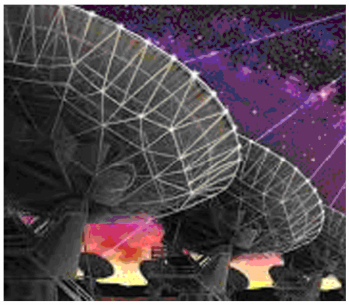
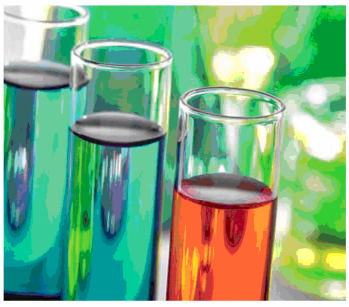
STUDY MATERIAL

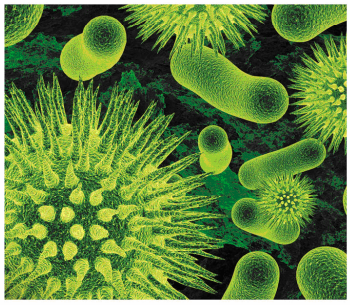
NEET

XI & XII STD



CHEMISTRY





CP PUBLICATION

CHEMISTRY

Study Material for NEET preparation

Prepared by Career Point Kota Experts

CAREER POINT

CONTENTS OF THE PACKAGE AT A GLANCE

CHEMISTRY

Class 11

Physical Chemistry (I)

- Atomic Structure
- Basic Concepts of Chemistry
- Redox & Volumetric Analysis
- Chemical Energetics
- Chemical Equilibrium
- Acid Base & Ionic Equilibrium

Inorganic Chemistry (I)

- Periodic Table
- Chemical Bonding

Organic Chemistry (I)

- Classifaction & Nomenclature
- Isomerism
- GOC
- Hydrocarbon
- Aromatic Hydrocarbons

Class 12

Physical Chemistry (II)

- Electro Chemistry
- Solution
- Chemical Kinetics

Organic Chemistry (II)

- Halogen Compounds
- Alcohol, Phenol, Ether
- Carbonyl Compound
- Carboxylic acid & Its Derivatives
- Nitrogen Compounds
- Biomolecules
- Purification Chemistry & Characterisation of Organic Compound

Inorganic Chemistry (II)

- p-Block Element
- d & f Block
- Coordination compound
- Practical Chemistry

Features of The Product

This study material is especially designed for NEET aspirants. The entire study material is arranged in such a way so that the learning process progresses gradually from the basic to advanced stages. This easy-to-grasp material enables students to apply the fundamentals they have learned and boost their confidence to tackle the problems asked in the NEET and other medical competitive examinations.

Theory & Concepts

Theory provides all the basic concepts in clear and precise manner. It comprises all the related and required diagrams, tables, graphs, real life examples, info graphics, conceptual questions that makes it more comprehensive. It also highlights tips and tricks, facts, notes, misconceptions, key points, and problem solving tactics.

SOLUTION

KEY CONCEPT

1. Solution

A solution is a homogeneous mixture of a solute, the substance that dissolves and a solvent, the substance in which the solute dissolves.

(a) The component of solution which is in lesser amount (Which is dissolved) is called **solute.**

(b) The component of solution in which solute is dissolved is called **solvent.**

Solution = Solute + Solvent

2. Concentration of Solution

It is calculated by following two methods

(a) Weight % : Weight of solute per 100 gram of solution.

(b) Volume % :

(i) Weight of solute per 100 ml of solution

(ii) Volume of solute per 100 ml of solution

(c) Concentration of a solution expressed in following terms.

2.1 MOLARITY (M)

It is the number of moles of solute in one litre of solution

$$\text{Molarity} = \frac{\text{No. of moles of solute}}{\text{Volume of solution (litre)}}$$

(a) Molarity is expressed by putting a suffix 'M' after a number, say 'X'. It means if concentration of a solution is given to be XM, it means X moles of solute are there per litre of solution.

(b) Some times amount of solute is given in grams. So,

$$\text{Moles of solute} = \frac{\text{amount (gram)}}{\text{mol.wt.in (gram)}}$$

(c) We Should be careful about unit of volume taken. We have to use volume in litre in the formula for molarity. So, if volume is given in ml (mili litre) convert it into litre as-

volume in litre = volume in ml $\times 10^{-3}$

(d) Some times we get confused when volume is given in cm^3. A cm^3 is nothing but a milliliter. So, volume in litre = volume (cm^3) $\times 10^{-3}$

(e) Unit of molarity is mole L^{-1}.

(f) Millimoles = M × V(ml) = $\frac{\text{wt.} \times 1000}{\text{mol. wt.}}$

(g) Strength of solution = $\frac{\text{wt. of solute} \times 1000}{\text{volume of solution (ml)}}$

(h) Molarity is a temperature dependent unit.

$$\text{Molarity} \propto \frac{1}{\text{temp.}}$$

2.2 MOLALITY (m)

It is the number of moles of solute per kilogram of solvent.

$$\text{Molality} = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}}$$

(a) Unit of molality is mole kg^{-1}

(b) Sometimes mass of solution is given instead of solvent, so subtract the mass of solute to get mass of solvent

(c) Represented by a suffix 'm' after a number x. xm means x moles of solute are there per kg of solvent.

(d) Molality does not change with increase of temperature.

(e) Relation between molarity and molality-

$$m = \frac{1000M}{1000d - MM_B}$$

Where,

m = Molality

M = Molarity

d = density of solution in gm/litre

M_B = Molecular wt. of solute

Derivation :–

$$\frac{M}{m} = \frac{\text{wt. of solvent}}{\text{volume of solution}}$$

$$\frac{M}{m} = \frac{W_A}{V(\text{litre})}$$

Since, wt. of solvent = wt. of solution – wt. of solute

$$= V \times d - MM_B$$

Therefore, $\frac{M}{m} = \frac{Vd - MM_B}{V}$

$$m = \frac{MV}{Vd - MM_B}$$

2.3 MOLE FRACTION (X)

(a) Mole fraction of a component in solution is equal to the ratio of number of moles of that component to the total number of moles of all the components in the solution. Mole fraction of component A is represented by x_A.

(b) Let, there be two components A (solvent) & B (solute)

$X_A = \frac{n_A}{n_A + n_B}$ and $X_B = \frac{n_B}{n_A + n_B}$ where,

X_A = Mole fraction of solvent and

X_B = Mole fraction of solute.

Here, $n_A = \frac{w_A}{M_A}$

(wt. of A in grams/mol.wt. of A, $x_A + x_B = 1$)

In Chapter Examples

To clarify the application of theory & concept accurately & correctly, there is number of solved in-chapter questions follpowng each topic. It proves practically very effective to understand and correct application of related theory.

Questions based on **Raoult's Law**

Ex.1 At 300 K, the vapour pressure of an ideal solution containing one mole of A and 3 moles of B is 550 mm of Hg. At the same temperature, if one mole of B is added to this solution, the vapour pressure of solution increases by 10mm of Hg. Calculate the vapour pressure of A and B in their pure state.

(1) 400 mm, 600 mm

(2) 600 mm, 400 mm

(3) 200 mm, 300 mm

(4) 300 mm, 200 mm **(Ans. 1)**

Sol. Initially,

$P_M = P^o_A \cdot X_A + P^o_B \cdot X_B$

$550 = P^o_A\left(\frac{1}{1+3}\right) + P^o_B\left(\frac{3}{1+3}\right)$

$P^o_A + 3P^o_B = 2200$

When 1 mole of B is further added to it

$P_M = P^o_A \cdot X_A + P^o_B \cdot X_B$

$560 = P^o_A\left(\frac{1}{1+4}\right) + P^o_B\left(\frac{4}{1+4}\right)$

or $P^o_A + 4P^o_B = 2800$

By (i) and (ii)

P^o_A = **400 mm** ; P^o_B = **600 mm**

Solved Examples

To understand the concept application, in end of the each chapter there is suffiecient number of solved examples.

SOLVED EXAMPLES

Ex.1 A 6.90 M solution of KOH in water has 30% by weight of KOH. Calculate density of solution.

(A) 1.288 g mL^{-1} (B) 12.88 g mL^{-1}

(C) 24.88 g mL^{-1} (D) 2.488 g mL^{-1}

(Ans. A)

Sol. KOH solution is 30% by weight.

$\therefore$ wt. of KOH = 30 g

and Wt. of solution = 100 g

$\therefore$ Volume of solution = $\frac{100}{d}$

$\therefore$ Molarity $= 6.90 = \left(\frac{30}{56 \times \frac{100}{1000 \times d}}\right)$

= **1.288 g mL^{-1}**

Ex.2 What is mole fraction in its one molal aqueous solution-

(A) 0.108 (B) 0.018

(C) 0.008 (D) None **(Ans. B)**

Sol. Mole fraction = $\frac{n_A}{n_A + n_B}$

$n_A = 1$ and $n_B = \frac{1000}{18} = 55.4$

$= \frac{1}{1+55.4} = \frac{1}{56.4}$ = **0.018**

Ex.4 Calculate the molality and mole fraction of the solute in aqueous solution containing 3.0 gm of urea per 250 gm of water (Mol. wt. of urea = 60).

(A) 0.2 m, 0.00357 (B) 0.4 m, 0.00357

(C) 0.5 m, 0.00357 (D) 0.7m, 0.00357

(Ans. A)

Sol. Wt. of solute (urea) dissolved = 3.0 gm

Wt. of the solvent (water) = 250 gm

Mol. wt. of the solute = 60

3.0 gm of the solute = $\frac{3.0}{60}$ moles = 0.05 moles

Thus 250 gm of the solvent contain = 0.05 moles of solute

$\therefore$ 1000 gm of the solvent contain

$= \frac{0.05 \times 100}{250} = 0.2$ moles

Hence molality of the solution = 0.2 m

In short,

Molality = No. of moles of solute/1000 g of solvent

$\therefore$ Molality = $\frac{3/60}{250} \times 1000$ = **0.2 m**

Calculation of mole fraction

3.0 gm of solute = 3/60 moles = 0.05 moles

250 gm of water = $\frac{250}{18}$ moles

= 13.94 moles

$\therefore$ Mole fraction of the solute

$= \frac{0.05}{0.05+13.94} = \frac{0.05}{13.99}$

= **0.00357**

Ex.5 15 gram of methyl alcohol is dissolved in 35 gram of water. What is the mass percentage of methyl alcohol

Practice Exercises

Exercise Level -1 : It contains TOPIC WISE single objective correct (SCQ) type concept building questions.

Exercise Level -2 : It contains single objective type good quality questions on all the concepts of the chapter in mixed manner.

EXERCISE # 2

Q.1 Select correct statement -
(1) b.p. of 1 molal NaCl solution is twice that of 1 molal sucrose solution
(2) b.p. elevation of 1 molal glucose solution is half of the 1 molal KCl solution
(3) b.p. is a colligative property
(4) All of the above

Q.2 At a given temperature, total vapour pressure in Torr of a mixture of volatile components A and B is given by
$P = 120 - 75\ X_B$
hence, vapour pressure of pure A and B respectively (in Torr) are -
(1) 120, 75 (2) 120, 195
(3) 120, 45 (4) 75, 45

Q.3 Decimolar solution of potassium ferricyanide, $K_3[Fe(CN)_6]$ has osmotic pressure of 3.94 atm at 27°C. Hence percent ionisation of the solute is -
(1) 10% (2) 20%
(3) 30% (4) 40%

Q.4 A complex containing K^+, Pt (IV) and Cl^- is 100% ionised giving i = 3. Thus, complex is -
(1) $K_2[PtCl_4]$ (2) $K_2[PtCl_6]$
(3) $K_3[PtCl_5]$ (4) $K[PtCl_3]$

Q.5 If $pK_a = -\log K_a = 4$, and $K_a = C\alpha^2$ then van't Hoff factor for weak monobasic acid when C = 0.01 M is -
(1) 0.01 (2) 1.02 (3) 1.10 (4) 1.20

Q.10 The value of K_b for water is 1.86, calculated from Glucose solution. The value of K_b for water calculated for NaCl solution will be -
(1) = 1.86 (2) < 1.86 (3) > 1.86 (4) Zero

Q.11 As a result of osmosis the volume of the concentrated solution -
(1) Gradually decreases (2) Gradually increases
(3) Suddenly increases (4) None

Q.12 If a thin slice of sugar beet is placed in concentrated solution of NaCl then -
(1) Sugar beet will lose water from its cells
(2) Sugar beet will absorb water from solution
(3) Sugar beet will neither absorb nor lose water
(4) Sugar beet will dissolve in solution

Q.13 If mole fraction of the solvent in solution decreases then -
(1) Vapour pressure of solution increases
(2) B. P. decreases
(3) Osmotic pressure increases
(4) All are correct

Q.14 A solution containing 4g of a non volatile organic solute per 100 ml was found to have an osmotic pressure equal to 500 cm of mercury at 27°C. The molecular weight of solute is -
(1) 14.97 (2) 149.7
(3) 1697 (4) 1.497

Q.15 If a 6.84% (wt./ vol.) solution of cane-sugar (mol. wt. 342) is isotonic with 1.52% (wt./vol.) solution of

Exercise Level -3 : It contains previous years NEET exam quesiotns from 2005 to upto to present year.

(4) $\Delta G_{mix} = 0$

Q.53 If molality of the dilute solution is doubled, the value of molal depression constant (K_f) will be **[NEET -2017]**
(1) unchanged (2) doubled
(3) halved (4) tripled

Q.54 Which of the following is dependent on temperature ? **[NEET-2017]**
(1) Weight percentage (2) Molality
(3) Molarity (4) Mole fraction

Q.55 The mixture that forms maximum boiling azeotrope is : **[NEET -2019]**
(1) Acetone + Carbon disulphide
(2) Heptane + Octane
(3) Water + Nitric acid
(4) Ethanol + Water

Q.56 For an ideal solution, the correct option is - **[NEET-2019]**
(1) Δ_{mix} H = 0 at constant T and P
(2) Δ_{min} G = 0 at constant T and P
(3) Δ_{mix} S = 0 at constant T and P
(4) Δ_{mix} V ≠ 0 at constant T and P

Q.57 The mixture which shows positive devation form Raoult's law is : **[NEET 2020]**
(1) Benzene + Toluene

Q.62 K_H value for some gases at the same temperature 'T' are given :

Gas	K_H/k bar
Ar	40.3
CO_2	1.67
HCHO	1.83×10^{-5}
CH_4	0.413

where K_H is Henry's Law constant in water. The order of their solubility in water is : **[Re-NEET-2022]**
(1) HCHO < CH_4 < CO_2 < Ar
(2) Ar < CO_2 < CH_4 < HCHO
(3) Ar < CO_2 < CH_4 < HCHO
(4) HCHO < CO_2 < CH_4 < Ar

Q.63 The Henry's law constant (K_H) values of three gases (A, B, C) in water are 145, 2×10^{-5} and 35 kbar, respectively. The solubility of these gases in water follow the order : **[NEET-2024]**
(1) A > C > B (2) A > B > C
(3) B > A > C (4) B > C > A

Exercise Level -4 : It contains previous years JEE Mains exam quesiotns from 2005 to upto to present year.

Q.41 What weight of glucose must be dissolved in 100 g of water to lower the vapour pressure by 0.20 mm Hg? (Assume dilute solution is being formed)
Given : Vapour pressure of pure water is 54.2 mm Hg at room temperature. Molar mass of glucose is 180 g mol^{-1}
[Main - 2023]
(1) 3.59 g (2) 3.69 g
(3) 4.69 g (4S) 2.59 g

Q.42 A solution containing 2 g of a non-volatile solute in 20 g of water boils at 373.52 K. The molecular mass of the solute is _____ g mol^{-1}. (Nearest integer)
Given, water boils at 373 K, K_b for water = 0.52 K kg mol^{-1}) **[Main - 2023]**

Q.43 The vapour pressure of 30% (w/v) aqueous solution of glucose is _____ mm Hg at 25°C.
[Given: The density of 30% (w/v), aqueous solution of glucose is 1.2 g cm^{-3} and vapour pressure of pure water is 24 mm Hg.] (Molar mass of glucose is 180 g mol^{-1})
[Main - 2023]

Q.44 A solution of two miscible liquids showing negative deviation from Raoult's law will have :
[Main - 2024]
(1) increased vapour pressure, decreased boiling point
(2) increased vapour pressure, increased boiling point
(3) decreased vapour pressure, decreased boiling point
(4) decreased vapour pressure, increased boiling point

Q.45 The osmotic pressure of a dilute solution is 7×10^5 Pa at 273K. Osmotic pressure of the same solution at 283K is _____ $\times 10^4$ Nm^{-2}. **[Main - 2024]**

Q.46 What happens to freezing point of benzene when small quantity of naphthalene is added to benzene ?
[Main - 2024]
(1) First decreases and then increases
(2) Increases
(3) Decreases
(4) Remains unchanged

Q.47 2.7 Kg of each of water and acetic acid are mixed, The freezing point of the solution will be –x °C. Consider the acetic acid does not dimerise in water, nor dissociates in water x = _____(nearest integer)
[Main - 2024]
[Given : Molar mass of water = 18 g mol^{-1}, acetic acid = 60 g mol^{-1}]
$^{Kf}H_2O$: 1.86 K kg mol^{-1}
^{Kf}acetic acid : 3.90 K kg mol^{-1}
freezing point : H_2O = 273 K, acetic acid = 290 K]

Q.48 An artificial cell is made by encapsulating 0.2 M glucose solution within a semipermeable membrane. The osmotic pressure developed when the artificial cell is placed within a 0.05 M solution of NaCl at 300 K is _____ $\times 10^{-1}$ bar (Nearest Integer) **[Main - 2024]**
[Given : R = 0.083 L bar mol^{-1} K^{-1}]
Assume complete dissociation of NaCl

Answer key

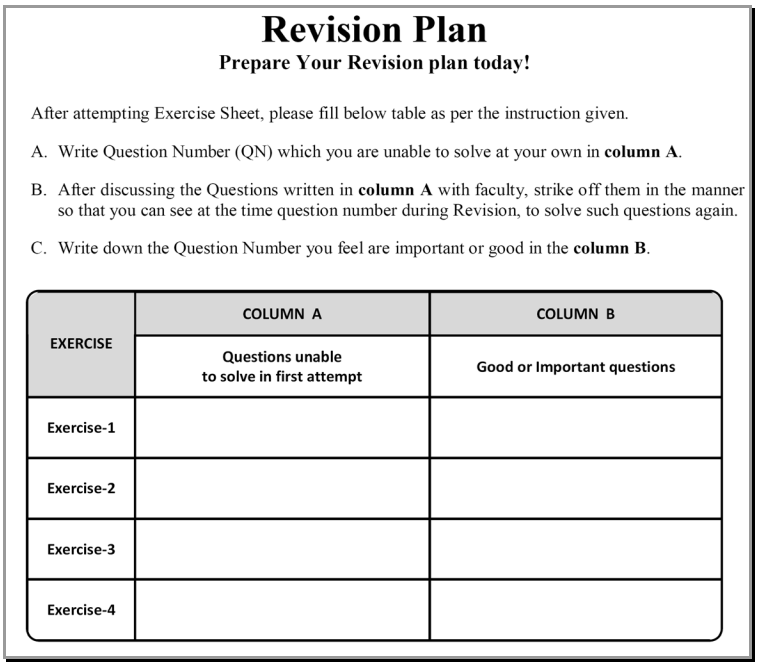
Above mentioned all exercises provided with answer key

EXERCISE # 1

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	2	1	1	3	1	2	3	1	4	3	4	2	3	3	4	1	2	1	3	1
Q.No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	2	1	4	2	1	4	4	2	1	2	1	4	2	3	3	1	3	2	3	3
Q.No.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	4	2	4	1	1	4	2	2	2	3	2	2	2	3	2	3	3	2	1	2
Q.No.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Ans.	2	4	3	1	3	4	3	3	4	3	4	3	1	2	4	3	4	1	3	1
Q.No.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Ans.	3	1	3	2	1	2	3	3	2	4	4	4	3	1	3	4	4	3	3	4
Q.No.	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115					
Ans.	3	1	3	2	2	4	3	4	1	1	2	4	2	2	2					

Revision Plan

We emphasis that every student should prepare his/her own revision plan. For this purpose there is Revision Plan Section in each chapter which student should prepare while going thorugh the study material. This will be useful at the time of final revision before final exam for quick & effective revision.



Revision Plan

Prepare Your Revision plan today!

After attempting Exercise Sheet, please fill below table as per the instruction given.

A. Write Question Number (QN) which you are unable to solve at your own in **column A**.

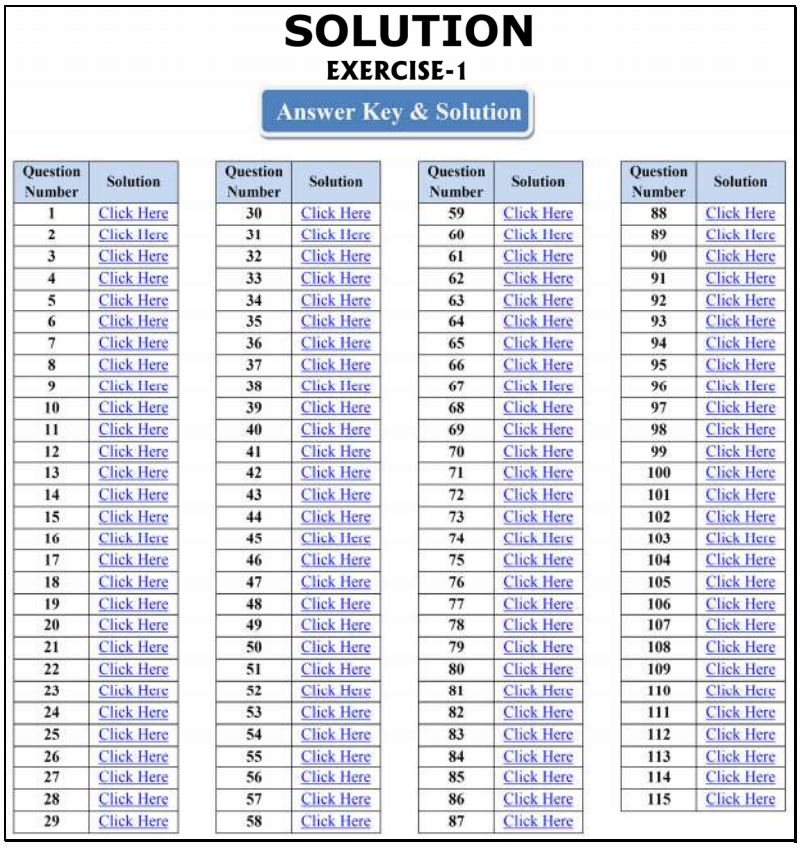
B. After discussing the Questions written in **column A** with faculty, strike off them in the manner so that you can see at the time question number during Revision, to solve such questions again.

C. Write down the Question Number you feel are important or good in the **column B**.

EXERCISE	COLUMN A	COLUMN B
	Questions unable to solve in first attempt	Good or Important questions
Exercise-1		
Exercise-2		
Exercise-3		
Exercise-4		

Online Solutions

Self explanatory and detailed soltuion of all excercises mentioned above are available on Career Point website **www.careerpoint.ac.in**



SOLUTION

EXERCISE-1

Answer Key & Solution

Question Number	Solution	Question Number	Solution	Question Number	Solution	Question Number	Solution
1	Click Here	30	Click Here	59	Click Here	88	Click Here
2	Click Here	31	Click Here	60	Click Here	89	Click Here
3	Click Here	32	Click Here	61	Click Here	90	Click Here
4	Click Here	33	Click Here	62	Click Here	91	Click Here
5	Click Here	34	Click Here	63	Click Here	92	Click Here
6	Click Here	35	Click Here	64	Click Here	93	Click Here
7	Click Here	36	Click Here	65	Click Here	94	Click Here
8	Click Here	37	Click Here	66	Click Here	95	Click Here
9	Click Here	38	Click Here	67	Click Here	96	Click Here
10	Click Here	39	Click Here	68	Click Here	97	Click Here
11	Click Here	40	Click Here	69	Click Here	98	Click Here
12	Click Here	41	Click Here	70	Click Here	99	Click Here
13	Click Here	42	Click Here	71	Click Here	100	Click Here
14	Click Here	43	Click Here	72	Click Here	101	Click Here
15	Click Here	44	Click Here	73	Click Here	102	Click Here
16	Click Here	45	Click Here	74	Click Here	103	Click Here
17	Click Here	46	Click Here	75	Click Here	104	Click Here
18	Click Here	47	Click Here	76	Click Here	105	Click Here
19	Click Here	48	Click Here	77	Click Here	106	Click Here
20	Click Here	49	Click Here	78	Click Here	107	Click Here
21	Click Here	50	Click Here	79	Click Here	108	Click Here
22	Click Here	51	Click Here	80	Click Here	109	Click Here
23	Click Here	52	Click Here	81	Click Here	110	Click Here
24	Click Here	53	Click Here	82	Click Here	111	Click Here
25	Click Here	54	Click Here	83	Click Here	112	Click Here
26	Click Here	55	Click Here	84	Click Here	113	Click Here
27	Click Here	56	Click Here	85	Click Here	114	Click Here
28	Click Here	57	Click Here	86	Click Here	115	Click Here
29	Click Here	58	Click Here	87	Click Here		

Solution

This chapter covers the following syllabus

1. Types of solution
2. Units of concentration
3. Mole fraction
4. Percentage [Volume & mass]
5. Vapour pressure, Roult's law.
6. Colligative properties [lowering of V.P., depression of F.P., elevation of B.P. & O.P.]
7. Determination of molecular masses, abnormal values of molecular masses.
8. Van't Hoff factor.

Revision Plan

Prepare Your Revision plan today!

After attempting Exercise Sheet, please fill below table as per the instruction given.

- Write Question Number (QN) which you are unable to solve at your own in **column A**.
- After discussing the Questions written in **column A** with faculty, strike off them in the manner so that you can see at the time question number during Revision, to solve such questions again.
- Write down the Question Number you feel are important or good in the **column B**.

EXERCISE	COLUMN A	COLUMN B
	Questions unable to solve in first attempt	Good or Important questions
Exercise-1		
Exercise-2		
Exercise-3		
Exercise-4		
Exercise-5		

Revision Strategy:

Whenever you wish to revision this chapter, follow the following steps -

- **Step-1:** Review your theory notes.
- **Step-2:** Solve Questions of column A
- **Step-3:** Solve Questions of Column B
- **Step-4:** Solve questions from other Question Bank, Problem book etc.

Key Concept

1. Solution

A solution is a homogeneous mixture of a solute, the substance that dissolves and a solvent, the substance in which the solute dissolves.

(a) The component of solution which is in lesser amount (Which is dissolved) is called **solute.**

(b) The component of solution in which solute is dissolved is called **solvent.**

Solution = Solute + Solvent

2. Concentration of Solution

It is calculated by following two methods

(a) Weight % : Weight of solute per 100 gram of solution.

(b) Volume % :

(i) Weight of solute per 100 ml of solution

(ii) Volume of solute per 100 ml of solution

(c) Concentration of a solution expressed in following terms.

2.1 MOLARITY (M)

It is the number of moles of solute in one litre of solution

$$\text{Molarity} = \frac{\text{No. of moles of solute}}{\text{Volume of solution (litre)}}$$

(a) Molarity is expressed by putting a suffix 'M' after a number, say 'X'. It means if concentration of a solution is given to be XM, it means X moles of solute are there per litre of solution.

(b) Some times amount of solute is given in grams. So,

$$\text{Moles of solute} = \frac{\text{amount (gram)}}{\text{mol.wt. in (gram)}}$$

(c) We Should be careful about unit of volume taken. We have to use volume in litre in the formula for molarity. So, if volume is given in ml (mili litre) convert it into litre as-

volume in litre = volume in ml $\times 10^{-3}$

(d) Some times we get confused when volume is given in cm^3. A cm^3 is nothing but a milliliter. So, volume in litre = volume (cm^3) $\times 10^{-3}$

(e) Unit of molarity is mole L^{-1}.

(f) $\text{Millimoles} = M \times V(ml) = \frac{\text{wt.} \times 1000}{\text{mol.wt.}}$

(g) $\text{Strength of solution} = \frac{\text{wt. of solute} \times 1000}{\text{volume of solution (ml)}}$

(h) Molarity is a temperature dependent unit.

$$\text{Molarity} \propto \frac{1}{\text{temp.}}$$

2.2 MOLALITY (m)

It is the number of moles of solute per kilogram of solvent.

$$\text{Molality} = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}}$$

(a) Unit of molality is mole kg^{-1}

(b) Sometimes mass of solution is given instead of solvent, so subtract the mass of solute to get mass of solvent

(c) Represented by a suffix 'm' after a number x. xm means x moles of solute are there per kg of solvent.

(d) Molality does not change with increase of temperature.

(e) Relation between molarity and molality-

$$m = \frac{1000M}{1000d - MM_B}$$

Where,

m = Molality

M = Molarity

d = density of solution in gm/litre

M_B = Molecular wt. of solute

Derivation :–

$$\frac{M}{m} = \frac{\text{wt. of solvent}}{\text{volume of solution}}$$

$$\frac{M}{m} = \frac{W_A}{V(\text{litre})}$$

Since, wt. of solvent = wt. of solution – wt. of solute

$= V \times d - MM_B$

Therefore, $\frac{M}{m} = \frac{Vd - MM_B}{V}$

$$m = \frac{MV}{Vd - MM_B}$$

2.3 MOLE FRACTION (X)

(a) Mole fraction of a component in solution is equal to the ratio of number of moles of that component to the total number of moles of all the components in the solution. Mole fraction of component A is represented by x_A.

(b) Let, there be two components A (solvent) & B (solute)

$X_A = \frac{n_A}{n_A + n_B}$ and $X_B = \frac{n_B}{n_A + n_B}$ where,

X_A = Mole fraction of solvent and

X_B = Mole fraction of solute.

Here, $n_A = \frac{w_A}{M_A}$

(wt. of A in grams/mol.wt. of A, $x_A + x_B = 1$)

(c) It is temperature independent unit.

(d) Relation between mole fraction and molality -

Mole fraction of solvent

$$X_A = \frac{n_A}{n_A + n_B}$$

Mole fraction of solute

$$X_B = \frac{n_B}{n_A + n_B}$$

$$\frac{X_A}{X_B} = \frac{n_A}{n_B}$$

On multiplying 1000 in both side

$$\frac{X_A}{X_B} \times 1000 = 1000 \times \frac{n_A}{n_B}$$

$$\frac{X_A}{X_B} = \frac{m \times M_A}{1000}$$

2.4 MASS FRACTION :

Ratio of mass of component to the total mass of components

$$\text{mass fraction of A} = \frac{w_A}{w_A + w_B}$$

where, w_A = weight of A, and w_B = weight of B.

2.5 MOLE PERCENT :

number of moles of a component in 100 moles

Mole percent = mass fraction × 100

2.6 PARTS PER MILLION (PPM) :

(a) amount of component in mg in 1 kg of solution.

$$\text{ppm} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 10^6$$

$$\text{ppm} = \frac{\text{wt. of solute}}{\text{wt. of solute} + \text{wt. of solvent}} \times 10^6$$

(b) Generally, it is used for very-very little concentrations.

3. Colligative properties

Certain properties of dilute solutions containing nonvolatile solute do not depend upon the nature of the solute dissolved but depend only upon the concentration. i.e the number of the particles of the solute present in the solution. Such properties are called colligative properties. The four well known examples of the colligative properties are -

(a) Lowering of vapour pressure of the solvent

(b) Osmotic pressure of the solution

(c) Elevation in boiling point of the solvent

(d) Depression in freezing point of the solvent

4. Vapour Pressure of a Liquid

It is the pressure that its vapours exert when in equilibrium with the liquid at a given temperature. It depends upon the following factors :

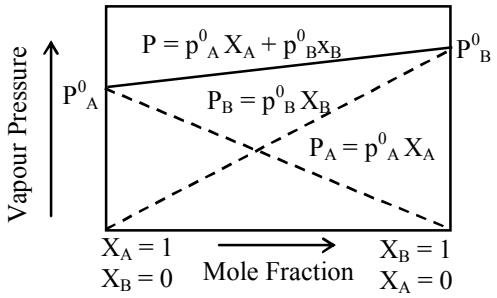
(a) Nature of solvent

(b) Temperature

5. Raoult's Law

(a) Raoult proposed a law which states that at a given temperature, the vapour pressure of a solvent in a solution containing non-volatile solute is directly proportional to its mole fraction.

Mathematically, $p = p^0 x \times$ solvent



(b) In the case of binary solutions of two volatile liquids, Raoult's law states that at a given temperature, the partial vapour pressure of any component of the solution is equal to the product of the vapour pressure of the pure component and its mole fraction in the solution i.e.

$p_A = p^0_A X_A$ and $p_B = p^0_B X_B$

(c) The total vapour pressure P of such a solution containing two components A and B is,

$$P = p_A + p_B = p^0_A X_A + p^0_B X_B$$

$$= (1 - X_B) p^0_A + p^0_B X_B$$

$$= (p^0_B - p^0_A) X_B + p^0_A$$

where, p_A and p_B are vapour pressures (of pure component) and X_A and X_B are mole fractions of components A and B respectively.

Plot of P should be a straight line which is true for ideal solution. Thus the addition of a solute may raise or lower the vapour pressure of solvent depending upon which one is more volatile.

(d) Raoult's Law mathematically expressed as

$$\frac{P_0 - P_S}{P_0} = \frac{n}{n + N} \qquad \text{..... (i)}$$

where, P_0 = Vapour pressure of pure solvent

P_S = Vapour pressure of solution

n = moles of non-volatile solute

N = moles of solvent

If the solution is very dilute, then

$n << N$

So, $\frac{P_0 - P_S}{P_0} = \frac{n}{N}$ ….. (ii)

or $\frac{P_0 - P_S}{P_0} = \frac{w/m}{W/M}$

where,w = wt. of solute dissolved in grams

W = wt. of solvent in grams

m = molecular mass of solute

M = molecular weight of solvent

$\frac{P_0 - P_S}{P_0} = \frac{w.M}{W.m}$ ..... (iii)

This expression (iii) can be used for calculating the molecular weight of solutes.

5.1 Limitations of Raoult's law

(i) As described earlier, Raoult's law is applicable only to very dilute solutions.

(ii) Raoult's law is applicable to solutions containing non-volatile solute only.

(iii) Raoult's law is not applicable to solutes which dissociate or associate in the particular solution

Questions based on **Raoult's Law**

Ex.1 At 300 K, the vapour pressure of an ideal solution containing one mole of A and 3 moles of B is 550 mm of Hg. At the same temperature, if one mole of B is added to this solution, the vapour pressure of solution increases by 10mm of Hg. Calculate the vapour pressure of A and B in their pure state.

(1) 400 mm, 600 mm

(2) 600 mm, 400 mm

(3) 200 mm, 300 mm

(4) 300 mm, 200 mm **(Ans. 1)**

Sol. Initially,

$P_M = P^o_A . X_A + P^o_B . X_B$

$550 = P^o_A \left(\frac{1}{1+3}\right) + P^o_B \left(\frac{3}{1+3}\right)$

$P^o_A + 3P^o_B = 2200$

When 1 mole of B is further added to it

$P_M = P^o_A . X_A + P^o_B . X_B$

$560 = P^o_A \left(\frac{1}{1+4}\right) + P^o_B \left(\frac{4}{1+4}\right)$

or $P^o_A + 4P^o_B = 2800$

By (i) and (ii)

P^o_A = **400 mm** ; P^o_B = **600 mm**

6. Ideal Solution

These are the solutions in which solute-solute and solvent-solvent interactions are almost similar to solute-solvent interactions. Ideal solutions obey Raoult's law for all range of concentrations and temperature.

$\Delta H_{mix} = 0$ $\Delta V_{mix} = 0$

eg. Hexane + Heptane, ethyl chloride + ethyl bromide, chlorobenzene + Bromobenzene etc.

7. Non Ideal Solutions

(a) These are the solutions in which solute-solvent interactions are different than solute-solute and solvent-solvent interactions. The non-ideal solutions do not obey Raoult's law for all concentrations

$\Delta H_{mix} \neq 0$ $\Delta V_{mix} \neq 0$

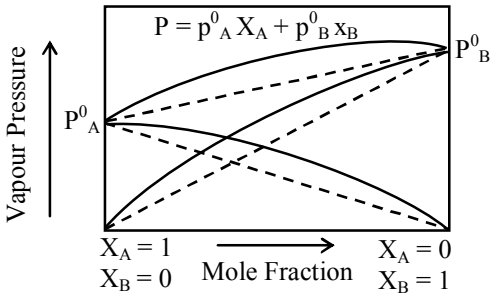
(b) These non-ideal solutions show two types of deviations from the ideal behaviour.

- If $\Delta V_{mix} > 0$ and $\Delta H_{mix} > 0$, then non-ideal solutions show positive deviations.
- If $\Delta V_{mix} < 0$ and $\Delta H_{mix} < 0$, then non-ideal solutions show negative deviations

7.1 Types of non-ideal solutions

7.1.1 Non-ideal solutions showing positive deviations : In such a case, the observed vapour pressure of each component and the total vapour pressure are greater than predicted by Raoult's law i.e.

$p_A > p^0_A X_A$, $p_B > p^0_B x_B$, $P > p_A + p_B$



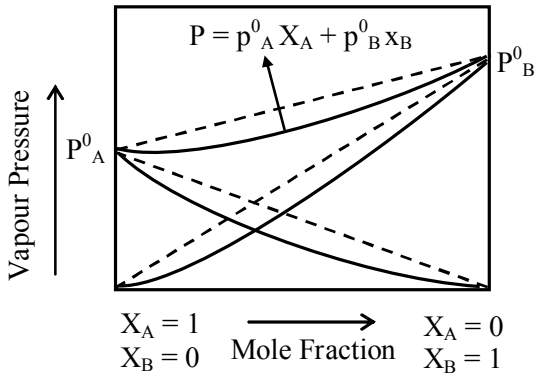
This is because the new interactions are weaker than those in the pure components.

eg. Acetone + Ethyl alcohol, Water + Ethyl alcohol, $CCl_4 + CHCl_3$

Ethanol + $CHCl_3$

Positive deviation (solid lines) from Raoult's law (dotted lines).

7.1.2 Non-ideal solutions showing negative deviations: In such a case the observed vapour pressure of each component and the total vapour pressure are less than predicted by Raoult's law i.e.



$p_A < p^0_A X_A$, $p_B < P^0_B X_B$, $P < p_A + p_B$

This is because the new interactions are stronger than those in the pure components.

eg. Acetone + Aniline, HCl + water,

HNO_3 + water,

water + H_2SO_4 etc

Negative deviations (solid lines) from Raoult's law (dotted lines)

8. Azeotropic Mixture

Azeotropic mixtures of two liquids which boil at a constant temperature and can be distilled unchanged in their composition. They are formed by non-ideal solutions.

8.1 TYPES OF AZEOTROPIC MIXTURES

8.1.1 "Minimum boiling azeotropes" are the mixture of two liquids, whose boiling points is less than either of the two pure components. They are formed by non-ideal solution showing positive deviation.

eg. ethanol (95.5%) + water (4.5%) mixture boiling at 351.15 K.

8.1.2 "Maximum boiling azeotropes" are the mixtures of two liquids, whose boiling points are more than either of the two components. They are formed by non-ideal solution showing negative deviation.

eg. HNO_3(68%) + water (32%) mixture boiling at 393.5 K

9. Colligative Properties of Dilute Solution

(a) A dilute solution is one in which the amount of the solute is very small in comparison to the amount of the solvent.

(b) Dilute solutions containing non-volatile solute exhibit some special properties which depend only upon the number of solute particles present in the solution irrespective of their nature. These properties are termed as colligative properties.

(c) The colligative properties are-

- Relative lowering of vapour pressure
- Elevation in boiling point
- Depression in freezing point
- Osmotic pressure

9.1 Expression for different colligative properties

(i) Osmotic pressure (π) = $\frac{n}{V}$ RT = CRT

when w gram of solute are dissolved in V litres of solutions and M is the molar mass of the solute, then

$$\pi = \frac{WRT}{MV} \left[\because n = \frac{W}{M}\right]$$

when height is involved π = hdg

(h = height, d = density, g = gravitational acceleration)

For isotonic or isosmotic solutions

$$\left[\frac{n_1}{V_1} = \frac{n_2}{V_2}\right] \quad [\because \pi_1 = \pi_2]$$

or $\frac{W_1}{M_1 V_1} = \frac{W_2}{M_2 V_2}$

(ii) Relative lowering in vapour pressure :

$$\frac{p^0_A - p_A}{p^0_A} = X_B = \frac{n}{n+N}$$

[n = moles of solute, N = moles of solvent]

(iii) Elevation in boiling point :

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

(iv) Depression in freezing point :

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

Here, A = refers to solvent, B = refers to solute

* Molal elevation constant (K_b)

$$K_b = \frac{RT_b^2}{1000 \ell_v}$$

[ℓ_v = latent heat of vapourisation]

* Molal depression constant (K_f)

$$K_f = \frac{RT_f^2}{1000 \ell_f}$$

[ℓ_f = latent heat of fusion]

Questions based on **Colligative properties of Dilute Solution**

Ex.2 What will be the temperature at which a solution containing 6 g of glucose per 1000 g water will boil, if molal elevation constant for water is 0.52 / 1000 g.

(1) 1000.173ºC (2) 100.0173ºC

(3) 100.173ºC (4) None **(Ans. 2)**

Sol. w = 6g, W = 1000 g,

Mol. wt. of glucose = 180

$$\Delta T_b = \frac{1000 \times k_b \times w}{m \times W}$$

$$= \frac{1000 \times 0.52 \times 6}{180 \times 1000}$$

$$= 0.0173^oC$$

Hence boiling point of solution

$$= \text{b.p. of water} + \Delta T_b$$

$$= 100 + 0.0173 = \mathbf{100.0173^oC}$$

10. Osmotic Pressure

(a) Osmotic pressure may be defined as the excess pressure which must be applied to a solution in order to prevent flow of solvent into the solution through the semipermeable membrane.

Osmotic pressure may also be defined in several other ways.

(b) Osmotic pressure is the excess pressure which must be applied to a given solution in order to increase its vapour pressure until it becomes equal to that of the solution

(c) Osmotic pressure is the negative pressure which must be applied to (i.e. the pressure which must be withdrawn from) the pure solvent in order to decrease its vapour pressure until it becomes equal to that of the solution

(d) Osmotic pressure is the hydrostatic pressure produced when a solution is separated from the solvent by a semipermeable membrane.

Measurements of Osmotic Pressure :

Following methods are used for the measurement of osmotic pressure

(a) Pfeffer's Method

(b) Morse and Frazer's method

(c) Bekeley and Hartley's method

(d) Townsend's negative pressure method

(e) De Vries plasmolytic method

11. Reverse Osmosis

If a pressure higher than osmotic pressure is applied on the solution , the solvent will flow from the solution into the pure solvent through the semipermeable membrane. Since here the flow of solvent is in the reverse direction to that observed in the usual osmosis, the process is called reverse osmosis.

12. Isotonic Solution

(a) A pair of solutions having the same osmotic pressure are known as isosmotic solutions. If two such solutions are separated by a semipermeable membrane there will be no transference of solvent from one solution to the other.

(b) Isotonic solutions have the same molar concentration. eg. 0.85% NaCl solutions is found to be isotonic with blood.

(c) A solution having lower or higher osmotic pressure than the other is said to be hypotonic or hypertonic respectively in respect to other solution.

(d) When cells are placed in hypotonic solutions, cells swell and burst (haemolysis)

(e) When placed in hypertonic solutions , cells contract in size (plasmolysis). When excess of fertilizers (like urea) are applied , plasmolysis takes place and plants dry up (wilt).

13. Colligative properties of Electrolytes

The colligative properties of solutions, viz, lowering of vapour pressure, osmotic pressure, elevation in b.p. and depression in freezing point, depend solely on the total number of solute particles present in solution. Since the electrolytes ionise and give more than one particle per formula unit in solution, the colligative effect of an electrolyte solution is always greater than that of a nonelectrolyte of the same molar concentration.

(a) Colligative properties $\propto$ Number of particles

$\propto$ Number of molecules (in case of nonelectrolytes)

$\propto$ Number of ions (In case of electrolytes)

$\propto$ Number of moles of solute

$\propto$ Mole fraction of solute

(b) For different solutes of same molar concentration, the magnitude of the colligative properties is more for that solution which gives more number of particles on ionisation.

(c) For different solutions of same molar concentration of different nonelectrolytes solutes, the magnitude of the colligative properties will be same for all.

(d) For different molar concentrations of the same solute, the magnitude of colligative properties is more for the more concentrated solution.

(e) For solutions of different solutes but of same percent strength, the magnitude of colligative property is more for the solute with least molecular weight.

(f) For solutions of different solutes of the same percent strength, the magnitude of colligative property is more for that solute which gives more number of particles which can be known by the knowledge of molecular weight and its ionisation behaviour.

eg. Among the 0.1M solutions of urea, NaCl, $BaCl_2$, Na_3PO_4 and $Al_2(SO_4)_3$ solutions

- Vapour pressure and freezing point will be lowest while b.p. will be highest for $Al_2(SO_4)_3$ solution
- The values of the four colligative properties will be highest for $Al_2(SO_4)_3$ solution

eg. Among 1% solution of urea, glucose and sucrose

- Vapour pressure and freezing point area lowest while boiling point is highest for urea solution
- The four colligative properties are highest for urea solution

eg. Among 0.1M glucose, 0.15M urea and 0.2M sucrose solutions

- Vapour pressure and freezing point is lowest, while boiling point is highest for sucrose solution
- The four colligative properties are highest for sucrose solution.

14. Van't Hoff Factor

Certain solutes which undergo dissociation or association in solutions are found to show abnormal molecular mass. Thus, in order to know about the extent of association or dissociation of solutes in solution Vant Hoff introduced a factor (i). It is defined as the ratio of the normal mass to the observed molecular mass of the solute i.e.

$$i = \frac{\text{Normal molar mass}}{\text{Observed molar mass}};$$

$$i = \frac{\text{Observed colligative property}}{\text{Normal colligative property}}$$

$$i = \frac{\text{Observed osmotic pressure}}{\text{Normal osmotic pressure}};$$

$$i = \frac{\text{Actual number of particles}}{\text{No. of particles for no ionisation}}$$

14.1 Van't Hoff factor and degree of association :

If a solute A forms associated molecules A_n and α is the degree of association then,

$$nA \rightleftharpoons A_n$$

Initial mole	1 mole	0
Associated change	$-\alpha$ mole	$+\alpha/n$ mole
Equilibrium mole	$(1-\alpha)$ mole	α/n mole

Total number of moles after association

1 mole of A = $[1 - \alpha + (\alpha/n)]$ mole

$$= [1 - \alpha (1 - \frac{1}{n})] \text{ mole}$$

Van't Hoff factor (i)

$$= \frac{\text{Number of moles after association}}{\text{Normal number of mole taken}}$$

$$= \frac{[1-\alpha(1-1/n)}{1} = 1 - \alpha\left(1-\frac{1}{n}\right)$$

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

$\therefore$ degree of association $\boxed{\alpha = (1-i)\frac{n}{n-1}}$

14.2 Van't Hoff factor and degree of dissociation:

If a molecule of solute on dissociation gives n ions and α is the degree of dissociation then,

$$(A)_n \rightleftharpoons nA$$

Initial mole	1 mole	0
dissociation change	$-\alpha$ mole	$+n\alpha$ mole
Equilibrium mole	$(1-\alpha)$ mole	$n\alpha$ mole

Total number of moles after dissociation of 1 mole of A

$= [(1 - \alpha) + n\alpha]$ mole

$= 1 + \alpha (n - 1)$ mole

$\therefore$ Van't Hoff factor (i)

$$= \frac{\text{Number of moles after dissociation}}{\text{Number of moles taken (normal)}}$$

$$= \frac{1+\alpha(n-1)}{1} = 1 + \alpha (n - 1)$$

$= 1 + n\alpha - \alpha$

$\therefore$ degree of dissociation $\boxed{(\alpha) = \frac{i-1}{n-1}}$

Questions based on Van't Hoff factor

Ex.3 The freezing point fo a solution containing 0.2g of acetic acid in 20.0 g benzene is lowered by 0.45ºC. Calculate the degree of association of acetic acid in benzene. Assume acetic acid dimerizes in benzene. K_f for benzene = 5.12 K mol^{-1} kg.

(1) 49.5 % (2) 94.5%

(3) 85.5% (4) 58.5% **(Ans. 2)**

Sol. Given, w = 0.2 g, W = 20 g, ΔT = 0.45ºC

$$\Delta T = \frac{1000 \times K \times w}{m \times W}$$

or $$0.45 = \frac{1000 \times 5.12 \times 0.2}{20 \times m}$$

$\therefore$ m (observed) = 113.78

Now for $1\ CH_3COOH \rightleftharpoons (CHCOOH)_2$

Before association	1	0
After association	$1-\alpha$	$\alpha/2$

Where α is degree of association

$\therefore$ $$\frac{M_{normal}}{M_{observed}} = 1 - \alpha + \alpha/2$$

or $$\frac{60}{113.78} = 1 - \alpha + \alpha/2$$

or **α = 0.945** or **94.5 %**

Table : 1 Example of ideal solution

Benzene + toluene, n-hexane + nheptane, $CCl_4 + SiCl_4$, $C_2H_5Br + C_2H_5I$ n-butyl chloride + n butyl bromide	Chlorobenzene + bromo – Benzene

Table : 2 Example of Non ideal solution -

Positive deviation from Raoult's law	Negative Deviation from Raoult's law
1. $(CH_3)_2CO + CS_2$	1. $(CH_3)_2CO + C_6H_5NH_2$
2. $(CH_3)_2CO + C_2H_5OH$	2. $(CH_3)_2 CO + CHCl_3$
3. $CH_3CHO + CS_2$	3. $CHCl_3 + C_6H_6$
4. $C_6H_6 + (CH_3)_2CO$	4. $CHCl_3 + CH_3COOH$
5. $CCl_4 + C_6H_6$	5. $CH_3OH + CH_3COOH$
6. $CCl_4 + C_6H_5CH_3$	6. $CHCl_3 + (C_2H_5)_2O$
7. $CCl_4 + CHCl_3$	7. $CH_3COOH + C_5H_5N$
8. $CCl_4 + CH_3OH$	8. $H_2O + HCl$
9. $C_6H_6 + C_2H_5OH$	9. $H_2O + HNO_3$
10. $CH_3OH + H_2O$	
11. $C_2H_5OH + H_2O$	

Table : 3. (Molal elevation constants of some solvents)

Solvent	B.Pt. (°C)	Molal elevation constant (K_b) (K kg mol^{-1})
Water	100.0	0.52
Acetone	56.0	1.70
Chloroform	61.2	3.67
Carbon tetrachloride	76.8	5.02
Benzene	80.0	2.70
Ethyl alcohol	78.4	1.15

Table : 4. (Molal depression constant of some solvents)

Solvent	E.P.(°C)	Molal depression constant (K_f) (K kg mol^{-1})
Water	0.0	1.86
Ehtyl alcohol	– 114.6	1.99
Chloroform	– 63.5	4.70
Carbon tetrachloride	– 22.8	29.80
Benzene	5.5	5.12
Camphor	179.0	39.70

SOLVED EXAMPLE

Ex.1 A 6.90 M solution of KOH in water has 30% by weight of KOH. Calculate density of solution.

(A) 1.288 g mL^{-1} (B) 12.88 g mL^{-1}

(C) 24.88 g mL^{-1} (D) 2.488 g mL^{-1}

(Ans. A)

Sol. KOH solution is 30% by weight.

$\therefore$ wt. of KOH = 30 g

and Wt. of solution = 100 g

$\therefore$ Volume of solution = $\frac{100}{d}$

$\therefore$ Molarity $= 6.90 = \left(\frac{30}{56 \times \frac{100}{1000 \times d}} \right)$

$= \mathbf{1.288\ g\ mL^{-1}}$

Ex.2 What is mole fraction in its one molal aqueous solution-

(A) 0.108 (B) 0.018

(C) 0.008 (D) None **(Ans. B)**

Sol. Mole fraction = $\frac{n_A}{n_A + n_B}$

$n_A = 1$ and $n_B = \frac{1000}{18} = 55.4$

$= \frac{1}{1+55.4} = \frac{1}{56.4} = \mathbf{0.018}$

Ex.3 The density of a solution containing 13% by mass of sulphuric acid is 1.09 g/mL. Calculate the molarity and normality of the solution-

(A) 1.445 M (B) 14.45 M

(C) 144.5 M (D) 0.1445 M

(Ans. A)

Sol. Volume of 100 gram of the solution = $\frac{100}{d}$

$= \frac{100}{1.09}$ mL $= \frac{100}{1.09 \times 1000}$ litre

$= \frac{1}{1.09 \times 10}$ litre

Number of moles of H_2SO_4 in 100 gram of the solution = $\frac{13}{98}$

Molarity = $\frac{\text{No. of moles of } H_2SO_4}{\text{Volume of solution in litre}}$

$= \frac{13}{98} \times \frac{1.09 \times 10}{1} = \mathbf{1.445\ M}$

Ex.4 Calculate the molality and mole fraction of the solute in aqueous solution containing 3.0 gm of urea per 250 gm of water (Mol. wt. of urea = 60).

(A) 0.2 m, 0.00357 (B) 0.4 m, 0.00357

(C) 0.5 m, 0.00357 (D) 0.7m, 0.00357

(Ans. A)

Sol. Wt. of solute (urea) dissolved = 3.0 gm

Wt. of the solvent (water) = 250 gm

Mol. wt. of the solute = 60

3.0 gm of the solute = $\frac{3.0}{60}$ moles = 0.05 moles

Thus 250 gm of the solvent contain = 0.05 moles of solute

$\therefore$ 1000 gm of the solvent contain

$= \frac{0.05 \times 100}{250} = 0.2$ moles

Hence molality of the solution = 0.2 m

In short,

Molality = No. of moles of solute/1000 g of solvent

$\therefore$ Molality = $\frac{3/60}{250} \times 1000 = \mathbf{0.2\ m}$

Calculation of mole fraction

3.0 gm of solute = 3/60 moles = 0.05 moles

250 gm of water = $\frac{250}{18}$ moles

= 13.94 moles

$\therefore$ Mole fraction of the solute

$= \frac{0.05}{0.05 + 13.94} = \frac{0.05}{13.99}$

$= \mathbf{0.00357}$

Ex.5 15 gram of methyl alcohol is dissolved in 35 gram of water. What is the mass percentage of methyl alcohol in solution ?

(A) 30% (B) 50%

(C) 70% (D) 75% **(Ans. A)**

Sol. Total mass of solution = (15 + 35) gram = 50 gram

mass percentage of methyl alcohol

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

$= \frac{15}{50} \times 100 = \mathbf{30\%}$

Ex.6 214.2 g of sugar syrup contains 34.2 g of sugar. Calculate (i) molality of the solution and (ii) mole fraction of sugar in the syrup.

[IIT 1988]

Sol. (i) Mass of sugar = 34.2

moles of sugar = $\frac{34.2}{342} = 0.1$

Mass of water = (214.2 – 34.2) = 180 gm

No. of moles of water = $\frac{180}{18} = 10$

molality = $\frac{0.1}{180} \times 1000 = 0.555$m

(ii) Mole fraction of sugar = $\frac{0.1}{10+0.1} = 0.0099$

Ex.7 At 300 K, the vapour pressure of an ideal solution containing one mole of A and 3 moles of B is 550 mm of Hg. At the same temperature, if one mole of B is added to this solution, the vapour pressure of solution increases by 10mm of Hg. Calculate the vapour pressure of A and B in their pure state.

(A) 400 mm, 600 mm (B) 600 mm, 400 mm

(C) 200 mm, 300 mm (D) 300 mm, 200 mm

(Ans. A)

Sol. Initially, $P_M = P^o_A \cdot X_A + P^o_B \cdot X_B$

$$550 = P^o_A\left(\frac{1}{1+3}\right) + P^o_B\left(\frac{3}{1+3}\right)$$

or $P^o_A + 3P^o_B = 2200$

When 1 mole of B is further added to it

$$P_M = P^o_A \cdot X_A + P^o_B \cdot X_B$$

$$560 = P^o_A\left(\frac{1}{1+4}\right) + P^o_B\left(\frac{1}{1+4}\right)$$

or $P^o_A + 4P^o_B = 2800$

By (i) and (ii)

P^o_A = **400 mm**;

P^o_B = **600 mm**

Ex.8 The vapour pressure of pure liquid 'A' at 310ºC is 120 torr. The vapour pressure of this liquid in solution with liquid B is 72 torr. Calculate the mole fraction of 'A' in solution if the mixture obeys Raoult's law.

(A) 0.06 (B) 0.9

(C) 0.3 (D) 0.6 **(Ans. D)**

Sol. Given is vapour pressure of pure component 'A', P^o_A = 120 torr

Partial vapour pressure of 'A', P_A = 72 torr

Suppose, its mole fraction in solution is x_A, then according to Raoult's law

$$P_A = P^o_A \cdot x_A$$

$$72 = 120 \times x_A$$

or $x_A = \frac{72}{120} =$ **0.6**

Ex.9 What will be the temperature at which a solution containing 6 g of glucose per 1000 g water will boil, if molal elevation constant for water is 0.52/1000 g.

(A) 1000.173ºC (B) 100.0173ºC

(C) 100.173ºC (D) None **(Ans. B)**

Sol. w = 6g, W = 1000g, Mol. wt. of glucose =180

$$\Delta T_b = \frac{1000 \times K_b \times w}{m \times W}$$

$$= \frac{1000 \times 0.52 \times 6}{180 \times 1000}$$

$$= 0.0173^oC$$

Hence boiling point of solution = b.p. of water + ΔT_b = 100 + 0.0173 = **100.0173ºC**.

Ex.10 Calculate the molal elevation constant of water evaporates at 100ºC with the absorption of 536 calories per gm (R = 2 cals).

(A) 0.519ºC (B) 0.0519ºC

(C) 1.519ºC (D) 2.519ºC **(Ans. A)**

Sol. Molal elevation constant of the solvent.

$$K_b = \frac{RT^2_b}{\ell_v \times 1000} = \frac{2 \times 373 \times 373}{536 \times 1000} =$$ **0.519ºC**

Ex.11 The vapour pressure of CCl_4 (density = 1.58 g cm^{-3}) at 30ºC is 143 mm. A 0.5 g of a non-volatile solute of molecular weight 65 is dissolved in 100 ml of CCl_4. Calculate the vapour pressure of the solution-

(A) 141.93 mm (B) 14.193 mm

(C) 1.4193 mm (D) None **(Ans. A)**

Sol. Here w = 0.5 g, W = 100 × 1.58 = 158 g (since d = W / V), m = 65,

$$M \text{ of } CCl_4 = 154. \frac{p^o - p}{p^o} = \frac{wM}{mW}$$

or $\frac{143-p}{143} = \frac{0.5 \times 154}{65 \times 158}$

or p = **141.93 mm**

Ex.12 The freezing point of a solution containing 0.2g of acetic acid in 20.0 g benzene is lowered by 0.45ºC. Calculate the degree of association of acetic acid in benzene. Assume acetic acid dimerizes in benzene. K_f for benzene = 5.12 K mol^{-1} kg.

(A) 49.5 % (B) 94.5%

(C) 85.5% (D) 58.5% **(Ans. B)**

Sol. Given, w = 0.2 g, W = 20 g,

ΔT = 0.45ºC

$$\Delta T = \frac{1000 \times K \times w}{m \times W}$$

or $0.45 = \frac{1000 \times 5.12 \times 0.2}{20 \times m}$

$\therefore$ m(observed) = 113.78

Now for $2CH_3COOH \rightleftharpoons (CH_3COOH)_2$

Before association 1 0

After association $1-\alpha$ $\alpha/2$

Where α is degree of association

$\therefore$ $\frac{m_{normal}}{m_{observed}} = 1 - \alpha + \alpha/2$

or $\frac{60}{113.78} = 1 - \alpha + \alpha/2$

or α = **0.945**

or **94.5 %**

Ex.13 An aqueous solution containing 28% by mass of a liquid A(mol. mass = 140) has a vapour pressure of 160 mm at 37^0C. Find the vapour pressure of the pure liquid A. (The vapour pressure of water at 37^0C is 150 mm).

(A) 360 mm (B) 150 mm

(C) 160 mm (D) None **(Ans. A)**

Sol. For two miscible liquids,

P_{total} = mol. fraction A x p^0_A mol. fraction B x p^0_B

No. of moles of A = $\frac{28}{140} = 0.2$

Liquid B is water. Its mass is (100 - 28) = i.e. 72

No. of moles of B = $\frac{72}{18} = 4.0$

Total number of moles = 0.2 + 4.0 = 4.2

Given P_{total} = 160 mm

p^0_B = 150 mm

So, $160 = \frac{0.2}{4.2} \times p^0_A + \frac{4.0}{4.2} \times 150$

$p^0_A = \frac{17.15 \times 4.2}{0.2}$

= 360.15 mm ≈ 360 mm

Ex.14 Twenty grams of a substance were dissolved in 500 ml. of water and the osmotic pressure of the solution was found to be 600 mm of mercury at 15^0C. Determine the molecular weight of the substance-

(A) 1120 (B) 1198

(C) 1200 (D) None of these

(Ans. B)

Sol. Here it is given that

w = 20 gm ; V = 500 ml .

$= \frac{500}{1000} = 0.5$ litre

$\pi = 600 \text{ mm} = \frac{600}{760}$ atm ;

$T = 15 + 273 = 288^0$A

m = ?

According to Van't Hoff equation ,

$\pi V = nST$

$\pi V = \frac{w}{m} ST$

$\therefore m = \frac{wST}{\pi V} = \frac{20 \times 0.0821 \times 288 \times 760}{600 \times 0.5}$

= 1198

Ex.15 Blood plasma has the following composition (milli-equivalents per litre). Calculate its osmotic pressure at 37^0C.

$Na^+ = 138$, $Ca^{2+} = 5.2$, $K^+ = 4.5$,

$Mg^{2+} = 2.0$, $Cl^- = 105$, $HCO_3^- = 25$,

$PO_4^{3-} = 2.2$, $SO_4^{2---} = 0.5$,

Proteins = 16, Others = 1.0

(A) 7.47 atm (B) 7.30 atm

(C) 7.29 atm (D) 7.40 atm

(Ans. A)

Sol. Since for calculating osmotic pressure we require millimoles/litre therefore

$Na^+ = 138$ $Ca^{2+} = \frac{5.2}{2} = 2.6$, $K^+ = 4.5$, Mg^{2+}

$= \frac{2.0}{2} = 1.0$, $Cl^- = 105$,

$HCO_3^- = 24, PO_4^{3-} = \frac{22}{3} = 0.73$,

$SO_4^{2-} = \frac{0.5}{2} = 0.25$, Proteins = 16 ,

others = 1.0

Total = 294.18 millimoles/litre = $\frac{294.18}{1000}$

= 0.294 moles/litre

Now since π = CST

= 0.294 x 0.0821 x .310 = 7.47 atm

Ex.16 0.15g of a substance dissolved in 15g of solvent boiled at a temperature higher by 0.216^0C than that of the pure solvent. Calculate the molecular weight of the substance. Molal elevation constant for the solvent is 2.16^0C.

(A) 216 (B) 100 (C) 178 (D) None of these

(Ans. B)

Sol. Here it is given that

w = 0.15 g,

$\Delta T_b = = 0.216^0$C

W = 15g $K_b = 2.16^0$C

m = ?

Substituting values in the expression ,

$m = \frac{1000 \times K_b \times w}{\Delta T_b \times W}$

$m = \frac{1000 \times 2.16 \times 0.15}{0.216 \times 15} = 100$

Ex.17 The freezing point of 0.2 molal K_2SO_4 is –1.1ºC. Calculate Van't Haff factor and percentage degree of dissociation of K_2SO_4. K_f for water is 1.86º

(A) 97.5 (B) 90.75

(C) 105.5 (D) 85.75 **(Ans. A)**

Sol. ΔT_f = freezing point of water – freezing point of solution = 0º C – (–1.1º C) = 1.1º

We know that,

$\Delta T_f = i \times K_f \times m$

$1.1 = i \times 1.86 \times 0.2$

$\therefore \quad i = \frac{1.1}{1.86 \times 0.2} = 2.95$

But we know

$i = 1 + (n - 1)\alpha$

$2.95 = 1 + (3 - 1)\ \alpha = 1 + 2\alpha$

$\alpha = 0.975$

Van't Haff factor (i) = 2.95

Degree of dissociation = 0.975

Percentage degree of dissociation = **97.5**

Ex.18 Pure benzene boiled at 80°C. The boiling point of a solution containing 1 g of substance dissolved in 83.4 g of benzene is 80.175°C. If latent heat of vaporization of benzene is 90 cal per g, calculate the molecular weight of solute .

Sol. Boiling point of $C_6H_6 = 80 + 273 = 353$ k
Latent heat (1_v) = 90 cal/g
$\Delta T = 80.175 - 80 = 0.175$, w = 1 g, W = 83.4 g

$$\because \quad K_b = \frac{RT^2}{1000 1_v}$$

$$\text{or} \quad k_b = \frac{2\times353\times353}{1000\times90} = 2.769 \text{ K mol}^{-1} \text{ kg}$$

$$\text{Now} \quad \Delta T = \frac{k_b \times 1000 \times w}{m \times W}$$

$$0.175 = \frac{2.769\times1000\times1}{m\times83.4}$$

$$\therefore \quad m = 189.79$$

Ex.19 At 27°C, 36 g of glucose per litre has an O.P. of 4.92 atm. If the osmotic pressure of solution is 1.5 atm at the same temperature, what should be its concentration ?

Sol. Given that, $\pi_1 = 4.92$ atm, $\pi_2 = 1.5$ atm

$$C_1 = \frac{36}{180\times1} \qquad \left(\because C = \frac{w}{m\times V}\right) \quad C_2 = ?$$

$\pi_1 V_1 = n_1 S_1 T_1$ and $\pi_2 V_2 = n_2 S T_2$
At same temperature

$$\frac{\pi_1}{\pi_2} = \frac{n_1}{n_2}\times\frac{V_2}{V_1} = \frac{C_1}{C_2} \quad \text{or} \quad \frac{4.92}{1.5} = \frac{36}{180\times C_2}$$

$C_2 = 0.061$ mol/litre

Ex.20 How many g of glucose must be present in 0.5 litre of a solution for its osmotic pressure to be same as that of solution of 9.2 g glucose per litre ?

Sol. For isotonic solutions, $C_1 = C_2$

$$\text{or} \quad \frac{w_1}{m_1 V_1} = \frac{w_2}{m_2 V_2}$$

$$\text{or} \quad \frac{w_1}{180\times0.5} = \frac{9.2}{180\times1}$$

$$\therefore \quad w_1 = 4.60 \text{ g}$$

Ex.21 Two liquids A and B form an ideal solution at temperature T. When the total vapour pressure above the solution is 400 torr, the mol fraction of A in the vapour phase is 0.4 and in the liquid phase 0.75. What are the vapour pressure of pure A and pure B at temperature T ?

Sol. Mole fraction of A in vapour phase $Y_A = 0.4$ & in liquid phase $X_A = 0.75$
$P_{total} = 400$ torr
Let V.P. of pure A and B are P_A^0 & P_B^0.

$$\because X_A P_A^0 = Y_A P_{total}$$

$$P_A^0 = \frac{Y_A P_{Total}}{x_A} = \frac{0.4\times400}{0.75} = \frac{160}{0.75}$$

$P_A^0 = 213.33$ torr

$$P_{total} = X_A P_A^0 + (1 - X_A) P_B^0$$

$$400 = 0.75\left(\frac{160}{0.75}\right) + (1 - 0.75) P_B^0$$

$P_B^0 = 960$ torr

Ex.22 Vapour pressure of solution containing 6g of a non-volatile solute in 180 g water is 20.0 torr. If 1 mol water is further added vapour pressure increases by 0.02 torr. Calculate vapour pressure of water and molecular weight of non-volatile solute temperature remaining constant

Sol. Let moelcualr wt. of solute = m
and V.P. of water (solvent) = P^0
$P_{solution} = 20$ torr

$$\text{moles of solute } n = \frac{6}{m}$$

$$\text{moles of solvent } N = \frac{180}{18} = 10$$

$$\because \quad P_S = \left(\frac{N}{n+N}\right) P^0$$

$$20 = \left(\frac{10}{\frac{6}{m}+10}\right) P^0$$

$$20 = \left(\frac{10m}{6+10m}\right) P^0 \quad \text{.....(1)}$$

If 1 mol water is further added moles of solvent
N = 10 + 1 = 11 mol
& V.P. of solution becomes

$$P_S = 20 + 0.02 = 20.02 \text{ torr}$$

$$P_S = \frac{N}{n+N} P^0$$

$$20.02 = \left(\frac{11}{\frac{6}{m}+11}\right) P^0$$

$$20.02 = \left(\frac{11m}{6+11m}\right) P^0 \quad \text{.....(2)}$$

divide eqn. (2) by (1)

$$\frac{20.02}{20} = \frac{11(6+10m)}{10(6+11m)}$$

m = 54 gm
Put this value of m in equation. (1) or (2)

$$P^0 = 22.22 \text{ torr}$$

Ex.23 Phenol associates in benzene to a certain extent to form dimmer. A solution containing 20×10^{-3} kg of phenol in 1.0 kg of benzene has its freezing point decreased by 0.69 K. Calculate the fraction of the phenol that has dimerised. (K_f of benzene is 5.12°Kmol^{-1}).
[Roorkee 1998]

Sol. Given
$w = 20 \times 10^{-3}$ kg. = 20 gm
$W = 1$ kg = 10^3 gm
Observed

$$\Delta T_f = i\left(\frac{w\times1000}{m\times W}\times K_f\right)$$

$$0.69 = i\left(\frac{20\times1000\times5.12}{94\times10^3}\right)$$

$$i = 1 - \alpha + \frac{\alpha}{n} \quad \text{or} \quad \alpha = \frac{(i-1)}{\left(\frac{1}{n}-1\right)}$$

$\alpha = 0.733$ or 73.3

Ex.24 Calculate the freezing point of an aqueous solution of a non-electrolyte having an osmotic pressure of 0.2 atmosphere at 300 K. **[Roorkee 1993]**

Sol. $\pi = CST$

$$C = \frac{\pi}{ST} = \frac{2}{0.0821\times300} \text{ mol lit}^{-1}$$

In dilute solution, the density fo water can be taken as 1.0 gm cm^{-3}.

Hence molality ≈ molarity

$$\Delta T_f = (\text{molality} \times K_f)$$

$$= \frac{2}{0.0821\times300} \times 1.86$$

$$\Delta T_f = 0.151 \text{ K}$$

$$\therefore \quad (T_f)_{solution} = (T_f)\text{solvent} - \Delta T_f$$

$$= (273 - 0.151)$$

$$(T_f)_{solution} = 272.749 \text{ K or } -0.151°C$$

Ex.25 x g of a non-electrolytic compound (molar mass = 200) is dissolved in 1.0 litre of 0.05 M NaCl solution. The osmotic pressure of this solution is found to be 4.92 atm at 27ºC. Calculate the value 'x'. Assume complete dissociation of NaCl and ideal behaviour of this solution. **[Roorkee 1998]**

Sol. (i) For NaCl : $\pi_1 = i\,(CST)$

$$\pi_1 = 2 \times 0.05 \times 0.0821 \times 300$$

$$\pi_1 = 2.463 \text{ atm}$$

(ii) for unknown compound :

$$\pi_2 = CST$$

$$\pi_2 = \frac{x}{200\times1} \times 0.0821 \times 300$$

$$\pi_2 = 0.1231\,x \text{ atm}$$

Total osmotic pressure $\pi = \pi_1 + \pi_2$

$$4.92 = 2.463 + 0.1231x$$

$$x = 19.959 \text{ gm}$$

Ex.26 To 500 cm^3 of water, 3.0×10^{-3} kg of acetic acid is added. If 23% of acetic acid is dissociated, what will be the depression in freezing point ? K_f and density of water are 1.86 K kg^{-1} mol^{-1} and 0.997 g cm^{-3} respectively. **[IIT 2000]**

Sol. Mass of solute = 3×10^{-3} Kg = 3gm

Mass of solvent = $500 \times 0.997 = 498.5$ gm

$\alpha = 23\% = 0.23$

$i = 1 - \alpha + n\alpha$

$= 1 - 0.23 + 2 \times 0.23$

$i = 1.23$

$\Delta T_f = i\,(\text{molality} \times k_f)$

$$= 1.23 \times \left(\frac{3\times1000}{60\times498.5}\right) \times 1.86$$

$\Delta T_f = 0.229$

Ex. 27 0.1 formal solution of NaCl is found to be isotonic with 1.10% solution urea. Calculate the apparent degree of ionization of NaCl.

Sol. 0.1 formal = 0.1 M solu. of NaCl

1.1% solution of urea means ⟶

100 ml solu. contains 1.1 gm urea

$\pi_{NaCl} = \pi_{urea}$

$$i(0.4 \times ST) = \frac{1.1\times1000}{60\times100} \times ST$$

$i = 1.83$

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

$$\Rightarrow \quad \frac{1.83-1}{2-1} = 0.83 \quad \alpha = 83\%$$