Liquid Solution

Question1

The osmotic pressure (in atm) of an aqueous solution containing 0.01 mol of NaCl (degree of dissociation 0.94) and 0.03 mol of glucose in 500 mL at 27°C is $\left(R=0.082 \mathrm{~L} \text{ atm } \mathrm{K}^{-1} \mathrm{~mol}^{-1}\right)$

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Options:

A.

2.43

B.

4.23

C.

3.24

D.

3.42

Answer: A

Solution:

$\mathrm{NaCl} \rightleftharpoons \mathrm{Na}^{+}+\mathrm{Cl}^{-}$

$i_{\mathrm{NaCl}}=1+\alpha(n-1)$
$n=2 ; i_{\mathrm{NaCl}}=1+0.94(2-1)=1.94$
$i_{\text {glucose }}=1$

Concentration of $\mathrm{NaCl}=\frac{0.01}{0.5}=0.02 \mathrm{M}$

Effective concentration of NaCl $= iC_{\mathrm{NaCl}}$

$$= 1.94 \times 0.02\mathrm{M} = 0.0388\mathrm{M}$$

$$C_{\text{glucose}} = \frac{0.03}{0.5} = 0.06\mathrm{M}$$

Effective concentration $= 0.06\mathrm{M}$

$$iC_{\text{total}} = 0.0388 + 0.06 = 0.0988\mathrm{M}$$

$$\pi = iC_{\text{total}} \quad RT$$

$$= 0.098 \times 0.082 \times 300.15 = 2.43 \text{ atm}$$

Question2

Which of the following solution has highest amount of solute?

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Options:

A.

1.0 L of $0.25\mathrm{M}\,\mathrm{Na_2CO_3}(106\mathrm{u})$

B.

0.25 L of $0.2\mathrm{M}\,\mathrm{Na_2SO_4}(142\mathrm{u})$

C.

0.5 L of $1.0\mathrm{M}\,\mathrm{KMnO_4}(158\mathrm{u})$

D.

0.75 L of $0.5\mathrm{M}\,(\mathrm{NH_2})_2\mathrm{CO}(60\mathrm{u})$

Answer: C

Solution:

Mass of solute $=$ Molarity $\times$ Volume (L) $\times$ Molar mass

(i) $0.25 \times 1 \times 106 = 26.5$ g

(ii) $0.2 \times 0.25 \times 142 = 7.1$ g

(iii) $1 \times 0.5 \times 158 = 79$ g

(iv) $0.5 \times 0.75 \times 60 = 22.5$ g

Hence, 0.5 L of $1.0 \mathrm{M} \mathrm{KMnO}_4$ has highest amount of solute.

Question3

Observe the following statements

Statement I : The boiling point of 0.1 M urea solution is less than that of 0.1 M KCl solution.

Statement II : Elevation of boiling point is inversely proportional to molar mass of solute.

The correct answer is

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Options:

A.

Both Statements I and II are correct.

B.

Statement I is correct, but Statement II is not correct.

C.

Statement I is not correct, but Statement II is correct.

D.

Both Statement I and II are not correct.

Answer: A

Solution:

Both Statement I and II are correct.

Question4

At 300 K , the vapour pressure of toluene and benzene are 3.63 kPa and 9.7 kPa respectively. What is the composition of vapour in equilibrium with the solution containing 0.4 mole fraction of toluene?

(Assume the solution is ideal)

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Options:

A. 0.40

B. 0.60

C. 0.80

D. 0.20

Answer: D

Solution:

Given the following information:

The vapor pressure of benzene at 300 K is $p_{\text{Benzene}}^{\circ} = 9.7\,\text{kPa}$.

The vapor pressure of toluene at 300 K is $p_{\text{Toluene}}^{\circ} = 3.63\,\text{kPa}$.

The mole fraction of toluene in the solution is $x_{\text{Toluene}} = 0.4$.

We need to determine the composition of the vapor in equilibrium with the solution, assuming it is an ideal solution.

Calculations:

Identify the mole fraction of benzene:

$x_{\text{Benzene}} = 1 - x_{\text{Toluene}} = 1 - 0.4 = 0.6$

Calculate the partial pressures using Raoult's Law:

Partial pressure of benzene:

$$p_{\text{Benzene}} = p^{\circ}_{\text{Benzene}} \times x_{\text{Benzene}} = 9.7\,\text{kPa} \times 0.6 = 5.82\,\text{kPa}$$

Partial pressure of toluene:

$$p_{\text{Toluene}} = p^{\circ}_{\text{Toluene}} \times x_{\text{Toluene}} = 3.63\,\text{kPa} \times 0.4 = 1.452\,\text{kPa}$$

Calculate the total pressure of the solution:

$$p_{\text{Total}} = p_{\text{Benzene}} + p_{\text{Toluene}} = 5.82\,\text{kPa} + 1.452\,\text{kPa} = 7.272\,\text{kPa}$$

Determine the mole fraction of toluene in the vapor phase using Dalton's Law:

$$Y_{\text{Toluene}} = \frac{p_{\text{Toluene}}}{p_{\text{Total}}} = \frac{1.452}{7.272} \approx 0.20$$

Conclusion:

The mole fraction of toluene in the vapor phase is approximately 0.20. Therefore, the composition of the vapor in equilibrium with the solution is ≈ 0.20 for toluene.

Question5

At $T(\text{ K}), 0.1$ mole of a non-volatile solute was dissolved in 0.9 mole of a volatile solvent. The vapour pressure of pure solvent is 0.9 bar. What is the vapour pressure (in bar) of solution ?

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Options:

A. 0.89

B. 0.81

C. 0.79

D. 0.71

Answer: B

Solution:

Given:

Moles of solute, $n_1 = 0.1$ mol

Moles of solvent, $n_2 = 0.9$ mol

Vapor pressure of pure solvent, $p^0 = 0.9$ bar

The relative lowering of vapor pressure is calculated using the formula:

$$\frac{p^0 - p}{p^0} = \frac{n_1}{n_1 + n_2}$$

Where:

p^0 is the vapor pressure of the pure solvent

n_1 is the number of moles of solute

n_2 is the number of moles of solvent

Substitute the given values into the equation:

$$\frac{0.9 - p}{0.9} = \frac{0.1}{0.1 + 0.9}$$

Simplifying the right side:

$$\frac{0.1}{1.0} = 0.1$$

Now, plug this value back into the equation:

$$\frac{0.9 - p}{0.9} = 0.1$$

This implies:

$$0.9 - p = 0.09$$

Solving for p:

$$p = 0.9 - 0.09 = 0.81 \text{ bar}$$

Thus, the vapor pressure of the solution is 0.81 bar.

Question6

At $300 \mathrm{~K}$, $0.06 \mathrm{~kg}$ of an organic solute is dissolved in 1 kg water. The vapour pressure of solution at 300 K is 3.768 kPa . If vapour pressure of water at that temperature is 3.78 kPa , what is the molar mass of the organic solute (in gmol^{-1})? Assume the solution is dilute

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Options:

A. 180

B. 120

C. 340

D. 260

Answer: C

Solution:

Given,

Pressure (vapour) of pure solvent $(\mathrm{H_2O})\ p^{\circ} = 3.78 \mathrm{kPa}$.

Vapour pressure after solute mixing $p = 3.768 \mathrm{kPa}$.

Relative lowering of vapour pressure

$= \frac{p^{\circ}-p}{p}$

$= \frac{3.78-3.768}{3.78} = 3.17 \times 10^{-3}$

Now, relative lowing of vapour pressure is given by

$\frac{p^{\circ}-p}{p^{\circ}} = \frac{W_B - M_A}{M_B \times W_A}$

where,

$W_A =$ mass of solvent $(\mathrm{H_2O})(1\ \mathrm{kg})$

$M_A =$ Molar mass of solvent

$W_B =$ Mass of solute $(\ 0.06\ \mathrm{kg}\ )$

$M_B =$ Molar mass of solvent

Substitute the values in Eq. (ii),

$3.17 \times 10^{-3} = \frac{60\ \mathrm{g} \times 18\ \mathrm{g/mol}}{M_B \times 1000\ \mathrm{g}}$

$M_B = 340\ \mathrm{g\ mol}^{-1}$

Question7

Dry air contains $79\%\ N_2$ and $21\% O_2$. At $T(\ \mathrm{K})$, if Henry's law constants for N_2 and O_2 in water are 857×10^4 atm and 4.56×10^4 atm, the ratio of mole fraction of N_2 and O_2 dissolved in water at 1 atm is

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Options:

A. 4 : 1

B. 1 : 4

C. 2 : 1

D. 1 : 2

Answer: C

Solution:

Given, percentage of nitrogen

$(N_2) = 79\%$

Percentage of oxygen $(O_2) = 21\%$

Pressure $= 1$ atm

Partial pressure of N_2 and O_2 are

$$p_{N_2} = p \times N_2$$

$$\Rightarrow \quad \frac{1 \times 79}{100} = 0.79 \text{ atm} \quad \ldots \text{(i)}$$

$$p_{O_2} = p \times O_2$$

$$\Rightarrow \quad \frac{1 \times 21}{100} = 0.21 \text{ atm} \quad \ldots \text{(ii)}$$

Applying Henry's law for N_2 and O_2,

$$p_{N_2} = K_{N_2} x_{N_2}$$

$$\Rightarrow \quad x_{N_2} = \frac{p_{N_2}}{K_{N_2}} = \frac{0.79}{8.57 \times 10^4}$$

$$x_{N_2} = 9.25 \times 10^{-6} \quad \ldots \text{(iii)}$$

$$p_{O_2} = K_{O_2} x_{O_2}$$

$$\Rightarrow \quad x_{O_2} = \frac{p_{O_2}}{K_{O_2}}$$

$$= \frac{0.21}{8.56 \times 10^4}$$

$$x_{O_2} = 4.60 \times 10^{-6} \quad \ldots \text{(iv)}$$

Ratio of mole fraction of N_2 and O_2,

$$\frac{x_{N_2}}{x_{O_2}} = \frac{9.25 \times 10^{-6}}{4.60 \times 10^{-6}} = 2.1$$

Question8

Distilled water boils at 373.15 K and freezes at 273.15 K . A solution of glucose in distilled water boils at 373.202 K . What is the freezing point (in K) of the same solution? (For water, $K_b = 0.52 \text{ K kg mol}^{-1}$,$K_f = 1.86 \text{ K kg mol}^{-1}$)

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Options:

A. 273.15

B. 273.0

C. 272.964

D. 273.336

Answer: C

Solution:

The relation between K_f and K_b is

$$K_f = K_b \times \frac{\Delta T_f}{\Delta T_b} \quad \ldots \text{(i)}$$

$\Delta T_b =$ elevation in boiling point
$= 373.202 - 373.15 = 0.052 \text{ K}$

K_f and K_b are given as,

$K_b = 0.052 \text{ K kg/mol}$
$K_f = 1.86 \text{ K kg/mol}$

Substitute all value in Eq. (i)

$$1.86 = 0.052 \times \frac{\Delta T_f}{0.52}$$

$$\Delta T_f = \frac{1.86}{10} \text{ or } 0.186 \quad \ldots \text{(ii)}$$

$\Delta T_f =$ depression in freezing point
$\Delta T_f = 0.186 = 273.15 \mathrm{~K} - x$
$x = 272.964 \mathrm{~K}$

Question9

At 300 K , the osmotic pressure of a decinormal solution of sodium chloride is 4.82 atm . The degree of dissociation of sodium chloride is $x \times 10^{-2}$. The value of x is $\left(R = 0.082 \mathrm{~L} \text{ atm } \mathrm{K}^{-1} \mathrm{~mol}^{-1}\right)$

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Options:

A. 90

B. 96

C. 93

D. 88

Answer: B

Solution:

To determine the degree of dissociation (α) of sodium chloride at 300 K given the osmotic pressure, we can use the van't Hoff factor (i) and the formula for osmotic pressure (π).

Given

Osmotic pressure (π) = 4.82 atm

Temperature (T) = 300 K

Concentration (C) = 0.1 N

R (gas constant) = 0.082 L atm K^{-1} mol^{-1}

Formula for Osmotic Pressure

$\pi = iCRT$

Calculation

First, calculate the van't Hoff factor (i):

$i = \frac{\pi}{CRT} = \frac{4.82}{0.1 \times 0.082 \times 300} = 1.96$

Understanding the Dissociation

For sodium chloride (NaCl), which dissociates into two ions Na^+ and Cl^-:

$i = 1 + \alpha$

where n (number of ions) for NaCl is 2. Therefore:

$1.96 = 1 + \alpha$

Solving for α:

$\alpha = 1.96 - 1 = 0.96$

Thus, the degree of dissociation $\alpha = 96 \times 10^{-2}$.

Conclusion

Therefore, $x = 96$.

Question10

The vapour pressure of a pure liquid A is 70 torr at 300 K . It forms an ideal solution with another liquid B. The mole fraction of B is 0.2 and total vapour pressure of the solution is 84 torr at the same temperature. The vapour pressure of pure liquid B (in torr) is

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Options:

A. 140

B. 90

C. 120

D. 80

Answer: A

Solution:

Given:

Vapour pressure of pure liquid A, $p_A^{\circ} = 70$ torr

Mole fraction of liquid B, $\chi_B = 0.2$

Total vapour pressure of the solution, $p_{\text{total}} = 84$ torr

Vapour pressure of pure liquid B, $p_B^{\circ} = ?$

First, identify the mole fraction of liquid A:

$\chi_A + \chi_B = 1$

$\chi_A = 1 - 0.2 = 0.8$

Using Dalton's law of partial pressures, express the total vapor pressure:

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

Apply Raoult's law to determine the partial pressures of components A and B:

For component A:

$p_A = p_A^{\circ} \cdot \chi_A$

$p_A = 70 \times 0.8 = 56$ torr

For component B:

$p_B = p_B^{\circ} \cdot \chi_B = p_B^{\circ} \times 0.2$

Substitute the values found for p_A and the expression for p_B into the equation for total pressure:

$84 = 56 + 0.2 \times p_B^{\circ}$

Solve for p_B°:

$p_B^{\circ} = \frac{84-56}{0.2} = 140$ torr
