

**SAMPLE CONTENT**



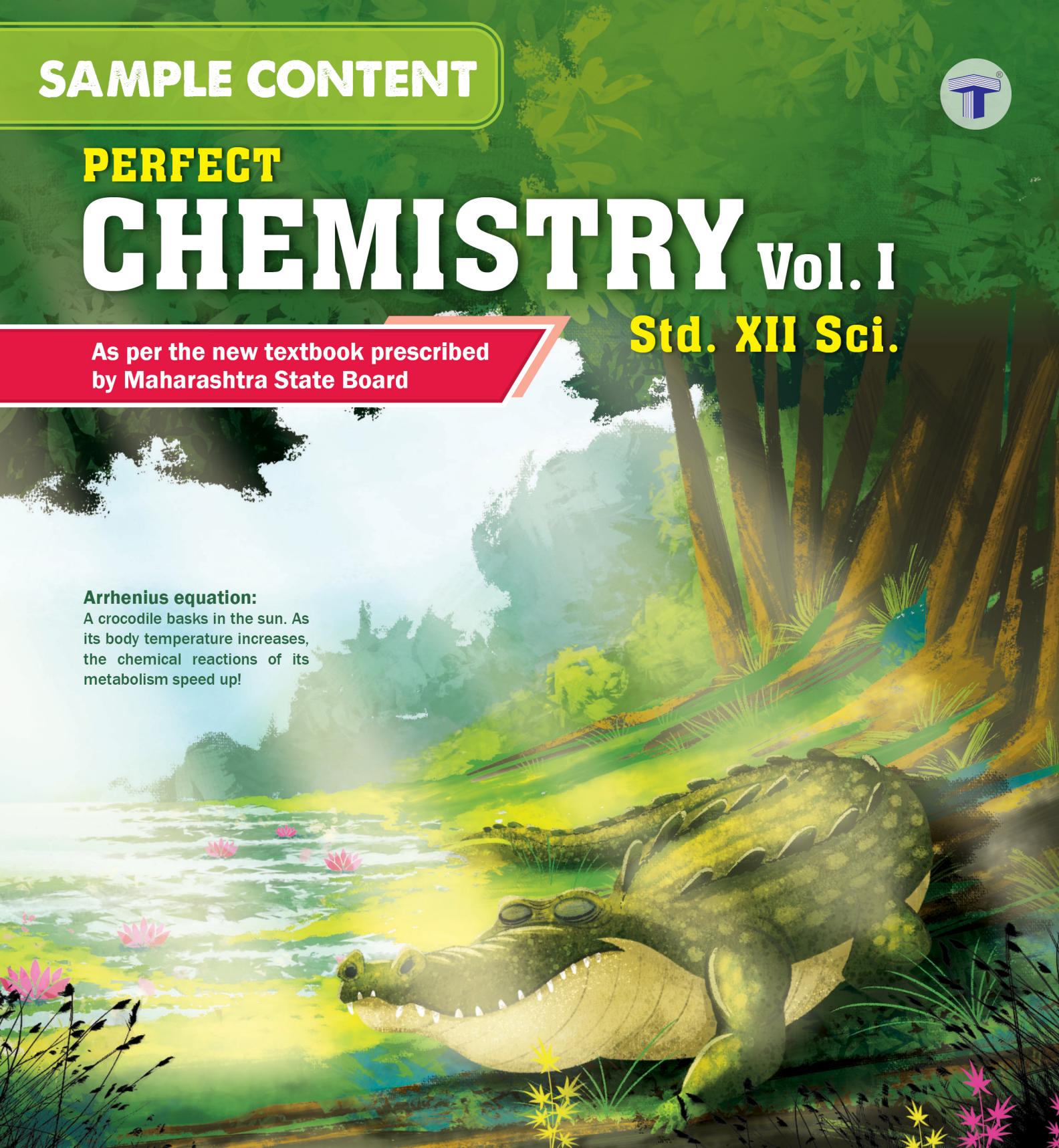
**PERFECT  
CHEMISTRY Vol. I**

As per the new textbook prescribed  
by Maharashtra State Board

**Std. XII Sci.**

**Arrhenius equation:**

A crocodile basks in the sun. As its body temperature increases, the chemical reactions of its metabolism speed up!



**Target** Publications® Pvt. Ltd.

**Written as per the latest textbook prescribed by the Maharashtra State Bureau of Textbook Production and Curriculum Research, Pune.**

# **PERFECT CHEMISTRY (Vol. II) Std. XII Sci.**

## **Salient Features**

- ☞ Written as per the new textbook
- ☞ Subtopic-wise segregation for powerful concept building
- ☞ Complete coverage of Textual Exercise Questions, Intext Questions and Numericals
- ☞ Extensive coverage of New Type Questions
- ☞ ‘Solved Examples’ guide you through every type of problem
- ☞ ‘Apply Your Knowledge’ section for application of concepts
- ☞ ‘Quick Review’ at the end of every chapter facilitates quick revision
- ☞ A compilation of all ‘Important Formulae’ in relevant chapters
- ☞ ‘Competitive Corner’ presents questions from prominent competitive examinations
- ☞ Reading Between the Lines, Enrich Your Knowledge, Gyan Guru, Connections, NCFE Corner are designed to impart holistic education
- ☞ Topic Test at the end of each chapter for self-assessment
- ☞ Video links provided via QR codes for boosting conceptual retention

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## PREFACE

**Perfect Chemistry Std. XII, Vol. I** is intended for every Maharashtra State Board aspirant of Std. XII, Science. The scope, sequence, and level of the book are designed to match the new textbook issued by the Maharashtra State board.

At this crucial juncture in their lives, when the students are grappling with the pressures of cracking a career-defining board examination, we wanted to create a book that not only develops the necessary knowledge, tools, and skills required to excel in the examination, but also enables students to appreciate the beauty of the subject and piques their curiosity.

We believe that students respond favourably to meaningful content, if it is presented in a way that is easy to read and understand, rather than being mired down with facts and information. Consequently, we have always placed the highest priority on writing clear and lucid explanations of fundamental concepts. Moreover, special care has been taken to ensure that the topics are presented in a logical order. The coherent Question/Answer approach helps students expand their horizon of understanding of the concepts.

The primary purpose of this book is to assist the students in preparing for the board examination. However, this is closely linked to other goals: to exemplify how important and how incredibly interesting chemistry is, and to help the student become an expert thinker and problem solver.

### Solving numericals is essential for success in chemistry!

To help the students hone their problem-solving skills, this book amalgamates numericals that are rich in both variety and number which provides the student with ample practice, ensuring mastery of each concept.

The scope of the book extends beyond the State Board examination as it also offers a plethora of Multiple Choice Questions (MCQs) in order to familiarize the students with the pattern of competitive examinations.

In addition, the chapter-test have been carefully crafted to focus on concepts thus providing the students with a quick opportunity for self-assessment and giving them an increased appreciation of chapter-preparedness.

We believe that the study of chemistry helps in the understanding of many fascinating and important phenomena. In this vein, we have put an effort to relate chemistry to real-world events in order to show students that chemistry is a vibrant, constantly evolving science that has relevance in our modern world. We hope this book becomes a valuable tool for you and helps you to not only understand the concepts of chemistry but also to see the world from a more scientific point of view.

*Our Perfect Chemistry Std. XII, Vol. I addresses our vision and achieves several goals: building concepts, developing competence to solve numericals, recapitulation, self-study, self-assessment and student engagement—all while encouraging students to think cognitively.*

The journey to create a complete book is strewn with triumphs, failures and near misses. If you think we've nearly missed something or want to applaud us for our triumphs, we'd love to hear from you.

Please write to us on: mail@targetpublications.org

*A book affects eternity; one can never tell where its influence stops.*

*Best of luck to all the aspirants!*

From,  
Publisher  
Edition : First

### Disclaimer

This reference book is transformative work based on textbook Chemistry; First edition: 2020 published by the Maharashtra State Bureau of Textbook Production and Curriculum Research, Pune. We the publishers are making this reference book which constitutes as fair use of textual contents which are transformed by adding and elaborating, with a view to simplify the same to enable the students to understand, memorize and reproduce the same in examinations.

This work is purely inspired upon the course work as prescribed by the Maharashtra State Bureau of Textbook Production and Curriculum Research, Pune. Every care has been taken in the publication of this reference book by the Authors while creating the contents. The Authors and the Publishers shall not be responsible for any loss or damages caused to any person on account of errors or omissions which might have crept in or disagreement of any third party on the point of view expressed in the reference book.

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## FEATURES

### Sub-topic wise Segregation

#### 1.7 Packing efficiency

**Q.65. Explain the term: Packing efficiency.**

**Ans:**

- i. The magnitude of packing efficiency gives a measure of how tightly particles are packed together.
- ii. **Packing efficiency is the fraction or a percentage of the total space occupied by the spheres (particles).**

Packing efficiency

$$= \frac{\text{Volume occupied by particles in unit cell}}{\text{Total volume of unit cell}} \times 100$$

Every chapter is segregated sub-topic wise. A subtopic encompasses textual content in the format of Question-Answers. *Textual Exercise questions, Intext questions, Can you tell?, Can you recall?, Try this, Use your brain power* and *Activity* are placed aptly amongst various additional questions in accordance with the flow of sub-topic. This is our attempt to enable easy assimilation of concepts and lay strong foundation for understanding as well as writing answers in exams.

### Reading between the lines

Reading between the lines provides elaboration or missing fragments of concept which is essential for complete understanding of the concept.

This is our attempt to help students to understand the underlying concept behind an answer.

### Reading between the lines

Weak acid + Its salt of strong base  $\Rightarrow$  Acidic buffer

Weak base + Its salt of strong acid  $\Rightarrow$  Basic buffer

i.  $H_3COOH$  is weak acid and  $CH_3COONa$  is its salt of strong base  $\Rightarrow$  Acidic buffer

ii.  $NH_4Cl$  is weak base and  $NH_4Cl$  is its salt of strong acid  $\Rightarrow$  Basic buffer

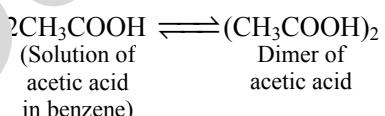
iii. Benzoic acid is weak acid and sodium benzoate is its salt of strong base  $\Rightarrow$  Acidic buffer

iv.  $Cu(OH)_2$  is weak base and  $CuCl_2$  is its salt of strong acid  $\Rightarrow$  Basic buffer

### NCERT Corner

#### Abnormal molar mass:

- i. Some substances undergo association when dissolved in non-polar solvents.  
e.g. Acetic acid undergoes association (i.e., it forms dimers due to intermolecular hydrogen bonding) when dissolved in benzene.



- ii. It can be undoubtedly stated here that if all the molecules of ethanoic acid associate in benzene, then  $\Delta T_f$  or  $\Delta T_b$  for ethanoic acid will be half of the normal value. Observed molar masses of such species are almost twice the expected values in dilute solutions.

### NCERT Corner

NCERT Corner covers information from NCERT textbook relevant to topic.

This is our attempt to bridge the gap between NCERT curriculum and State Board textbook, thereby benefitting students in their preparation of National level competitive examinations.

### Connections

**Connections** enable students to interlink concepts covered in different chapters.  
*This is our attempt to encourage students to appreciate the subject as a whole.*

### Connections

*In Std. XI, Chapter 5: Chemical Bonding, you studied limitations of octet rule and VSEPR theory.*

**[Note:** Students can scan the adjacent QR code to get conceptual clarity with the aid of a relevant video.]



### QR Code

QR code provides access to a video/ppt in order to boost understanding of a concept or activity.  
*This is our attempt to facilitate learning with visual aids.*

### Enrich Your Knowledge



### Enrich Your Knowledge

**Enrich Your Knowledge** presents fascinating information about the concept covered.

*This is our attempt to create interest in the students about the concept.*

#### Alkaline dry cell:

- i. The Leclanche' dry cell works under acidic conditions due to the presence of  $\text{NH}_4\text{Cl}$ .
- ii.
- iii. Corrosion of Zn anode occurs due to its actions with  $\text{H}^+$  ions from  $\text{NH}_4^+$  ions. This results in shortening the life of dry cell. To avoid this a modified form of the dry cell called alkaline dry cell has been proposed.
- iv. In alkaline dry cell  $\text{NaOH}$  or  $\text{KOH}$  is used as electrolyte in place of  $\text{NH}_4\text{Cl}$ . Since zinc corrodes more slowly in alkaline dry cell, it has a longer life than acidic dry cell.



### GG-Gyan Guru

#### A unique gold medal !!

The Nobel Prizes are widely regarded as the most prestigious awards given for intellectual achievement in the world.



The **Nobel Prize medals** are 18 carat green gold (an alloy of gold and silver) plated with 24 carat gold. Before 1980, they were made from 23 carat gold. The term 'carat' indicates the amount of gold present in an alloy.  
24 carat is pure gold.

### GG-Gyan Guru

Gyan Guru illustrates real life applications or examples related to the concept discussed.

*This is our attempt to link learning to the life.*

### Solved Examples

Solved Examples offer complete solution to numerical including log calculations (as seemed required).

This is our attempt to prepare students with the numerical aspect of the subject and promote problem solving abilities in students.

### Solved Examples

\*Q.83. What fraction of molecules in a gas at 300 K collide with an energy equal to activation energy of 50 kJ/mol?

**Solution:**

Given: Activation energy ( $E_a$ ) = 50 kJ mol<sup>-1</sup>  
=  $50 \times 10^3$  J mol<sup>-1</sup>

Temperature (T) = 300 K

To find: Fraction of molecule (f) with energy equal to  $E_a$

Formula:  $f = e^{-E_a/RT}$

Calculation: Substituting the given value above

$$f = e^{\frac{-50 \times 10^3 \text{ J mol}^{-1}}{8.314 \text{ J K}^{-1} \text{ mol}^{-1} \times 300}}$$

$$\log_{10} f = \frac{-50 \times 10^3}{8.314 \times 300} \approx -2.303$$

$$\log_{10} f = -8.70$$

$$f = \text{antilog}(-8.70)$$

$$f = 1.90 \times 10^{-9} \approx 2.0 \times 10^{-9}$$

**Ans:** Fraction of molecules having energy equal to activation energy is  $2.0 \times 10^{-9}$ .

### Apply Your Knowledge

Q.122. In cold countries due to the snowfall the roads are often covered with snow. This leads to the problem of traffic jams. To avoid this problem, the salts are sprinkled over snow, which helps in clearing the roads covered with snow.

- As a student of chemistry, can you tell how does sprinkling of salt help in clearing the roads?
- Explain depression in freezing point and write its mathematical expression.

**Ans:**

When salt is spread over snow, depression in freezing point of water takes place. Hence, the roads are cleared due to the melting of snow at ambient temperature.

- Refer Q.74.

### Apply Your Knowledge

Apply Your Knowledge includes challenging questions.

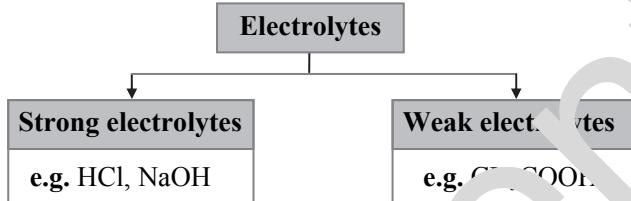
This is our attempt to take students one step further and challenge their conceptual understanding.

## Quick Review

### Quick Review

Quick review includes tables/ flow chart to summarize the key points in chapter.  
*This is our attempt to help students to reinforce key concepts.*

#### ➤ Types of electrolytes:



## Important Formulae

### 3. Relationship between radius of atom ( $r$ ) and edge length ( $a$ ):

$$\text{sc: } r = \frac{a}{2} = 0.5000 a$$

$$\text{bcc: } r = \frac{\sqrt{3}}{4}a = 0.4330 a$$

$$\text{fcc: } r = \frac{\sqrt{2}}{4}a = 0.3535 a$$

## Important Formulae

Important Formulae includes all of the key formulae in the chapter.

*This is our attempt to offer students tools of formulae handy while solving problems and last minute revision at a glance.*

## Exercise

Exercise includes subtopic-wise additional questions and problems.

*This is our attempt to provide additional practice to students to gauge their preparation.*

## Exercise

### 5.6 Galvanic or voltaic cells

19. Define salt bridge.

**Ans:** Refer Q.72.

### 5.7 Electrode potential and cell potential

20. Define electrode potential.

**Ans:** Refer Q.86. (iii)

### Multiple Choice Questions

- \*10. When an excess of  $\text{AgNO}_3$  is added to the complex one mole of  $\text{AgCl}$  is precipitated. The formula of the complex is \_\_\_\_\_.  
(A)  $[\text{CoCl}_2(\text{NH}_3)_4]\text{Cl}$   
(B)  $[\text{CoCl}(\text{NH}_3)_4]\text{Cl}_2$   
(C)  $[\text{CoCl}_3(\text{NH}_3)_3]$   
(D)  $[\text{Co}(\text{NH}_3)_4]\text{Cl}_3$

### Multiple Choice Questions

**Multiple Choice Question** includes textual as well as additional MCQs.  
*This is our attempt to give students practice of MCQs and prepare them thoroughly for board examination.*

### Competitive Corner

**Competitive Corner** presents latest questions from prominent [NEET (UG), JEE (Main), NEET (ODISHA), MHT CET] competitive exams based entirely on the syllabus covered in the chapter.  
*This is our attempt to introduce students to MCQs asked in competitive exams.*

### Competitive Corner

2. Which one of the following equations does NOT CORRECTLY represent the first law of thermodynamics for the given processes involving an ideal gas? (Assume non-expansion coefficient is zero) [JEE (Main) 2019]

- (A) Adiabatic process:  $\Delta U = -W$   
(B) Isobaric process:  $\Delta U = Q$   
(C) Isothermal process:  $q = -W$   
(D) Cyclic process:  $q = -W$

**Hint:** In an adiabatic process, no heat is allowed to enter or leave the system.

Hence,  $Q = 0$

From the 1<sup>st</sup> law of thermodynamics,  
 $\Delta U = Q + W$   
 $\therefore \Delta U = W$

Time: 1 Hour 30 Min

### TOPIC TEST

Total Marks: 25

#### SECTION A

Q.1. Select and write the correct answer:

[04]

- i. In the reaction  $A + 3B \longrightarrow 2C$ , the rate of formation of C is \_\_\_\_\_.  
(A) the same as rate of consumption of A  
(B) the same as the rate of consumption of B  
(C) twice the rate of consumption of A  
(D) 3/2 times the rate of consumption of B

### Topic Test

**Topic Test** covers questions from chapter for self-evaluation purpose.  
*This is our attempt to provide the students with revision and help them assess their knowledge of chapter.*

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**[Reference:** Maharashtra State Board of Secondary and Higher Secondary Education, Pune - 04]

- Note:**
1. ^ mark represents Textual question.
  2. # mark represents Intext question.
  3. + mark represents Textual examples.
  4. ☰ symbol represents textual questions that need external reference for an answer.

**Contents and Concepts**

- |  |   |
|--|---|
| 2.1 Introduction<br>2.2 Types of solutions<br>2.3 Capacity of solutions to dissolve solute<br>2.4 Solubility<br>2.5 Vapour pressure of solutions of liquids in liquids | 2.6 Colligative properties of nonelectrolyte solutions<br>2.7 Vapour pressure lowering<br>2.8 Boiling point elevation<br>2.9 Depression in freezing point<br>2.10 Osmotic pressure<br>2.11 Colligative properties of electrolytes |
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**2.1 Introduction**

**Q.1. What is a mixture? Give examples.**

**Ans:** The mixture is a combination of two or more substances.

e.g. Air is a mixture of gases, rock is a mixture of two or more minerals.

**Q.2. What is the difference between homogeneous mixture and heterogeneous mixture?**

**Ans:** In homogeneous mixture, the mixing of components is uniform while in heterogeneous mixture, the mixing of components is nonuniform.

**Q.3. Based on what property are homogeneous mixtures classified?**

**Ans:** Homogeneous mixtures are classified according to the size of their constituent particles as colloids or as true solutions.

**Q.4. Can you recall? (Textbook page no. 26)**

**What is the size of particles of colloids and those of true solutions?**

**Ans:**

- Colloids contain particles of dispersed phase with diameters in the range of 2 to 500 nm.
- True solutions contain solute particles with diameters in the range of 0.1 to 2 nm.

**Q.5. What is a solution? What are two components of true solution?**

**Ans:**

- The solution is a homogeneous mixture of two or more pure substances.
- A true solution consists of a solvent and one or more solutes.

**Q.6. Can you recall? (Textbook page no. 28)**

**Define the terms solute and solvent.**

**Ans:**

- The component of a solution which is in smaller proportion is called **solute**.
- The component of a solution which is in larger proportion is called **solvent**.

**2.2 Types of solutions**

**Q.7. There are nine types of solution. Explain the statement.**

**Ans:**

- In solution, the solute and the solvent may be in any of the three states namely, solid, liquid or gas.
- The solutions may involve any combination of these three states of their components.

This gives rise to nine types of solutions depending on the states of solute and solvent.

**Note:** Types of solutions:

No.	State of solute	State of solvent	Examples
i.	Solid	Liquid	Sea water, benzoic acid in benzene, sugar in water
ii.	Solid	Solid	Metal alloys such as brass, bronze.
iii.	Solid	Gas	Iodine in air
iv.	Liquid	Liquid	Gasoline, ethanol in water
v.	Liquid	Solid	Amalgams of mercury with metals i.e., mercury in silver
vi.	Liquid	Gas	Chloroform in nitrogen
vii.	Gas	Liquid	Carbonated water ( $\text{CO}_2$ in water), oxygen in water
viii.	Gas	Solid	$\text{H}_2$ in palladium
ix.	Gas	Gas	Air ( $\text{O}_2$ , $\text{N}_2$ , Ar and other gases)

**Q.8.** Give two examples of each of the following:

- i. A solution in which state of solute is solid and that of solvent is liquid.
- ii. A solution in which state of solute is gas and that of solvent is liquid.

**Ans:**

- i. Sea water, sugar in water
- ii. Carbonated water, oxygen in water

**Q.9.** State TRUE or FALSE. If false, correct the statement.

- i. The body fluids are solutions.
- ii. Binary true solutions contain two different solutes
- iii. Metal alloys are examples of solid in solid type solution.
- iv. Gasoline is an example of liquid in solid type solution.

**Ans:**

- i. True
- ii. False  
Binary true solutions contain only one solute
- iii. True
- iv. False  
Gasoline is an example of liquid in liquid type solution.

**Q.10.** Complete the following table.

State of solute	State of solvent	Example
Solid	-----	Metal alloys such as brass
Solid	Gas	-----
Liquid	-----	Gasoline
-----	Gas	Chloroform in nitrogen
Gas	Solid	-----

**Ans:**

State of solute	State of solvent	Example
Solid	Solid	Metal alloys such as brass
Solid	Gas	Iodine in air
Liquid	Liquid	Gasoline
Liquid	Gas	Chloroform in nitrogen
Gas	Solid	$\text{H}_2$ in palladium

**Q.11.** Can you recall? (Textbook page no. 28)

Name the different units used to express the concentrations of solutions.

**Ans:** Different units used to express the concentrations of solutions:

- i. Mass percent or weight percent (w/w %)
- ii. Mole fraction
- iii. Molarity (M)
- iv. Molality (m)



## 2.3 Capacity of solution to dissolve solute

**Q.12. Explain the terms:**

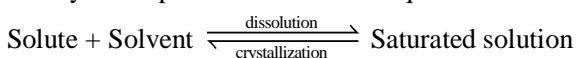
i. Saturated solution

ii. Supersaturated solution

**Ans:**

i. **Saturated solution:**

- A **saturated solution** is a solution which contains maximum amount of solute dissolved in a given amount of solvent at a given temperature.
- In saturated solution, a dynamic equilibrium is reached where the number of solute molecules leaving the crystal to pass into solution is equal to the number returning from the solution to the crystal.



### Reading between the lines



When a solute added to a solvent, it dissolves readily at first. The dissolution then slows down as more solute is added. If we continue the addition of solute, the dissolution stops. The solution at that point is said to be saturated.

ii. **Supersaturated solution:**

- A solution containing greater than the equilibrium amount of solute is said to be **supersaturated solution**.
- Supersaturated solutions are unstable.
- The precipitation occurs by the addition of a tiny crystal of solute.
- The supersaturated solution changes to saturated solution upon precipitation.



GG - Gyan Guru

Seedling of supersaturated solution!!

Supersaturated solutions are prepared by saturating a solution at a high temperature. The saturated solution is cooled slowly without agitation, to a temperature at which the solute is less soluble. This results in supersaturated solution which is temporarily stable. A supersaturated solution produces crystals rapidly if it is slightly disturbed or if it is "seeded" with a tiny crystal or dust particle. The adjacent image shows seeding a supersaturated solution by pouring it very slowly onto a seed crystal.



## 2.4 Solubility

**Q.13. What is Solubility?**

**Ans:** The **solubility** of a solute is its amount per unit volume of saturated solution at a specific temperature. The solubility of a solute is its maximum concentration and is expressed in the concentration units mol L<sup>-1</sup>.

**Q.14. Can you recall? (Textbook page no. 29)**

Name the different types of force between molecules.

**Ans:** The types of forces between molecules are as follows:

- |   |                             |
|---|-----------------------------|
| i. Dipole-dipole interactions           | ii. Ion-dipole interactions |
| iii. Dipole-induced dipole interactions | iv. Hydrogen bonding        |
| v. London dispersion forces             |                             |



### Q.15. How does the nature of solute and solvent affect solubility?

**Ans:**

- Generally, the compounds with similar chemical character are more readily soluble in each other than those with entirely different chemical characters. The ‘like dissolves like’ principle guides to predict the solubility of a solute in a given solvent. Thus, substances having similar intermolecular forces are likely to be soluble in each other.
- Generally, polar solutes dissolve in polar solvents. This is because in these, solute-solute, solute-solvent and solvent-solvent interactions are all of similar magnitude.  
**e.g.** NaCl dissolves in water. The strong ion-dipole interactions of  $\text{Na}^+$  and  $\text{Cl}^-$  ions with water molecules, hydrogen bonding between water molecules and ion-ion attractions between  $\text{Na}^+$  and  $\text{Cl}^-$  ions are comparable.
- Nonpolar organic compounds like cholesterol dissolves in nonpolar solvent such as benzene.
- Sugar dissolves in water because the dissolution of sugar in water is due to intermolecular hydrogen bonding between sugar and water.

### Q.16. Can you tell? (Textbook page no. 29)

**Why does naphthalene dissolve in benzene but not in water?**

**Ans:**

- The ‘like dissolves like’ principle guides to predict the solubility of a solute in a given solvent. Thus, substances having similar intermolecular forces are likely to be soluble in each other.
- Both, naphthalene and benzene are nonpolar while water is polar.  
Hence, naphthalene dissolves in benzene but not in water.

### Q.17. Can you recall? (Textbook page no. 29)

**State Le Chatelier principle for exothermic and endothermic processes**

**Ans:**

- According to Le Chatelier's principle for an exothermic reaction, an increase in temperature shifts the position of equilibrium to the left, i.e., more reactants are formed.
- According to Le Chatelier's principle for an endothermic reaction, an increase in temperature shifts the position of equilibrium to the right, i.e., more product is formed.



### Connections

In Std XI, chapter 12: *Chemical Equilibrium*, you have studied in details on Le Chatelier's principle.

### \*Q.18. What is the effect of temperature on solubility of solids in water? Give examples.

**Ans:**

- The effect of temperature on solubility of a substance depends on enthalpy of solution.
  - When the substance dissolves in water by an endothermic process, that is, with the absorption of heat, its solubility increases with an increase of temperature.  
**e.g.**  $\text{KCl}$  dissolve in water by endothermic process.
  - On the other hand, when the substance dissolves in water by an exothermic process, that is, with the release of heat, its solubility decreases with an increase of temperature.  
**e.g.**  $\text{CaCl}_2$  and  $\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$  dissolve in water releasing heat.
- It is important to understand that there is no direct correlation between solubility and exothermicity or endothermicity. For example, dissolution of  $\text{CaCl}_2$  in water is exothermic and that of  $\text{NH}_4\text{NO}_3$  is endothermic. However, the solubility of these substances increases with the temperature.

### Q.19. Can you tell? (Textbook page no. 29)

**Anhydrous sodium sulphate dissolves in water with the evolution of heat. What is the effect of temperature on its solubility?**

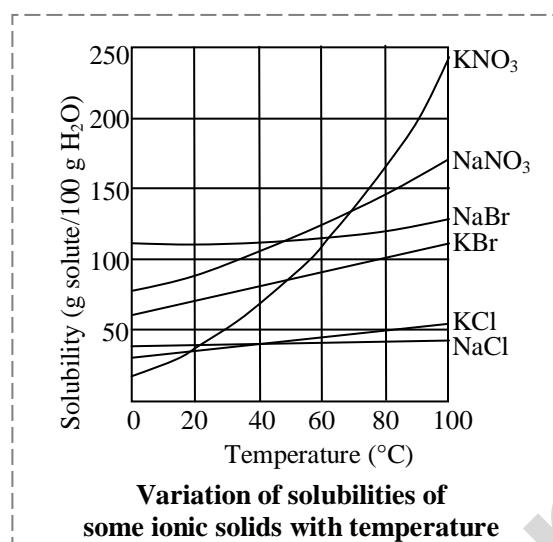
**Ans:**

- Since anhydrous sodium sulphate dissolves in water with the evolution of heat, the dissolution reaction is exothermic.
- When the substance dissolves in water by an exothermic process, that is, with the release of heat, its solubility decreases with an increase of temperature.

Hence, solubility of anhydrous sodium sulphate in water decreases with increase in temperature.



**Q.20.** Following graph shows experimental determination of solubilities of some ionic solids in water at various temperatures. Comment on the effect of temperature on solubilities of these compounds in water.



**Ans:**

- Solubilities of NaBr, NaCl and KCl change slightly with temperature.
- Solubilities of KNO<sub>3</sub>, NaNO<sub>3</sub> and KBr increase appreciably with increasing temperature.

**Q.21.** Give reason: The solubility of gases in water usually decreases with increase of temperature.

**Ans:**

- When gases are dissolved in water, the gas molecules in liquid phase are condensed.
- The condensation is an exothermic process.

Hence, the solubility of gases in water decreases with increase in temperature.

### Enrich Your Knowledge



In United States, about 1000000 billion gallons of water from rivers and lakes are used for industrial cooling. The cooling process heats water. The hot water then returns to rivers and lakes. The solubility of oxygen decreases in hot water thereby affecting the life of cold blooded animals like fish.

**Q.22.** What is the effect of pressure on solubilities of solids, liquids and gases?

**Ans:**

- Pressure has no effect on the solubilities of solids and liquids as they are incompressible.
- The solubility of gases in liquids increases with increasing pressure.

**Q.23.** State and explain Henry's law.

**Ans:**

- Statement:** Henry's law states that the solubility of a gas in a liquid is directly proportional to the pressure of the gas over the solution.

Thus

$$S \propto P \quad \therefore S = K_H P$$

where, S is the solubility of the gas in mol L<sup>-1</sup>, P is the pressure of the gas in bar over the solution. K<sub>H</sub>, the proportionality constant is called **Henry's law constant** and its unit is mol L<sup>-1</sup> bar<sup>-1</sup>.

- When P = 1 bar, K<sub>H</sub> = S. Thus, K<sub>H</sub> is the solubility of the gas in a liquid when its pressure over the solution is 1 bar.

### Reading between the lines



$$\text{Units of } K_H: K_H = \frac{S}{P} = \frac{\text{mol L}^{-1}}{\text{bar}} = \text{mol L}^{-1} \text{ bar}^{-1}$$



**Q.24. Give reason: When the bottle of soft drink is opened, effervescence is observed.**

**Ans:**

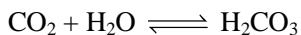
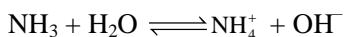
- Before sealing the bottle of soft drink, it is pressurised with a mixture of air,  $\text{CO}_2$  saturated with water vapour.
- Because of high partial pressure of  $\text{CO}_2$ , its amount dissolved in soft drink is higher than the solubility of  $\text{CO}_2$  under normal conditions.

Hence, when the bottle of soft drink is opened, excess dissolved  $\text{CO}_2$  comes out with effervescence.

**Q.25. Give reason: Gases like  $\text{NH}_3$  and  $\text{CO}_2$  do not obey Henry's law.**

**Ans:**

- Gases like  $\text{NH}_3$  and  $\text{CO}_2$  react with water as follows:



- Because of these reactions,  $\text{NH}_3$  and  $\text{CO}_2$  gases have higher solubilities than expected by Henry's law. Hence, Gases like  $\text{NH}_3$  and  $\text{CO}_2$  do not obey Henry's law.

### Enrich Your Knowledge



$\text{O}_2$  gas has very low solubility in water. However, its solubility in blood is exceedingly high. This is because of binding of  $\text{O}_2$  molecule to haemoglobin present in blood.



### Solved Examples

**+Q.26. The solubility of  $\text{N}_2$  gas in water at  $25^\circ\text{C}$  and 1 bar is  $6.85 \times 10^{-4}$  mol L $^{-1}$ . Calculate (i) Henry's law constant (ii) molarity of  $\text{N}_2$  gas dissolved in water under atmospheric conditions when partial pressure of  $\text{N}_2$  in atmosphere is 0.75 bar.**

**Solution:**

**Given:** Solubility of  $\text{N}_2$  gas =  $6.85 \times 10^{-4}$  mol L $^{-1}$

Pressure = 1 bar

Pressure of  $\text{N}_2$  in atmosphere = 0.75 bar

**To find:** i. Henry's law constant

ii. Molarity of  $\text{N}_2$  gas in water

**Formula:**  $S = K_H P$

**Calculation:** i. Using formula and rearranging,

$$K_H = \frac{S}{P} = \frac{6.85 \times 10^{-4} \text{ mol L}^{-1}}{1 \text{ bar}}$$

$$= 6.85 \times 10^{-4} \text{ mol L}^{-1} \text{ bar}^{-1}$$

$$\text{ii. } S = K_H P = 6.85 \times 10^{-4} \text{ mol L}^{-1} \text{ bar}^{-1} \times 0.75 \text{ bar}$$

$$= 5.138 \times 10^{-4} \text{ mol L}^{-1}$$

**Ans:** i. Henry's law constant =  $6.85 \times 10^{-4}$  mol L $^{-1}$  bar $^{-1}$

ii. Molarity of  $\text{N}_2$  gas dissolved in water =  $5.138 \times 10^{-4}$  mol L $^{-1}$

**Q.27. Henry's law constant for solubility of methane in benzene is  $3.25 \times 10^{-2}$  mol L $^{-1}$  atm $^{-1}$  at constant temperature. Calculate solubility of methane at 1 bar pressure and at same temperature.**

**Solution:**

**Given:** Henry's law constant =  $K_H = 3.25 \times 10^{-2}$  mol L $^{-1}$  atm $^{-1}$ , Pressure of the gas =  $P = 1$  bar

**To find:** Solubility of methane (S)

**Formula:**  $S = K_H P$

**Calculation:**  $K_H = 3.25 \times 10^{-2}$  mol L $^{-1}$  atm $^{-1}$  =  $\frac{3.25 \times 10^{-2}}{1.013} = 3.21 \times 10^{-2}$  mol L $^{-1}$  bar $^{-1}$

Now, using formula

$$S = K_H P = 3.21 \times 10^{-2} \text{ mol L}^{-1} \text{ bar}^{-1} \times 1 \text{ bar} = 3.21 \times 10^{-2} \text{ mol L}^{-1}$$

**Ans:** Solubility of methane is  $3.21 \times 10^{-2}$  mol L $^{-1}$ .



**+Q.28.** The Henry's law constant of methyl bromide ( $\text{CH}_3\text{Br}$ ), is  $0.159 \text{ mol L}^{-1} \text{ bar}^{-1}$  at  $25^\circ\text{C}$ . What is the solubility of methyl bromide in water at  $25^\circ\text{C}$  and at pressure of  $130 \text{ mm Hg}$ ?

**Solution:**

Given: Henry's law constant =  $0.159 \text{ mol L}^{-1} \text{ bar}^{-1}$

Pressure =  $130 \text{ mm Hg}$

To find: Solubility of methyl bromide

Formula:  $S = K_H P$

$$\begin{aligned}\text{Calculation: } \text{Pressure} &= 130 \text{ mm Hg} \times \frac{1}{760 \text{ mm Hg / atm}} \\ &= 0.171 \text{ atm} \times 1.013 \text{ bar/atm} = 0.173 \text{ bar}\end{aligned}$$

Now, using formula,

$$S = K_H P = 0.159 \text{ mol L}^{-1} \text{ bar}^{-1} \times 0.173 \text{ bar} = \mathbf{0.0275 \text{ M}}$$

**Ans:** The solubility of methyl bromide in water at  $25^\circ\text{C}$  and at pressure of  $130 \text{ mm Hg}$  is  $0.0275 \text{ M}$ .

**\*Q.29.** Fish generally needs  $\text{O}_2$  concentration in water at least  $3.8 \text{ mg/L}$  for survival. What partial pressure of  $\text{O}_2$  above the water is needed for the survival of fish? Given the solubility of  $\text{O}_2$  in water at  $0^\circ\text{C}$  and 1 atm partial pressure is  $2.2 \times 10^{-3} \text{ mol/L}$ .

**Solution:**

Given:  $\text{O}_2$  concentration in water required for fishes =  $3.8 \text{ mg/L}$

Solubility of  $\text{O}_2$  in water =  $2.2 \times 10^{-3} \text{ mol/L}$

Pressure = 1 atm

To find: Partial pressure of  $\text{O}_2$  above the water needed for the survival of fish.

Formula:  $S = K_H P$

Calculation: Pressure = 1 atm = 1.013 bar

Now, using formula and rearranging,

$$K_H = \frac{S}{P} = \frac{2.2 \times 10^{-3} \text{ mol/L}}{1.013 \text{ bar}} = 2.17 \times 10^{-3} \text{ mol L}^{-1} \text{ bar}^{-1}$$

$$\text{O}_2 \text{ concentration in water required for fishes} = 3.8 \text{ mg/L} = \frac{3.8 \times 10^{-3} \text{ g/L}}{32 \text{ g/mol}} = 1.19 \times 10^{-4} \text{ mol L}^{-1}$$

Now, using formula and rearranging,

$$P = \frac{S}{K_H} = \frac{1.19 \times 10^{-4} \text{ mol L}^{-1}}{2.17 \times 10^{-3} \text{ mol L}^{-1} \text{ bar}^{-1}} = \mathbf{0.054 \text{ bar}}$$

**Ans:** The partial pressure of  $\text{O}_2$  above the water needed for the survival of fish is  $0.0548 \text{ bar}$ .

**Q.30.** The partial pressure of ethane over a solution containing  $6.56 \times 10^{-2} \text{ g}$  of ethane is 1 bar. If the solution contains  $5.00 \times 10^{-2} \text{ g}$  of ethane, then what shall be the partial pressure of the gas?

**Solution:**

Given: Mass of ethane =  $6.56 \times 10^{-2} \text{ g}$ ,  $P = 1 \text{ bar}$

To find:  $P$  (partial pressure of ethane) =  $5.00 \times 10^{-2} \text{ g}$

Formula:  $S = K_H P$

Calculation: First solution contains  $6.56 \times 10^{-2} \text{ g}$  of ethane dissolved in specific amount of solution; say V L.

∴ Solubility of ethane in first solution is ( $S_1$ ) =  $\frac{6.56 \times 10^{-2}}{V \times M} \text{ mol L}^{-1}$  (where M is molar mass of ethane)

Second solution contains  $5.00 \times 10^{-2} \text{ g}$  of ethane dissolved in same amount of solution, i.e., V L.

Solubility of ethane in second solution ( $S_2$ ) =  $\frac{5.00 \times 10^{-2}}{V \times M} \text{ mol L}^{-1}$

By Henry's law,  $S = K_H P$

$$\frac{S_1}{S_2} = \frac{K_H P_1}{K_H P_2}$$

$$\frac{6.56 \times 10^{-2}}{5.00 \times 10^{-2}} = \frac{1}{P_2}$$

$$\therefore P_2 = \frac{5.00 \times 10^{-2}}{6.56 \times 10^{-2}} = \mathbf{0.7622 \text{ bar}}$$

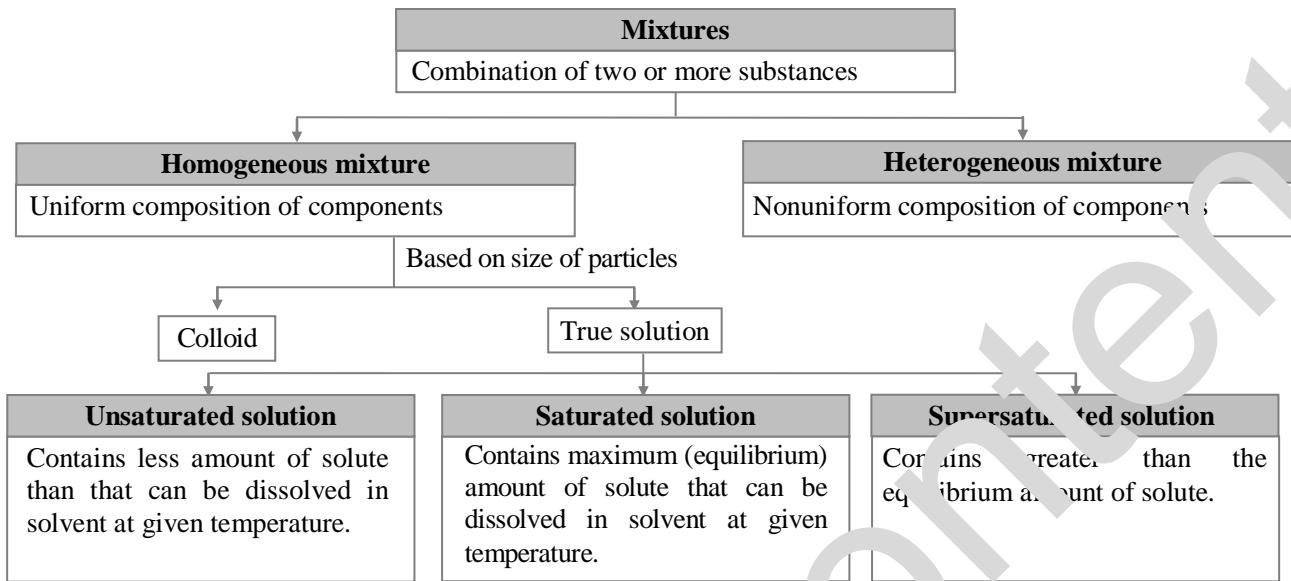
**Ans:** The partial pressure of the ethane gas will be  $0.7622 \text{ bar}$ .

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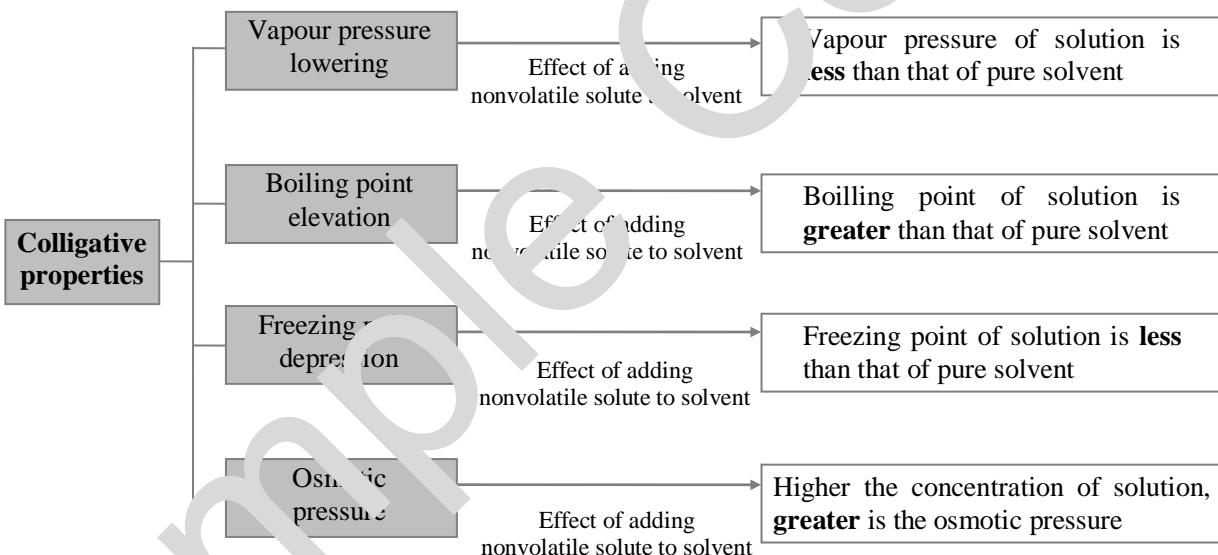
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## Quick Review

➤ **Classification of mixtures:**



➤ **Colligative properties:**



### Important Formulae

**1. Henry's law:**

$$S = K_H P$$

where, S = solubility,

P = pressure of the gas

$K_H$  = Henry's constant

**2. Raoult's law:**

For a binary solution of two volatile components:

$$P_1 = P_1^0 x_1$$

$$P_2 = P_2^0 x_2$$

where,

$P_1^0$  is the vapour pressure of pure component 1 and  $P_1$  is the partial vapour pressure of component 1 in solution.

$x_1$  is the mole fraction of component 1 in solution.

$P_2^0$  is the vapour pressure of pure component 2 and  $P_2$  is the partial vapour pressure of component 2.

$x_2$  is the mole fraction of component 2 in solution.

**3. Dalton's law of partial pressures:**

$$P = P_1 + P_2 \quad \text{OR} \quad P = P_1^0 x_1 + P_2^0 x_2$$

where, P is the total pressure of solution.

**4. Partial pressures in vapour phase:**

$$P_1 = y_1 P$$

$$P_2 = y_2 P$$

where,  $y_1$  and  $y_2$  as the mole fractions of two components in the vapour.

$P_1$  and  $P_2$  are the partial pressures of two components in the vapour.

$P$  is the total vapour pressure.

**5. For a solution containing a non-volatile solute:**

$$P_1 = P_1^0 x_1$$

where,  $P_1$  is the vapour pressure of the solution,

$P_1^0$  is the vapour pressure of pure solvent and  $x_1$  is its mole fraction in solution.

**6. Relative lowering of vapour pressure:**

$$\frac{\Delta P}{P_1} = \frac{P_1^0 - P_1}{P_1^0}$$

where,  $P_1^0$  = vapour pressure of pure solvent and

$P_1$  = vapour pressure of solution

**7. Molecular mass determination from lowering of vapour pressure:**

$$i. \frac{\Delta P}{P_1^0} = x_2 = \frac{P_1^0 - P_1}{P_1^0} = \frac{n_2}{n_1 + n_2}$$

where,  $P_1^0$  = Vapour pressure of pure solvent and  $P_1$  = Vapour pressure of solution

$x_2$  = Mole fraction of solute

$n_1$  = Moles of solvent

$n_2$  = Moles of solute

$$ii. n_2 = \frac{W_2}{M_2} \text{ and } n_1 = \frac{W_1}{M_1}$$

where,  $W_2$  = Mass of solute.

$W_1$  = Mass of solvent,

$M_2$  = Molar mass of solute,

$M_1$  = Molar mass of solvent.

**iii. Relative lowering of vapour pressure,**

$$\frac{P_1^0 - P_1}{P_1^0} = \frac{\Delta P}{F} = \frac{V_2 M_1}{V_1 M_2}$$

**8. Elevation of boiling point:**

$$i. \Delta T_b = T_b - T_b^0$$

where  $\Delta T_b$  = Elevation in boiling point,

$T_b$  = boiling point of solution and

$T_b^0$  = Boiling point of pure solvent.

$$ii. \Delta T_b = K_b m$$

where,  $m$  = Molality of solution

$K_b$  = boiling point elevation constant

$$iii. \Delta T_b = \frac{1000 K_b W_2}{M_2 W_1}$$

where,  $\Delta T_b$  = Elevation in boiling point,

$K_b$  = Molal elevation constant,

$W_1$  = Mass of solvent,

$W_2$  = Mass of solute,

$M_2$  = Molar mass of solute

**iv. Molecular mass determination from elevation of boiling point:**

$$\text{Molecular mass of solute, } M_2 = \frac{1000 K_b W_2}{\Delta T_b W_1}$$

**9. Depression of freezing point:**

$$i. \Delta T_f = T_f^0 - T_f$$

where,  $\Delta T_f$  = Depression in freezing point,

$T_f$  = Freezing point of solution and

$T_f^0$  = Freezing point of pure solvent.

$$ii. \Delta T_f = K_f m$$

where,  $m$  = Molality of solution

$K_f$  = Freezing point depression constant

$$iii. \Delta T_f = \frac{1000 K_f W_2}{M_2 W_1}$$

where,  $\Delta T_f$  = Depression in freezing point,

$K_f$  = Molal depression constant,

$W_2$  = Mass of solute,

$W_1$  = Mass of solvent,

$M_2$  = Molar mass of solute

**iv. Molecular mass determination from depression of freezing point:**

$$\text{Molecular mass of solute, } M_2 = \frac{1000 K_f W_2}{\Delta T_f W_1}$$

**10. van't Hoff equation for osmotic pressure:**

$$\pi = iRT = CRT$$

where,  $\pi$  = Osmotic pressure,

$M = C$  = Concentration of solution

in mol L<sup>-1</sup>,

$R$  = Gas constant

$T$  = Temperature in Kelvin

**11. Molecular mass from osmotic pressure:**

$$\pi = \frac{W_2 RT}{M_2 V} \quad \text{OR} \quad M_2 = \frac{W_2 RT}{\pi V}$$

where,  $\pi$  = Osmotic pressure,

$R$  = Gas constant (0.08205 atm dm<sup>-3</sup>

K<sup>-1</sup> mol<sup>-1</sup>),

$M_2$  = Molecular mass of solute,

$W_2$  = Mass of solute,

$T$  = Temperature in Kelvin,

$n$  = number of moles of solute,

$V$  = volume in dm<sup>3</sup>

**12. van't Hoff factor (i):**

$$i = \frac{\text{Colligative property of electrolyte solution}}{\text{Colligative property of nonelectrolyte solution}}$$

of the same concentration

Actual moles of particles in solution

after dissociation

$$= \frac{\text{Moles of formula units dissolved in solution}}{\text{Moles of formula units dissolved in solution}}$$

$$= \frac{\text{Formula mass of substance}}{\text{Observed molar mass of substance}}$$

$$= \frac{M_{\text{Theoretical}}}{M_{\text{Observed}}}$$

**13. Modified equations for colligative properties by inclusion of van't Hoff factor:**

- $\Delta P = i P_1^0 x_2 = i \frac{W_2 M_1}{M_2 W_1}$
- $\Delta T_b = i K_b m = i \frac{1000 K_b W_2}{M_2 W_1}$
- $\Delta T_f = i K_f m = i \frac{1000 K_f W_2}{M_2 W_1}$
- $\pi = i MRT = i \frac{W_2 RT}{M_2 V}$

**14. Degree of dissociation ( $\alpha$ ):**

$$\alpha = \frac{i-1}{n-1}$$

where,  $\alpha$  = Degree of dissociation,  
 $i$  = van't Hoff factor,  
 $n$  = Moles of ions obtained from dissociation of 1 mole of electrolyte

### Exercise

**2.1 Introduction**

1. Give two examples of a mixture.

**Ans:** Refer Q.1.

2. What are two types of homogeneous mixture?

**Ans:** Refer Q.3.

**2.2 Types of solutions**

3. What is the state of each solute and solvent in amalgams of mercury?

**Ans:** Refer Q.7. (Note)

4. Give two examples of solution in liquid type of solution.

**Ans:** Refer Q.7. (Note)

**2.3 Capacity of solution to dissolve a solute**

5. Define saturated solution.

**Ans:** Refer Q.12. i-a)

6. How is the precipitation in supersaturated solution obtained?

**Ans:** Refer Q.12. ii)

**2.4 Solubility**

7. Name any two factors affecting solubility of a solid in a liquid.

**Ans:**

i. Nature of solute

ii. Nature of solvent

8. Write a short note on: Effect of temperature on solubility of solids in water

**Ans:** Refer Q.18.

9. What is the effect of temperature on solubility of a gas in a liquid?

**Ans:** Refer Q.21.

10. State the units of Henry's law constant.

**Ans:** Refer Q.23. (i)

11. Why do not gases like  $\text{NH}_3$  and  $\text{CO}_2$  obey Henry's law?

**Ans:** Refer Q.25.

12. At what partial pressure, oxygen will have a solubility of  $2.6 \times 10^{-4} \text{ mol L}^{-1}$  in water at  $25^\circ\text{C}$ ? Henry's constant for  $\text{O}_2$  in water at  $25^\circ\text{C}$  is  $1.3 \times 10^{-3} \text{ mol L}^{-1} \text{ atm}^{-1}$ .

**Ans:**  $0.20 \text{ atm}$

13. The Henry's law constant of an unknown gas, is  $0.130 \text{ mol L}^{-1} \text{ bar}^{-1}$  at  $25^\circ\text{C}$ . What is the solubility of unknown gas in water at  $25^\circ\text{C}$  and at pressure of  $130 \text{ mmHg}$ ?

**Ans:**  $0.0225 \text{ mol L}^{-1}$

**2.5 Vapour pressure of solutions of liquids in liquids**

1. Explain Raoult's law of vapour pressure for binary solution of two volatile components.

**Ans:** Refer Q.31.

15. Explain positive deviations from Raoult's law with a neat and labelled diagram.

**Ans:** Refer Q.35. and Diagram.

16. Give two examples of nonideal solutions.

**Ans:** Refer Q.38.

17. The vapour pressure of liquid 'A' at  $298 \text{ K}$  is  $60 \text{ mm Hg}$ . Its mole fraction in a solution with benzene is  $0.120$ . What is its vapour pressure in solution if the mixture obeys Raoult's law?

**Ans:**  $7.2 \text{ mm Hg}$

18.  $100 \text{ g}$  of liquid A (molar mass  $140 \text{ g mol}^{-1}$ ) was dissolved in  $1000 \text{ g}$  of liquid B (molar mass  $180 \text{ g mol}^{-1}$ ). The vapour pressure of pure liquid B was found to be  $500 \text{ torr}$ . Calculate the vapour pressure of pure liquid A and its vapour pressure in the solution if the total vapour pressure of the solution is  $475 \text{ torr}$ .

**Ans:** Liquid A;  $280.7 \text{ torr}$

Liquid B;  $32 \text{ torr}$

**2.6 Colligative properties of nonelectrolyte solutions**

19. What are colligative properties? Give examples.

**Ans:** Refer Q.43.

**2.7 Vapour pressure lowering**

20. Give reason: Vapour pressure of a solvent is lowered by dissolving a nonvolatile solute into it?

**Ans:** Refer Q.48.



21. State and explain Raoult's law of vapour pressure for a solution containing non-volatile solute.

**Ans:** Refer Q.49. and Q.50.

22. What is relative lowering of vapour pressure?

**Ans:** Refer Q.52.

23. Derive the following expression:

$$\frac{P_1^0 - P_1}{P_1^0} = \frac{W_2 M_1}{W_1 M_2}$$

**Ans:** Refer Q.54.

24. An aqueous solution is made by dissolving 20 g of nonvolatile solute (molar mass = 60 g mol<sup>-1</sup>) in 90 g of water at certain temperature. If the vapour pressure of pure water at the given temperature is 29.5 mm Hg. What would be the vapour pressure of the solution?

**Ans:** 27.67 mm Hg

25. The vapour pressure of water at 20 °C is 17 mm Hg. What is the vapour pressure of solution containing 4.0 g urea in 100 g of water?

**Ans:** 16.80 mm Hg

## 2.8 Boiling point elevation

26. Define: Elevation of boiling point

**Ans:** Refer Q.61.

27. Give reason: Vapour pressure lowering is related to a rise in boiling point of solution.

**Ans:** Refer Q.63.

28. Write the units of ebullioscopic constant.

**Ans:** Refer Q.66. (ii)

29. Derive the following equation:

$$M_2 = \frac{1000 K_b W_2}{\Delta T_b W_1}$$

**Ans:** Refer Q.67.

30. A solution of a nonvolatile solute in 50 g of water has a boiling point elevation of 10.765 K. If K<sub>b</sub> for water is 0.51 K kg mol<sup>-1</sup>, what is the molality of the solution?

**Ans:** 1.50

31. Boiling point of water at 750 mm Hg is 99.6°C. How much sucrose is to be added to 500 g of water such that it boils at 100 °C? Molal elevation constant for water is 0.51 K kg mol<sup>-1</sup>

**Ans:** 4.06 g

## 2.9 Depression in freezing point

32. Define: Freezing point of liquid

**Ans:** Refer Q.73.

33. Explain with diagram the depression in freezing point of a solution containing non-volatile solute.

**Ans:** Refer Q.75.

34. Explain: Cryoscopic constant

**Ans:** Refer Q.78.

35. Derive relationship between freezing point depression of a solution containing nonvolatile nonelectrolyte and its molar mass.

**Ans:** Refer Q.79.

36. Calculate the mass of vitamin C (C<sub>6</sub>H<sub>8</sub>O<sub>6</sub>) to be dissolved in 75 g of acetic acid to lower its melting point by 1.5 °C. (K<sub>f</sub> of acetic acid = 3.9 K kg mol<sup>-1</sup>)

**Ans:** 5.08 g

37. 1.0 g of urea when dissolved in 5.0 g of a solvent decreases freezing point of the solvent by 0.211 K. Calculate cryoscopic constant of a solvent.

**Ans:** 1.247 K kg mol<sup>-1</sup>

## 2.10 Osmotic pressure

38. Write a short note on semi-permeable membrane.

**Ans:** Refer Q.84.

39. What happens when a solvent and its solution containing a non-volatile solute are separated by a semi-permeable membrane?

**Ans:** Refer Q.85.

40. State TRUE or FALSE. If false, correct the statement.

i. The osmotic pressure cannot be used to determine molar masses of dissolved solutes.

ii. As a result of osmosis, the amount of liquid on the pure solvent side or more dilute solution side decreases.

iii. As a result of osmosis, the concentration of solution increases.

**Ans:**

i. False

*The osmotic pressure is associated with vapour pressure lowering and can be used to determine molar masses of dissolved solutes.*

ii. True

iii. False

*As a result of osmosis, the concentration of solution decreases.*

41. Explain isotonic solution giving an example.

**Ans:** Refer Q.92. (i)

42. How molar mass of a solute is determined from osmotic pressure measurements?

**Ans:** Refer Q.96.

## 2.11 Colligative properties of electrolytes

43. Define van't Hoff factor.

**Ans:** Refer Q.105.

44. Derive the following equation:

$$\alpha = \frac{i-1}{n-1}$$

**Ans:** Refer Q.109.

45. An organic substance ( $M = 169 \text{ g mol}^{-1}$ ) is dissolved in  $2000 \text{ cm}^3$  of water. Its osmotic pressure at  $12^\circ\text{C}$  was found to be  $0.54 \text{ atm}$ . If  $R = 0.0821 \text{ L atm K}^{-1} \text{ mol}^{-1}$ , calculate the mass of the solute.

**Ans:**  $7.796 \text{ g}$

46.  $0.636 \text{ g}$  of glacial acetic acid is dissolved in  $1 \text{ kg}$  water and the solution froze at  $-0.0205^\circ\text{C}$ . Calculate van't Hoff factor.  $K_f$  for water is  $1.86 \text{ K kg mol}^{-1}$ .

**Ans:**  $1.040$

47.  $19.5 \text{ g}$  of  $\text{CH}_2\text{FCOOH}$  is dissolved in  $500 \text{ g}$  water. The depression in the freezing point observed is  $1.0^\circ\text{C}$ . Calculate the van't Hoff factor and degree of dissociation of monofluoroacetic acid.  $K_f$  for water is  $1.86 \text{ K kg mol}^{-1}$ .

**Ans:**  $i = 1.0753, \alpha = 7.53\%$

### Multiple Choice Questions

- The solubility of a gas in water depends on \_\_\_\_\_.
  - (A) nature of the gas
  - (B) temperature
  - (C) pressure of the gas
  - (D) all of the above
- \* Henry's law constant for a gas  $\text{CH}_3\text{Br}$  is  $0.159 \text{ mol dm}^{-3} \text{ atm}^{-1}$  at  $25^\circ\text{C}$ . What is the solubility of  $\text{CH}_3\text{Br}$  in water at  $25^\circ\text{C}$  and a partial pressure of  $0.164 \text{ atm}$ ?
  - (A)  $0.0159 \text{ mol L}^{-1}$
  - (B)  $0.0164 \text{ mol L}^{-1}$
  - (C)  $0.026 \text{ M}$
  - (D)  $0.032 \text{ M}$
- For a dilute solution, Raoult's law states that \_\_\_\_\_.
  - (A) The lowering of vapour pressure is equal to mole fraction of solute
  - (B) The relative lowering of vapour pressure is equal to mole fraction of solute
  - (C) The relative lowering of vapour pressure is equal to mole fraction of solvent
  - (D) The vapour pressure of the solution is equal to mole fraction of the solute
- \* The colligative property of a solution is \_\_\_\_\_.
  - (A) vapour pressure
  - (B) boiling point
  - (C) osmotic pressure
  - (D) freezing point
- Which of the following is 'NOT' a colligative property?
  - (A) Vapour pressure
  - (B) Depression in freezing point
  - (C) Elevation in boiling point
  - (D) Osmotic pressure

- \* Vapour pressure of a solution is \_\_\_\_\_.
  - (A) directly proportional to the mole fraction of the solute
  - (B) inversely proportional to the mole fraction of the solute
  - (C) inversely proportional to the mole fraction of the solvent
  - (D) directly proportional to the mole fraction of the solvent
- \* The vapour pressure of a solution containing  $2 \text{ moles}$  of a solute in  $2 \text{ moles}$  of water (vapour pressure of pure water =  $24 \text{ mm Hg}$ ) is \_\_\_\_\_.
  - (A)  $24 \text{ mm Hg}$
  - (B)  $32 \text{ mm Hg}$
  - (C)  $48 \text{ mm Hg}$
  - (D)  $1.1 \text{ mm Hg}$
8. Molal elevation constant is elevation in boiling point produced by \_\_\_\_\_.
  - (A)  $1 \text{ g}$  of solute in  $100 \text{ g}$  of solvent
  - (B)  $100 \text{ g}$  of solute in  $100 \text{ g}$  of solvent
  - (C)  $1 \text{ mole}$  of solute in  $1 \text{ L}$  of solvent
  - (D)  $1 \text{ mole}$  of solute in  $1 \text{ kg}$  of solvent
- \* Ebulloscopic constant is the boiling point elevation when the concentration of solution is \_\_\_\_\_.
  - (A)  $1 \text{ m}$
  - (B)  $1 \text{ M}$
  - (C)  $1 \text{ mass \%}$
  - (D)  $1 \text{ mole fraction of solute}$
- \* Pressure cooker reduces cooking time for food because \_\_\_\_\_.
  - (A) boiling point of water involved in cooking is increased
  - (B) heat is more evenly distributed in the cooking space
  - (C) the higher pressure inside the cooker crushes the food material
  - (D) cooking involves chemical changes helped by a rise in temperature.
- \* Cryoscopic constant depends on \_\_\_\_\_.
  - (A) nature of solvent
  - (B) nature of solute
  - (C) nature of solution
  - (D) number of solvent molecules
12.  $6 \text{ g}$  of substance A dissolved in  $100 \text{ g}$  of water freezes at  $-0.93^\circ\text{C}$ . The molar mass of A is \_\_\_\_\_  $\text{g mol}^{-1}$ . ( $K_f = 1.86 \text{ K m}^{-1}$ )
  - (A)  $60$
  - (B)  $120$
  - (C)  $180$
  - (D)  $140$
13. What is the molality of ethyl alcohol (Molecular mass  $46$ ) in aqueous solution which will freeze at  $-10^\circ\text{C}$ ? ( $K_f$  for water =  $1.86$ )
  - (A)  $3.540 \text{ m}$
  - (B)  $4.567 \text{ m}$
  - (C)  $5.376 \text{ m}$
  - (D)  $6.315 \text{ m}$



14. Isotonic solutions have \_\_\_\_\_.  
 (A) equal temperature  
 (B) equal osmotic pressure  
 (C) equal volume  
 (D) equal amount of solute
15. Which of the following solution will have the highest boiling point?  
 (A) 1% solution of glucose in water  
 (B) 1% solution of sodium chloride in water  
 (C) 1% solution of sucrose in water  
 (D) 1% solution of urea in water
- \*16. Identify the CORRECT statement.  
 (A) Vapour pressure of solution is higher than that of pure solvent.  
 (B) Boiling point of solvent is lower than that of solution.  
 (C) Osmotic pressure of solution is lower than that of solvent.  
 (D) Osmosis is a colligative property.
- \*17. In calculating osmotic pressure the concentration of solute is expressed in \_\_\_\_\_.  
 (A) molarity  
 (B) molality  
 (C) mole fraction  
 (D) mass percent
18. Which of the following 0.1 M aqueous solutions will exert highest osmotic pressure?  
 (A)  $\text{Al}_2(\text{SO}_4)_3$       (B)  $\text{Na}_2\text{SO}_4$   
 (C)  $\text{MgCl}_2$       (D)  $\text{KCl}$
- \*19. Which of the following statement is NOT CORRECT for 0.1 M urea solution compared to 0.05 M sucrose solution?  
 (A) Osmotic pressure exhibited by urea solution is higher than that exhibited by sucrose solution.  
 (B) Urea solution is hypertonic to sucrose solution.  
 (C) They are isotonic solutions.  
 (D) Sucrose solution is hypotonic to urea solution.
- \*20. A living cell contains a solution which is isotonic with 0.3 M sugar solution. What osmotic pressure develops when the cell is placed in 0.1 M KCl solution at body temperature?  
 (A) 5.08 atm      (B) 2.54 atm  
 (C) 4.92 atm      (D) 2.46 atm
- \*21. The osmotic pressure of blood is 7.65 atm at 310 K. An aqueous solution of glucose is tonic with blood has the percentage (by volume) \_\_\_\_\_.  
 (A) 5.41 %      (B) 3.54 %  
 (C) 4.53 %      (D) 53.4 %

### Answers to Multiple Choice Questions

1. (D) 2. (C) 3. (B) 4. (C)  
 5. (A) 6. (B) 7. (D) 8. (D)  
 9. (A) 10. (A) 11. (D) 12. (B)  
 13. (C) 14. (B) 15. (B) 16. (B)  
 17. (A) 18. (A) 19. (C) 20. (B)  
 21. (A)

### Hints to Multiple Choice Questions

$$\text{S} = \frac{\pi \text{H}}{V} = 0.159 \text{ mol dm}^{-3} \text{ atm}^{-1} \times 0.164 \text{ atm} \\ = 0.026 \text{ M}$$

$$20. \pi = i_1 M_1 RT - i_2 M_2 RT \\ = [(1 \times 0.3 \text{ mol dm}^{-3}) - (2 \times 0.1 \text{ mol dm}^{-3})] \\ \times 0.08205 \text{ atm dm}^3 \text{ K}^{-1} \text{ mol}^{-1} \times 310 \text{ K} \\ = 2.54 \text{ atm}$$

$$21. M_2 = \frac{W_2 RT}{\pi V} \\ \frac{W_2}{V} = \frac{\pi M_2}{RT} \\ = \frac{7.65 \text{ atm} \times 180 \text{ g mol}^{-1}}{0.08205 \text{ atm dm}^3 \text{ K}^{-1} \text{ mol}^{-1} \times 310 \text{ K}} \\ = 54.1 \text{ g dm}^{-3} = 5.41 \text{ g cm}^{-3} = 5.41\%$$

### Competitive Corner

1. For an ideal solution, the CORRECT option is \_\_\_\_\_. [NEET (UG) 2019]  
 (A)  $\Delta_{\text{mix}}V \neq 0$  at constant T and P  
 (C)  $\Delta_{\text{mix}}G = 0$  at constant T and P      (B)  $\Delta_{\text{mix}}H = 0$  at constant T and P  
 (D)  $\Delta_{\text{mix}}S = 0$  at constant T and P
2. Which of the following statements is CORRECT regarding a solution of two components A and B exhibiting positive deviation from ideal behaviour? [NEET (Odisha) 2019]  
 (A) Intermolecular attractive forces between A–A and B–B are equal to those between A–B.  
 (B) Intermolecular attractive forces between A–A and B–B are stronger than those between A–B.  
 (C)  $\Delta_{\text{mix}}H = 0$  at constant T and P.  
 (D)  $\Delta_{\text{mix}}V = 0$  at constant T and P.

3. If the elevation in boiling point of a solution of 50 g of solute (molar mass = 100) in 500 g of water is  $\Delta T_b$ . The ebullioscopic constant  $K_b$  of water is equal to \_\_\_\_\_. [MHT CET 2019]

(A)  $100 \Delta T_b$       (B)  $\frac{\Delta T_b}{50}$       (C)  $10 \Delta T_b$       (D)  $\Delta T_b$

**Hint:**  $\Delta T_b = \frac{1000 K_b W_2}{M_2 W_1}$  or  $K_b = \frac{\Delta T_b M_2 W_1}{1000 W_2} = \frac{\Delta T_b \times 100 \times 500}{1000 \times 50} = \Delta T_b$

4. The osmotic pressure of solution at 0 °C is 4 atm. What will be the osmotic pressure at 546 K under similar condition? [MHT CET 2019]

(A) 2 atm      (B) 8 atm      (C) 4 atm      (D) 0.5 atm

**Hint:**  $\pi = MRT$

$$\frac{\pi_1}{\pi_2} = \frac{T_1}{T_2}$$

$$\pi_2 = \frac{\pi_1 T_2}{T_1} = \frac{4 \text{ atm} \times 546 \text{ K}}{273 \text{ K}} = 8 \text{ atm}$$

5. vant Hoff's factor for 0.1 m Ba(NO<sub>3</sub>)<sub>2</sub> solution is 2.74. The percentage dissociation of Ba(NO<sub>3</sub>)<sub>2</sub> is \_\_\_\_\_. [MHT CET 2019]

(A) 90%      (B) 100%      (C) 87%      (D) 15%

**Hint:**  $\alpha = \frac{i - 1}{n - 1} = \frac{2.74 - 1}{3 - 1} = 0.87 = 87\%$

Time: 1 Hour 30 Min

### TOPIC TEST

Total Marks: 25

#### SECTION A

**Q.1. Select and write the correct answer:**

[04]

- Which of the following 0.1 M aqueous solutions will exert the highest osmotic pressure?  
 (A) NaCl      (B) MgSO<sub>4</sub>      (C) MgCl<sub>2</sub>      (D) KCl
- The osmotic pressure of solution at 273 K is 6 atm. What will be the osmotic pressure at 600 K under similar condition?  
 (A) 2 atm      (B) 12 atm      (C) 8 atm      (D) 16 atm
- Molal elevation constant is elevation in boiling point produced by \_\_\_\_\_.  
 (A) 1 g of solute in 100 g of solvent      (B) 100 g of solute in 100 g of solvent  
 (C) 1 mole of solute in 1 L of solvent      (D) 1 mole of solute in 1 kg of solvent
- Which of the following is 'OT' a colligative property?  
 (A) Vapour pressure lowering      (B) Depression in freezing point  
 (C) Boiling point      (D) Osmotic pressure

**Q.2. Answer the following:**

[03]

- What is the effect of pressure on solubilities of solids and liquids?
- State Raoult's law.
- What is depression in freezing point?

#### SECTION B

**Attempt any Four:**

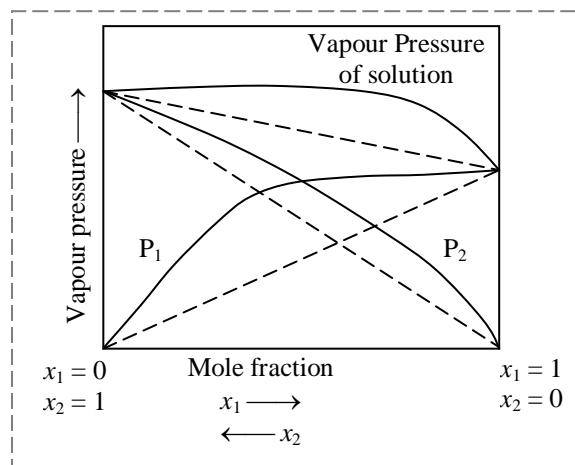
[08]

- While considering boiling point elevation and freezing point depression a solution concentration is expressed in molality and not in molarity. Why?
- A one litre solution of a substance having mass 1.8 g is prepared. Calculate osmotic pressure of a solution at 300 K. (Molar mass of a substance = 60 g mol<sup>-1</sup>)



Q.5. State and explain Henry's law.

Q.6. Write a note on the following diagram:



Q.7. How vapour pressure lowering is related to a rise in boiling point of solution?

Q.8. How molar mass of a solute is determined by osmotic pressure measurement?

### SECTION C

**Attempt any Two:**

[06]

Q.9. 3.795 g of sulphur is dissolved in 100 g of  $\text{CS}_2$ . The solution boils at 319.81 K. What is molecular formula of sulphur in solution? The boiling point of  $\text{CS}_2$  is 319.45 K.  
(Given that  $K_b$  for  $\text{CS}_2$  = 2.42 K kg mol $^{-1}$  and atomic mass of S = 32 u)

Q.10. Define:

- i. Isotonic solution
- ii. Hypertonic solution
- iii. Hypotonic solution

Q.11. Obtain the relationship between freezing point depression of a solution containing nonvolatile nonelectrolyte and its molal mass.

### SECTION D

**Attempt any One:**

[04]

Q.12. i. Define Solubility  
ii. How does the nature of solute and solvent affect solubility?

Q.13. i. Define van't Hoff factor  
ii. At 25°C, a 0.1 molal solution of  $\text{CH}_3\text{COOH}$  is 1.35 % dissociated in an aqueous solution. Calculate freezing point and osmotic pressure of the solution assuming molality and molarity to be identical.

Download the answers of the Topic Test by scanning the given Q.R. Code.

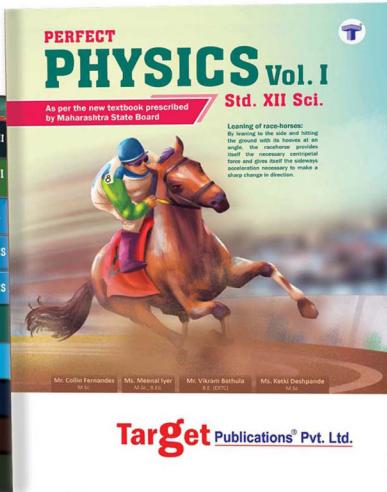
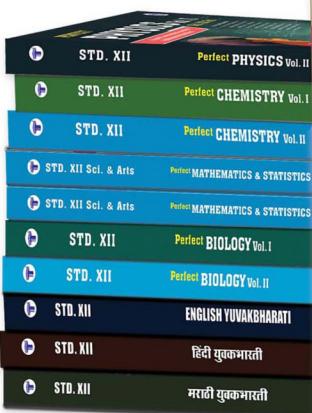




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