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19<sup>th</sup> EDITION

YEAR 2023-24



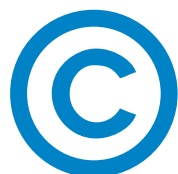
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**SYLLABUS  
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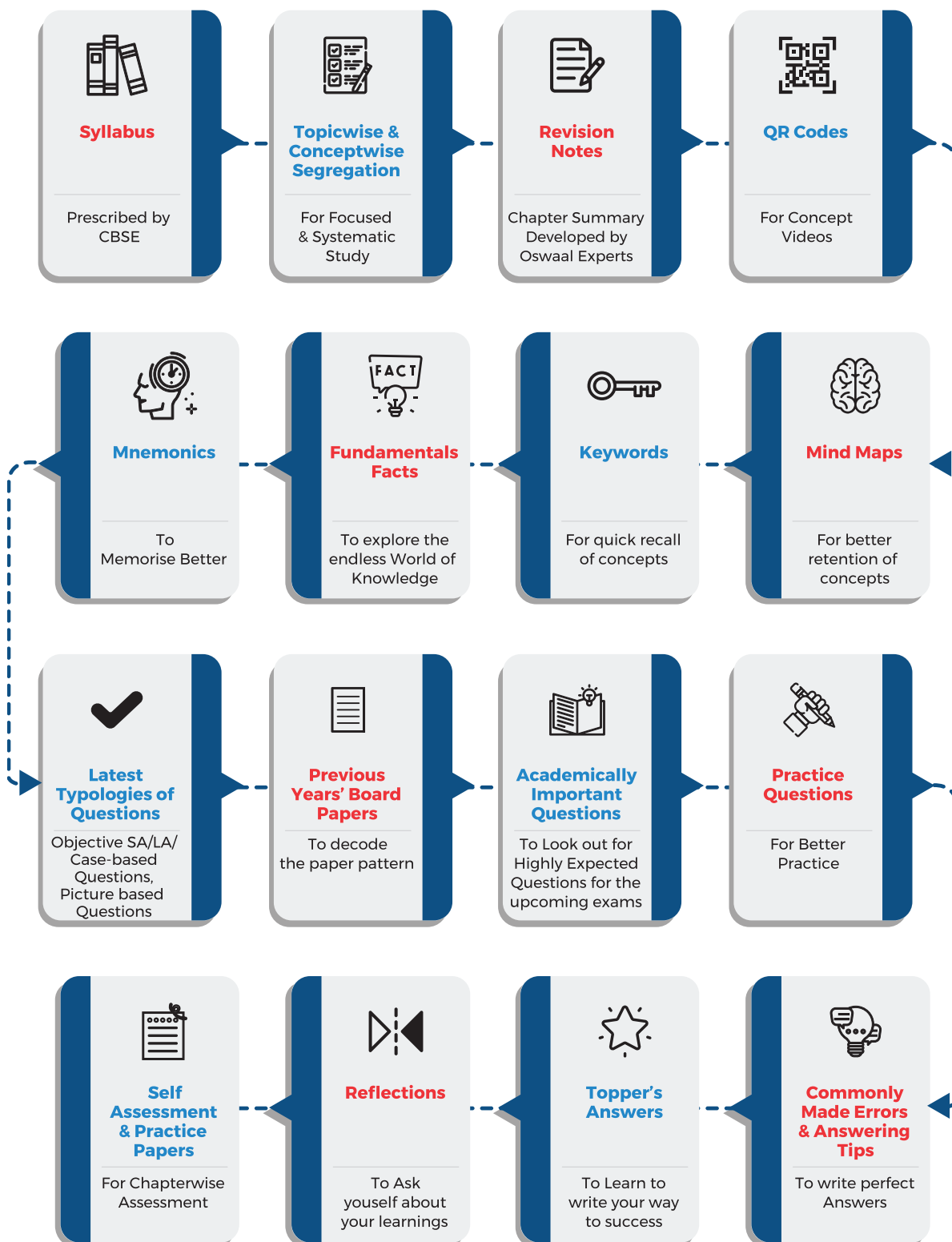
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## Chapter Navigation Tools



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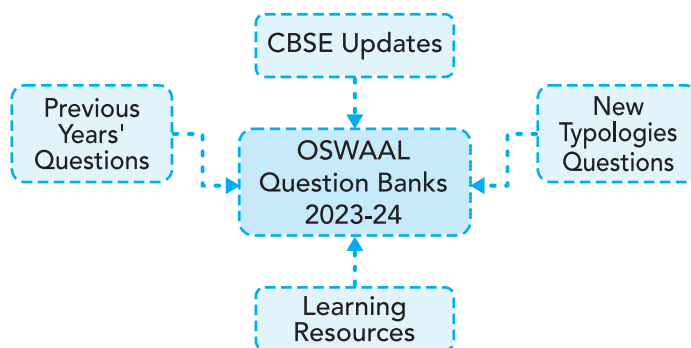
**You said it, we heard it!**

*Practice means to perform, repeatedly in the face of all obstacles, some act of vision, of faith, of desire. Practice is a means of inviting the perfection desired.*

**-Martha Graham**

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All the best Students!! Be the perfectionist that you are!

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# Syllabus

## Latest Syllabus CHEMISTRY (Code No. 043) CLASS-XII (Theory)

Total Periods (Theory 160 + Practical 60)

Time : 3 Hours

70 Marks

S. No.	Title	No. of Periods	Marks
1.	Solutions	15	7
2.	Electrochemistry	18	9
3.	Chemical Kinetics	15	7
4.	<i>d</i> - and <i>f</i> -Block Elements	18	7
5.	Coordination Compounds	18	7
6.	Haloalkanes and Haloarenes	15	6
7.	Alcohols, Phenols and Ethers	14	6
8.	Aldehydes, Ketones and Carboxylic Acids	15	8
9.	Amines	14	6
10.	Biomolecules	18	7
<b>Total</b>		<b>160</b>	<b>70</b>

### Unit II : Solutions

15 Periods

Types of solutions, expression of concentration of solutions of solids in liquids, solubility of gases in liquids, solid solutions, Raoult's law, colligative properties - relative lowering of vapour pressure, elevation of boiling point, depression of freezing point, osmotic pressure, determination of molecular masses using colligative properties, abnormal molecular mass, Van't Hoff factor.

### Unit III : Electrochemistry

18 Periods

Redox reactions, EMF of a cell, standard electrode potential, Nernst equation and its application to chemical cells, Relation between Gibbs energy change and EMF of a cell, conductance in electrolytic solutions, specific and molar conductivity, variations of conductivity with concentration, Kohlrausch's Law, electrolysis and law of electrolysis (elementary idea), dry cell-electrolytic cells and Galvanic cells, lead accumulator, fuel cells, corrosion.

### Unit IV : Chemical Kinetics

15 Periods

Rate of a reaction (Average and instantaneous), factors affecting rate of reaction: concentration, temperature, catalyst; order and molecularity of a reaction, rate law and specific rate constant, integrated rate equations and half-life (only for zero and first order reactions), concept of collision theory (elementary idea, no mathematical treatment), activation energy, Arrhenius equation.

### Unit VIII : *d* and *f* Block Elements

18 Periods

General introduction, electronic configuration, occurrence and characteristics of transition metals, general trends in properties of the first-row transition metals – metallic character, ionization enthalpy, oxidation states, ionic radii, colour, catalytic property, magnetic properties, interstitial compounds, alloy formation, preparation and properties of  $K_2Cr_2O_7$  and  $KMnO_4$ .

#### Lanthanoids –

Electronic configuration, oxidation states, chemical reactivity and lanthanoid contraction and its consequences.

**Actinoids** - Electronic configuration, oxidation states and comparison with lanthanoids.

### Unit IX : Coordination Compounds

18 Periods

Coordination compounds - Introduction, ligands, coordination number, colour, magnetic properties and shapes, IUPAC nomenclature of mononuclear coordination compounds. Bonding,

# Syllabus

Werner's theory, VBT, and CFT ; structure and stereoisomerism, importance of coordination compounds (in qualitative analysis, extraction of metals and biological system).

## Unit X : Haloalkanes and Haloarenes

15 Periods

**Haloalkanes** : Nomenclature, nature of C–X bond, physical and chemical properties, optical rotation mechanism of substitution reactions.

**Haloarenes** : Nature of C–X bond, substitution reactions (Directive influence of halogen in monosubstituted compounds only).

Uses and environmental effects of - dichloromethane, trichloromethane, tetrachloromethane, iodoform, freons, DDT .

## Unit XI : Alcohols, Phenols and Ethers

14 Periods

**Alcohols** : Nomenclature, methods of preparation, physical and chemical properties (of primary alcohols only), identification of primary, secondary and tertiary alcohols, mechanism of dehydration, uses with special reference to methanol and ethanol.

**Phenols** : Nomenclature, methods of preparation, physical and chemical properties, acidic nature of phenol, electrophilic substitution reactions, uses of phenols.

**Ethers** : Nomenclature, methods of preparation, physical and chemical properties, uses.

## Unit XII : Aldehydes, Ketones and Carboxylic Acids

15 Periods

**Aldehydes and Ketones** : Nomenclature, nature of carbonyl group, methods of preparation, physical and chemical properties, mechanism of nucleophilic addition, reactivity of alpha hydrogen in aldehydes, uses.

**Carboxylic Acids** : Nomenclature, acidic nature, methods of preparation, physical and chemical properties; uses.

## Unit XIII : Amines

14 Periods

**Amines** : Nomenclature, classification, structure, methods of preparation, physical and chemical properties, uses, identification of primary, secondary and tertiary amines.

**Diazonium salts**: Preparation, chemical reactions and importance in synthetic organic chemistry.

## Unit XIV : Biomolecules

18 Periods

**Carbohydrates** - Classification (aldoses and ketoses), monosaccharides (glucose and fructose), D-L configuration oligosaccharides (sucrose, lactose, maltose), polysaccharides (starch, cellulose, glycogen); Importance of carbohydrates.

**Proteins** - Elementary idea of - amino acids, peptide bond, polypeptides, proteins, structure of proteins - primary, secondary, tertiary structure and quaternary structures (qualitative idea only), denaturation of proteins; enzymes. Hormones - Elementary idea excluding structure.

**Vitamins** : Classification and functions.

**Nucleic Acids** : DNA and RNA.

Note : *The content indicated in NCERT textbooks as excluded for the year 2022-23 is not to be tested by schools.*

# Syllabus

## PRACTICALS

3 Hours/30 Marks

Evaluation Scheme for Examination	Marks
Volumetric Analysis	08
Salt Analysis	08
Content Based Experiment	06
Project Work	04
Class record and Viva	04
<b>Total</b>	<b>30</b>

### PRACTICALS SYLLABUS

60 Periods

Micro-chemical methods are available for several of the practical experiments. Wherever possible, such techniques should be used.

#### A. Surface Chemistry

- Preparation of one lyophilic and one lyophobic sol  
Lyophilic sol - starch, egg albumin and gum  
Lyophobic sol - aluminium hydroxide, ferric hydroxide, arsenous sulphide.
- Dialysis of sol-prepared in (a) above.
- Study of the role of emulsifying agents in stabilizing the emulsion of different oils.

#### B. Chemical Kinetics

- Effect of concentration and temperature on the rate of reaction between Sodium Thiosulphate and Hydrochloric acid.
- Study of reaction rates of any one of the following:
  - Reaction of Iodide ion with Hydrogen Peroxide at room temperature using different concentration of Iodide ions.
  - Reaction between Potassium Iodate, ( $\text{KIO}_3$ ) and Sodium Sulphite: ( $\text{Na}_2\text{SO}_3$ ) using starch solution as indicator (clock reaction).

#### C. Thermochemistry

Any one of the following experiments

- Enthalpy of dissolution of Copper Sulphate or Potassium Nitrate.
- Enthalpy of neutralization of strong acid (HCl) and strong base (NaOH).
- Determination of enthalpy change during interaction (Hydrogen bond formation) between Acetone and Chloroform.

#### D. Electrochemistry :

Variation of cell potential in  $\text{Zn}/\text{Zn}^{2+} || \text{Cu}^{2+}/\text{Cu}$  with change in concentration of electrolytes ( $\text{CuSO}_4$  or  $\text{ZnSO}_4$ ) at room temperature.

#### E. Chromatography :

- Separation of pigments from extracts of leaves and flowers by paper chromatography and determination of  $R_f$  values.
- Separation of constituents present in an inorganic mixture containing two cations only (constituents having large difference in  $R_f$  values to be provided).

#### F. Preparation of Inorganic Compounds :

Preparation of double salt of Ferrous Ammonium Sulphate or Potash Alum. Preparation of Potassium Ferric Oxalate.



# Syllabus

## G. Preparation of Organic Compounds :

Preparation of any one of the following compounds

- (i) Acetanilide
- (ii) Di-benzal Acetone
- (iii) *p*-Nitroacetanilide
- (iv) Aniline yellow or 2-Naphthol Aniline dye.

## H. Tests for the functional groups present in organic compounds :

Unsaturation, alcoholic, phenolic, aldehydic, ketonic, carboxylic and amino (Primary) groups.

## I. Characteristic tests of carbohydrates, fats and proteins in pure samples and their detection in given foodstuffs.

## J. Determination of concentration/ molarity of $\text{KMnO}_4$ solution by titrating it against a standard solution of :

- (a) Oxalic acid,
- (b) Ferrous Ammonium Sulphate

(Students will be required to prepare standard solutions by weighing themselves).

## K. Qualitative analysis

Determination of one cation and one anion in a given salt.

**Cation:**  $\text{Pb}^{2+}$ ,  $\text{Cu}^{2+}$ ,  $\text{As}^{3+}$ ,  $\text{Al}^{3+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{NH}_4^+$

**Anions:**  $(\text{CO}_3)^{2-}$ ,  $\text{S}^{2-}$ ,  $(\text{SO}_3)^{2-}$ ,  $(\text{NO}_2)^-$ ,  $(\text{SO}_4)^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$ ,  $\text{PO}_4^{3-}$ ,  $(\text{C}_2\text{O}_4)^{2-}$ ,  $\text{CH}_3\text{COO}^-$ ,  $\text{NO}_3^-$

(Note: Insoluble salts excluded)

## INVESTIGATORY PROJECT

Scientific investigations involving laboratory testing and collecting information from other sources.

A few suggested Projects.

- Study of the presence of oxalate ions in guava fruit at different stages of ripening.
- Study of quantity of casein present in different samples of milk.
- Preparation of soyabean milk and its comparison with the natural milk with respect to curd formation, effect of a temperature, etc.
- Study of the effect of Potassium Bisulphate as food preservative under various conditions (temperature, concentration, time, etc.)
- Study of digestion of starch by salivary amylase and effect of pH and temperature on it.
- Comparative study of the rate of fermentation of following materials: wheat flour, gram flour, potato juice, carrot juice, etc.
- Extraction of essential oils present in Saunf (aniseed), Ajwain (carum), Illaichi (cardamom).
- Study of common food adulterants in fat, oil, butter, sugar, turmeric powder, chilli powder and pepper.

**Note :** Any other investigatory project, which involves about 10 periods of work, can be chosen with the approval of the teacher.

# Syllabus

## Practical Examination for Visually Impaired Students of Classes XI and XII Evaluation Scheme

Time Allowed : Two hours

Max. Marks : 30

Topic	Marks
Identification/ Familiarity with the apparatus	5
Written test (based on given/ prescribed practicals)	10
Practical Record	5
Viva	10
<b>Total</b>	<b>30</b>

### General Guidelines

- The practical examination will be of two hour duration.
- A separate list of ten experiments is included here.
- The written examination in practicals for these students will be conducted at the time of practical examination of all other students.
- The written test will be of 30 minutes duration.
- The question paper given to the students should be legibly typed. It should contain a total of 15 practical skill based very short answer type questions. A student would be required to answer any 10 questions.
- A writer may be allowed to such students as per CBSE examination rules.
- All questions included in the question papers should be related to the listed practicals. Every question should require about two minutes to be answered.
- These students are also required to maintain a practical file. A student is expected to record at least five of the listed experiments as per the specific instructions for each subject. These practicals should be duly checked and signed by the internal examiner.
- The format of writing any experiment in the practical file should include aim, apparatus required, simple theory, procedure, related practical skills, precautions, etc.
- Questions may be generated jointly by the external/internal examiners and used for assessment.
- The viva questions may include questions based on basic theory/principle/concept, apparatus/materials/chemicals required, procedure, precautions, sources of error, etc.

### 1. Items for Identification/Familiarity of the apparatus for assessment in practicals (All experiments)

Beaker, glass rod, tripod stand, wire gauze, Bunsen burner, Whatman filter paper, gas jar, capillary tube, pestle and mortar, test tubes, tongs, test tube holder, test tube stand, burette, pipette, conical flask, standard flask, clamp stand, funnel, filter paper

Hands-on Assessment

- Identification/familiarity with the apparatus
- Odour detection in qualitative analysis

### 2. List of Practical

The experiments have been divided into two sections:

Section A and Section B.

The experiments mentioned in Section B are mandatory.

# Syllabus

## SECTION - A

### A. Surface Chemistry

- (1) Preparation of one lyophilic sol  
Lyophilic sol - starch, egg albumin and gum
- (2) Preparation of one lyophobic sol  
Lyophobic sol – Ferric hydroxide

### B. Chromatography

Separation of pigments from extracts of leaves and flowers by paper chromatography and determination of  $R_f$  values (distance values may be provided).

### C. Tests for the functional groups present in organic compounds:

- (1) Alcoholic and Carboxylic groups.
- (2) Aldehydic and Ketonic

### D. Characteristic tests of carbohydrates and proteins in the given foodstuffs.

### E. Preparation of Inorganic Compounds- Potash Alum

## SECTION - B (Mandatory)

### F. Quantitative analysis

- (1) (a) Preparation of the standard solution of Oxalic acid of a given volume  
(b) Determination of molarity of  $\text{KMnO}_4$  solution by titrating it against a standard solution of Oxalic acid.
- (2) The above exercise [F 1 (a) and (b)] to be conducted using Ferrous ammonium sulphate (Mohr's salt)

### G. Qualitative analysis :

- (1) Determination of one cation and one anion in a given salt.  
Cations-  $\text{NH}_4^+$   
Anions –  $(\text{CO}_3)^{2-}$ ,  $\text{S}^{2-}$ ,  $(\text{SO}_3)^{2-}$ ,  $\text{Cl}^-$ ,  $\text{CH}_3\text{COO}^-$  (Note: Insoluble salts excluded)

**Note:** The above practicals may be carried out in an experiential manner rather than recording observations.

### Prescribed Books:

1. Chemistry Part -I, Class-XII, Published by NCERT.
2. Chemistry Part -II, Class-XII, Published by NCERT.
3. Laboratory Manual of Chemistry, Class XI Published by NCERT.
4. Other related books and manuals of NCERT including multimedia and online sources.

# Syllabus

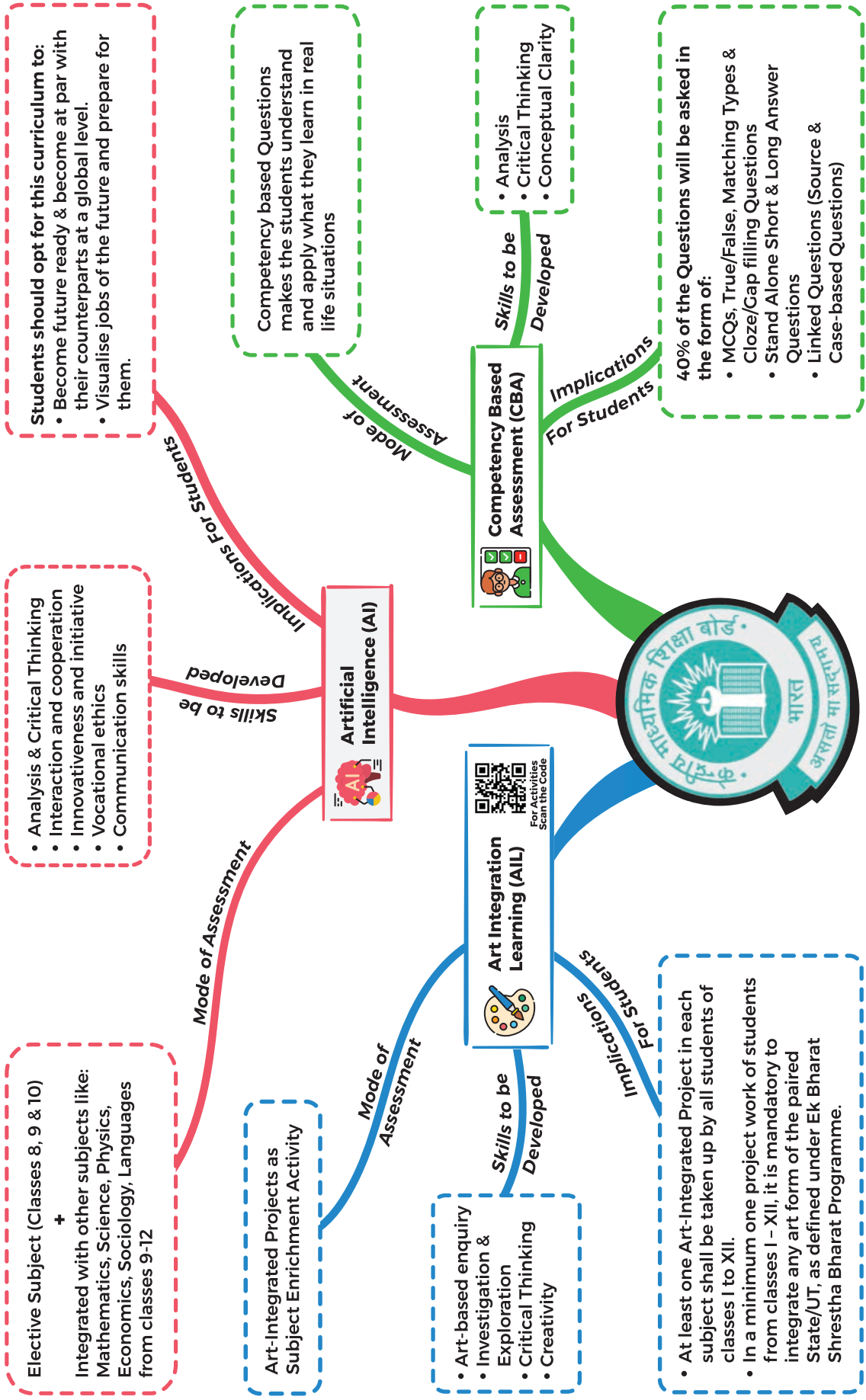
## QUESTION PAPER DESIGN

Classes –XI and XII

S.No.	Domains	Marks	%
1.	<b>Remembering and Understanding:</b> Exhibit memory of previously learned material by recalling facts, terms, basic concepts and answers. Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions and stating main ideas.	28	40
2.	<b>Applying :</b> Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	21	30
3.	<b>Analysing, Evaluating and Creating:</b> Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations. Present and defend opinions by making judgments about information, validity of ideas or quality of work based on a set of criteria. Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions.	21	30

□□

# NEP Derived Learning Resources Prescribed by CBSE for Year 2023-24



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Avishake Kar



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Amrik Singh Gujral



Very good book for 12th class preparation. This book contains Previous Years' Questions which is very helpful in exams. It also includes VSAQs, SAQs and one mark questions for exam practice. One must read this book to achieve high percentile in exams.

Priya J.



## Outstanding Book!

It is really an outstanding book. With this question bank, we are able to get 90+ % in CBSE Board. It is really helpful.

Om Lingyat



I would definitely recommend this book for 12th Boards. It is covering the latest and updated syllabus with great-quality of questions.

Aryan



## Fantastic book!

Along with Previous Years Questions & Board Marking scheme answers this book also includes new typology of questions: MCQs, Assertion-Reason, VSA, SA, LA & case-based questions. Fantastic to study!!

Sumit

# CHAPTER

# 1

# SOLUTIONS



## Syllabus

*Types of solutions, expression of concentration of solutions of solids in liquids, solubility of gases in liquids, solid solutions, Raoult's law, colligative properties - relative lowering of vapour pressure, elevation of boiling point, depression of freezing point, osmotic pressure, determination of molecular masses using colligative properties, abnormal molar mass, Van't Hoff factor.*

## List of Topics

**Topic- 1:** Types of Solutions, Expression of Concentration and Solubility **Page No. 1**

**Topic- 2 :** Raoult's Law, Ideal and Non Ideal Solutions **Page No. 10**

**Topic- 3 :** Colligative Properties, Determination of Molecular Mass, abnormal Molecular Mass, Van't Hoff Factor

**Page No. 17**

## In this chapter you will study

*Types of solutions, Different expression of concentration, Solubility of gases in liquids, Raoult's Law for volatile and non volatile liquids, Colligative Properties, Determination of molecular masses using Colligative properties, Abnormal molecular mass and Van't Hoff factor*

## Topic- 1

## Types of Solutions, Expression of Concentration of Solutions and Solubility

**Concepts Covered** • Types of solution, • Molarity, • Normality, • ppm, • Mass by volume% , • Mole Fraction, • Volume by volume%, • Henry's Law



## Revision Notes

- ▶ **Solution:** A homogeneous mixture of two or more pure substances is known as solution.
- ▶ If the constituents of the solution are two, it is called binary, if three then ternary, if four then quaternary and so on.
- ▶ **Two constituents of the solution are:**
  - (i) **Solute:** A substance that is dissolved in another substance in lesser amount, forming a solution. For example: Sugar, salt, etc.

Scan to know more about this topic

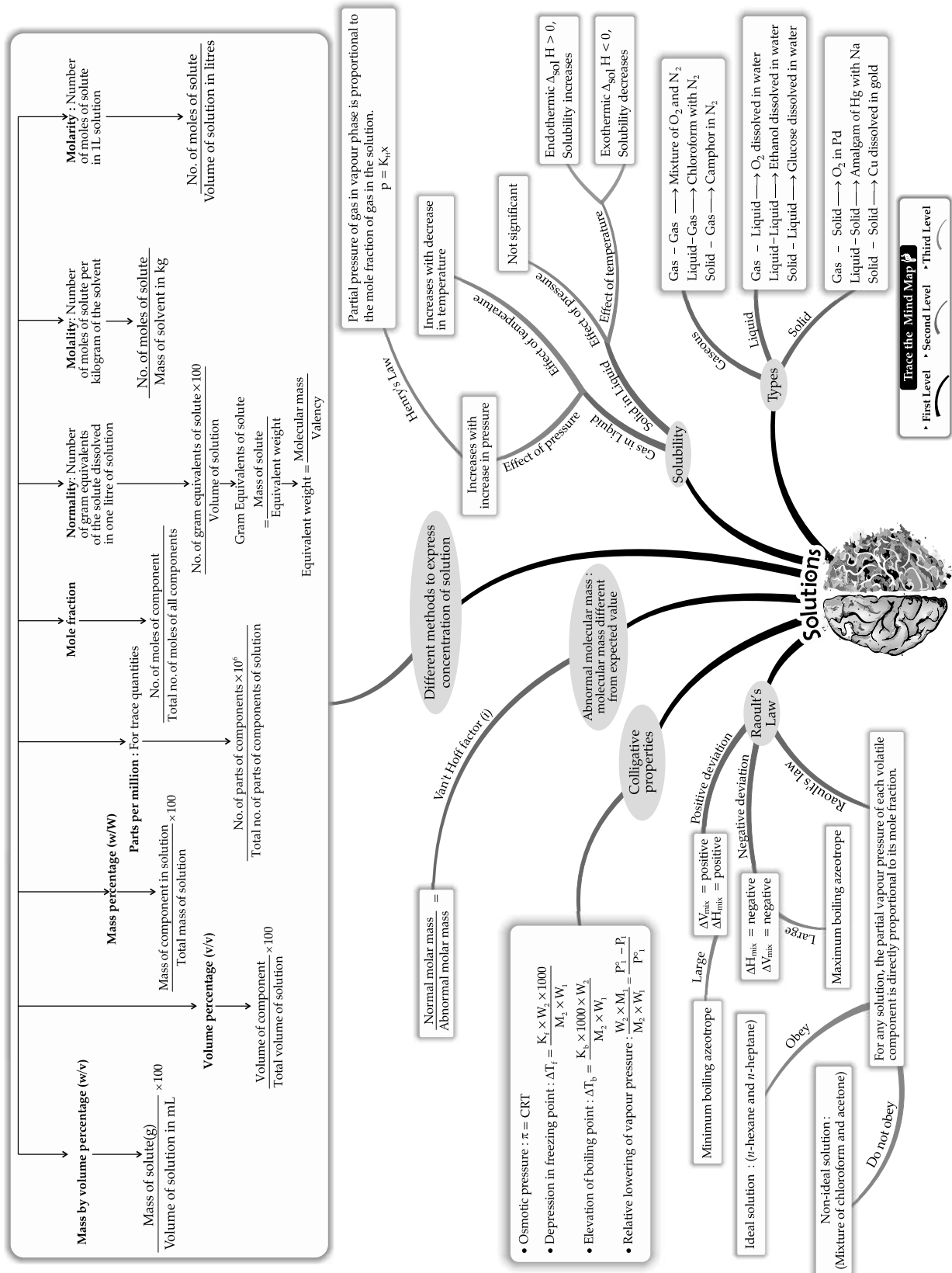


Types of solutions

- (ii) **Solvent:** A substance in which another substance is dissolved in larger amount, forming a solution. For example: Water, milk, etc.

**Note:** Solvent determines the physical state of the solution.

- ▶ **Types of Solutions:** Any state of matter (solid, liquid or gas) can act both as a solvent and as a solute during the formation of a solution. Therefore, depending upon the physical states of solute and solvent, we can have following nine different types of solutions:





S. No.	Types of Solution	Solute	Solvent	Examples
1.	Solid – Solid	Solid	Solid	Alloys like brass, bronze, etc.
2.	Solid – Liquid	Solid	Liquid	Solution of sugar, salt, urea, etc., in water.
3.	Solid – Gas	Solid	Gas	Sublimation of substances like iodine, camphor, etc., into air, dust or smoke particles in air.
4.	Liquid – Solid	Liquid	Solid	Hydrated salts, mercury in amalgamated zinc, etc.
5.	Liquid – Liquid	Liquid	Liquid	Alcohol in water, benzene in toluene.
6.	Liquid – Gas	Liquid	Gas	<b>Aerosol</b> , water vapour in air.
7.	Gas – Solid	Gas	Solid	Hydrogen adsorbed in palladium.
8.	Gas – Liquid	Gas	Liquid	Aerated drinks.
9.	Gas – Gas	Gas	Gas	Mixture of gases, etc.



### Key Word

**Aerosol:** It is suspension of fine solid or liquid particles in air, e.g., Fog.

- ▶ **Aqueous solution:** A solution containing water as solvent is known as aqueous solution. For example, sugar solution.
- ▶ **Non- aqueous solution:** A solution containing solvent other than water is known as non- aqueous solution. For example, iodine dissolved in alcohol.
- ▶ **Saturated solution:** A solution in which no more solute can be dissolved at the same temperature is known as saturated solution.
- ▶ **Unsaturated solution:** A solution in which more amount of solute can be dissolved at the same temperature is known as unsaturated solution.
- ▶ **Method of expressing concentration of solution:** The concentration of solution is the amount of solute present in the given quantity of solute or solvent. It can be expressed in any of the following types:

(i) **Mass percentage**  $\frac{w}{W}$ : It is the amount of solute

in grams dissolved per 100 g of solution.

Mass% of a solute =

$$\frac{\text{Mass of solute in the solution}}{\text{Total mass of the solution}} \times 100$$

(ii) **Volume percentage**  $\frac{v}{V}$ : It is defined as volume

of a solute dissolved per 100 mL of solution.

Volume% of a solute

$$= \frac{\text{Volume of solute}}{\text{Total volume of the solution}} \times 100$$

(iii) **Mass by volume percentage**  $\frac{w}{V}$ : It is defined

as mass of solute dissolved per 100 mL of solution. It is commonly used in medicine and pharmacy.

Mass by volume % of solute

$$= \frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$$

(iv) **Parts per million (ppm):** It can be defined as the parts of a component per million ( $10^6$ ) parts of the solution. It is used to express the concentration of a solute present in trace quantities.

$$\text{ppm (A)} = \frac{\text{Number of the parts of the component (A)}}{\text{Total number of parts of all the components of the solution}} \times 10^6$$

**Parts per million can be expressed in three ways:**

(a) Mass to mass

$$\text{ppm (mass to mass)} = \frac{\text{Mass of a component}}{\text{Total mass of solution}} \times 10^6$$

(b) Volume to volume

$$\begin{aligned} \text{ppm (volume to volume)} \\ = \frac{\text{Volume of a component}}{\text{Total volume of solution}} \times 10^6 \end{aligned}$$

(c) Mass to volume

$$\text{ppm (mass to volume)} = \frac{\text{Mass of a component}}{\text{Volume of solution}} \times 10^6$$

(v) **Mole Fraction:** It is the ratio of number of moles of a particular component to the total number of moles of all the components. e.g., mole fraction of component A.

$$\chi_A = \frac{n_A}{n_A + n_B},$$

where  $n_A$  is the number of moles of component 'A' and  $n_B$  is the number of moles of component 'B'.

$$\text{Similarly, } \chi_B = \frac{n_B}{n_A + n_B}$$

Sum of mole fractions of all the components is always one.

$$\chi_A + \chi_B = 1$$

(vi) **Molarity (M):** It is defined as the number of moles of solute per litre of solution.

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in Litres)}}$$

$$M = \frac{W_B \times 1000}{M_B \times V}$$

where,  $W_B$  = Weight of solute,  $V$  = Volume of solution in mL,  $M_B$  = Molar mass of solute.

Unit is  $\text{mol L}^{-1}$  or M (molar).

And

$$\frac{\text{Weight of solute } (W_B)}{\text{Molar mass of solute } (M_B)} = \text{Moles of solute}$$

(vii) **Molality ( $m$ ):** It is defined as the number of moles of solute per 1000 g or 1 kg of solvent.

$$\text{Molality} = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}}$$

$$m = \frac{W_B \times 1000}{M_B \times W}$$

where,  $W_B$  = Weight of the solute,  $M_B$  = Molar mass of solute,  $W$  = Mass of solvent in g

Unit is  $\text{mol kg}^{-1}$  or molal ( $m$ ). Molality and mole fraction do not change with change in temperature.



## Key Formulæ

$$\text{Mole fraction of a component} = \frac{\text{Number of moles of the component}}{\text{Total number of moles of all the components}}$$

$$x_1 = \frac{n_1}{n_1 + n_2}, \quad x_2 = \frac{n_2}{n_1 + n_2} \quad (x_1 + x_2 = 1)$$

$$\text{Molarity (M)} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in Litre}}$$

$$\text{Molality (m)} = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}}$$

$$\text{Normality (N)} = \frac{\text{Number of gram equivalent of solute}}{\text{Volume of solution in Litre}}$$

$$\text{Mass percentage} \left( \frac{w}{W} \right) = \frac{\text{Mass of solute in the solution}}{\text{Total mass of the solution}} \times 100$$

$$\text{Volume percentage} \left( \frac{v}{V} \right) = \frac{\text{Volume of solute}}{\text{Total volume of the solution}} \times 100$$

$$\text{Mass by volume percentage} \left( \frac{w}{V} \right) = \frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$$

$$\text{ppm of component A} = \frac{\text{Mass of component A}}{\text{Total mass of solution}} \times 10^6$$

(viii) **Normality (N):** It is defined as number of gram equivalents of solute dissolved per litre of solution.

$$\text{Normality} = \frac{\text{Number of gram equivalents of solute}}{\text{Volume of solution in Litre}}$$

$$N = \frac{W_B \times 1000}{E_B \times V}$$

where,  $W_B$  = Mass of solute,  $E_B$  = Equivalent weight of solute,  $V$  = Volume of solution in mL

► **Relationship between Molarity (M) and Molality (m):**

$$\frac{1}{m} = \frac{d}{M} - \frac{M_B}{1000}$$

where,  $m$  = Molality of solution,  $M$  = Molarity of solution,

$M_B$  = Molar mass of solute,  $d$  = Density of solution in  $\text{g ml}^{-1}$

► **Relationship between Mole fraction of solute ( $\chi_B$ ) and Molality ( $m$ ):**

$$m = \frac{\chi_B \times 1000}{(1 - \chi_B) \times M_A}$$

where  $\chi_B$  is mole fraction of solute,  $m$  is molality and  $M_A$  is molar mass of solvent.

► **Solubility:** Solubility can be defined as the maximum amount of solute that can be dissolved in 100 g of solvent to form a saturated solution at a given temperature.

● **Factors affecting Solubility:**

(i) **Nature of Solute and Solvent:** "Like dissolves like" *i.e.*, polar solvents like water and ammonia can dissolve polar solute or ionic solute while non-polar solvents can dissolve non-polar organic solutes.

Scan to know more about this topic



Solubility of gases in water

(ii) **Temperature:** Solubility increases with increase in temperature. It increases for endothermic reaction while it decreases for exothermic reaction.

(iii) **Pressure:** The solubility of solid in liquid is not affected significantly by pressure because solids and liquids cannot be compressed.

► **Henry's Law:**

The relationship between pressure and solubility is guided by Henry's Law. According to this law, "The mass of a gas dissolved in given volume of the liquid at a constant temperature depends upon the pressure applied."

It can also be stated as the partial pressure of the gas ( $p$ ) in vapour phase is proportional to the mole fraction of the gas ( $\chi$ ) in the solution.

$$p = K_H \chi,$$

where  $K_H$  = Henry's constant.

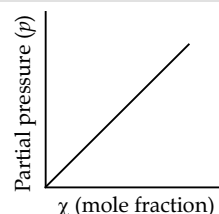
● **Applications of Henry's law:**

(i) To increase the solubility of  $\text{CO}_2$  in soda water and soft drinks, the bottle is sealed under high pressure.

🔑 **Key Formulae**

- $m = \frac{\chi_B \times 1000}{(1 - \chi_B) \times M_A}$
- **Henry's Law:**  $p = K_H x$

🔑 **Key Diagram**



The slope of the line in Henry's constant, ( $K_H$ )

(ii) To avoid the toxic effects of high concentration of nitrogen in blood, the tanks used by scuba divers are filled with air diluted with helium (11.7%), nitrogen (56.2%) and oxygen (32.1%).

(iii) At high altitudes, low blood oxygen causes climber to become weak and make them unable to think clearly, which are symptoms of a condition known as anoxia.

● **Limitations of Henry's law:** This law is applicable only when:

(i) The pressure of gas is not too high and temperature is not too low.

(ii) The gas should not undergo any chemical change.

(iii) The gas should not undergo association or dissociation in the solution.

Scan to know more about this topic



Pressure and Gas solubility (Henry's Law)



## OBJECTIVE TYPE QUESTIONS

(1 mark each)

### A Multiple Choice Questions

Q. 1. A molar solution is one that contains one mole of a solute in:

- (A) 1000 g of the solvent
- (B) one litre of the solvent
- (C) one litre of the solution
- (D) 22.4 litre of the solution

Ⓜ

Ans. Option (C) is correct.

**Explanation:** A molar solution is one that contains one mole of a solute in one litre of the solution.

$$\text{Molarity (M)} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in L}}$$

Q. 2. In which mode of expression, the concentration of a solution remains independent of temperature?

- (A) Molarity
- (B) Normality
- (C) Formality
- (D) Molality

Ⓜ

Q. 3. The increase in the temperature of the aqueous solution will result in its:

- (A) Molarity to increase
- (B) Molarity to decrease
- (C) Mole fraction to increase
- (D) Mass % to increase

Ⓜ

Ans. Option (B) is correct.

**Explanation:** An increase in temperature increase the volume of solution and therefore it will result in its molarity to decrease.

Q. 4.  $K_H$  value for Ar(g),  $CO_2$ (g), HCHO(g) and  $CH_4$ (g) are 4.039, 1.67,  $1.83 \times 10^{-5}$ , and 0.143, respectively. Arrange these gases in the order of their increasing solubility:

- (A)  $HCHO < CH_4 < CO_2 < Ar$   
 (B)  $HCHO < CO_2 < CH_4 < Ar$   
 (C)  $Ar < CO_2 < CH_4 < HCHO$   
 (D)  $Ar < CH_4 < CO_2 < HCHO$

[Ap]

Ans. Option (C) is correct.

Explanation: According to Henry's law,

$$P = K_H C$$

$$K_H \propto \frac{1}{C}$$

Where P = Partial pressure of gas

C = Concentration of gas

$K_H$  = Henry's constant

It implies that as the value of  $K_H$  increases, mole fraction of gas solute in solvent decreases.

Hence, higher the  $K_H$  value, lower is the solubility of gas.

The order of increasing solubility of gases in:



#### Concept Applied

Henry's law

Q. 5. A beaker contains a solution of substance 'A'. Precipitation of substance 'A' takes place when small amount of 'A' is added to the solution. The solution is \_\_\_\_\_.

- (A) saturated (B) supersaturated  
 (C) unsaturated (D) concentrated

[A] [R]

Ans. Option (B) is correct.

Explanation: When a small amount of solute is added to its solution, it does not dissolve and get precipitated then this type of solution is called as supersaturated solution.

Q. 6. Which of the following units is useful in relating concentration of solution with its vapour pressure?

- (A) Mole fraction (B) Parts per million  
 (C) Mass percentage (D) Molality

[A] [A]

Ans. Option (A) is correct.

Explanation: Mole fraction is used in relating vapour pressure with concentration of solution and according to the Raoult's law, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction.

Q. 7. Value of Henry's constant  $K_H$  is \_\_\_\_\_.

- (A) Increases with increase in temperature.  
 (B) Decreases with increase in temperature  
 (C) Remains constant  
 (D) First increases then decreases.

[R]

Q. 8. The concentration of pollutants in water is expressed in:

- (A)  $\mu g/mL$  (B)  $w/v$   
 (C)  $v/v$  (D)  $w/w$

[R]

Ans. Option (A) is correct.

Explanation: The concentration of pollutants in water is expressed in  $\mu g/mL$ .

Q. 9. Which of the following unit is used in medicine and pharmacy?

- (A) mass by volume percentage  
 (B) parts per million  
 (C) mass percentage  
 (D) molarity

[R]

Ans. Option (A) is correct.

Explanation: The unit is used as it is easy to measure volumes of solvents and solutions rather than their weights.

Q. 10. Find the molarity of a solution having 5 g of NaOH is 450 mL of solution?

- (A) 0.125 mol (B) 0.278 mol/L  
 (C) 27.8 mol/L (D) 450 mL

[Ap]

Ans. Option (A) is correct.

Explanation: Moles of NaOH =  $\frac{5}{40} = 0.125$  mol

Volume of solution in litres =  $\frac{450}{1000}$

Molarity =  $\frac{0.125 \times 1000}{450} = 0.278$  mol/L

## B Assertion & Reason Type

Directions: In the following questions, A statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as.

- (A) Both A and R are true and R is the correct explanation of A.  
 (B) Both A and R are true but R is NOT the correct explanation of A.  
 (C) A is true but R is false.  
 (D) A is false and R is true.

Q. 1. Assertion (A): A molar solution is more concentrated than molal solution.

Reason (R): A molar solution contains one mole of solute in 1000 mL of solution. [U]

Ans. Option (A) is correct.

Explanation: A molar solution is more concentrated than molal solution because 1 molar solution contains 1 mole of solute in 1 litre of the solution which include both solute and solvent.




Q. 2. Assertion (A): Molarity of 0.1 N solution of HCl is 0.1 M.

Reason (R): Normality and molarity of a solution are always equal. [U]

Ans. Option (C) is correct.

**Explanation:** Normality and molarity of a solution are not always equal. Normality depends on chemical equivalent of the substance while molarity depends on molecular mass of the substance.

Q. 3. **Assertion (A):** Molarity of a solution changes with temperature.

**Reason (R):** Molarity is dependent on volume of solution.   

Q. 4. **Assertion (A):** If a liquid solute more volatile than the solvent is added to the solvent, the vapour pressure of the solution may increase, i.e.,  $p_s > p_o$ .

**Reason (R):** In the presence of a more volatile liquid solute, only the solute will form the vapours and solvent will not.

Ans. Option (C) is correct.

**Explanation:** Both the solute and solvent will form the vapours but vapour phase will become richer in the more volatile component.

Q. 5. **Assertion (A):** Greater the value of Henry's constant of a gas in a particular solvent, greater is the solubility of the gas at the same pressure and temperature.

**Reason (R):** Solubility of a gas is directly proportional to its Henry's constant at the same pressure and temperature.

Ans. Option (D) is correct.

**Explanation:** The higher the value of  $K_H$  at a given pressure, the lower is the solubility of the gas in the liquid, as Henry's constant is inversely proportional to solubility or vice versa, that is solubility of gas is inversely proportional to Henry's constant.



## SUBJECTIVE TYPE QUESTIONS



### Short Answer Type Questions-I (2 marks each)


Q. 1. State Henry's law. Calculate the solubility of  $\text{CO}_2$  in water at 298K under 760 mm Hg.

( $K_H$  for  $\text{CO}_2$  in water at 298 K is  $1.25 \times 10^6$  mm Hg)

    [CBSE Outside Delhi Set-1, 2020]

Q. 2. State Henry's law and write its two applications.

   [CBSE Delhi Set-3 2019]

Q. 3. Calculate the molarity of NaOH solution obtained by dissolving 2g of NaOH in 50 mL of its solution. 

Ans. 50 mL of NaOH solution contains = 2g of NaOH

$\therefore$  1000 mL of NaOH solution will contain

$$= \frac{2}{50} \times 1000$$

$$= 40 \text{ g of NaOH [1]}$$

$$\text{Molecular mass of NaOH} = 23 + 16 + 1 = 40$$

$$\text{Number of moles of NaOH} = \frac{\text{Mass}}{\text{molecular mass}}$$

$$= \frac{40}{40} = 1 \text{ mol}$$

$$\therefore \text{Molarity of the solution} = 1 \text{ M [1]}$$

Q. 4. State two points of difference between Molarity and Molality.

Ans. (i) Molarity is number of moles of solute dissolved per litre of solvent, while Molality is number of moles of solute present in 1 kg of solvent.

(ii) Molarity increases with increase in temperature while Molality is not affected by increase or decrease in the temperature.

Q. 5. Calculate the mass percentage of benzene ( $\text{C}_6\text{H}_6$ ) and carbon tetrachloride ( $\text{CCl}_4$ ) if 22 g of benzene is dissolved in 122 g of carbon tetrachloride. (ncert exercise)


Ans. Mass of solution = Mass of  $\text{C}_6\text{H}_6$  + Mass of  $\text{CCl}_4$   
 $= 22 \text{ g} + 122 \text{ g} = 144 \text{ g}$


$$\text{Mass \% of benzene} = \frac{22}{144} \times 100 = 15.28 \%$$

$$\text{Mass \% of } \text{CCl}_4 = \frac{122}{144} \times 100 = 84.72 \%$$



### Short Answer Type Questions-II (3 marks each)

Q. 1. (i) What is the relationship between Molarity and Normality? 

(ii) One litre of water at N.T.P. dissolves 0.08 g of nitrogen. Calculate the amount of nitrogen that can be dissolved in four litres of water at  $0^\circ\text{C}$  and at a pressure of 1520 mm. 

Ans. (i) Molarity (M)  $\times$  Molecular mass of solute = Normality (N)  $\times$  Equivalent mass of solute [1]

(ii) Solubility of gas ( $C_1$ ) = 0.08 g/litre

$$P_1 = 760 \text{ mm}$$

$$P_2 = 1520 \text{ mm}$$

$$\text{Solubility of gas } (C_2) \text{ at pressure } P_2 = ?$$

By Henry's law,

$$\frac{C_1}{C_2} = \frac{P_1}{P_2}$$

$$\frac{C_1}{C_2} = \frac{P_1}{P_2}$$

$$C_2 = \frac{C_1 \times P_2}{P_1} = \frac{0.08 \times 1520}{760} = 0.16 \text{ g/litre}$$

$$\therefore \text{Solubility of nitrogen in 4 litres of water} = 0.16 \times 4 = 0.64 \text{ g [1]}$$



### Commonly Made Error

Some students get confused in using correct formula for calculation of solubility of gas.



### Answering Tip

► Students must understand Henry's law.

**Q. 2.**  $8.0575 \times 10^{-2}$  kg of Glauber's salt is dissolved in water to obtain  $1 \text{ dm}^3$  of a solution of density  $1077.2 \text{ kg m}^{-3}$ . Calculate the molarity, molality and mole fraction of  $\text{Na}_2\text{SO}_4$  in the solution. [Ap]

**Ans.** Mass of Glauber's salt =  $8.0575 \times 10^{-2}$  kg  
 $= 8.0575 \times 10^{-2} \times 10^3 \text{ g}$   
 $= 80.575 \text{ g}$

Molecular mass of Glauber's salt ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ )  
 $= 322$

Number of moles Glauber's salt  
 $= \frac{80.575}{322} = 0.25$

Mass of solution per  $\text{dm}^3 = 1077.2 \text{ kg m}^{-3}$   
 $= 1077.2 \times 10^3 \text{ g m}^{-3}$   
 $= 1077.2 \times 10^3 \times 10^{-3} \text{ g dm}^{-3}$   
 $= 1077.2 \text{ g}$

Mass of water =  $1077.2 - 80.575 = 996.625 \text{ g}$

Molarity =  $\frac{0.25}{1 \text{ dm}^3} = 0.25$

Molality =  $\frac{0.25 \times 1000}{996.625} = 0.2508$

Mole fraction =  $\frac{\text{Molarity}}{\text{Molarity} + \frac{\text{mass of water}}{\text{molecular mass of water}}}$   
 $= \frac{0.25}{0.25 + \frac{996.625}{18}} = 4.49 \times 10^{-3}$  [3]

**Q. 3.** Calculate the concentration of a solution that is obtained by mixing 300 g of 25% solution  $\text{NH}_4\text{NO}_3$  with 150 g of 40% solution of  $\text{NH}_4\text{NO}_3$ . [Ap]

**Ans.** Total mass of solution =  $300 + 150 = 450 \text{ g}$   
 Amount of solute present in 300 g of 25% solution  
 $= 300 \times \frac{25}{100} = 75 \text{ g}$  [1]

Similarly,

Amount of solute present in 150 g of 40% solution  
 $= 150 \times \frac{40}{100} = 60 \text{ g}$  [1]

Total mass of solute =  $75 + 60 = 135 \text{ g}$   
 Concentration of solution (in %)

$= \frac{\text{mass of solute in g}}{\text{mass of solution in g}} \times 100$   
 $= \frac{135}{450} \times 100$   
 $= 30\%$  [1]

**Q. 4.** (a) Define mole fraction.  
 (b) Explain the following phenomena with the help of Henry's law:  
 (i) Painful condition known as bends.  
 (ii) Feeling of weakness and discomfort in breathing at high altitude. [R]

**Ans.** (a) It may be defined as the ratio of number of moles of one component to the total number of moles of all the components (solvent and solute) present in the solution. [1]

(b) (i) Deep sea divers depend upon compressed air for breathing at high pressure under water. The compressed air contains N in addition to  $\text{O}_2$ , which are not very soluble in blood at normal pressure. However, at depths when the diver breathes in compressed air from the supply tank, more  $\text{N}_2$  dissolves in the blood and other body fluids because the pressure at that depth is far greater than the surface atmospheric pressure. When the diver comes towards the surface, the pressure decreases,  $\text{N}_2$  comes out of the body quickly forming bubbles in the blood stream. These bubbles restrict blood flow, affect the transmission of nerve impulses. The bubbles can even burst the capillaries or block them and starve the tissues of  $\text{O}_2$ . This condition is called the bends, which are painful and life-threatening. [1]

(ii) At high altitudes, the partial pressure of  $\text{O}_2$  is less than that at the ground level. This results in low concentration of oxygen in the blood and tissues of the people living at high altitudes or climbers. The low blood oxygen causes climbers to become weak and unable to think clearly known as anoxia. [1]

**Q. 5.** Define the following modes of expressing the concentration of a solution. Which of these modes are independent of temperature and why?

- w/w (mass percentage)
- v/V (volume percentage)
- M (molarity)
- w/V (mass by volume percentage)
- m (molality)
- ppm (parts per million) (NCERT Exemplar) [R]

**Q. 6.** Calculate the molality of ethanol solution in which the mole fraction of water is 0.88. [Ap]

**Ans.** Mole fraction of water,  $X_{\text{H}_2\text{O}} = 0.88$

Mole fraction of ethanol,

$$X_{\text{C}_2\text{H}_5\text{OH}} = 1 - 0.88 = 0.12 \quad [1/2]$$

$$X_{\text{C}_2\text{H}_5\text{OH}} = \frac{n_2}{n_1 + n_2} \quad \dots(1)$$

$n_2 =$  number of moles of ethanol.

$n_1 =$  number of moles of water.

Molality of ethanol means the number of moles of ethanol present in 1000 g of water.

$$n_1 = \frac{1000}{18} = 55.5 \text{ moles} \quad [1/2]$$

Substituting the value of  $n_1$  in equation (1)

$$\frac{n_2}{55.5 + n_2} = 0.12$$

$$n_2 = 7.57 \text{ moles} \quad [1/2]$$

Molality of ethanol ( $\text{C}_2\text{H}_5\text{OH}$ ) = 7.57 m

Alternatively,

$$\text{Mole fraction of water} = 0.88 \quad [1/2]$$

$$\text{Mole fraction of ethanol} = 1 - 0.88 = 0.12 \quad [1/2]$$

Therefore 0.12 moles of ethanol are present in 0.88 moles of water.

$$\text{Mass of water} = 0.88 \times 18 = 15.84 \text{ g of water.} \quad [1/2]$$

Molality = number of moles of solute (ethanol) present in 1000 g of solvent (water)

$$= \frac{0.12 \times 1000}{15.84} \\ = 7.57 \text{ m} \quad [1/2]$$

Molality of ethanol ( $\text{C}_2\text{H}_5\text{OH}$ ) = 7.57 m

[CBSE Marking Scheme 2018]



### Commonly Made Error

- ▶ Students get confused between the terms molarity and molality.



### Answering Tip

- ▶ Students should remember that molarity is volume based concept and molality is mass based concept.



### Long Answer Type Questions (5 marks each)

Q. 1. (i) Calculate the mass percentage of aspirin ( $\text{C}_9\text{H}_8\text{O}_4$ ) in acetonitrile ( $\text{CH}_3\text{CN}$ ) when 6.5 g of  $\text{C}_9\text{H}_8\text{O}_4$  is dissolved in 450 g of  $\text{CH}_3\text{CN}$ .

(ii) Commercially available concentrated hydro-chloric acid contains 38% HCl by mass and has density  $1.19 \text{ g cm}^{-3}$ . What is the molarity of this solution? +

Q. 2. 4.0 g of NaOH are contained in one decilitre of solution. Calculate the following:

(i) Molality fraction of NaOH

(ii) Molarity of NaOH

(iii) Molality of NaOH

Density of solution =  $1.038 \text{ g/cm}^3$

Ans. (i) Density of solution =  $1.038 \text{ g/cm}^3$

$$\text{Mass of } 100 \text{ cm}^3 \text{ of solution} = 1.038 \times 100 \\ = 103.8 \text{ g}$$

$$\text{Mass of NaOH in } 100 \text{ cm}^3 \text{ solution} = 4 \text{ g}$$

$$\text{Mass of water} = 103.8 - 4.0 = 99.8 \text{ g} \quad [1]$$

$$\text{Number of moles of NaOH } (n_A) = \frac{4.0}{40}$$

$$= 0.1 \text{ mol}$$

$$\text{Number of moles of water } (n_B) = \frac{99.8}{18}$$

$$= 5.54 \text{ mol}$$

$$\therefore \text{Mole fraction of NaOH } X_A = \frac{n_A}{n_A + n_B}$$

$$= \frac{0.1}{0.1 + 5.54} = 0.018 \quad [1]$$

(ii) Molarity of NaOH solution

$$= \frac{\text{Mass of NaOH per litre of solution}}{\text{Molecular mass of NaOH}} = \frac{40}{40} = 1 \text{ M}$$

(iii) Mass of NaOH in 99.8 g of water = 4.0 g

$\therefore$  Mass of NaOH in 1000 g of water

$$= \frac{4.0}{99.8} \times 1000$$

$$= 40.08 \text{ g} \quad [1]$$

Molality of NaOH solution

$$= \frac{\text{Mass of NaOH per 100 g of water}}{\text{Molecular mass of NaOH}}$$

$$= \frac{40.08}{40}$$

$$= 1.002 \text{ mol kg}^{-1} \quad [1]$$



### Commonly Made Error

- ▶ Sometimes, students are unable to calculate the concentration of solution from given data.



### Answering Tip

- ▶ Understand the formulae to calculate the concentration of solution in different ways.

## Topic-2

### Raoult's Law, Ideal and Non-ideal Solutions

**Concepts Covered** • Raoult's law, Ideal solutions, Non - Ideal Solutions, Azeotropes- Maximum boiling and Minimum Boiling



#### Revision Notes

- ▶ Vapour pressure is the pressure exerted by vapours over a liquid at equilibrium state at constant temperature.
- ▶ Vapour pressure depends on the following factors:
  - Nature of the liquid:** Liquids having intermolecular forces are volatile and possess higher vapour pressure.
  - Temperature:** Vapour pressure of a liquid increases with increase in temperature.
- ▶ **Raoult's law for a solution of volatile liquids:** It 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 in solution.

Suppose a solution is prepared by mixing two volatile liquids A and B. Let  $\chi_A$  and  $\chi_B$  respectively be their mole fractions, and let  $p_A$  and  $p_B$  be their partial vapour pressures respectively in the solution at a particular temperature.

If  $p_A^0$  and  $p_B^0$  are their vapour pressures in the pure state respectively, then according to Raoult's law:

$$p_A = p_A^0 \chi_A$$

$$p_B = p_B^0 \chi_B$$

Considering Dalton's law of partial pressure,

$$p_{\text{total}} = p_A + p_B$$

Substituting values of  $p_A$  and  $p_B$ ,

$$\begin{aligned} p_{\text{total}} &= \chi_A p_A^0 + \chi_B p_B^0 \\ &= (1 - \chi_B) p_A^0 + \chi_B p_B^0 \\ &= p_A^0 + (p_B^0 - p_A^0) \chi_B \end{aligned}$$

The composition of the vapour phase in equilibrium with the solution can be determined from the partial pressure of the two components. If  $\chi_A$  and  $\chi_B$  are the mole fractions of components A and B respectively in the vapour phase, then

$$p_A = \chi_A p_{\text{total}}$$

$$\text{and } p_B = \chi_B p_{\text{total}}$$

In general  $p_i = \chi_i p_{\text{total}}$

- ▶ **Raoult's law as a special case of Henry's law:** According to Raoult's law, the vapour pressure of volatile component (A) in a given solution is given as:

$$p_A = p_A^0 \chi_A$$

According to Henry's law, in the solution of a gas in a liquid, the gaseous component is normally so volatile that it exists as a gas and solubility depends upon Henry's law to which:

$$p_A = K_H \chi_A$$

On comparing both expressions  $p_A^0$  is equal to  $K_H$ .

- ▶ **Raoult's law for non-volatile solute:** For a solution containing non-volatile solute present in a volatile solvent, Raoult's law may be stated as the relative lowering of vapour pressure for a solution is equal to the mole fraction of solute.

$$\chi_B = \frac{p_A^0 - p_A}{p_A^0},$$

where,  $\chi_B$  = Mole fraction of solute,

$p_A^0 - p_A$  = Lowering of vapour pressure.



#### Key formula

**Raoult's law for volatile liquids:** Raoult's law for volatile liquids:

$$P_{\text{solute}} = \chi_{\text{solute}} \cdot P_{\text{solute}}^0$$

$$P_{\text{solvent}} = \chi_{\text{solvent}} \cdot P_{\text{solvent}}^0$$

where,  $P^0$  is the vapour pressure of pure component

Raoult's law for non volatile solute:

$$\chi_B = (P_A^0 - P_A) / P_A^0$$

where,  $P_A^0 - P_A$  = lowering of vapour pressure

$\chi_B$  = mole fraction of solute

- ▶ **Ideal solution:** A solution which obeys Raoult's law over a wide range of concentration at specific temperature is called ideal solution.



#### Mnemonics

**Concept:** Raoult's law for Non- volatile Solute

**Mnemonics:** R.L. is Very Poor Student = Most Failure Student

**Interpretations:**

Relative Lowering Of Vapour Pressure For A Solution Is Equal To The Mole Fraction Of Solute.

- Raoult's law is obeyed.  $p_A = p_A^0 \chi_A$ ,  $p_B = p_B^0 \chi_B$
- $\Delta_{\text{mix}} H = 0$ ,
- $\Delta_{\text{mix}} V = 0$ ,
- The force of attraction between A-A and B-B is nearly equal to A-B.



Some examples of ideal solutions are:

- (i) *n*-hexane and *n*-heptane,
- (ii) Ethyl bromide and ethyl chloride,
- (iii) Benzene and toluene,
- (iv) Chlorobenzene and bromobenzene.

► **Non-ideal solution:** A solution which does not obey Raoult's law for all the concentrations is called a non-ideal solution.

(i) Raoult's law is not obeyed, i.e.,  $p_A \neq p_A^0 \chi_A$  and

$$p_B \neq p_B^0 \chi_B$$

(ii)  $\Delta_{\text{mix}}H \neq 0$ ,

(iii)  $\Delta_{\text{mix}}V \neq 0$ ,

(iv) The force of attraction between A-A and B-B is not equal to A-B.

Some examples of non-ideal solutions are:

- (i) Water and ethanol
- (ii) Chloroform and acetone
- (iii) Ethanol and cyclohexane



## Mnemonics

**Concept:** Ideal solution

**Mnemonics:** ISRAeL

**Interpretations:**

Ideal Solution Obeys Raoult's Law

**Concept:** Non-Ideal solution

**Mnemonics:** Nano Scale Device Research Laboratory

**Interpretations:**

Non-Ideal Solution Does Not Obey Raoult's Law

A non-ideal solution can show either positive or negative deviation from Raoult's law.

► **Positive deviation from Raoult's law:** In this type of deviation, A-B interactions are weaker than the interaction between A-A or B-B and leads to increase in vapour pressure.

Some examples are:

- (i) Water and ethanol,
- (ii) Chloroform and water,
- (iii) Ethanol and  $\text{CCl}_4$ ,
- (iv) Methanol and chloroform,
- (v) Benzene and methanol,
- (vi) Acetic acid and toluene.

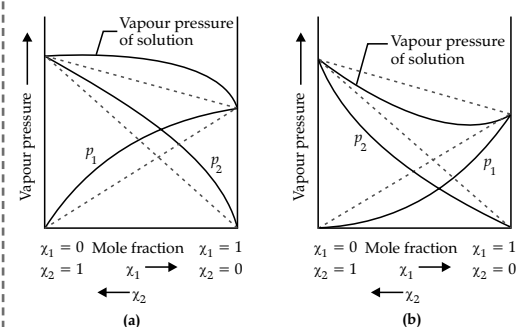
► **Negative deviation from Raoult's law:** In this type of deviation in non-ideal solutions, the intermolecular attractive forces between A-A and B-B are weaker than those between A-B and leads to decrease in vapour pressure.

Some examples are:

- (i) Chloroform and acetone,
- (ii) Chloroform and methyl acetate,
- (iii)  $\text{H}_2\text{O}$  and  $\text{HCl}$ ,
- (iv)  $\text{H}_2\text{O}$  and  $\text{HNO}_3$ ,
- (v) Acetic acid and pyridine,
- (vi) Chloroform and benzene.



## Key Diagram



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.

► **Azeotropes:** Liquid mixtures which distil over without change in composition are called constant boiling mixtures or azeotropes or azeotropic mixtures.

► **Minimum boiling azeotropes:** Non-ideal solutions showing large positive deviation from Raoult's law form minimum boiling azeotropes at a specific composition. e.g. water and benzene, chloroform and methanol.

► **Maximum boiling azeotropes:**

Non-ideal solutions showing large negative deviation from Raoult's law form maximum boiling azeotropes which boil at temperature higher than the boiling points of its components. e.g., mixture of  $\text{HNO}_3$  and  $\text{H}_2\text{O}$ .

Scan to know more about this topic



Maximum and Minimum boiling azeotropes




## OBJECTIVE TYPE QUESTIONS

(1 mark each)


### A Multiple Choice Questions

Q.1. If two liquids A and B form minimum boiling azeotrope at some specific composition then \_\_\_\_\_.

- (A) A-B interactions are stronger than those between A-A or B-B.
- (B) Vapour pressure of solution increases because more number of molecules of liquids A and B can escape from the solution.

- (C) Vapour pressure of solution decreases because less number of molecules of only one of the liquids escape from the solution.
- (D) A-B interactions are weaker than those between A-A or B-B. 



**Q. 2. At equilibrium, the rate of dissolution of a solid solute in a volatile liquid solvent is \_\_\_\_\_.**

- (A) less than the rate of crystallisation
- (B) greater than the rate of crystallisation
- (C) equal to the rate of crystallisation
- (D) zero 

**Ans. Option (C) is correct.**

**Explanation:** In equilibrium state, the rate of dissolution of a solid solute in a volatile liquid solvent is equal to the rate of crystallization.

**Q. 3. For a dilute solution, Raoult's law states that:**

- (A) The lowering of vapour pressure is equal to the mole fraction of solute.
- (B) The relative lowering of vapour pressure is equal to the mole fraction of solute.
- (C) The relative lowering of vapour pressure is proportional to the amount of solute in solution.
- (D) The vapour pressure of the solution is equal to the mole fraction of the solute.  

**Ans. Option (B) is correct.**



**Explanation:** According to Raoult's law, for a dilute solution, the relative lowering of vapour pressure is equal to the mole fraction of solute.

$$\frac{P_A^0 - P_A}{P_A^0} = X_B$$

Where

$$\frac{P_A^0 - P_A}{P_A^0} \quad \text{Relative lowering of vapour pressure}$$

X mole fraction of solute

**Q. 4. When 1 mole of benzene is mixed with 1 mole of toluene, the vapour will contain: (Given: vapour of benzene = 12.8 kPa and vapour pressure of toluene = 3.85 kPa).   [CBSE, SQP, 2020-2021]**

- (A) equal amount of benzene and toluene as it forms an ideal solution.
- (B) unequal amount of benzene and toluene as it forms a non ideal solution.
- (C) higher percentage of benzene
- (D) higher percentage of toluene

**Ans. Option (C) is correct.**

**Explanation:** When 1 mole of benzene is mixed with 1 mole of toluene the vapour will contain higher percentage of benzene. As it is an ideal solution, it follows Raoult's law.



The vapour pressure of the solution depends on the mole fraction of the solvent.

$$P_{\text{soln}} = \gamma_{\text{solvent}} P_{\text{solvent}}^0$$


$P_{\text{soln}}$  is the vapour pressure of the solution  
 $\gamma_{\text{solvent}}$  is the mole fraction of the solvent

$P_{\text{solvent}}^0$  is the vapour pressure of the pure solvent  
 Since the mole fraction of both the components is same, but the vapour pressure of benzene is higher than the toluene, its percentage will be greater in the vapour of the solution.

**Q. 5. Considering the formation, breaking and strength of hydrogen bond, predict which of the following mixtures will show a positive deviation from Raoult's law?**

- (A) Methanol and acetone.
- (B) Chloroform and acetone.
- (C) Nitric acid and water.
- (D) Phenol and aniline.  

**Q. 6. Which one is not equal to zero for an ideal solution ?**

- (A)  $\Delta H_{\text{mix}}$
- (B)  $\Delta S_{\text{mix}}$
- (C)  $\Delta V_{\text{mix}}$
- (D)  $\Delta P = P_{\text{observed}} - P_{\text{observed}}$  

**Ans. Option (B) is correct**

**Explanation:** For an ideal solution, entropy mixing ( $\Delta_{\text{mix}}S$ ) is not zero. It is positive because a solvent (or solute) in a solution has more molecular disorder.

**Q. 7. For any solution the partial vapour pressure of each volatile component in the solution is directly proportional to its \_\_\_\_\_.**

- (A) solvent molecules
- (B) mole fraction
- (C) solute molecules
- (D) non volatile component

**Ans. Option (B) is correct.**


**Explanation:** According to Raoult's law, for any solution the partial vapour pressure of each volatile component in the solution is directly proportional to its mole fraction.

## B Assertion & Reason

**Directions:** In the following questions, A statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as.

- (A) Both A and R are true and R is the correct explanation of A.
- (B) Both A and R are true but R is NOT the correct explanation of A.
- (C) A is true but R is false.
- (D) A is false and R is true.

**Q. 1. Assertion (A):** Dimethyl ether is less volatile than ethyl alcohol.

**Reason (R):** Dimethyl ether has greater vapour pressure than ethyl alcohol. 

**Ans. Option (D) is correct.**

**Explanation:** Dimethyl ether is more volatile than ethyl alcohol.

**Q. 2. Assertion (A):** Vapour pressure increase with increase in temperature.

**Reason (R):** With increase in temperature, more molecules of the liquid can go into vapour phase.

**A1**

**Ans. Option (A) is correct.**

**Explanation:** Vapour pressure increase with increase in temperature because more molecules of the liquid can go into vapour phase with increase in temperature.

**Q. 3. Assertion (A):** An ideal solution obeys Henry's law.

**Reason (R):** In an ideal solution, solute-solute as well as solvent-solvent interactions are similar to solute-solvent interaction.

**A1**  [CBSE Delhi Set-III, 2020]

**Q. 4. Assertion (A):** If one component of a solution obeys Raoult's law over a certain range of composition, the other component will not obey Henry's law in that range.

**Reason(R):** Raoult's law is a special case of Henry's law.

**Ans. Option (B) is correct.**

**Q. 5. Assertion(A):** In an ideal solution,  $\Delta_{\text{mix}} H$  is zero.

**Reason(R):** In an ideal solution, A – B interactions are lower than A-A and B-B interactions.

**Ans. Option (C) is correct.**

**Explanation:** In an ideal solution, A–B interactions are the same as A–A and B–B interaction



## SUBJECTIVE TYPE QUESTIONS



### Short Answer Type Questions-I (2 marks each)

**Q. 1. State Raoult's law for a solution containing volatile components. What is the similarity between Raoult's law and Henry's law?**

**A1**  [CBSE, Delhi Set 1 & 2, 2020]

**Q. 2. State Raoult's law for a solution containing volatile components. Write two characteristics of the solution which obey Raoult's law at all concentrations.**  [CBSE, Delhi Set-1, 2019]

**Ans.** 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. **[1]**

(i)  $\Delta_{\text{mix}} H = 0$  (ii)  $\Delta_{\text{mix}} V = 0$  (iii) The components have nearly same intermolecular force of attraction **[½, ½]**

**(any two) [CBSE Marking Scheme, 2019]**

**Detailed Answer:**

According to Raoult's law for a solution containing volatile components - The partial vapour pressure of each volatile components of the solution is directly proportional to mole fraction present in solution.

**Detailed Answer:**

	Ideal solution	Non-ideal solution
<b>(i) Raoult's Law</b>	Solutions which obey Raoult's law over the entire range of concentrations.	Do not obey Raoult's law over the entire range of concentrations.
<b>(ii) <math>\Delta_{\text{mix}} H</math></b>	The enthalpy of mixing of the pure components to form a solution is zero. $\Delta_{\text{mix}} H = 0$	The enthalpy of mixing of pure components to form a solution is not zero. $\Delta_{\text{mix}} H > 0$
<b>(iii) <math>\Delta_{\text{mix}} V</math></b>	The volume of the mixing is also zero, $\Delta_{\text{mix}} V = 0$ . That means the total volume of the solution is equal to the sum of the volume of the two components.	The volume of the mixing is not zero, $\Delta_{\text{mix}} V \neq 0$ . The total volume of the solution is not equal to the sum of the volume of the two components.

The ideal solutions have characteristics to obey Raoult's law for the following conditions.

(i) The enthalpy of mixing of the pure components to form the solution is zero,  $\Delta_{\text{mix}} H = 0$ . That means no heat is absorbed or released during the mixing of the two pure components.

(ii) The volume of the mixing also be zero,  $\Delta_{\text{mix}} V = 0$ . That means the total volume of the solution is equal to the sum of the volume of the two components.

(iii) In pure components, A and B, the intermolecular attractions between solute-solute interactions and solvent-solvent interaction are almost similar to the solute-solvent interaction.

**(Any two) [2]**

**Q. 3. Write two differences between ideal solutions and non-ideal solutions.**  [CBSE, Delhi Set 2, 2019]

**Ans.**

Ideal solution	Non-ideal solution
Obeys Raoult's law at all range of concentrations.	Does not obey
$\Delta_{\text{mix}} H = 0, \Delta_{\text{mix}} V = 0$	$\Delta_{\text{mix}} H \neq 0, \Delta_{\text{mix}} V \neq 0$ (or any other difference)

**[1 + 1] [CBSE Marking Scheme, 2019]**

(iv) Intermolecular interactions	In pure components, A and B, the intermolecular attractions between solute-solute interactions and solvent-solvent interactions are almost similar to the solute-solvent interaction.	In pure components, A and B, the intermolecular attractions between solute-solute interactions and solvent-solvent interaction are not similar to the solute-solvent interaction.
-------------------------------------	---	---

[2]

Q. 4. Give reasons:

- (a) A decrease in temperature is observed on mixing ethanol and acetone.  
 (b) Potassium chloride solution freezes at a lower temperature than water. [2]

[AI] [Ap] [CBSE, Outside Delhi, 2019]

Ans. (a) Ethanol-acetone interaction is weaker than pure ethanol or acetone interactions.

- (b) On adding KCl, vapour pressure of the solution decreases [1 + 1]

[CBSE Marking Scheme 2019]

Detailed Answer:

- (a) When ethanol is mixed with acetone, it shows positive deviation from Raoult's law and acetone molecules get in between the host molecules and break some hydrogen bonds, which requires higher energy than energy released in the formation of new hydrogen bonds. This results fall in temperature.  
 (b) According to Raoult's law, when a non-volatile solid is added to the solvent, its vapour pressure decreases resulting in decrease in freezing point. Also, the freezing point of water is higher than when water contains KCl. [2]

Q. 5. Give reasons:

- (a) An increase in temperature is observed on mixing chloroform and acetone.  
 (b) Aquatic animals are more comfortable in cold water than in warm water. [2]

[AI] [Ap] [CBSE, Outside Delhi Set 3, 2019]

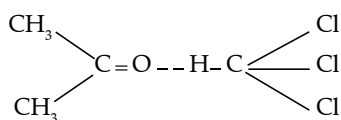
Ans. (a) Due to stronger interaction between chloroform and acetone than pure chloroform or acetone interactions. [1]

- (b) Because of high solubility of oxygen gas /low  $K_H$  value in cold water than in warm water. [1]

[CBSE Marking Scheme 2019]

Detailed Answer:

- (a) On addition of chloroform and acetone, chloroform forms strong hydrogen bonding with acetone.



This results in release of energy due to increase in attractive forces. Hence, the dissolution is an exothermic process.

- (b) At a given pressure, the solubility of oxygen in water increases with decrease in temperature. Therefore, the concentration of oxygen in sea is more in cold water and thus, the presence of more oxygen at lower temperature makes the aquatic animals more comfortable in cold water. [2]

Q. 6. Define the following terms:

- (i) Ideal solution (ii) Molarity (M) [2]

[AI] [R] [CBSE, Delhi Set 2, 2017]

Ans. (i) The solution that obeys Raoult's Law over the entire range of concentration. [1]

- (ii) Number of moles of solute dissolved per litre of solution or  $M = \frac{w_b \times 1000}{M_b \times V(\text{mL})}$ . [1]

[CBSE Marking Scheme, 2017]

Detailed Answer:

- (i) An ideal solution which obeys Raoult's law over entire range of concentration. The necessary condition to reach ideal solution is:  
 Enthalpy of mixing of the pure components to form the solution,  $\Delta H_{\text{mix}} = 0$  and volume of mixing,  $\Delta V_{\text{mix}} = 0$  [1]  
 (ii) Molarity is defined as the number of moles of solute present in 1000 mL of the solution. Molarity is represented by M.

$$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution in mL}} \times 1000 \quad [1]$$

Q. 7. Why a mixture of carbon disulphide and acetone shows positive deviation from Raoult's law? What type of azeotrope is formed by this mixture? [1]

- Ans. Intermolecular forces of attraction between carbon disulphide and acetone are weaker than the pure components. [1]  
 Minimum boiling azeotrope at a specific composition. [1]



### Short Answer Type Questions-II (3 marks each)

Q. 1. (a) Define vapour pressure of the liquid.

- (b) (i) Gas (A) is more soluble in water than Gas (B) at the same temperature. Which one of the two gases will have the higher value of  $K_H$  (Henry's constant) and why?

- (ii) In non-ideal solution, what type of deviation shows the formation of maximum boiling azeotropes? [R] + [Ap]

**Ans. (a)** The pressure exerted by the vapours above the liquid surface in equilibrium with the liquid at a given temperature is called vapour pressure of the liquid. [1]

**(b) (i)** Gas B will have the higher value of  $K_H$  (Henry's constant) as lower is the solubility of the gas in the liquid higher is the value of  $K_H$ . [1]


**(ii)** In non-ideal solution, negative deviation shows the formation of maximum boiling azeotropes. [1]

**Q. 2. (i)** Give the factors affecting the vapour pressure of a liquid.

**(ii)** Suggest the most important type of intermolecular attractive interaction in the following pairs:

(a) *n*-hexane and *n*-octane

(b)  $I_2$  and  $CCl_4$   [1]

**Q. 3.** In aqueous solution containing 20% by weight of liquid 'A' (Mol.wt = 140) has vapour pressure of 160 mm at 57° C. Find the vapour pressure of pure A, if that of water is 150 mm at this temperature.  [1]

**Q. 4.** The vapour pressure of pure liquids A and B at 400 K are 450 and 700 mm Hg respectively. Find out the composition of liquid mixture if total pressure at this temperature is 600 mm Hg.

 [CBSE Comptt. Delhi 2017]

**Ans.**  $p_{\text{total}} = p_1^0 + (p_2^0 - p_1^0)x_2$  [1]

$$600 = 450 + (700 - 450)x_2 \quad [1]$$

$$x_2 = 0.6 \quad [1/2]$$

$$x_1 = 1 - 0.6 = 0.4 \quad [1/2]$$

[CBSE Marking Scheme 2017]

**Detailed Answer:**

$$p_A^0 = 450 \text{ mm Hg}, p_B^0 = 700 \text{ mm Hg}$$

$$p_{\text{Total}} = 600 \text{ mm Hg}$$

According to Raoult's law,

$$p_A = \chi_A \times p_A^0$$

$$p_B = \chi_B \times p_B^0$$

$$p_{\text{Total}} = p_A + p_B$$

$$= (1 - \chi_B) p_A^0 + \chi_B p_B^0 = p_A^0 + (\chi_B p_B^0 - p_A^0) \chi_B$$

$$600 = 450 + (700 - 450)\chi_B$$

$$600 - 450 = 250\chi_B$$

$$150 = 250\chi_B$$

$$\chi_B = \frac{150}{250} = 0.6$$

$$\Rightarrow \chi_A = 1 - 0.6 = 0.4$$

**Q. 5.** Why is it not possible to obtain pure ethanol by fractional distillation? What general name is given to binary mixtures which show deviation from Raoult's law and whose components cannot be separated by fractional distillation? How many types of such mixtures are there?

 [NCERT Exemp.]

**Ans.** The solution or mixture having same composition in liquid as well as in vapour phase and boils at a constant temperature is known as azeotropes. Due to constant composition, it cannot be separated by fractional distillation. There are two types of azeotropes:

**(i) Minimum boiling azeotropes:** Solution which shows large positive deviation from Raoult's law form minimum boiling azeotropes at a specific composition, e.g., ethanol-water mixture.

**(ii) Maximum boiling azeotropes:** Solutions which show large negative deviation from Raoult's law form maximum boiling azeotropes, e.g., solution having composition 68%  $HNO_3$  and 32% water by mass.



### Long Answer Type

#### Questions

(5 marks each)

**Q. 1. (a)** 30 g of urea ( $M = 60 \text{ g mol}^{-1}$ ) is dissolved in 846 g of water. Calculate the vapour pressure of water for this solution if vapour pressure of pure water at 298 K is 23.8 mm Hg.

**(b)** Write two differences between ideal solutions and non-ideal solutions.

 +  [CBSE OD Set-1, 2 & 3, 2017]

**Ans. (a) (i)**  $(p_A^0 - p_A)/p_A^0 = (w_B \times M_A)/(M_B \times w_A)$

$$\frac{23.8 - p_A}{23.8} = (30 \times 18)/60 \times 846 \quad 1$$

$$23.8 - p_A = 23.8 \times [(30 \times 18)/60 \times 846] \quad 1/2$$

$$23.8 - p_A = 0.2532 \quad 1/2$$

$$p_A = 23.8 - 0.2532$$

$$= 23.55 \text{ mmHg} \quad 1$$

**(b)**

Ideal solution	Non-ideal solution
(a) It obeys Raoult's law over the entire range of concentration.	(a) Does not obeys Raoult's law over the entire range of concentration.
(b) $\Delta_{\text{mix}} H = 0$	(b) $\Delta_{\text{mix}} H$ is not equal to 0.
(c) $\Delta_{\text{mix}} V = 0$	(c) $\Delta_{\text{mix}} V$ is not equal to 0.

1 + 1 (Any two correct difference)

[CBSE Marking Scheme, 2017]

OR



Topper Answer, 2017

(a) Given mass of solute ( $w_2$ ) = 30g.  
 molar mass of solute,  $M_2 = 60 \text{ g mol}^{-1}$ .  
 mass of solvent ( $w_1$ ) = 846g.  
 molar mass of solvent,  $M_1 = 18 \text{ g mol}^{-1}$ .  
 at 298K,  
 Vapour pressure of pure solvent ( $P_1^\circ$ ) = 23.8 mmHg.  
 Vapour pressure of solution,  $P_1$  (let)  
 Since,  
 relative lowering in vapour pressure is a colligative property  

$$\frac{P_1^\circ - P_1}{P_1^\circ} = x_2 \quad [x_2 \rightarrow \text{mole fraction of solute}]$$
  

$$x_2 = \frac{n_2}{n_1 + n_2}$$
  
 now, no. of moles of solute,  $n_2 = \frac{30}{60} = 0.5 \text{ mol}$   
 & no. of moles of solvent,  $n_1 = \frac{846}{18} = 47 \text{ mol}$   

$$\therefore x_2 = \frac{0.5}{47 + 0.5} = \frac{0.5}{47.5} = \frac{5}{475} = \frac{1}{95}$$

$$\therefore \frac{P_1^\circ - P_1}{P_1^\circ} = \frac{1}{95}$$

$$\Rightarrow \frac{23.8 - P_1}{23.8} = \frac{1}{95}$$

$$\Rightarrow 23.8 - P_1 = \frac{23.8}{95}$$

$$23.8 - P_1 = 0.2505$$

$$\Rightarrow P_1 = 23.8 - 0.2505$$

$$= 23.5495 \text{ mmHg}$$

$$\therefore P_1 \approx 23.55 \text{ mmHg}$$

Vapour pressure of given solution at 298K is 23.55 mmHg.

Ideal Solution	Non-Ideal Solution
(i) The solution which follows Raoult's law strictly over the entire range of temperature & concentration, is called ideal solution.	(i) The solution which does not follow Raoult's law is called non-ideal solution.
(ii) The change in enthalpy of mixture, $\Delta H_{\text{mix}} = 0$ , and the change in volume of mixture, $\Delta V_{\text{mix}} = 0$ . The interaction between A---B is the same as those between A---A and B---B. - Solution of n-hexane and n-heptane.	(ii) The change in enthalpy of mixture, $\Delta H_{\text{mix}} \neq 0$ and the change in volume of mixture, $\Delta V_{\text{mix}} \neq 0$ . (iii) The interaction between A---B is not the same as in A---A and B---B. Example - solution of phenol and aniline.

**Commonly Made Error**

- Some students cannot calculate the vapour pressure of water for the solution from given data.

**Answering Tip**

- Students must understand the relationship between relative lowering of vapour pressure and mole fraction.

**Q. 2.** The vapour pressures of ethanol and methanol are 44.5 mm Hg and 88.7 mm Hg respectively. An ideal solution is formed at the same temperature by mixing 60 g of ethanol with 40 g of methanol. Calculate the total vapour pressure of the solution and the mole fraction of methanol in the vapour.

[AP]

**Ans.** Mass of ethanol = 60 g

Molecular mass of ethanol ( $C_2H_5OH$ )  
 $= (12 \times 2) + (1 \times 5) + 16 + 1 = 46$

$\therefore$  Number of moles of ethanol  $= \frac{60}{46} = 1.304$  [½]

Given mass of methanol = 40 g

Molecular mass of methanol ( $CH_3OH$ )  
 $= (12 \times 1) + (1 \times 3) + 16 + 1 = 32$

$\therefore$  Number of moles of methanol  $= \frac{40}{32} = 1.250$  [½]

$$\text{Mole fraction of ethanol} = \frac{1.304}{1.304 + 1.250} = 0.51 \quad [½]$$

$$\text{Mole fraction of methanol} = 1 - 0.51 = 0.49 \quad [½]$$

Vapour pressure of pure ethanol

$$p_{C_2H_5OH}^{\circ} = 44.5 \text{ mm}$$

Vapour pressure of pure methanol

$$p_{CH_3OH}^{\circ} = 88.7 \text{ mm}$$

Vapour pressure due to ethanol

$$\begin{aligned} p_{C_2H_5OH} &= p_{C_2H_5OH}^{\circ} \times 0.51 \\ &= 44.5 \text{ mm} \times 0.51 = 22.69 \text{ mm} \quad [½] \end{aligned}$$

Vapour pressure due to methanol,

$$\begin{aligned} p_{CH_3OH} &= p_{CH_3OH}^{\circ} \times 0.49 \\ &= 88.7 \text{ mm} \times 0.49 = 43.46 \text{ mm} \quad [½] \end{aligned}$$

Total Vapour pressure

$$\begin{aligned} &= p_{C_2H_5OH} + p_{CH_3OH} \\ &= 22.69 + 43.46 = 66.15 \text{ mm} \quad [1] \end{aligned}$$

Mole fraction of methanol in the vapour state

$$\begin{aligned} &= \frac{p_{CH_3OH}}{\text{Total vapour pressure}} = \frac{43.46}{66.15} \quad [1] \\ &= 0.657 \end{aligned}$$

**Q. 3.** What is meant by positive and negative deviations from Raoult's law and how is the sign of  $\Delta_{\text{mix}}H$  related to positive and negative deviations from Raoult's law?

**Topic- 3****Colligative Properties, Determination of Molecular Mass, abnormal Molecular Mass, van't Hoff Factor**

**Concepts Covered** • Colligative properties, calculation of abnormal molecular mass and Van't Hoff Factor

**Revision Notes**

- **Colligative properties:** Certain properties of solutions depend only on the number of particles of the solute (molecules or ions) and do not depend on the nature of solute, such properties are called colligative properties. These are:
- Relative lowering of vapour pressure,
  - Depression of freezing point,
  - Elevation of boiling point,
  - Osmotic pressure of the solution.
- **Relative lowering of vapour pressure:** The relative lowering of vapour pressure is the ratio of lowering

of vapour pressure and vapour pressure of pure solvent which is equal to the mole fraction of solute.

$$\text{Vapour pressure of pure solvent} = p_A^{\circ}$$

$$\text{Lowering of vapour pressure} = p_A^{\circ} - p_A$$

Relative lowering of vapour pressure

$$\frac{p_A^{\circ} - p_A}{p_A^{\circ}} = \chi_{\text{solute}} = \frac{n}{N + n}$$

where  $n$  and  $N$  are the number of moles of solute and solvent respectively.

- **Elevation of the boiling point:** The difference in boiling point of solution and pure solvent is called elevation of the boiling point.

Boiling point of pure solvent =  $T_b^\circ$

Boiling point of solution =  $T_b$

Increase in boiling point  $\Delta T_b = T_b - T_b^\circ$  is known as elevation of boiling point for dilute solution.

$$\Delta T_b \propto m$$

$$\Delta T_b = K_b m$$

$$\Delta T_b = \frac{K_b \times 1000 \times w_2}{M_2 \times w_1}$$

Where,

$w_2$  = weight of solute in g

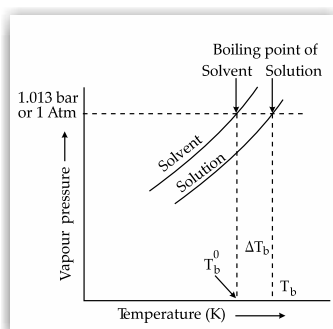
$M_2$  = Molar mass of solute

$w_1$  = weight of solvent in g

$$\Delta T_b = K_b m$$

$K_b$  = Boiling point elevation constant or molal elevation constant or **Ebullioscopic constant**.

### Key Diagram



Elevation of boiling point

- **Depression of freezing point:** According to Raoult's law, when a non-volatile solid is added to the solvent its vapour pressure decreases and it would become equal to that of solid solvent at lower temperature. Thus, the difference in the freezing point of pure solvent and that of the solution is known as depression of freezing point.

The freezing point of pure solvent =  $T_f^\circ$

The freezing point when non-volatile solute is dissolved in it =  $T_f$  (Freezing point of solution)

The decrease in freezing point  $\Delta T_f = T_f^\circ - T_f$  is known as depression in freezing point.

For dilute solution,

$$\Delta T_f \propto m$$

$$\Delta T_f = K_f m.$$

We know,

$$(i) \quad \frac{W_B \times 1000}{M_B \times W_A} = \text{molality}$$

$$(ii) \quad \Delta T_f = \frac{K_f \times 1000 \times W_2}{M_2 \times W_1}$$

$K_f$  = Freezing point depression constant or molal depression constant or **Cryoscopic constant**.

### Key Diagram

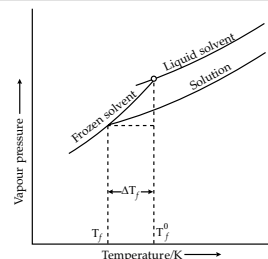


Diagram showing  $\Delta T_f$ , depression of the freezing point of a solvent in a solution.

### Key Formulae

- **Modified equations for colligative properties :**  
(i) Relative lowering of vapour pressure of solvent

$$\frac{p_A^\circ - p_A}{p_A^\circ} = \frac{n}{N+n}$$

- (ii) Elevation of boiling point

$$\Delta T_b = iK_b m$$

- (iii) Depression of freezing point

$$\Delta T_f = iK_f m$$

- (iv) Osmotic pressure of solution

$$\pi = \frac{imRT}{V}$$

or

$$\pi = iCRT \quad \left[ \because \frac{m}{V} = C \right]$$

- **Osmosis:** The process in which there is net flow of solvent to the solution by a semipermeable membrane is called osmosis.

- **Osmotic pressure:** The extra pressure that is applied to stop the flow of solvent to solution across a semipermeable membrane is called osmotic pressure of the solution.

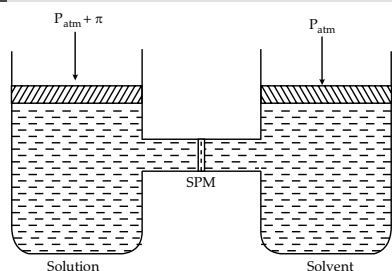
For dilute solution, osmotic pressure is proportional to the molar concentration (C) of the solution at a given temperature T.

Thus  $\pi = CRT$  as  $\pi$  is the osmotic pressure and R is the gas constant.

$\pi = \frac{n}{VRT}$  ( $n$  is the number of moles,  $V$  is the volume of solution)



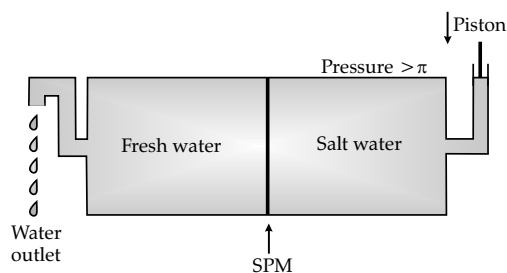
### Key Diagram



The excess pressure equal to the osmotic pressure must be applied on the solution side to prevent osmosis.

- **Reverse osmosis:** The direction of osmosis can be reversed, if a pressure larger than the osmotic pressure is applied to the solution side. Now the pure solvent flows out of the solution through the semipermeable membrane. This phenomenon is called reverse osmosis.

### Key Diagram



Reverse osmosis occurs when a pressure larger than the osmotic pressure is applied to the solution.

- **Abnormal molecular mass:** When the molecular mass calculated with the help of colligative property is different from theoretical molecular mass, it is called abnormal molecular mass.
- **van't Hoff factor ( $i$ ):** The ratio of the observed (experimental) value of a colligative property to the normal (calculated) value of the same property is called as van't Hoff factor.

Mathematically,

$$i = \frac{\text{Observed (experimental) value of a colligative property}}{\text{Normal (calculated) value of the same colligative property}}$$

Or, 
$$i = \frac{\Delta_{\text{obs}}}{\Delta_{\text{cal}}}$$

where  $\Delta_{\text{obs}}$  and  $\Delta_{\text{cal}}$  respectively represent the observed and calculated value of a colligative property.

Thus,

- (i) For lowering of vapour pressure,

$$i = \frac{(\Delta p)_{\text{obs}}}{(\Delta p)_{\text{cal}}}$$

- (ii) For elevation of boiling point,

$$i = \frac{(\Delta T_b)_{\text{obs}}}{(\Delta T_b)_{\text{cal}}};$$

- (iii) For depression of freezing point,

$$i = \frac{(\Delta T_f)_{\text{obs}}}{(\Delta T_f)_{\text{cal}}}$$

- (iv) For osmotic pressure,

$$i = \frac{\pi_{\text{obs}}}{\pi_{\text{cal}}}$$

Since a colligative property is proportional to number of particles of solute.

$$i = \frac{\text{Normal molecular mass}}{\text{Observed molecular mass}}$$

Normal molecular mass =  $i \times$  Calculated molecular mass.

$$i = \frac{\text{Total number of moles of particle after association/dissociation}}{\text{Total number of moles of particle before association/dissociation}}$$

- **Hypertonic solution:** A solution is called hypertonic, if its concentration is higher than that of the solution separating it by a semipermeable membrane.
- **Hypotonic solution:** A solution is called hypotonic, if its concentration is lower than that of the solution separating it by a semipermeable membrane.
- **Isotonic solution:** Two solutions are called isotonic, if they exert the same osmotic pressure at a given temperature. Isotonic solutions have same molar concentration. When such solutions are separated by semipermeable membrane no osmosis occurs between them.



### Mnemonics

**Concept:** Different Colligative properties

**Mnemonics:** RLVP\_DFP\_EBP\_OP

**Interpretations:**

Relative Lowering Of Vapour Pressure

Depression OF Freezing Point

Elevation Of Boiling Point

Osmotic Pressure

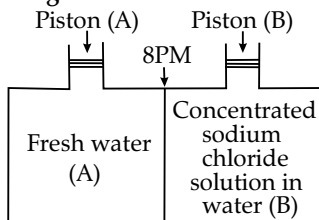


## OBJECTIVE TYPE QUESTIONS

(1 mark each)

### A Multiple Choice Questions

Q. 1. Consider the figure and mark the correct option.



- (A) Water will move from side (A) to side (B) if pressure lower than osmotic pressure is applied on piston (B).  
 (B) Water will move from side (B) to side (A) if pressure greater than osmotic pressure is applied on piston (B).  
 (C) Water will move from side (B) to side (A) if pressure equal to osmotic pressure is applied on piston (B).  
 (D) Water will move from side (A) to side (B) if pressure equal to osmotic pressure is applied on piston (A).

Ans. Option (B) is correct.

*Explanation:* Water will move from side (B) to side (A) if a pressure greater than osmotic pressure is applied on piston (B). This is a process of reverse osmosis.

Q. 2. Which of the following is not an example of osmosis?

- (A) Raw mangoes shrivel when pickled in brine  
 (B) Wilted flowers revive when placed in fresh water  
 (C) Blood cells collapse when suspended in saline water.  
 (D) Exchange of gases in lungs.

Q. 3. Osmotic pressure of a sugar solution is 2.46 atmosphere at 27°C. What will be the concentration of solution in g/litre?

- (A) 26.6 g/litre (B) 38.8 g/litre  
 (C) 24.2 g/litre (D) 34.2 g/litre

Ans. Option (D) is correct.

*Explanation:*  $T = 27 + 273 = 300 \text{ K}$

Osmotic Pressure  $\pi = CRT$

$$\begin{aligned} \therefore C &= \frac{\pi}{RT} \\ &= \frac{2.46}{0.0821 \times 300} \\ &= 0.1 \text{ mol/L} \end{aligned}$$

Molar mass of sucrose ( $C_{12}H_{22}O_{11}$ ) = 342

$$\begin{aligned} \text{Osmotic pressure in g / litre} &= 0.342 \text{ g/litre} \\ &= 34.2 \text{ g/litre} \end{aligned}$$

Q. 4. Which of the following methods is most suitable for determination of molecular mass of polymers?

- (A) Vapour pressure (B) Boiling point  
 (C) Osmotic pressure (D) Freezing point

Ans. Option (C) is correct.

*Explanation:* Molecular mass of polymers can be calculated using osmotic pressure method. This is because the values given by other colligative properties are so low that they cannot be measured.

Q. 5. Which of the following solutions has the highest boiling point at one atmospheric pressure?

- (A) 0.1 M NaCl (B) 0.1 M Sucrose  
 (C) 0.1 M  $CaCl_2$  (D) 0.1 M Glucose

Ans. Option (C) is correct.

*Explanation:* Since,

$$\begin{aligned} \Delta T_b &= imK_b \\ \Delta T_b &= T_b - T_b^0 \end{aligned}$$

So,  $\Delta T_b \propto i$

For NaCl,  $i = 2$ ; For sucrose,  $i = 1$

For  $CaCl_2$ ,  $i = 3$ ; For glucose,  $i = 1$

Hence, 0.1 M  $CaCl_2$  has highest boiling point at 1 atm.

Q. 6. A solution of glucose is prepared with 0.052 g of glucose in 80.2 g of water. Molality of the given solution is:

- (A) 0.0052 m (B) 0.0036 m  
 (C) 0.0006 m (D) 1.29 m

Ans. Option (B) is correct.

$$\begin{aligned} \text{Explanation: } m &= \frac{0.052}{180} \times \frac{1000}{80.2} \\ m &= 0.0036 \end{aligned}$$

Q. 7. When a non volatile solid is added to pure water it will:

- (A) boil above 100°C and freeze above 0°C  
 (B) boil below 100°C and freeze above 0°C  
 (C) boil above 100°C and freeze below 0°C  
 (D) boil below 100°C and freeze below 0°C

Ans. Option (C) is correct.

*Explanation:* This is in relation with colligative property elevation of boiling point and depression of freezing point.

Q. 8. Assume three samples of juices A, B and C have glucose as the only sugar present in them.

The concentration of sample A, B and C are 0.1M, 0.5 M and 0.2 M respectively. Freezing point will be highest for the fruit juice:

- (A) A  
 (B) B

- (C) C  
(D) All have same freezing point

**Ans. Option (A) is correct.**

**Explanation:** Lower the molar mass, higher is the freezing point.

**Q. 9. The value of van't Hoff factors for  $K_2SO_4$ , NaCl and KCl is:**

- (A) 2,2,2                      (B) 3,2,2  
(C) 2,2,3                      (D) 3,3,2

**Ans. Option (B) is correct.**

**Explanation:**  $K_2SO_4$  ionizes to give  $2K^+$  and  $SO_4^-$  ions (total 3 ions). NaCl gives  $Na^+$  and  $Cl^-$  ions (total 2 ions) KCl gives  $K^+$  and  $Cl^-$  ions (total 2 ions).

## B Assertion & Reason

**Directions:** In the following questions, A statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as.

- (A) Both A and R are true and R is the correct explanation of A.  
(B) Both A and R are true but R is NOT the correct explanation of A.  
(C) A is true but R is false.  
(D) A is false and R is true.

**Q. 1. Assertion (A):** Elevation in boiling point is a colligative property.

**Reason (R):** Elevation in boiling point is directly proportional to molarity.

 [CBSE Delhi Set-I, II 2020]

**Q. 2. Assertion (A):** 0.1 M solution of KCl has great osmotic pressure than 0.1 M solution of glucose at same temperature.

**Reason (R):** In solution KCl dissociates to produce

more number of particles.

 [CBSE Delhi Set 2, 2020]

**Ans. Option (A) is correct.**

**Explanation:** KCl is ionic compound, hence dissociates into ions but glucose is a covalent compound which does not dissociate into ions.

**Q. 3. Assertion:** When NaCl is added to water a depression in freezing point is observed.


**Reason:** The lowering of vapour pressure of a solution causes depression in the freezing point.

**Ans. Option (A) is correct.**

**Explanation:** When a non-volatile solute is added to water, freezing point lowers due to lowering of vapour pressure.


**Q. 4. Assertion:** When methyl alcohol is added to water, boiling point of water decreases.

**Reason:** When a volatile solute is added to a volatile solvent, elevation in boiling point is observed. 

**Ans. Option (C) is correct.**

**Explanation:** When methyl alcohol (volatile) is added to water, boiling point of water decreases because vapour pressure increases when volatile solute is added to volatile solvent.

**Q. 5. Assertion (A):** Osmosis is the process used in desalination of sea water.

**Reason (R):** The direction of osmosis can be reversed if a pressure smaller than the osmotic pressure is applied to the solution side. 

**Ans. Option (C) is correct.**

**Explanation:** Reverse osmosis is used in desalination of sea water. Reverse osmosis takes place at very high pressure.



## SUBJECTIVE TYPE QUESTIONS



### Short Answer Type Questions-I (2 marks each)

**Q. 1. Give reasons:**

- (a) Cooking is faster in pressure cooker than in cooking pan.  
(b) Red Blood Cells (RBC) shrink when placed in saline water but swell in distilled water.

 [CBSE OD Set-1 2019]

**Ans. (a)** In case of liquids, due to increase of pressure inside the cooker, the boiling point of water increases leading to faster cooking than in pan.

- (b) RBC shrink in saline water due to loss of water owing to exosmosis. In distilled water they swell due to endosmosis as the water enters the RBC.

[1+1]

**Q. 2. Calculate the freezing point of a solution containing 60 g of glucose (Molar mass =  $180 \text{ g mol}^{-1}$ ) in 250 g of water. ( $K_f$  of water =  $1.86 \text{ K kg mol}^{-1}$ )**

 [CBSE D/OD, 2018]

**Ans.**

$$\Delta T_f = K_f m$$

$$= K_f \times \frac{w_2 \times 1000}{M_2 \times w_1}$$

$$= \frac{1.86 \times 60 \times 1000}{180 \times 250}$$

$$= 2.48 \text{ K}$$

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

$$2.48 = 273.15 - T_f$$

$$T_f = 273.15 - 2.48 = 270.67 \text{ K} \quad [2]$$

Concept Applied

Depression of freezing point

OR



Topper Answer, 2018

j) Mass of glucose,  $W_2 = 60\text{g}$   
 Molar mass of glucose,  $M_2 = 180\text{g mol}^{-1}$   
 Mass of water,  $W_1 = 250\text{g}$   
 $K_f = 1.86\text{ K kg mol}^{-1}$   
 Molality of the solution,  $m = \frac{W_2 \times 1000}{M_2 \times W_1}$   
 $m = \frac{60\text{g} \times 1000}{180\text{g mol}^{-1} \times 250\text{g}}$

$\log(1.24) = 0.09345$   
 $\log(1.15) = 0.1239$   
 diff. (0.3944)  
 2.479

$T_f^* - T_f = 2.474\text{K} \quad 2.48\text{K}$   
 $273.15\text{K} - T_f = 2.474\text{K} \quad 2.48\text{K}$   
 $T_f = 273.15\text{K} - 2.474\text{K} \quad 2.48\text{K}$   
 $T_f = 270.676\text{K} \quad 270.67\text{K}$   
 (or)  
 $T_f = -2.474^\circ\text{C} \quad -2.48^\circ\text{C}$

$\therefore$  The freezing point of the solution is  $270.67\text{K}$  or  $-2.48^\circ\text{C}$



### Commonly Made Error

- Students do not write applied formula or sometimes miss the next step of value assignment to all the entities in it.



### Answering Tip

- Always state the formula applied before starting the calculations. Write each step clearly as it carries marks.

Q. 3. Define the following terms:

(i) Colligative properties

(ii) Molality (m) [CBSE D/OD, 2017]

Q. 4. Define the following terms:

(i) Abnormal molar mass

(ii) van't Hoff factor ( $i$ )

[CBSE Delhi set 3, 2017]

Ans. (i) If the molar mass calculated by using any of the colligative properties to be different than theoretically expected molar mass. [1]

(ii) Extent of dissociation or association or ratio of the observed colligative property to calculated colligative property. [1]

[CBSE Marking Scheme, 2017]

Detailed Answer:

(i) **Abnormal molar mass** – There are certain cases where due to association or dissociation of molecules, the molar mass of a substance calculated from its colligative property is either lower or higher than the expected or normal value. Such molar mass is called abnormal molar mass. [1]

(ii) **van't Hoff factor** – To account for the extent of dissociation or association, van't Hoff introduced a factor  $i$ , known as the van't Hoff factor.

$$i = \frac{\text{Normal molar mass}}{\text{Abnormal molar mass}}$$

$$= \frac{\text{Observed colligative property}}{\text{Calculated colligative property}}$$

Value of  $i$  is less than 1 in case of association.

Value of  $i$  is greater than 1 in case of dissociation.

Value of  $i$  is equal to 1 in case of no association or dissociation. [1]

Q. 5. Explain why on addition of 1 mol of NaCl to 1 litre of water, the boiling point of water increases, while addition of 1 mol of methyl alcohol to one litre of water decreases its boiling point.

Ans. Sodium chloride (NaCl) is a non-volatile solute, therefore, addition of NaCl to water lowers the vapour pressure of water. As a result, boiling point of water increases. Methyl alcohol, on the other hand, is more volatile than water, hence, its addition increases the total vapour pressure of the solution and in decrease in boiling point of water results. [2]

Q. 6. 18 g of glucose,  $\text{C}_6\text{H}_{12}\text{O}_6$  (Molar Mass =  $180\text{g mol}^{-1}$ ) is dissolved in 1 kg of water in a saucepan. At what temperature will this solution boil?

( $K_b$  for water =  $0.52\text{ K kg mol}^{-1}$ , boiling point of pure water =  $373.15\text{ K}$ ) [E]

Ans.  $\Delta T_b = K_b \times m$  [1/2]

$$T_b - T_b^\circ = 0.52\text{ K kg mol}^{-1} \times \frac{18\text{g}}{180\text{g mol}^{-1}} \times \frac{1}{1\text{kg}}$$

$$\Rightarrow T_b - 373.15 = \frac{0.52}{10}$$

$$\Rightarrow T_b - 373.15 = 0.052\text{ K} \quad [1/2]$$

$$\Rightarrow T_b = 0.052 + 373.15$$

$$\therefore T_b = 373.202\text{ K} \quad [1/2]$$

Q. 7. What are colligative properties? Write the colligative property which is used to find the molecular mass of macromolecules. [R]



### Short Answer Type Questions-II (3 marks each)

Q. 1. A 4% solution w/W of sucrose ( $M = 342 \text{ g mol}^{-1}$ ) in water has a freezing point of 271.15K. Calculate the freezing point of 5% glucose ( $M = 180 \text{ g mol}^{-1}$ ) in water.

(Given: Freezing point of pure water = 273.15 K)

[AI] [Ap] [CBSE Delhi Set 1, 2019]

Ans.

$$\Delta T_f = K_f m$$

$$K_f = \Delta T_f \times \frac{M_2 \times w_1}{w_2 \times 1000} = \frac{2 \times 342 \times 96}{4 \times 1000}$$

$$= 16.4 \text{ Km}^{-1}$$

$$\Delta T_f = K_f m'$$

$$= \frac{K_f w_2 \times 1000}{M_2 \times w_1} = \frac{16.4 \times 5 \times 1000}{95 \times 180}$$

$$= 4.8 \text{ K}$$

$$\Delta T_f = T_f^\circ - T_f$$

$$4.8 = 273.15 - T_f$$

$$T_f = 268.35 \text{ K}$$

[CBSE Marking Scheme, 2019]

OR



Topper Answer, 2019

14. Concentration of sucrose solution = 4% (w/w)  
 (considering 100g of solution)  
 Mass of sucrose = 4g ( $m_s$ )  
 Mass of water = 100 - 4 = 96g ( $m_w$ )  
 Molar mass of sucrose,  $M_s = 342 \text{ g mol}^{-1}$   
 Moles of sucrose molecules  
 $n_s = \frac{m_s}{M_s} = \frac{4}{342} \text{ mol} = 2 \text{ mol}$   
 $\frac{171}{171}$

Molality of solution =  $\frac{n_s}{m_w \text{ (in kg)}}$   
 $m = \frac{2 (1000)}{171 (96)} \text{ mol kg}^{-1}$   
 $m = \frac{2000}{171 \times 96} \text{ mol kg}^{-1}$

Freezing point of solution = 271.15 K  
 Depression in freezing point = (273.15 - 271.15)  
 $= 2 \text{ K} = \Delta T$

Now,  $\Delta T_f = K_f m$   
 where  $K_f$  = molal depression constant of water.

Substituting values,  
 $2 = K_f \times \frac{2000}{171 \times 96}$   
 OR  $K_f = \frac{2 \times 171 \times 96}{2000} = \frac{171 \times 96}{1000} \text{ K kg mol}^{-1}$  (1)

Now, given 5% glucose solution  
 considering 100g of solution [Mass of water = 95g]  
 Mass of glucose = 5g =  $m_g$   
 Molar mass of glucose =  $180 \text{ g mol}^{-1} = M_g$   
 Moles of glucose,  $n_g = \frac{m_g}{M_g} = \frac{5}{180} \text{ mol} = 1 \text{ mol}$   
 $\frac{36}{36}$

Molality of solution =  $\frac{n_g}{m_{\text{mass of water (in kg)}}$   
 $m = \frac{1 (1000)}{36 (95)} \text{ mol kg}^{-1} = \frac{1000}{34.2} \text{ mol kg}^{-1}$

Using,  $\Delta T_f = K_f m$   
 $\Delta T_f = \frac{171 \times 96}{1000} \times \frac{1000}{36 \times 95}$  (From 1)  
 $\Delta T_f = \frac{171 \times 96}{36 \times 95} \text{ K} = 4.8 \text{ K}$

So, actual freezing point = 273.15 K - 4.8 K  
 $= 273.15$   
 $4.80$   
 $268.35$   
 $= 268.35 \text{ K}$

Hence, the freezing point of 5% glucose solution in water is 268.35 K.

Q. 2. Give reasons for the following:

- Measurement of osmotic pressure method is preferred for the determination of molar masses of macromolecules such as proteins and polymers.
- Aquatic animals are more comfortable in cold water than in warm water.
- Elevation of boiling point of 1 M KCl solution is nearly double than that of 1 M sugar solution.

[A] [CBSE Delhi/OD 2018]

Ans. (a) As compared to other colligative properties, its magnitude is large even for very dilute

solutions / macromolecules are generally not stable at higher temperatures and polymers have poor solubility / pressure measurement is around the room temperature and the molarity of the solution is used instead of molality. 1

(b) Because oxygen is more soluble in cold water or at low temperature. 1

(c) Due to dissociation of KCl /  $\text{KCl (aq)} \rightarrow \text{K}^+ + \text{Cl}^-$ ,  $i$  is nearly equal to 2. 1

[CBSE Marking Scheme, 2018]

OR



Topper Answer, 2018

(a) The measurement of osmotic pressure is preferred for the determination of molar masses of macromolecules such as proteins and polymers because  
 i) Molarity is used instead of molality.  
 ii) Observation is made around room temperature. Since, biomolecules are unstable at high temperature, this is best method.  
 iii) Its value is large even for very dilute solution. So, polymers having poor solubility can use this method to find their molar mass.

(b) Solute + Solvent  $\rightarrow$  Solution + Heat  
 Dissolution is an exothermic process and it is in equilibrium. So, according to Le Chatelier's principle, the solubility increases with decrease

in temperature. So, more oxygen dissolves in water at low temperature.

So aquatic animals are more comfortable in cold water than in warm water.

(c) Elevation in boiling point is a colligative property and depends only on number of solute particles and not on their nature.

KCl is a strong electrolyte and dissociates completely into  $\text{K}^+$  and  $\text{Cl}^-$ . Thus 1M KCl produces two ions which can be considered as double the particles (nearly).

But glucose sugar does not undergo dissociation.

Thus number of particles in 1M KCl is nearly double that of 1M sugar solution.

Since, Elevation in boiling point  $\propto$  Number of solute particles

The Elevation in boiling point is also nearly double for 1M KCl solution than 1M sugar solution.

Q. 3. A solution of glucose (molar mass =  $180 \text{ g mol}^{-1}$ ) in water has a boiling point of  $100.20^\circ\text{C}$ . Calculate the freezing point of the same solution. Molal

constants for water  $K_f$  and  $K_b$  are  $1.86 \text{ K kg mol}^{-1}$  and  $0.512 \text{ K kg mol}^{-1}$  respectively.

[AP] [CBSE Foreign Set-1, 2, 3 2017]

Q. 4. 45 g of ethylene glycol ( $C_2H_4O_2$ ) is mixed with 600 g of water. Calculate

- (i) the freezing point depression and  
(ii) the freezing point of the solution

(Given:  $K_f$  of water =  $1.86 \text{ K kg mol}^{-1}$ )

[AP] [CBSE Comptt. Delhi 2015]

Ans. (i)  $\Delta T_f = K_f m$  [½]

$\Rightarrow \Delta T_f = K_f \frac{W_B \times 1000}{M_B \times W_A}$  [½]

$\Rightarrow \Delta T_f = \frac{1.86 \text{ K kg mol}^{-1} \times 45 \text{ g} \times 1000 \text{ g kg}^{-1}}{60 \text{ g mol}^{-1} \times 600 \text{ g}}$

$\Delta T_f = 2.325 \text{ K or } 2.325 \text{ }^\circ\text{C}$  [1]

(ii)  $T_f^\circ - T_f = 2.325 \text{ }^\circ\text{C}$

$\Rightarrow 0 \text{ }^\circ\text{C} - T_f = 2.325 \text{ }^\circ\text{C}$

$\Rightarrow T_f = -2.325 \text{ }^\circ\text{C or } 270.675 \text{ K}$  [1]

[CBSE Marking Scheme 2015]



### Commonly Made Error

- Students often forget to mention the formula applied. Formula carries marks.



### Answering Tip

- Write working formula followed by data in the working formula.

Q. 5. A solution is prepared by dissolving 10 g of non-volatile solute in 200 g of water. It has a vapour pressure of 31.84 mm Hg at 308 K. Calculate the molar mass of the solute.

(Vapour pressure of pure water at 308 K

= 32 mm Hg) [AI] [AP] [CBSE OD 2015]

Q. 6. 3.9 g of benzoic acid dissolved in 49 g of benzene shows a depression in freezing point of 1.62 K. Calculate the van't Hoff factor and predict the nature of solute (associated or dissociated).

(Given: Molar mass of benzoic acid =  $122 \text{ g mol}^{-1}$ ,  $K_f$  for benzene =  $4.9 \text{ K kg mol}^{-1}$ )

[AP] [CBSE Delhi, 2015]

Ans.  $\Delta T_f = iK_f m$

$m = \frac{W_B \times 1000}{M_B \times W_A}$

$\Delta T_f = \text{Depression in Freezing point} = 1.62$

$i = \text{van't Hoff factor}$

$K_f = \text{constant} = 4.9$

$m = \frac{3.9 \times 1000}{122 \times 4.9}$

= 0.65

$i = \frac{\Delta T}{K_f \times m}$

=  $\frac{1.62}{4.9 \times 0.65}$

= 0.50

As the value of  $i < 1$ , the solute is associated.



## Long Answer Type

### Questions

(5 marks each)

Q. 1. (i) A 10% solution (by mass) of sucrose in water has a freezing point of 269.15 K. Calculate the freezing point of 10% glucose in water if the freezing point of pure water is 273.15 K.

Given: (Molar mass of sucrose =  $342 \text{ g mol}^{-1}$ )

(Molar mass of glucose =  $180 \text{ g mol}^{-1}$ )

[CBSE Delhi Set-1, 2, 3 2017]

(ii) Define the term: Molality (m)

[AI] [AP] + [R] [CBSE OD Set-1, 2, 3 2017]

Q. 2. (a) When 2.56 g of sulphur was dissolved in 100 g of  $CS_2$ , the freezing point lowered by 0.383 K. Calculate the formula of sulphur ( $S_x$ ). ( $K_f$  for  $CS_2 = 3.83 \text{ K kg mol}^{-1}$ , Atomic mass of Sulphur =  $32 \text{ g mol}^{-1}$ ).

(b) Blood cells are isotonic with 0.9% sodium chloride solution. What happens if we place blood cells in a solution containing;

(i) 1.2% sodium chloride solution ?

(ii) 0.4% sodium chloride solution ?

[AP]

Ans. (a)  $\Delta T_f = \frac{K_f W_b \times 1000}{M_b \times W_a}$  [1]

$0.383 = \left( \frac{3.83 \times 2.56}{M \times 100} \right) \times 1000$  [1]

$M = 256$

$S \times x = 256$

$32 \times x = 256$

$x = 8$

[1]

(b) (i) Shrinks

[1]

(ii) Swells

[1]

[CBSE Marking Scheme, 2016]

Detailed Answer:

(b) (i) Water moves out from blood cell, hence will shrink. (ii) Water will enter into blood cell, hence will swell.

[1 × 2]



## COMPETENCY BASED QUESTIONS (4 marks each)

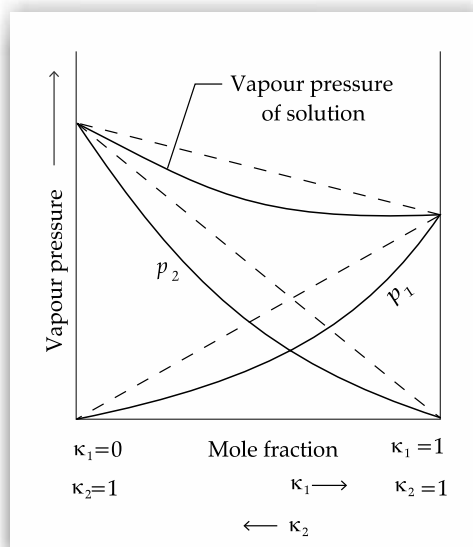


### Case based MCQs

I. Read the passage given below and answer the following questions: **AI**

Raoult's law 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. Dalton's law of partial pressure states that the total pressure ( $p_{\text{total}}$ ) 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:  

$$P_{\text{total}} = P_1 + P_2$$



Q. 1. What type of deviation from Raoult's law does the above graph represent?

- (A) First positive then negative  
 (B) Negative deviation  
 (C) Positive deviation  
 (D) First negative then positive

Ans. Option (B) is correct.

Explanation: Negative deviation

Q. 2. In comparison to a 0.01 M solution of glucose, the depression in freezing point of a 0.01 M  $\text{MgCl}_2$  solution is \_\_\_\_\_.

- (A) the same (B) about twice  
 (C) about three times (D) about six times

Ans. Option (C) is correct.

Explanation:  $\Delta T_f = iK_f m$ , where  $i=1$  for glucose.

$$\Delta T_f^{\text{glucose}} = 1 \times K_f \times 0.01$$

In case of  $\text{MgCl}_2 \rightarrow \text{Mg}^{2+} + 2\text{Cl}^-$ , where  $i = 3$ ,

$$\Delta T_f^{\text{MgCl}_2} = 3 \times 0.01 \times K_f$$

$$\Rightarrow \Delta T_f^{\text{MgCl}_2} = 3 \times \Delta T_f^{\text{glucose}}$$

Hence, the depression in freezing point of  $\text{MgCl}_2$  is three times that of glucose.

Q. 3. A solution of two liquids boils at a temperature more than the boiling point of either of them. What

type of deviation will be shown by the solution formed in terms of Raoult's law?

- (A) Negative deviation  
 (B) Positive deviation  
 (C) First positive then negative  
 (D) First negative then positive

Ans. Option (A) is correct.

Explanation: Since the boiling point of the solution is more than the boiling point of the individual components in the solution, it indicates that the vapour pressure exerted by the solution is less than the expected, as boiling starts when vapour pressure equals the atmospheric pressure. Hence, the solution shows a negative deviation from the Raoult's law.

Q. 4. Which of the following aqueous solutions should have the highest boiling point?

- (A) 1.0 M NaOH (B) 1.0 M  $\text{Na}_2\text{SO}_4$   
 (C) 1.0 M  $\text{NH}_4\text{NO}_3$  (D) 1.0 M  $\text{KNO}_3$

Ans. Option (B) is correct.

Explanation:  $\text{Na}_2\text{SO}_4$  will release 3 moles of ions/ moles of  $\text{Na}_2\text{SO}_4$  in the aqueous solution, and Boiling point being a colligative property, the Boiling point of this solution will be the highest as other solutions release only 2 ions each.

II. Read the passage given below and answer the following questions: **AI**

Solution plays a very important role in our daily life. Alloys, a homogeneous mixture of metal are solutions of solid in solid. 1 ppm (parts per million) of fluoride ions prevent tooth decay. All intravenous injections must be isotonic with our body fluids, i.e., should have the same concentration as blood plasma. Diabetic patients are more likely to have a heart attack and high blood pressure due to the higher glucose levels in the blood. Common salt increases blood pressure because  $\text{Na}^+$  mixes up with blood. Aquatic species are more comfortable in cold water than warm water.

Q. 1. What will happen if blood cells are kept in hypertonic solution?

- (A) They swell (B) They shrink  
 (C) They remain same (D) They die

Ans. Option (B) is correct.

Q. 2. When solvent and solution are separated by semi-permeable membrane, and the pressure applied on the solution side is more than the osmotic pressure, the process which takes place is:

- (A) Diffusion (B) Osmosis  
 (C) Reverse osmosis (D) Disintegration

Ans. Option (C) is correct.

Q. 3. Calculate the molarity of 30 g of  $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  in 4.3 liter of solution.

(molar mass of solute = 290.7g/mol)

- (A) 0.103 M (B) 0.24M  
 (C) 0.48 M (D) 30M

Ans. Option (B) is correct.

Explanation: No. of moles of  $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$   
 $= 30/290.7 = 0.103 \text{ mol}$

$$\text{Molarity} = 0.103/4.3 \text{ L}$$

$$= 0.239 \text{ M} \approx 0.24 \text{ M}$$

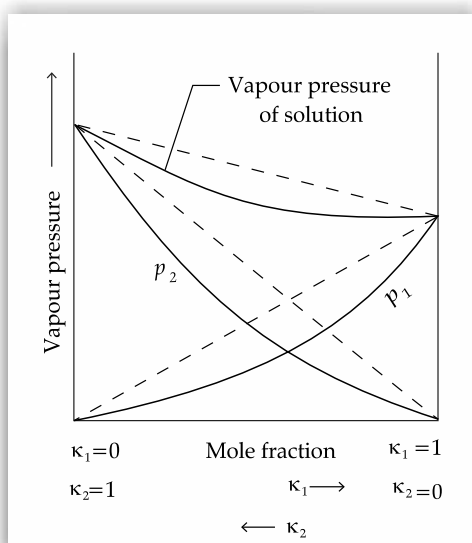




### Case based Subjective Questions

Read the passage given below and answer the following questions:

Raoult's law 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. Dalton's law of partial pressure states that the total pressure ( $p_{\text{total}}$ ) 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:  $P_{\text{total}} = P_1 + P_2$



**Q. 1.** Is the above mentioned Raoult's law applicable for non-volatile liquids ?

**Ans.** KCl in a kg of water would be expected to increase the boiling point by  $2 \times 0.52 \text{ K} = 1.04 \text{ K}$ . This could lead us to conclude that mass of 2 moles of particles is 74.5 g hence mass of 1 mole of KCl would be 37.25 g. Hence, in case of KCl where dissociation occurs experimentally determined molar mass is always lower than true value.

**Q. 2.** What type of deviation from Raoult's law does the above graph represent ?

**Ans.** Negative Deviation.

**Q. 3.** Give an example of such system.

**Ans.** A liquid mixture consisting of 20% acetone and 80% chloroform by mass.

**Q. 4.** A solution of two liquids boils at a temperature more than the boiling point of either of them. What type of deviation will be shown by the solution formed in terms of Raoult's law ?

**Ans.** Negative Deviation.



### Solutions for Practice Questions (Topic-1)

#### Multiple Choice Questions

**Ans. 2:** Option (D) is correct.

*Explanation:* The molality of a solution does not change with temperature.

**Ans. 7:** Option (A) is correct.

*Explanation:* Value of Henry's constant increases with increase in temperature.

#### Assertion & Reason

**Ans. 3:** Option (A) is correct.

*Explanation:* As molarity is dependent on volume of solution and volume rises with increase in temperature. Molarity is inversely proportional to temperature. So, as temperature increases, volume increases and molarity decreases.

#### Short Answer Type Questions-I

**Ans.1:** **Henry's law:** The mass of a gas dissolved in a given volume of the liquid at a constant temperature depends upon the pressure which is applied.

$$K_H \text{ for } \text{CO}_2 = 1.25 \times 10^6 \text{ mm Hg}$$

$$\begin{aligned} x_{\text{CO}_2} &= \frac{\text{Partial pressure of } \text{CO}_2}{K_H \text{ for } \text{CO}_2} \\ &= \frac{760 \text{ mm Hg}}{1.25 \times 10^6 \text{ mm Hg}} \\ &= 608 \times 10^{-6} \end{aligned}$$

Mole fraction represents the solubility of  $\text{CO}_2$  in water. [2]

**Ans.2:** Henry's law states that "The partial pressure of the gas ( $p$ ) in vapour phase is proportional to the mole fraction of the gas ( $\chi$ ) in the solution". [1]

- To increase the solubility of  $\text{CO}_2$  in soft drinks
- 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.
- 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. (Any two)

[½ + ½] [CBSE Marking Scheme, 2019]

**Short Answer Type Questions-II**

Ans. 5:

$$(i) w/w \text{ (Mass percentage)} \\ = \frac{\text{Mass of component in the solution}}{\text{Total mass of the solution}} \times 100$$

$$(ii) v/V \text{ (Volume percentage)} \\ = \frac{\text{Volume of the component}}{\text{Total volume of the solution}} \times 100$$

$$(iii) M \text{ (Molarity)} M = \frac{\text{Moles of solute}}{\text{Volume of solution in litre}}$$

$$(iv) w/V \text{ (Mass by volume percentage)} \\ = \frac{\text{Mass of solute}}{100 \text{ mL of solution}} \times 100$$

$$(v) m \text{ (Molality)} = \frac{\text{Moles of solute}}{\text{Mass of solvent in kg}}$$

Mass percentage, ppm and molality are independent of temperature since mass does not change with temperature.

$$(vi) ppm \text{ (Part per million)} \\ = \frac{\text{Number of parts of component}}{\text{Total number of parts of all components of the solution}} \times 10^6$$

**Long Answer Type Questions**Ans.1: (i) 6.5 g of  $C_9H_8O_4$  is dissolved in 450 g of  $CH_3CN$ .

$$\text{Then, total mass of the solution} = (6.5 + 450) \text{ g} \\ = 456.5 \text{ g}$$

$$\text{Therefore, mass percentage of } C_9H_8O_4 \\ = \frac{6.5}{456.5} \times 100\% \\ = 1.424\% \quad [2]$$

$$(ii) \text{ Density of HCl} = 1.19 \text{ g cm}^{-3} \\ \text{Mass of } 1000 \text{ cm}^3 \text{ of commercial HCl} \\ = 1000 \times 1.19 = 1190 \text{ g} \quad [1] \\ \text{Mass of HCl in } 1190 \text{ g (} 1000 \text{ cm}^3 \text{) of the solution} \\ = \frac{1190 \times 38}{100} = 452.2 \text{ g} \quad [1]$$

$$\text{Molar mass of HCl} = 1 + 35.5 = 36.5 \text{ g}$$

$$452.2 \text{ g of HCl} = \frac{452.2}{36.5} \text{ moles of HCl}$$

$$= 12.4 \text{ moles of HCl}$$

$\therefore$  1.0 L of the commercial HCl solution contains 12.4 moles of HCl.

$$\text{Molarity of the commercial HCl solution} \\ = 12.4 \text{ M} \quad [1]$$

**Solutions for Practice Questions (Topic-2)****Multiple Choice Questions**

Ans.1: Option (D) is correct.

**Explanation:** When solute-solvent or A-B interactions are weaker than the A-A or B-B interactions, molecules of A or B will find it easier to escape than in pure state. This will increase the vapour pressure and result in positive deviation from Raoult's law. Such solutions are called minimum boiling azeotropes.

Ans.5: Option (A) is correct.

**Explanation:** Mixture of methanol and acetone exhibits positive deviation because methanol-methanol and acetone-acetone interaction is more than methanol-acetone. The more number of hydrogen bonds are broken the less number of new hydrogen bonds are formed.

**Assertion & Reason**

Ans.3: Option (D) is correct.

**Explanation:** An ideal solution obeys Raoult's law.

**Short Answer Type Questions-I**

Ans.1: Raoult's law for a solution containing volatile components states that the partial pressure of a volatile component present in a solution is directly proportional to the mole fraction of that component at a given temperature.

$$p_A \propto \chi_A \text{ or } p_A = p_A^\circ \chi_A$$

Raoult's law and Henry's law are similar as both

gives equation to find partial pressure of gases.

$$p_A = p_A^\circ \chi_A \quad p_A = K_H \chi_A \\ \text{(Raoult's law)} \quad \text{(Henry's law)} \quad [2]$$

**Short Answer Type Questions-II**

Ans. 2: (i) **Nature of liquid:** Liquids having weak intermolecular forces are volatile and possess higher vapour pressure.

**Temperature:** Vapour pressure increases with increase in temperature. [ $\frac{1}{2} + \frac{1}{2}$ ]

(ii) (a) van der Waals forces of attraction.

(b) van der Waals forces of attraction. [1]

$$\text{Ans. 3: Number of moles of A dissolved} = \frac{20}{140} \\ = 0.143 \quad [\frac{1}{2}]$$

$$\text{Number of moles of B} = \frac{80}{18} = 4.44 \quad [\frac{1}{2}]$$

$$\text{Mole fraction of A } (\chi_A) = \frac{0.143}{0.143 + 4.44} = 0.031 \quad [\frac{1}{2}]$$

$$\text{Mole fraction of B } (\chi_B) = \frac{4.44}{0.143 + 4.44} = 0.969 \quad [\frac{1}{2}]$$

$$\text{Total pressure} = 160 \text{ mm}$$

$$= p_A \times \chi_A + p_B \times \chi_B$$

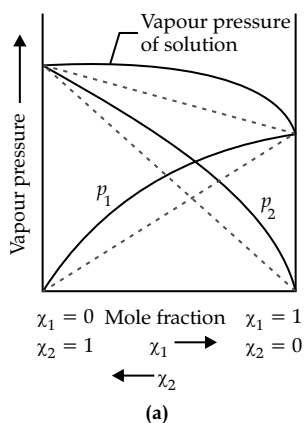
$$160 = p_A \times 0.031 + 150 \times 0.969$$

$$\therefore p_A = 472.58 \text{ mm} \quad [1]$$

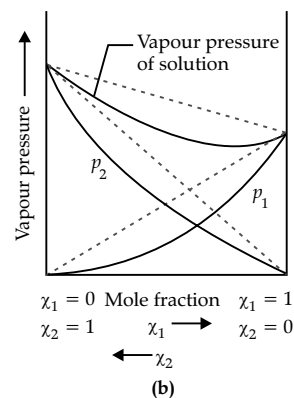
### Long Answer Type Questions

**Ans. 3:** According to Raoult's law, the partial vapour pressure of each volatile component in any solution is directly proportional to its mole fraction. The solutions which obey Raoult's law over the entire range of concentration are known as ideal solutions. The solutions that do not obey Raoult's law (non-ideal solutions) have vapour pressures either higher or lower than that predicted by Raoult's law (given in figure). [1]

If the vapour pressure is higher, then the solution is said to exhibit positive deviation, and if it is lower, then the solution is said to exhibit negative deviation from Raoult's law.



[1]



[1]

In the case of solutions showing positive deviations, absorption of heat takes place.

so,  $\Delta_{\text{sol}}H = \text{Positive}$  [fig (a)]

In the case of solutions showing negative deviations, evolution of heat takes place.

so,  $\Delta_{\text{sol}}H = \text{Negative}$  [fig (b)]

[2]

In the case of an ideal solution, the enthalpy of the mixing of the pure components for forming the solution is zero.

$$\Delta_{\text{sol}}H = 0$$



## Solutions for Practice Questions (Topic-3)

### Multiple Choice Questions

**Ans.2:** Option (D) is correct.

*Explanation:* Exchanges of gases is an example of diffusion.

### Assertion & Reason Type Questions

**Ans. 1:** Option (A) is correct.

*Explanation:* Elevation in boiling point is a colligative property. It is directly proportional to molarity.

$$\Delta T_b = K_b \times m$$

### Short Answer Type Questions-I

**Ans. 3: (i)** Properties that are independent of nature of solute and depend on number of moles of solute only. 1

**(ii)** Number of moles of solute dissolved per kg of the solvent. 1

[CBSE Marking Scheme, 2017]

#### Detailed Answer:

**(i)** Colligative properties are those properties of the solutions which depend upon the number of solute particles present in the solution irrespective of their nature and are relative to the total number of particles present in the solution. Some colligative properties are elevation of boiling point, depression of freezing point, etc.

**(ii)** Molality is the number of moles of solute dissolved in 100 g of a solvent. It is represented by  $m$  and is used to express concentration of a solution. It can be calculated as: [1]

$$m = \frac{\text{Number of moles of solute}}{\text{Weight of solvent in grams}} \times 1000.$$

**Ans. 7:** Properties that depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution. [1]

Osmotic pressure [1]

### Short Answer Type Questions-II

**Ans. 3: Given:**  $T_b$  of glucose solution =  $100.20^\circ\text{C}$

$$\Delta T_b = K_b \cdot m$$

$$m = 0.20/0.512$$

$$m = 0.390 \text{ mol/kg} \quad [1]$$

$$\Delta T_f = K_f \cdot m \quad [1/2]$$

$$\Delta T_f = 1.86 \text{ K kg/mol} \times 0.390 \text{ mol/kg} \quad [1/2]$$

$$\Delta T_f = 0.725 \text{ K}$$

$$\begin{aligned} \text{Freezing point of solution} &= 273.15 - 0.725 \\ &= 272.425 \text{ K} \quad [1] \end{aligned}$$

[CBSE Marking Scheme 2017]

$$\text{Ans. 5: } \frac{p^0 - p}{p^0} = \frac{W_s \times M_{\text{solvent}}}{M_s \times W_{\text{solvent}}}, s = \text{solute} \quad [1]$$

$$\Rightarrow (32 - 31.84)/32 = 10 \times 18/M_s \times 200 \quad [1]$$

$$M_s = 180 \text{ g/mol} \quad [1]$$

[CBSE Marking Scheme 2015]

### Long Answer Type Questions

$$\text{Ans. 1. (i)} \quad \Delta T_f = K_f m \quad [1]$$

Here,  $m = w_2 \times 1000/M_2 \times W_1$

$$273.15 - 269.15 = K_f \times 10 \times 1000/342 \times 90 \quad [1]$$

$$K_f = 12.3 \text{ K kg/mol} \quad [1]$$

$$\Delta T_f = K_f m$$

$$= 12.3 \times 10 \times 1000/180 \times 90$$

$$= 7.6 \text{ K}$$

$$T_f = 273.15 - 7.6 = 265.55 \text{ K}$$

(or any other correct method)[1]

(ii) Number of moles of solute dissolved in per kilogram of the solvent. [1]

[CBSE Marking Scheme 2017]



## REFLECTIONS

- (a) Were you able to understand why aquatic animals are more comfortable in cold water than in warm water?
- (b) Did you able to understand why climbers becomes weak and are unable to think clearly while moving towards high altitudes?



# SELF ASSESSMENT PAPER - 1

Maximum Marks: 30

Max. Time: 1 Hour

The following questions (No. 1 to 4) are Multiple Choice Questions carrying 1 mark each.

- Q. 1. What is the molarity of a solution with a mass of solute 10 kg mass and 100 litre volume? [1]
- (A) 0.1 molar  
(B) 1 molar  
(C) 10 molar  
(D) 100 molar
- Q. 2. The value of Henry's constant  $K_H$  is [1]
- (A) greater for gases with higher solubility.  
(B) greater for gases with lower solubility.  
(C) constant for all gases.  
(D) not related to the solubility of gases.
- Q. 3. People add sodium chloride to water while boiling eggs. This is to [1]
- (A) decrease the boiling point.  
(B) increase the boiling point.  
(C) prevent the breaking of eggs.  
(D) make eggs tasty.
- Q. 4. Which of the following is not an example of osmosis ? [1]
- (A) Raw mangoes shrink when picked in brine.  
(B) Wilted flowers revive when placed in fresh water.  
(C) Blood cells collapse when suspended in saline water.  
(D) Exchange of gases in lungs.

In the following questions (Q No. 5–6), a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

- (A) Both A and R are true and R is the correct explanation of A.  
(B) Both A and R are true but R is NOT the correct explanation of A.  
(C) A is true but R is false.  
(D) A is false and R is true.
- Q. 5. Assertion (A): In an ideal solution,  $\Delta_{\text{mix}} H$  is zero.  
Reason (R): In an ideal solution, A - B interactions are equal to A-A and B-B interactions. [1]
- Q. 6. Assertion (A): 1M solution of NaCl has greater osmotic pressure than 1 M solution of sucrose at same temperature.  
Reason (R): In solution NaCl dissociates to produce more number of particles. [1]

Case-based

- Q. 7. Read the passage given below and answer any four questions: [1 × 4 = 4]

Ideal solution, homogeneous mixture of substances that has physical properties linearly related to the properties of the pure components. The classic statement of this condition is Raoult's law. Solutions of benzene and toluene, which have very similar molecular structures, are ideal. The vapour pressures of the solutions are mathematically represented by a linear function of the molecular composition.

When the components of non ideal solutions are mixed, the volume of the mixture ordinarily differs from the sum of the volumes of the pure components, and heat is evolved or absorbed. The properties of such solutions often are described in terms of their deviations from those of ideal solutions. Mixtures of acetone and chloroform, for example, are said to show negative deviations from ideality their vapour pressures are lower than those calculated on the assumption of a linear relationship to the molecular composition. Solutions of acetone and carbon disulfide, on the other hand, have higher vapour pressures than those that would characterize an ideal solution.

(i) Which of the following statements regarding ideal solutions is false?

- (A) Ideal solutions obey Raoult's law under all conditions of temperature and concentrations  
 (B) There will be some change in volume on mixing the components, i.e.,  $\Delta V_{\text{mixing}} \neq 0$   
 (C) There will be no change in enthalpy when the two components are mixed, i.e.,  $\Delta H_{\text{mixing}} = 0$   
 (D) There will be no change in volume on mixing the components, i.e.,  $\Delta V_{\text{mixing}} = 0$

(ii) If liquids A and B form an ideal solution, then what is the Gibbs' free energy of mixing?

- (A)  $> 0$  (B)  $< 0$   
 (C)  $= 0$  (D) Not Defined

(iii) Which of the following is not an example of an Ideal solution?

- (A) Benzene + Toluene (B) *n*-Hexane + *n*-Heptane  
 (C) Ethyl alcohol + Water (D) Ethyl bromide + Ethyl chloride

(iv) Which of the following is an example of a non-ideal solution showing positive deviation?

- (A) Acetone + Carbon disulphide (B) Chlorobenzene + Bromobenzene  
 (C) Chloroform + Benzene (D) Acetone + Aniline

(v) Which of the following is false regarding Non-Ideal solutions?

- (A) They do not obey Raoult's law (B)  $\Delta V_{\text{mixing}} \neq 0$   
 (C)  $\Delta H_{\text{mixing}} = 0$  (D) They form azeotropes

The following questions (No. 8 - 10), are Very Short Answer Type and carry 1 mark each.

Q. 8. Why helium is mixed with Nitrogen and Oxygen in diving cylinders? [1]

Q. 9. Define azeotropes. [1]

Q. 10. What type of azeotrope is formed by positive deviation from Raoult's law? Give an example. [1]

The following questions (No. 11 - 13), are Short Answer Type-I and carry 2 marks each.

Q. 11. Define osmotic pressure. How is the osmotic pressure related to the concentration of a solute in a solution? [2]

Q. 12. What are colligative properties? Write the colligative property which is used to find the molecular mass of macromolecules. [2]

Q. 13. Will the elevation in boiling point be same if 0.1 mol of sodium chloride or 0.1 mol of sugar is dissolved in 1L of water? Explain. [2]

Question No. 14 & 15 are Short Answer Type-II and carry 3 marks each.

Q. 14. A solution is prepared by dissolving 10 g of nonvolatile solute in 200 g of water. It has a vapour pressure of 31.84 mm Hg at 308K. Calculate the molar mass of the solute.

(Vapour pressure of pure water at 308K = 32 mm Hg) [3]

Q. 15. Calculate the boiling point of a 1M aqueous solution (density  $1.04 \text{ g mL}^{-1}$ ) of Potassium chloride ( $K_b$  for water =  $0.52 \text{ K kg mol}^{-1}$ , Atomic masses: K = 39 u, Cl = 35.5 u). Assume, Potassium chloride is completely dissociated in solution. [3]

Question No 16 is a Long Answer Type Question and carry 5 marks each.

Q. 16. (i) Define the following terms:

- (a) Mole fraction.
- (b) Ideal solution.

(ii) 15.0 g of an unknown molecular material is dissolved in 450 g of water. The resulting solution freezes at  $-0.34$  °C. What is the molar mass of the material ? [ $K_f$  for water =  $1.86 \text{ K kg mol}^{-1}$ ][2+3]

Finished Solving the Paper ?  
Time to evaluate yourself !

OR

SCAN THE CODE



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