Chapter – 9

Solutions

Textbook Evaluation:

I. Choose the best answer:

Question 1.
The molality of a solution containing 1.8 g of glucose dissolved in 250 g of water is
a) 0.2 M
b) 0.01 M
c) 0.02 M
d) 0.04 M

Answer:
d) 0.04 M

Question 2.
Which of the following concentration terms is / are independent of temperature
a) molality
b) molarity
c) mole fraction
d) a and b

Answer:
d) a and b

Question 3.
Stomach acid, a dilute solution of HCl can be neutralized by reaction with aluminium hydroxide $Al(OH)_3 + 3HCl\ (aq) \rightarrow AlCl_3 + 3H_2O$. How many milliliters of 0.1 M $Al(OH)_3$ solution is needed to neutralize 21 ml of 0.1 M HCl?
a) 14 mL
b) 7 mL
c) 21 mL
d) none of these

Answer:
b) 7 mL

Question 4.
The partial pressure of nitrogen in air is 0.76 atm and its Henry's law constant is 7.6×10^4 atm at 300 K. What is the mole fraction of nitrogen gas in the solution obtained when air is bubbled through water at 300 K ?
a) 1×10^{-4}
b) 1×10^4
c) 2×10^{-5}
d) 1×10^{-5}

Answer:
d) 1×10^{-5}

Question 5.
The Henry's law constant for the solubility of Nitrogen gas in water at 350 K is 8×10^4 atm. The mole fraction of nitrogen in air is 0.5. The number of moles of Nitrogen from air dissolved in 10 moles of water at 350 K and 4 atm pressure is
a) 4×10^{-4}
b) 4×10^4
c) 2×10^{-2}
d) 2.5×10^{-4}

Answer:
d) 2.5×10^{-4}

Question 6.
Which one of the following is incorrect for an ideal solution?
a) $\Delta H_{mix} = 0$
b) $\Delta U_{mix} = 0$
c) $\Delta P = P_{observed} - P_{calculated\ by\ Raoults\ law} = 0$
d) $\Delta G_{mix} = 0$

Answer:
d) $\Delta G_{mix} = 0$

Question 7.
Which one of the following gases has the lowest value of Henry's law constant?
a) N_2
b) He
c) CO_2
d) H_2

Answer:
c) CO_2

Question 8.
P_1 and P_2 are the vapour pressures of pure liquid components, 1 and 2 respectively of an ideal binary solution If x_1 represents the mole fraction of component 1, the total pressure of the solution formed by 1 and 2 will be
a) $P_1 + x_1 (P_2 - P_1)$
b) $P_2 - x_1 (P_2 + P_1)$
c) $P_1 - x_2(P_1 - P_2)$
d) $P_1 + x_2(P_1 - P_2)$
Answer:
c) $P_1 - x_2(P_1 - P_2)$

Question 9.
Osomotic pressure (π) of a solution is given by the relation
a) $\pi = nRT$
b) $\pi V = nRT$
c) $\pi RT = n$
d) none of these

Answer:
b) $\pi V = nRT$

Question 10.
Which one of the following binary liquid mixtures exhibits positive deviation from Raoults law?
a) acetone + chloroform
b) water + nitric acid
c) HCl + water
d) ethanol + water

Answer:
d) ethanol + water

Question 11.
The Henry's law constants for two gases A and B are x and y respectively. The ratio of mole fractions of A to B 0.2. The ratio of mole fraction of B and A dissolved in water will be

a) $\frac{2x}{y}$

b) $\frac{y}{0.2x}$

c) $\frac{0.2x}{y}$

d) $\frac{5x}{y}$

Answer:

d) $\frac{5x}{y}$

Question 12.
At 100°C the vapour pressure of a solution containing 6.5g a solute in 100g water is 732 mm. If $K_b = 0.52$, the boiling point of this solution will be
a) 102°C
b) 100°C
c) 101°C
d) 100.52°C

Answer:
c) 101°C

Question 13.
According to Raoults law, the relative lowering of vapour pressure for a solution is equal to
a) mole fraction of solvent
b) mole fraction of solute

c) number of moles of solute
d) number of moles of solvent

Answer:
b) mole fraction of solute

Question 14.
At same temperature, which pair of the following solutions are isotonic?
a) 0.2 M $BaCl_2$ and 0.2 M urea
b) 0.1 M glucose and 0.2 M urea
c) 0.1 M NaCl and 0.1 M K_2SO_4
d) 0.1 M $Ba(NO_3)_2$ and 0.1 M Na_2SO_4

Answer:
d) 0.1 M $Ba(NO_3)_2$ and 0.1 M Na_2SO_4

Question 15.
The empirical formula of a non – electrolyte (X) is CH_2O. A solution containing six grams of X exerts the same osmotic pressure as that of 0.025 M glucose solution at the same temperature. The molecular formula of X is
a) $C_2H_4O_2$
b) $C_8H_{16}O_8$
c) $C_4H_8O_4$
d) CH_2O

Answer:
b) $C_8H_{16}O_8$

Question 16.
The K_H for the solution of oxygen dissolved in water is 4×10^4 atm at a given temperature. If the partial pressure of oxygen in air is 0.4 atm, the mole fraction of oxygen in solution is
a) 4.6×10^3
b) 1.6×10^4
c) 1×10^{-5}
d) 1×10^5

Answer:
c) 1×10^{-5}

Question 17.
Normality of 1.25 M sulphuric acid is
a) 1.25 N
b) 3.75 N
c) 2.5 N
d) 2.25 N

Answer:
c) 2.5 N

Question 18.
Two liquids X and Y on mixing gives a warm solution. The solution is
a) ideal
b) non-ideal and shows positive deviation from Raoults law
c) ideal and shows negative deviation from Raoults Law
d) non-ideal and shows negative deviation from Raoults Law

Answer:
d) non-ideal and shows negative deviation from Raoults Law

Question 19.
The relative lowering of vapour pressure of a sugar solution in water is 2.5×10^{-3}. The mole fraction of water in that solution is
a) 0.0035
b) 0.35
c) 0.0035/18
d) 0.9965

Answer:
d) 0.9965

Question 20.
The mass of a non – volatile solute (molar mass 80 g mol^{-1}) which should be dissolved in 92g of toluene to reduce its vapour pressure to 90%
a) 10 g
b) 20 g
c) 9.2 g
d) 8 g

Answer:
d) 8 g

Question 21.
For a solution, the plot of osmotic pressure (π) versus the concentration (c in mol L^{-1}) gives a straight line with slope 310 R where 'R' is the gas constant. The temperature at which osmotic pressure measured is

a) 310 × 0.082 K

b) 310° C

c) 37°C

d) $\frac{310}{0.082}$ K

Answer:
c) 37°C

Question 22.
200 ml of an aqueous solution of a protein contains 1.26 g of protein. At 300 K, the osmotic pressure of this solution is found to be 2.52×10^{-3} bar. The molar mass of protein will be (R = 0.083 L bar mol^{-1} K^{-1}}
a) 62.22 kg mol^{-1}
b) 12444 g mol^{-1}
c) 300 g mol^{-1}
d) None of these

Answer:
a) 62.22 kg mol^{-1}

Question 23.
The Van't Hoff factor (i) for a dilute aqueous solution of the strong electrolyte barium hydroxide is
a) 0
b) 1
c) 2
d) 3

Answer:
d) 3

Question 24.
Which is the molality of a 10% w/w aqueous sodium hydroxide solution?
a) 2.778
b) 2.5
c) 10
d) 0.4

Answer:
b) 2.5

Question 25.
The correct equation for the degree of an associating solute, 'n' molecules of which undergoes association in solution, is

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

b) $\alpha^2 = \frac{n(1-i)}{(n-1)}$

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

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

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

Question 26.
Which of the following aqueous solutions has the highest boiling point?
a) 0.1 M KNO_3
b) 0.1 M Na_3PO_4
c) 0.1 M $BaCl_2$
d) 0.1 M K_2SO_4

Answer:
b) 0.1 M Na_3PO_4

Question 27.
The freezing point depression constant for water is 1.86° K Kg mol^{-1}. If 5 g Na_2SO_4 is dissolved in 45 g water, the depression in freezing point is 3.64°C. The Vant Hoff factor for Na_2SO_4 is
a) 2.57
b) 2.63
c) 3.64
d) 5.50

Answer:
a) 2.57

Question 28.
Equimolal aqueous solutions of NaCl and KCl are prepared,. If the freezing point of NaCl is -2°C, the freezing point of KCl solution is expected to be
a) -2°C
b) -4°C
c) -1°C
d) 0°C

Answer:
a) -2°C

Question 29.
Phenol dimerises in benzene having van't Hoff factor 0.54. What is the degree of association?
a) 0.46
b) 92
c) 46
d) 0.92

Answer:
d) 0.92

Question 30.
Assertion:
An ideal solution obeys Raoults Law.

Reason:

In an ideal solution, solvent – solvent as well as solute – solute interactions are similar to solute-solvent interactions.

a) both assertion and reason are true and reason is the correct explanation of assertion
b) both assertion and reason are true but reason is not the correct explanation of assertion
c) assertion is true but reason is false
d) both assertion and reason are false

Answer:
a) both assertion and reason are true and reason is the correct explanation of assertion

II. Write brief answer to the following questions:

Question 31.
Define:
(i) Molality
(ii) Normality

Answer:
(i)Molality :
Molality (m) is defined as the number of moles of the solute dissolved in one kilogram (Kg) of the solvent. The units of molality are moles per kilogram, i.e., mole kg^{-1}. The molality is preferred over molarity if volume of the solution is either expanding or contracting with temperature.

$$\text{molality (m)} = \frac{\text{Number of mole of solute}}{\text{mess of solvent in kg}}$$

ii) Normality:
Normality (N) of a solution is defined as the number of gram equivalents of the solute present in one liter of the solution. Normality is used in acid-based redox titrations.

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

Question 32.
a) What is a vapour pressure of liquid?

Answer:
"The pressure exerted by the vapors above the liquid surface which is in equilibrium with the liquid at a given temperature is called vapor pressure".

b) What is a relative lowering of vapour pressure?

Answer:
The relative lowering of vapour pressure is defined as the ratio of lowering of vapour pressure to the vapour pressure of pure solvent (P_0) RLVP = $\frac{p^0 - P}{P^0}$

Question 33.
State and explain Henry's law.

Answer:
"The partial pressure of the gas in vapor phase (vapour pressure of the solute) is directly proportional to the mole fraction (x) of the gaseous solute in the solution at low concentrations". This statement is known as Henry's law.
Henry's law can be expressed as,
$P_{solute} \alpha x_{solute\ in\ solution}$
$P_{solute} = K_H x_{solute\ solution}$
Here, P_{solute} represents the partial pressure of the gas in vapour state which is commonly called as vapour pressure. X_{solute} in solution represents the mole fraction of solute in the solution. K_H is a empirical constant with the dimensions of pressure.

Question 34.
State Raoult law and obtain expression for lowering of vapour pressure when nonvolatile solute is dissolved In solvent.

Answer:
In an ideal solution, the vapour pressure of the solution is decreased when a non-volatile solute is dissolved in a solvent. The magnitude of decrease in the vapour pressure of the solution depends on the amount of solute added.
Let us consider the solution with the following features.

Mole fraction of the solvent = x_A
Mole fraction of the solute = x_B
Vapour pressure of the pure solvent = $P°_A$

Vapour pressure of solution = P

As the solute is nonvolatile, the vapour pressure of the solution is only due to the solvent. Therefore, the vapour pressure of the solution (P) will be equal to the vapour pressure of the solvent (P_A) over the solution.
i.e., $P = P_A$

According to Raoult's law, the vapour pressure of solvent over the solution is equal to the product or its vapour pressure in a pure state and its mole fraction.
$P_A = P°_A x_A$ or
$P = P°_A x_A$

Question 35.
What is molal depression constant? Does it depend on nature of the solute?

Answer:
If $m = 1$ then $\Delta T_f = K_f$
"Then K_f is equal to the depression in freezing point for 1 molal solution". No, it does not depends on nature of the solute.

Question 36.
What is osmosis?

Answer:
"The phenomenon of the flow of solvent through a semipermeable membrane from pure solvent to the solution is called osmosis". Osmosis can also be defined as "the excess pressure which must be applied to a solution to prevent the passage of solvent into it through the semipermeable membrane". Osmotic pressure is the pressure applied to the solution to prevent osmosis.

Question 37.
Define the term 'isotonic solution'.

Answer:
Two solutions having same osmotic pressure at a given temperature are called isotonic solutions.

Question 38.
You are provided with a solid. 'A' and three solutions of A dissolved in water –

one saturated, one unsaturated, and one supersaturated. How would you determine which solution is which?

Answer:
(A) Unsaturated solution:
It can dissolve salt an additional to it.
(B) Saturated solution:
Further solubility of salt does not takes place but solubility can takes place on heating.
(c) Supersaturated solution:
Solubility of salt do not takes place on even an further heating.

Question 39.
Explain the effect of pressure on the solubility.

Answer:
Generally, the change in pressure does not have any significant effect in the solubility of solids and liquids as they are not compressible. However, the solubility of gases generally increases with increase of pressure.

Consider a saturated solution of a gaseous solute dissolved in a liquid solvent in a closed container. In such a system, the following equilibrium exists.
Gas $\rightleftharpoons$ Gas
(in gaseous state) (in solution)

According to Le-Chatelier principle, the increase in pressure will shift the equilibrium in the direction which will reduce the pressure. Therefore, more number of gaseous molecules dissolves in the solvent and the solubility increases.

Question 40.
A sample of 12 M Concentrated hydrochloric acid has a density 1.2 M gL^{-1} calculate the molality.

Solution:
Given:
Molarity = 12 M HCl
density of solution = 1.2 g L^{-1}
In 12 M HCl solution, there are 12 moles of HCl in 1 litre of the solution.

$$\text{Molality} = \frac{\text{no of moles of solute}}{\text{mass of solvent (in kg)}}$$

Calculate mass of water(solvent)
mass of 1 litre HCl solution = density × volume
$= 1.2 \times \text{gmL}^{-1} \times 1000\ \text{mL} = 1200\ \text{g}$

mass of HCl = no. of moles of HCl × molar mass of HCl
$= 12\ \text{mol} \times 36.5\ \text{g mol}^{-1}$
= 438 g.
mass of water = mass of HCl solution – mass of HCl
mass of water = 1200 – 438 = 762 g

$$\text{molality(m)} = \frac{12}{0.762} = 15.75\ \text{m}$$

Question 41.
A 0.25 M glucose solution, at 370.28 K has approximately the pressure as blood does what is the osmotic pressure of blood?

Solution:
C = 0.25 M
T = 370.28 K
$(\pi)_{\text{glucose}} = \text{CRT}$
$(\pi) = 0.25\ \text{mol L}^{-1} \times 0.082\text{L atm K}^{-1}\text{mol}^{-1} \times 370.28\text{K}$
= 7.59 atm

Question 42.
Calculate the molality of a solution containing 7.5 g glycine(NH_2-CH_2-COOH) dissolved in 500g of water.

Solution:

$$\text{Molality} = \frac{\text{no. of moles of solute}}{\text{mass of solvent (in kg)}}$$

$$\text{no. of moles of glycine} = \frac{\text{mass of glycine}}{\text{molar mass of glycine}}$$

$$= \frac{7.5}{75} = 0.1$$

$$\text{molality} = \frac{0.1}{0.5\ \text{kg}} = 0.2\ \text{m}$$

Question 43.
Which solution has the lower freezing point? 10 g of methanol (CH_3OH) in 100g g of water (or) 20 g of ethanol (C_2H_5OH) in 200 g of water.

Solution:
$\Delta T_f = K_f$ i.e
$\Delta T_f \alpha$ m

$$m_{CH_3\text{-}OH} = \frac{\left(\frac{10}{32}\right)}{0.1}$$
$$= 3.125\ \text{m}$$

$$m_{C_2H_5\text{-}OH} = \frac{\left(\frac{20}{46}\right)}{0.2}$$
$$= 2.174\ \text{m}$$

∴ Depression in freezing point is more in methanol solution and it will have lower freezing point.

Question 44.
How many moles of solute particles are present in one liter of 10^{-4} M potassium sulphate?

Answer:
In 10^{-4} M K_2SO_4 solution, there are 10^{-4} moles of potassium sulphate.
K_2SO_4 molecule contains 3 ions (2K+ and 1 SO_4^{2-})
1 mole of K_2SO_4 molecule contains $3 \times 6.023 \times 10^{23}$ ions
10^{-4} mole of K_2SO_4 contains $3 \times 6.023 \times 10^{23} \times 10^{-4}$ ions
$= 18.069 \times 10^{19}$

Question 45.
Henry's law constant for solubility of methane in benzene is 4.2×10^{-5} mm Hg at a particular constant temperature. At this temperature calculate the solubility of methane at
i) 750 mm Hg
ii) 840 mm Hg.

Solution:
$(K_H)_{benzene} = 4.2 \times 10^{-5}$ mm
Solubility of methane =?
P = 750 mm Hg P = 840 mm Hg
According to Henrys Law,
$P = K_H X_{in\ solution}$
$750\ mm\ Hg = 4.2 \times 10^{-5}\ mm\ Hg.\ X_{in\ solution}$

$$\Rightarrow X_{in\ solution} = \frac{750}{4.2 \times 10^{-5}}$$

i. e solubility = 178.5×10^5

similarly at P = 840 mm Hg

$$\text{solubility} = \frac{840}{4.2 \times 10^{-5}} = 200 \times 10^{-5}$$

Question 46.
The observed depression in freezing point of water for a particular solution is 0.093°C calculate the concentration of the solution in molality. Given that molal depression constant for water is 1.86 K Kg mol^{-1}.

Solution:
$\Delta T_f = 0.093°C = 0.093\ K,\ m = ?$

$K_f = 1.86\ K\ Kg\ mol^{-1}$

$\Delta T_f = K_f.m$

$$\therefore m = \frac{\Delta T_f}{K_f} = \frac{0.093\ K}{1.86\ KKgmol^{-1}}$$

$= 0.05\ mol\ Kg^{-1} = 0.05\ m$

Question 47.
The vapour pressure of pure benzene (C_6H_6) at a given temperature is 640 mm Hg. 2.2 g of non – volatile solute is added to 40 g of benzene. The vapour pressure of the solution is 600 mm Hg. Calculate the molar mass of the solute?

Solution:
$P°C_6H_6 = 640$ mm Hg
$W_2 = 2.2$ g (nonvolatile solute)

$W_1 = 40$ g (benzene)
$P_{solution} = 600$ mm Hg
$M_2 = ?$

$$\frac{P^0 - P}{P^0} = X_2$$

$$\frac{640 - 600}{640} = \frac{n_2}{n_1 + n_2} \quad [\therefore n_1 >> n_2 ; n_1 + n_2 \approx n_1]$$

$$\frac{40}{640} = \frac{n_2}{n_1}$$

$$0.0625 = \frac{W_2 \times M_1}{M_2 \times W_1}$$

$$M_2 = \frac{2.2 \times 78}{0.0625 \times 40}$$

$$= 68.64 \text{ g mol}^{-1}$$