowers are invariably autogamous as there is no chance of cross-pollen landing on the stigma. Cleistogamous flowers produce assured seed-set even in the absence of pollinators. Do you think that cleistogamy is advantageous or disadvantageous to the plant? Why?

(ii) ***Geitonogamy*** – Transfer of pollen grains from the anther to the stigma of another flower of the same plant. Although geitonogamy is functionally cross-pollination involving a pollinating agent, genetically it is similar to autogamy since the pollen grains come from the same plant.

(iii) ***Xenogamy*** – Transfer of pollen grains from anther to the stigma of a different plant (Figure 1.9b). This is the only type of pollination which during pollination brings genetically different types of pollen grains to the stigma.

Agents of Pollination : Plants use two abiotic (wind and water) and one biotic (animals) agents to achieve pollination. Majority of plants use biotic agents for pollination. Only a small proportion of plants use abiotic agents. Pollen grains coming in contact with the stigma is a chance factor in both wind and water pollination. To compensate for this uncertainties and associated loss of pollen grains, the flowers produce enormous amount of pollen when compared to the number of ovules available for pollination.

Pollination by wind is more common amongst abiotic pollinations. Wind pollination also requires that the pollen grains are light and non-sticky so that they can be transported in wind currents. They often possess well-exposed stamens (so that the pollens are easily dispersed into wind currents, Figure 1.10) and large often-feathery stigma to easily trap air-borne pollen grains. Wind-pollinated flowers often have a single ovule in each ovary and numerous flowers packed into an inflorescence; a familiar example is the corn cob – the ears you see are nothing but the stigma and style which wave in the wind to trap pollen grains. Wind-pollination is quite common in grasses.

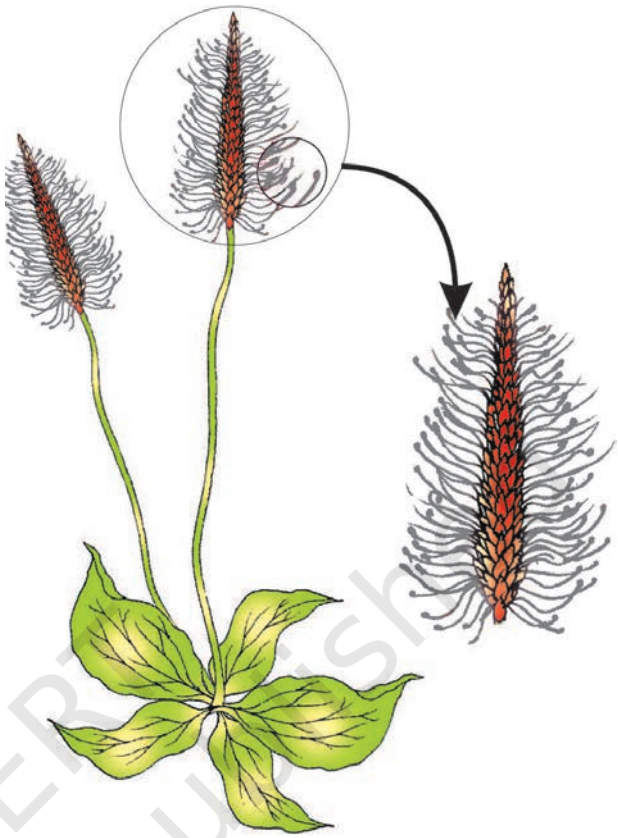
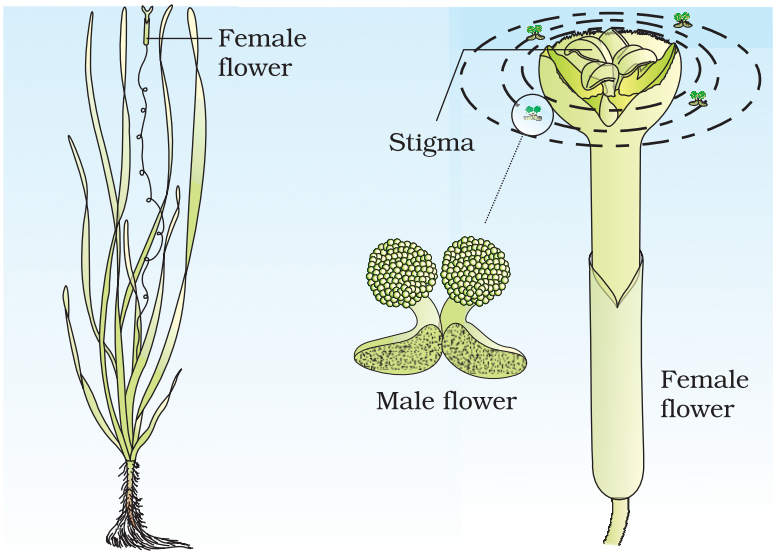


Figure 1.10 A wind-pollinated plant showing compact inflorecence and well-exposed stamens

Pollination by water is quite rare in flowering plants and is limited to about 30 genera, mostly monocotyledons. As against this, you would recall that water is a regular mode of transport for the male gametes among the lower plant groups such as algae, bryophytes and pteridophytes. It is believed, particularly for some bryophytes and pteridophytes, that their distribution is limited because of the need for water for the transport of male gametes and fertilisation. Some examples of water pollinated plants are *Vallisneria* and *Hydrilla* which grow in fresh water and several marine sea-grasses such as *Zostera*. Not all aquatic plants use water for pollination. In a majority of aquatic plants such as water hyacinth and water lily, the flowers emerge above the level of water and are pollinated by insects or wind as in most of the land plants. In *Vallisneria,* the female flower reach the surface of water by the long stalk and the male flowers or pollen grains are released on to the surface of water. They are carried passively by water currents (Figure 1.11a); some of them eventually reach the female flowers and the stigma. In another group of water pollinated plants such as seagrasses, female flowers remain submerged in water and the pollen grains are released inside the water. Pollen grains in many such species are long, ribbon like and they are carried passively inside the water; some of them reach the stigma and achieve pollination. In most of the water-pollinated species, pollen grains are protected from wetting by a mucilaginous covering.

Both wind and water pollinated flowers are not very colourful and do not produce nectar. *What would be the reason for this?*



(a)

(b)

Figure 1.11 (a) Pollination by water in *Vallisneria*; (b) Insect pollination

Majority of flowering plants use a range of animals as pollinating agents. Bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds and humming birds) and bats are the common pollinating agents. (Figure 1.11b). Among the animals, insects, particularly bees are the dominant biotic pollinating agents. Even larger animals such as some primates (lemurs), arboreal (tree-dwelling) rodents, or even reptiles (gecko lizard and garden lizard) have also been reported as pollinators in some species.

Often flowers of animal-pollinated plants are specifically adapted for a particular species of animal.

Majority of insect-pollinated flowers are large, colourful, fragrant and rich in nectar. When the flowers are small, a number of flowers are clustered into an inflorescence to make them conspicuous. Animals are attracted to flowers by colour and/or fragrance. The flowers pollinated by flies and beetles secrete foul odours to attract these animals. To sustain animal visits, the flowers have to provide rewards to the animals. Nectar and pollen grains are the usual floral rewards. For harvesting the reward(s) from the flower the animal visitor comes in contact with the anthers and the stigma. The body of the animal gets a coating of pollen grains, which are generally sticky in animal pollinated flowers. When the animal carrying pollen on its body comes in contact with the stigma, it brings about pollination.

In some species floral rewards are in providing safe places to lay eggs; an example is that of the tallest flower of *Amorphophallus* (the flower itself is about 6 feet in height). A similar relationship exists between a species of moth and the plant *Yucca* where both species – moth and the

plant – cannot complete their life cycles without each other. The moth deposits its eggs in the locule of the ovary and the flower, in turn, gets pollinated by the moth. The larvae of the moth come out of the eggs as the seeds start developing.

Why don't you observe some flowers of the following plants (or any others available to you): Cucumber, Mango, Peepal, Coriander, Papaya, Onion, Lobia, Cotton, Tobacco, Rose, Lemon, Eucalyptus, Banana? Try to find out which animals visit them and whether they could be pollinators.You'll have to patiently observe the flowers over a few days and at different times of the day. You could also try to see whether there is any correlation in the characteristics of a flower to the animal that visits it. Carefully observe if any of the visitors come in contact with the anthers and the stigma as only such visitors can bring about pollination. Many insects may consume pollen or the nectar without bringing about pollination. Such floral visitors are referred to as pollen/nectar robbers. You may or may not be able to identify the pollinators, but you will surely enjoy your efforts!

Outbreeding Devices : Majority of flowering plants produce hermaphrodite flowers and pollen grains are likely to come in contact with the stigma of the same flower. Continued self-pollination result in inbreeding depression. Flowering plants have developed many devices to discourage self-pollination and to encourage cross-pollination. In some species, pollen release and stigma receptivity are not synchronised. Either the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen. In some other species, the anther and stigma are placed at different positions so that the pollen cannot come in contact with the stigma of the same flower. Both these devices prevent autogamy. The third device to prevent inbreeding is self-incompatibility. This is a genetic mechanism and prevents self-pollen (from the same flower or other flowers of the same plant) from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil. Another device to prevent self-pollination is the production of unisexual flowers. If both male and female flowers are present on the same plant such as castor and maize (monoecious), it prevents autogamy but not geitonogamy. In several species such as papaya, male and female flowers are present on different plants, that is each plant is either male or female (dioecy). This condition prevents both autogamy and geitonogamy.

Pollen-pistil Interaction : Pollination does not guarantee the transfer of the right type of pollen (compatible pollen of the same species as the stigma). Often, pollen of the wrong type, either from other species or from the same plant (if it is self-incompatible), also land on the stigma. The pistil has the ability to recognise the pollen, whether it is of the right type (compatible) or of the wrong type (incompatible). If it is of the right type, the pistil accepts the pollen and promotes post-pollination events that

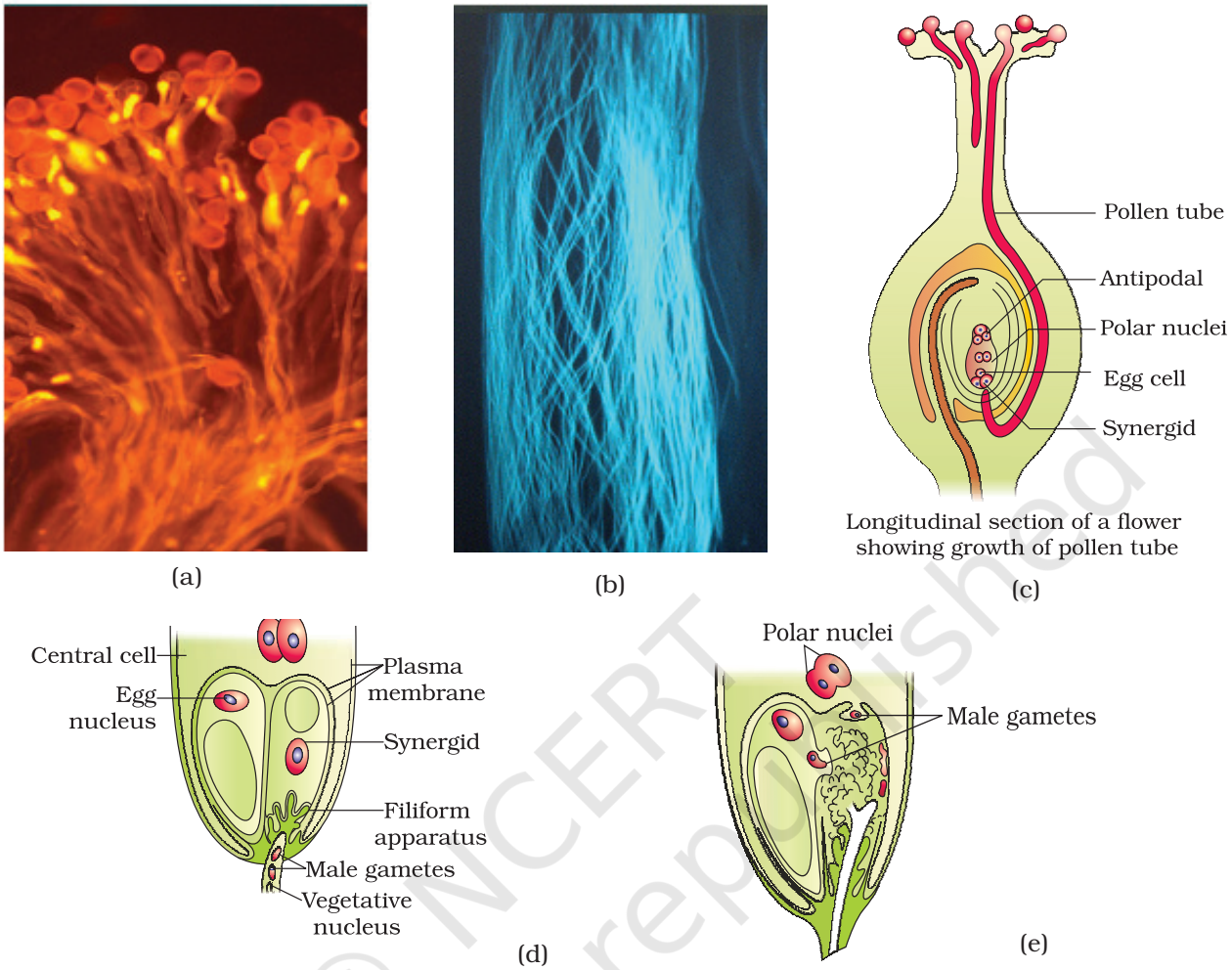


Figure 1.12 (a) Pollen grains germinating on the stigma; (b) Pollen tubes growing through the style; (c) L.S. of pistil showing path of pollen tube growth; (d) enlarged view of an egg apparatus showing entry of pollen tube into a synergid; (e) Discharge of male gametes into a synergid and the movements of the sperms, one into the egg and the other into the central cell

leads to fertilisation. If the pollen is of the wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style. The ability of the pistil to recognise the pollen followed by its acceptance or rejection is the result of a continuous dialogue between pollen grain and the pistil. This dialogue is mediated by chemical components of the pollen interacting with those of the pistil. It is only in recent years that botanists have been able to identify some of the pollen and pistil components and the interactions leading to the recognition, followed by acceptance or rejection.

As mentioned earlier, following compatible pollination, the pollen grain germinates on the stigma to produce a pollen tube through one of the germ pores (Figure 1.12a). The contents of the pollen grain move into the

pollen tube. Pollen tube grows through the tissues of the stigma and style and reaches the ovary (Figure 1.12b, c). You would recall that in some plants, pollen grains are shed at two-celled condition (a vegetative cell and a generative cell). In such plants, the generative cell divides and forms the two male gametes during the growth of pollen tube in the stigma. In plants which shed pollen in the three-celled condition, pollen tubes carry the two male gametes from the beginning. Pollen tube, after reaching the ovary, enters the ovule through the micropyle and then enters one of the synergids through the filiform apparatus (Figure 1.12d, e). Many recent studies have shown that filiform apparatus present at the micropylar part of the synergids guides the entry of pollen tube. All these events–from pollen deposition on the stigma until pollen tubes enter the ovule–are together referred to as pollen-pistil interaction. As pointed out earlier, pollen-pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen. The knowledge gained in this area would help the plant breeder in manipulating pollen-pistil interaction, even in incompatible pollinations, to get desired hybrids.

You can easily study pollen germination by dusting some pollen from flowers such as pea, chickpea, *Crotalaria*, balsam and *Vinca* on a glass slide containing a drop of sugar solution (about 10 per cent). After about 15–30 minutes, observe the slide under the low power lens of the microscope. You are likely to see pollen tubes coming out of the pollen grains.

A breeder is interested in crossing different species and often genera to combine desirable characters to produce commercially 'superior' varieties. **Artificial hybridisation** is one of the major approaches of crop improvement programme. In such crossing experiments it is important to make sure that only the desired pollen grains are used for pollination and the stigma is protected from contamination (from unwanted pollen). This is achieved by emasculation and bagging techniques.

If the female parent bears bisexual flowers, removal of anthers from the flower bud before the anther dehisces using a pair of forceps is necessary. This step is referred to as **emasculation**. Emasculated flowers have to be covered with a bag of suitable size, generally made up of butter paper, to prevent contamination of its stigma with unwanted pollen. This process is called **bagging**. When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma, and the flowers are rebagged, and the fruits allowed to develop.

If the female parent produces unisexual flowers, there is no need for emasculation. The female flower buds are bagged before the flowers open. When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.

1.3 Double Fertilisation

After entering one of the synergids, the pollen tube releases the two male gametes into the cytoplasm of the synergid. One of the male gametes moves towards the egg cell and fuses with its nucleus thus completing the **syngamy**. This results in the formation of a diploid cell, the **zygote.** The other male gamete moves towards the two polar nuclei located in the central cell and fuses with them to produce a triploid **primary endosperm nucleus** (PEN) (Figure 1.13a). As this involves the fusion of three haploid nuclei it is termed **triple fusion.** Since two types of fusions, syngamy and triple fusion take place in an embryo sac the phenomenon is termed **double fertilisation**, an event unique to flowering plants. The central cell after triple fusion becomes the **primary endosperm cell** (PEC) and develops into the **endosperm** while the zygote develops into an **embryo.**

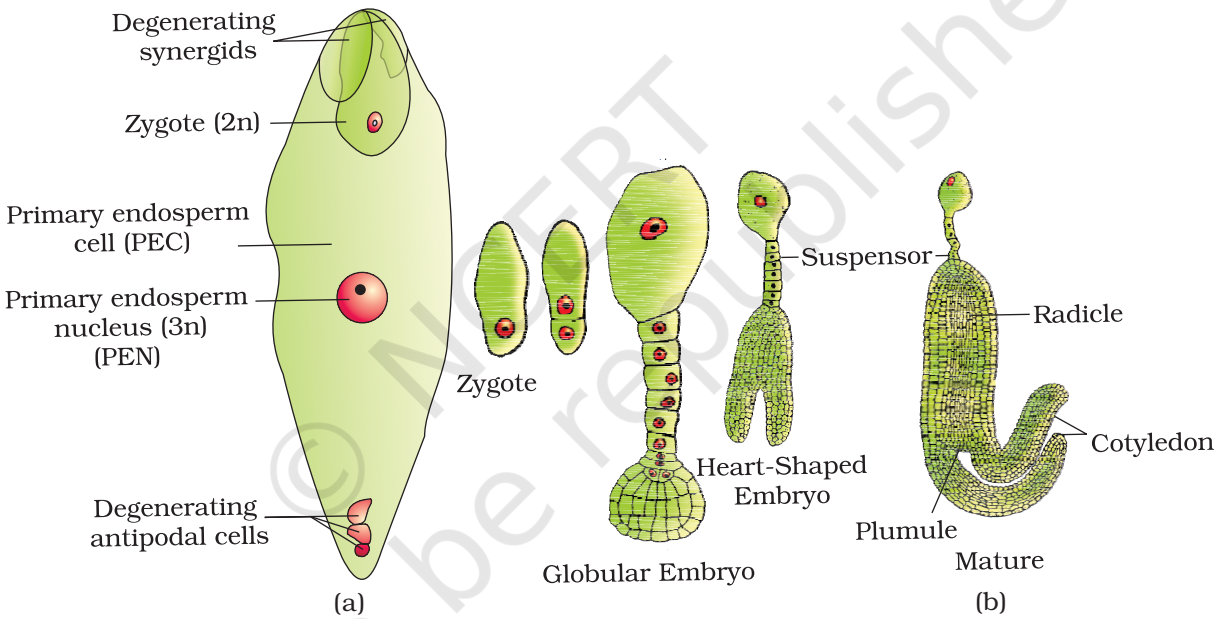


Figure 1.13 (a) Fertilised embryo sac showing zygote and Primary Endosperm Nucleus (PEN); (b) Stages in embryo development in a dicot [shown in reduced size as compared to (a)]

1.4 Post-fertilisation : Structures and Events

Following double fertilisation, events of endosperm and embryo development, maturation of ovule(s) into seed(s) and ovary into fruit, are collectively termed **post-fertilisation events.**

1.4.1 Endosperm

Endosperm development precedes embryo development. *Why?* The primary endosperm cell divides repeatedly and forms a triploid

endosperm tissue. The cells of this tissue are filled with reserve food materials and are used for the nutrition of the developing embryo. In the most common type of endosperm development, the PEN undergoes successive nuclear divisions to give rise to free nuclei. This stage of endosperm development is called free-nuclear endosperm. Subsequently cell wall formation occurs and the endosperm becomes cellular. The number of free nuclei formed before cellularisation varies greatly. The coconut water from tender coconut that you are familiar with, is nothing but free-nuclear endosperm (made up of thousands of nuclei) and the surrounding white kernel is the cellular endosperm.

Endosperm may either be completely consumed by the developing embryo (e.g., pea, groundnut, beans) before seed maturation or it may persist in the mature seed (e.g. castor and coconut) and be used up during seed germination. *Split open some seeds of castor, peas, beans, groundnut, fruit of coconut and look for the endosperm in each case. Find out whether the endosperm is persistent in cereals – wheat, rice and maize.*

1.4.2 Embryo

Embryo develops at the micropylar end of the embryo sac where the zygote is situated. Most zygotes divide only after certain amount of endosperm is formed. This is an adaptation to provide assured nutrition to the developing embryo. Though the seeds differ greatly, the early stages of embryo development **(embryogeny)** are similar in both monocotyledons and dicotyledons. Figure 1.13 depicts the stages of embryogeny in a dicotyledonous embryo. The zygote gives rise to the **proembryo** and subsequently to the **globular, heart-shaped** and **mature embryo**.

A typical dicotyledonous embryo (Figure 1.14a), consists of an **embryonal axis** and two **cotyledons.** The portion of embryonal axis above the level of cotyledons is the **epicotyl,** which terminates with the **plumule** or stem tip. The cylindrical portion below the level of cotyledons is **hypocotyl** that terminates at its lower end in the **radicle** or **root tip.** The root tip is covered with a **root cap.**

Embryos of monocotyledons (Figure 1.14 b) possess only one cotyledon. In the grass family the cotyledon is called **scutellum** that is situated towards one side (lateral) of the embryonal axis. At its lower end, the embryonal axis has the

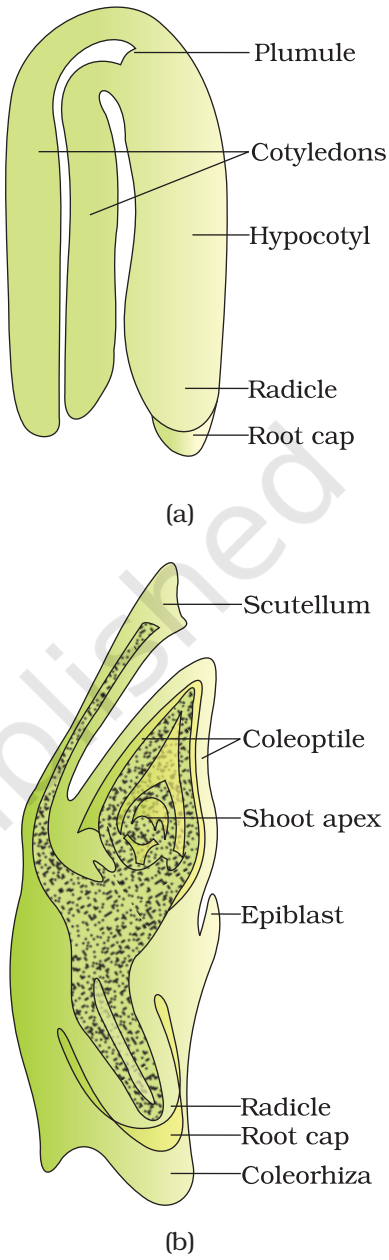


Figure 1.14 (a) A typical dicot embryo; (b) L.S. of an embryo of grass

radical and root cap enclosed in an undifferentiated sheath called **coleorrhiza.** The portion of the embryonal axis above the level of attachment of scutellum is the epicotyl. Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the **coleoptile.**

Soak a few seeds in water (say of wheat, maize, peas, chickpeas, ground nut) overnight. Then split the seeds and observe the various parts of the embryo and the seed.

1.4.3 Seed

In angiosperms, the seed is the final product of sexual reproduction. It is often described as a fertilised ovule. Seeds are formed inside fruits. A seed typically consists of seed coat(s), cotyledon(s) and an embryo axis. The cotyledons (Figure 1.15a) of the embryo are simple structures, generally thick and swollen due to storage of food reserves (as in legumes). Mature seeds may be **non-albuminous** or **ex-albuminous**. Non-albuminous seeds have no residual endosperm as it is completely consumed during embryo development (e.g., pea, groundnut). Albuminous seeds retain a part of endosperm as it is not completely used up during embryo development (e.g., wheat, maize, barley, castor). Occasionally, in some seeds such as black pepper and beet, remnants of nucellus are also persistent. This residual, persistent nucellus is the **perisperm.**

Integuments of ovules harden as tough protective seed coats (Figure 1.15a). The micropyle remains as a small pore in the seed coat. This facilitates entry of oxygen and water into the seed during germination. As the seed matures, its water content is reduced and seeds become relatively dry (10-15 per cent moisture by mass). The general metabolic activity of the embryo slows down. The embryo may enter a state of inactivity called **dormancy,** or if favourable conditions are available (adequate moisture, oxygen and suitable temperature), they germinate.

As ovules mature into seeds, the ovary develops into a fruit, i.e., the transformation of ovules into seeds and ovary into fruit proceeds simultaneously. The wall of the ovary develops into the wall of fruit called **pericarp**. The fruits may be fleshy as in guava, orange, mango, etc., or may be dry, as in groundnut, and mustard, etc. Many fruits have evolved mechanisms for dispersal of seeds. Recall the classification of fruits and their dispersal mechanisms that you have studied in an earlier class. *Is there any relationship between number of ovules in an ovary and the number of seeds present in a fruit?*

In most plants, by the time the fruit develops from the ovary, other floral parts degenerate and fall off. However, in a few species such as apple, strawberry, cashew, etc., the thalamus also contributes to fruit formation. Such fruits are called **false fruits** (Figure 1.15b). Most fruits however develop only from the ovary and are called **true fruits**. Although in most of the species, fruits are the results of fertilisation, there are a few species

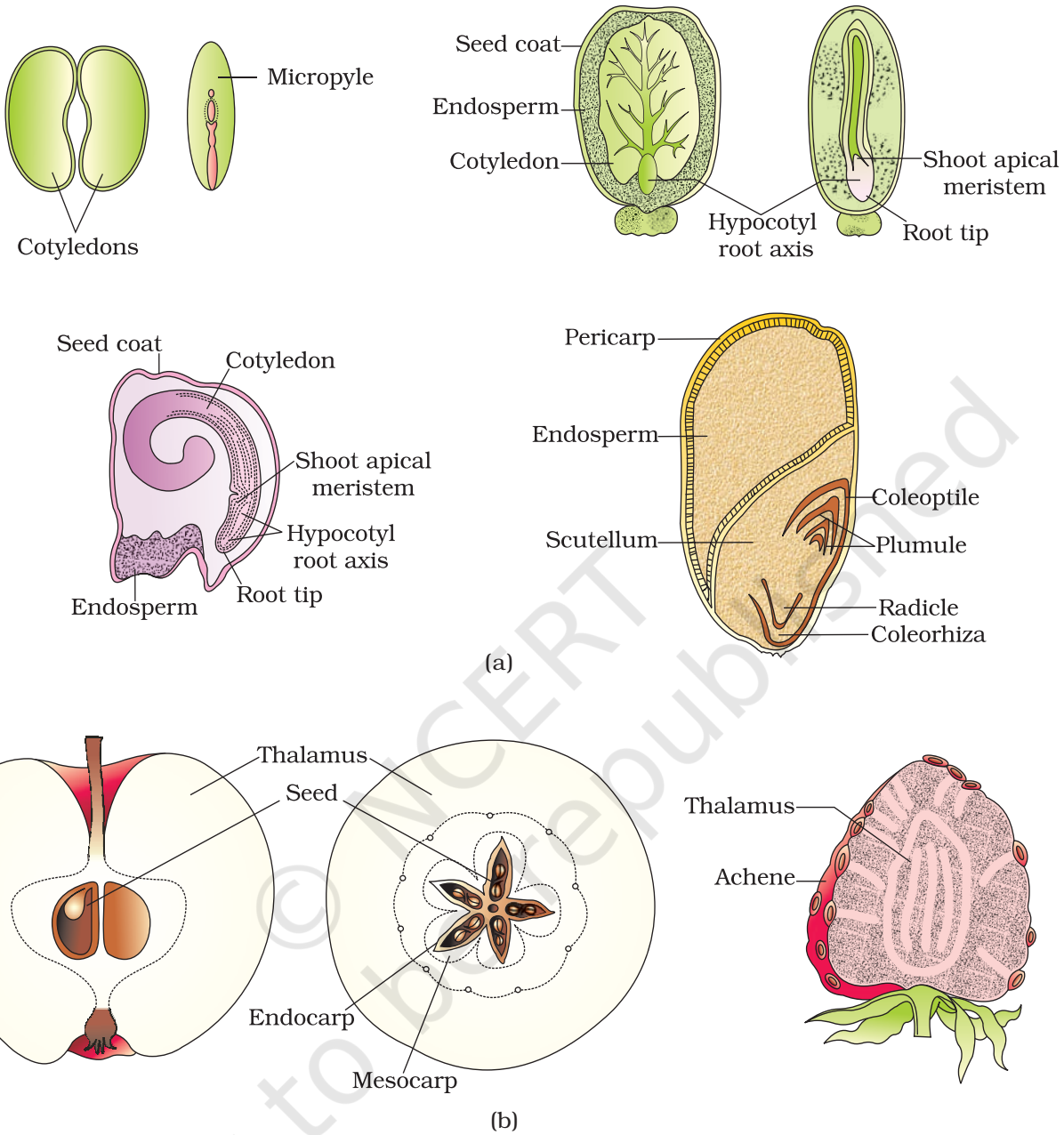


Figure 1.15 (a) Structure of some seeds. (b) False fruits of apple and strawberry

in which fruits develop without fertilisation. Such fruits are called **parthenocarpic fruits.** Banana is one such example. Parthenocarpy can be induced through the application of growth hormones and such fruits are seedless.

Seeds offer several advantages to angiosperms. Firstly, since reproductive processes such as pollination and fertilisation are independent of water, seed formation is more dependable. Also seeds have better adaptive strategies for dispersal to new habitats and help the species

to colonise in other areas. As they have sufficient food reserves, young seedlings are nourished until they are capable of photosynthesis on their own. The hard seed coat provides protection to the young embryo. Being products of sexual reproduction, they generate new genetic combinations leading to variations.

Seed is the basis of our agriculture. Dehydration and dormancy of mature seeds are crucial for storage of seeds which can be used as food throughout the year and also to raise crop in the next season. Can you imagine agriculture in the absence of seeds, or in the presence of seeds which germinate straight away soon after formation and cannot be stored?

How long do the seeds remain alive after they are dispersed? This period again varies greatly. In a few species the seeds lose viability within a few months. Seeds of a large number of species live for several years. Some seeds can remain alive for hundreds of years. There are several records of very old yet viable seeds. The oldest is that of a lupine, *Lupinus arcticus* excavated from Arctic Tundra. The seed germinated and flowered after an estimated record of 10,000 years of dormancy. A recent record of 2000 years old viable seed is of the date palm, *Phoenix dactylifera* discovered during the archeological excavation at King Herod's palace near the Dead Sea.

After completing a brief account of sexual reproduction of flowering plants it would be worth attempting to comprehend the enormous reproductive capacity of some flowering plants by asking the following questions: How many eggs are present in an embryo sac? How many embryo sacs are present in an ovule? How many ovules are present in an ovary? How many ovaries are present in a typical flower? How many flowers are present on a tree? And so on...

Can you think of some plants in which fruits contain very large number of seeds. Orchid fruits are one such category and each fruit contain thousands of tiny seeds. Similar is the case in fruits of some parasitic species such as Orobanche and Striga. Have you seen a tiny seed of Ficus? How large is the tree of Ficus developed from that tiny seed. How many billions of seeds does each Ficus tree produce? Can you imagine any other example in which such a tiny structure can produce such a large biomass over the years?

1.5 Apomixis and Polyembryony

Although seeds, in general are the products of fertilisation, a few flowering plants such as some species of *Asteraceae* and grasses, have evolved a special mechanism, to produce seeds without fertilisation, called **apomixis.** *What is fruit production without fertilisation called?* Thus, apomixis is a form of asexual reproduction that mimics sexual reproduction. There are several ways of development of apomictic seeds. In some species, the diploid egg cell is formed without reduction division and develops into the embryo without fertilisation. More often, as in many *Citrus* and *Mango*

varieties some of the nucellar cells surrounding the embryo sac start dividing, protrude into the embryo sac and develop into the embryos. In such species each ovule contains many embryos. Occurrence of more than one embryo in a seed is referred to as **polyembryony**. *Take out some seeds of orange and squeeze them. Observe the many embryos of different sizes and shapes from each seed. Count the number of embryos in each seed. What would be the genetic nature of apomictic embryos? Can they be called clones?*

Hybrid varieties of several of our food and vegetable crops are being extensively cultivated. Cultivation of hybrids has tremendously increased productivity. One of the problems of hybrids is that hybrid seeds have to be produced every year. If the seeds collected from hybrids are sown, the plants in the progeny will segregate and do not maintain hybrid characters. Production of hybrid seeds is costly and hence the cost of hybrid seeds become too expensive for the farmers. If these hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny. Then the farmers can keep on using the hybrid seeds to raise new crop year after year and he does not have to buy hybrid seeds every year. Because of the importance of apomixis in hybrid seed industry, active research is going on in many laboratories around the world to understand the genetics of apomixis and to transfer apomictic genes into hybrid varieties.

SUMMARY

Flowers are the seat of sexual reproduction in angiosperms. In the flower, androecium consisting of stamens represents the male reproductive organs and gynoecium consisting of pistils represents the female reproductive organs.

A typical anther is bilobed, dithecous and tetrasporangiate. Pollen grains develop inside the microsporangia. Four wall layers, the epidermis, endothecium, middle layers and the tapetum surround the microsporangium. Cells of the sporogenous tissue lying in the centre of the microsporangium, undergo meiosis (microsporogenesis) to form tetrads of microspores. Individual microspores mature into pollen grains.

Pollen grains represents the male gametophytic generation. The pollen grains have a two-layered wall, the outer exine and inner intine. The exine is made up of sporopollenin and has germ pores. Pollen grains may have two cells (a vegetative cell and generative cell) or three cells (a vegetative cell and two male gametes) at the time of shedding.

The pistil has three parts – the stigma, style and the ovary. Ovules are present in the ovary. The ovules have a stalk called funicle, protective integument(s), and an opening called micropyle. The central tissue is the nucellus in which the archesporium differentiates. A cell of the archesporium, the megaspore mother cell divides meiotically and one of the megaspores forms the embryo sac (the female gametophyte). The mature embryo sac is 7-celled and 8-nucleate. At the micropylar end is

the egg apparatus consisting of two synergids and an egg cell. At the chalazal end are three antipodals. At the centre is a large central cell with two polar nuclei.

Pollination is the mechanism to transfer pollen grains from the anther to the stigma. Pollinating agents are either abiotic (wind and water) or biotic (animals).

Pollen-pistil interaction involves all events from the landing of pollen grains on the stigma until the pollen tube enters the embryo sac (when the pollen is compatible) or pollen inhibition (when the pollen is incompatible). Following compatible pollination, pollen grain germinates on the stigma and the resulting pollen tube grow through the style, enter the ovules and finally discharges two male gametes in one of the synergids. Angiosperms exhibit double fertilisation because two fusion events occur in each embryo sac, namely syngamy and triple fusion. The products of these fusions are the diploid zygote and the triploid primary endosperm nucleus (in the primary endosperm cell). Zygote develops into the embryo and the primary endosperm cell forms the endosperm tissue. Formation of endosperm always precedes development of the embryo.

The developing embryo passes through different stages such as the proembryo, globular and heart-shaped stages before maturation. Mature dicotyledonous embryo has two cotyledons and an embryonal axis with epicotyl and hypocotyl. Embryos of monocotyledons have a single cotyledon. After fertilisation, ovary develops into fruit and ovules develop into seeds.

A phenomenon called apomixis is found in some angiosperms, particularly in grasses. It results in the formation of seeds without fertilisation. Apomicts have several advantages in horticulture and agriculture.

Some angiosperms produce more than one embryo in their seed. This phenomenon is called polyembryony.

EXERCISES

1. Name the parts of an angiosperm flower in which development of male and female gametophyte take place.
2. Differentiate between microsporogenesis and megasporogenesis. Which type of cell division occurs during these events? Name the structures formed at the end of these two events.
3. Arrange the following terms in the correct developmental sequence:

   Pollen grain, sporogenous tissue, microspore tetrad, pollen mother cell, male gametes.
4. With a neat, labelled diagram, describe the parts of a typical angiosperm ovule.
5. What is meant by monosporic development of female gametophyte?
6. With a neat diagram explain the 7-celled, 8-nucleate nature of the female gametophyte.

7. What are chasmogamous flowers? Can cross-pollination occur in cleistogamous flowers? Give reasons for your answer.
8. Mention two strategies evolved to prevent self-pollination in flowers.
9. What is self-incompatibility? Why does self-pollination not lead to seed formation in self-incompatible species?
10. What is bagging technique? How is it useful in a plant breeding programme?
11. What is triple fusion? Where and how does it take place? Name the nuclei involved in triple fusion.
12. Why do you think the zygote is dormant for sometime in a fertilised ovule?
13. Differentiate between:
    (a) hypocotyl and epicotyl;
    (b) coleoptile and coleorrhiza;
    (c) integument and testa;
    (d) perisperm and pericarp.
14. Why is apple called a false fruit? Which part(s) of the flower forms the fruit?
15. What is meant by emasculation? When and why does a plant breeder employ this technique?
16. If one can induce parthenocarpy through the application of growth substances, which fruits would you select to induce parthenocarpy and why?
17. Explain the role of tapetum in the formation of pollen-grain wall.
18. What is apomixis and what is its importance?