Colligative Properties Chemistry Questions with Solutions

Q-1: Which of the following aqueous solutions has the highest vapour pressure at 300 K?

a) 1 M Na_3PO_4
b) 1 M $CaCl_2$
c) 1 M KNO_3
d) 1 M $C_6H_{12}O_6$

Answer: d) 1 M $C_6H_{12}O_6$

Explanation: The Van't Hoff Factor(i) quantifies the effect of a solute on various colligative properties of solutions.An electrolytic solute's van't Hoff factor is always equal to the number of ions in which it is ionised. It is equal to one for a non-electrolytic solute.

Upon ionisation of electrolytic solutes Na_3PO_4, $CaCl_2$ and KNO_3, the value of the van't hoff factor(i) comes out to be 4,3 and 2 respectively. Because $C_6H_{12}O$ is a non-electrolytic solute, it has i=1.

The greater the value of the Van't Hoff factor(i), the lower the vapour pressure, and vice versa. As a result of the lower van't hoff factor(i) value, $C_6H_{12}O_6$ has a higher vapour pressure.

Q-2: 1 molal aqueous solution of an electrolyte A_2B_3 is ionised 60%. The boiling point of the solution at 1 atm is ($K_b(H_2O)$ = 0.52 K kg/mol)

a) 274.76 K
b) 377 K
c) 374.76 K
d) 376.5 K

Answer: c) 374.76 K

Explanation:

Given: Molality, m = 1m = 1mol/kg , Degree of dissociation,α= 60% = 0.6

For dissociation,
Van't Hoff factor, i = 1+(n-1)α

The value of "n" is equal to the number of ions in which the electrolyte A_2B_3 dissociates.

$A_2B_3 \rightarrow 2A^{3+} + 3B^{2-}$

This makes n= 5

Van't Hoff factor, i = 1+(5-1)0.6 = 3.4

Elevation in boiling point, $\Delta T_b = i \times K_b \times m = (3.4) \times (0.52K\ kg/mol) \times (1mol/kg)$
On solving,
$\Delta T_b = 1.768\ K$

$\Delta T_b = T_b - T_b^o$

Where, T_b^o is boiling point of water = 373 K
T_b is the boiling point of solution at 1 atm

Substituting the values,

$1.768\ K = T_b - 373K$

$T_b = 374.76\ K$

Q-3: Which of the following has equal boiling point?

a) 0.1 M Na_2SO_3
b) 0,1 M $C_{12}H_{22}O_{11}$
c) 0.1 $MgCl_2$
d) 0.1 M $Al(NO_3)_3$

Answer: a,c

Explanation: Boiling point will be the same for those solutes which will have the same value for van't Hoff factor.

Solute	Van't Hoff factor(i)
Na_2SO_3	3
$C_{12}H_{22}O_{11}$	1

$Al(NO_3)_3$	4
$MgCl_2$	3

Hence, Na_2SO_3 and $MgCl_2$ will have the same value for van't hoff factor(i).

Note: $C_{12}H_{22}O_{11}$ is a non electrolyte, therefore the value of the van't hoff factor will be equal to one. In the rest of the cases, it will be equal to the number of ions it produces.

Q-4: In a closed container, vapour pressure of a liquid depends upon

a) Volume of the container
b) Temperature
c) Volume of the liquid
d) All of the above

Answer: b) Temperature

Explanation: The tendency of a material to change into a gaseous state is referred to as vapour pressure. In other words, the pressure exerted by a liquid's vapour in thermodynamic equilibrium with the condensed phases in a closed system is termed as vapour pressure.

Effect of Temperature on Vapour pressure:

The K.E associated with the liquid increases as the temperature of the liquid rises. And as kinetic energy increases, the escaping tendency of the molecule increases, causing vapour pressure to rise. As a result, we can conclude that vapour pressure is directly proportional to temperature.
The volume of the container and liquid has no effect on the vapour pressure.

Q-5: Which of the following observations demonstrates colligative properties?

a) A 0.1 M NaCl solution has a higher vapour pressure than 0.1 M $CaCl_2$ solution.
b) A 0.1 M KOH solution freezes at lower temperature than pure water
c) Pure water freezes at a high temperature than pure methanol.

Answer: a) and b)

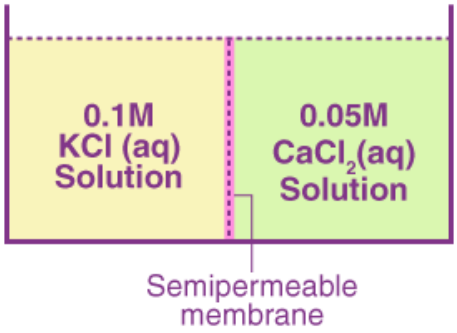
Explanation:

a) The greater the value of the Van't Hoff factor(i), the lower the vapour pressure, and vice versa. The van't Hoff factor value(i) of NaCl is 2, while $CaCl_2$ has a value of 3. NaCl has a higher vapour pressure than $CaCl_2$ solution due to its lower “i” value.
This demonstrates the relative lowering in vapour pressure colligative property.

b) Substances in a pure state have a higher freezing point than the solutions with solute present in it.This demonstrates the depression in freezing point colligative property.

c) Colligative properties cannot be demonstrated in pure substances.

Q-6: Examine the diagram below and select the appropriate options.



a) There will be no substance movement across the membrane.
b) $CaCl_2$ will flow towards the KCl solution
c) The $CaCl_2$ solution will be approached by KCl.
d) The osmotic pressure of 0.1 M KCl solution is greater than that of 0.05 M $CaCl_2$ solution.(assuming complete dissociation of electrolyte)

Answer: d) The osmotic pressure of 0.1 M KCl solution is greater than that of 0.05 M $CaCl_2$ solution.

Explanation: The diagram depicts the osmosis phenomenon. Osmosis is the flow of solvent molecules from its high concentration to its low concentration.

Only solvent molecules, not solute particles, move across the membrane. Because $CaCl_2$ and KCl are solutes, they will not move or flow.

Osmotic pressure,π = i×c×R×T

Osmotic pressure is directly proportional to the magnitude of (i×c) provided temperature and R are constant.

Value of "i" is 2 and 3 for KCl and $CaCl_2$ respectively.
For KCl, π = 2×0.1= 0.2
For $CaCl_2$,π = 3 ×0.05=0.15

We can clearly see, 0.1 M KCl has higher osmotic pressure than 0.05 M $CaCl_2$.

Q-7: When 0.643 g of a compound is added to 50 mL of benzene (density:0.879g/mL),the freezing point is reduced from 5.51 to 5.03 degrees Celsius. What is the compound's molecular mass?(K_f for benzene = 5.12)

Answer: Let molecular mass of solute(compound) be y
Density of benzene = Mass of benzene/Volume
0.879 g/mL= Mass of benzene/ 50mL
Mass of benzene = 43.95 g = 0.04395 Kg
Moles of solute(compound) = Weight of solute/ Molecular mass of solute
= 0.643 g/ y
Molality(m) = Moles of solute/ Mass of benzene(Kg)
= 0.643 g/(y × 0.04395 Kg)
Depression in freezing point, $\Delta T_f = K_f \times m$
(5.51-5.03) K = 5.12 K Kg/mol ×[0.643 g/(y × 0.04395 Kg)]

On solving, y = 156 g/mol

Q–8: The unit of cryoscopic constant is

a) K g/mol
b) Kg/mol K
c) K Kg/mol
d) mol/ Kg K

Answer: c) K Kg/mol

Explanation:

Cryoscopic constant $K_f = \Delta T_f / m$

Unit of ΔT_f = K
Unit of m(molality) is mol/Kg

This makes unit of K_f = K Kg/mol

Q-9: Determine the elevation of the boiling point of a aqueous solution with 1 mol of solute(glucose).(density=1.2g/mL)

a) K_b
b) 0.2 K_b
c) 0.02K_b
d) 0.98K_b

Answer: d) 0.98K_b

Explanation:
Density of solution = Mass of solution/Volume of solution
1.2 g/mL= Mass of solution/ 1000 mL

Mass of solution = 1200g = 1.2Kg

Now, glucose acts as a solute in the solution, and its molar mass is 180g.

Mass of solvent = Mass of solution-Mass of solute = 1200 - 180 = 1020g = 1.02 Kg
Molality of solution, m = Moles of solute/Weight of solvent(Kg)
= 1/1.02 = 0.98

Elevation in boiling point, $\Delta T_b = K_b \times m = 0.98K_b$

Q-10: Why is osmotic pressure preferable to other colligative properties?

Answer: The osmotic pressure method has an advantage over other methods because pressure is measured at room temperature and molarity of the solution is used instead of molality.Its magnitude is large in comparison to other colligative properties, even in very dilute solutions.

Q-11: Define K_b and the factors that influence it.

Answer: The molal elevation constant is denoted by K_b. The molal elevation constant is the increase in boiling point caused by dissolving one mole of solute in 1000g (1Kg) of solvent. Ebullioscopic constant is another name for the molal elevation constant.

Molal elevation constant is characteristic for the type of solvent and not on the solute dissolved in it.

Q-12: When SPM is placed between two isotonic solutions, then

a) Osmosis occur more efficiently
b) Osmosis do not occur
c) Reverse osmosis occur
d) Flow of solute takes place

Answer: b) Osmosis do not occur

Explanation: Isotonic solutions are two solutions that have the same osmotic pressure at the same temperature. Osmosis does not occur when such solutions are separated by a semipermeable membrane.

Q-13: Define
a) Hypertonic solutions
b) Hypotonic solutions

Answer:
a) If the water flows out of the cells when placed in a solution, it shrinks and the solution is said to be hypertonic.
b) If water flows into the cells and they swell when placed in a solution, then the solution is said to be hypotonic.

Q-14: Which colligative property is used for the determination of molar masses of biomolecules?

a) Lowering in vapour pressure
b) Depression in freezing point
c) Osmotic pressure
d) Boiling point

Answer: c) Osmotic pressure

Q-15: In 1L of glacial CH_3COOH, 0.1 M acetamide is dissolved. When the solution is cooled, the molecule contains the first crystal that forms at the freezing point is

a) Glacial CH_3COOH
b) Acetamide
c) Both acetamide and glacial CH_3COOH
d) None of the above

Answer: a) Glacial CH_3COOH

Explanation: Only solvent molecules solidify at the freezing point in the depression of the freezing point experiment. Because the solvent molecule in this case is glacial CH_3COOH, the first crystal of it appears.

Practise Questions on Colligative Properties

Q-1: Which of the following statements are correct for depression in freezing point?

I) The solution has a lower vapour pressure than pure solvent.
II) The solution has a higher vapour pressure than pure solvent.
III) At the freezing point, only solvent molecules solidify.
IV) At the freezing point, only solute molecules solidify.

Answer: I and III

Q-2: Which of the following 0.1M aqueous solution will have the lowest freezing point?

a) Urea
b) Barium sulphate
c) Potassium chloride
d) Fructose

Answer: b) Barium sulphate

Explanation: As we know that

Depression in freezing point, $\Delta T_f = i \times K_f \times m$

From the above expression, we can clearly see that more is the value of the van't hoff factor(i), more is the depression in the freezing point(keeping $K_f \times m$ constant)

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Solute	Van't Hoff factor(i)
Urea	1
Sodium Sulphate(Na_2SO_4)	3
Potassium chloride(KCl)	2

Fructose	1

Because sodium sulphate has a higher “i” value, it will have a lower freezing point.

Q-3: Which of the following liquid pairs is most likely to separate into two layers when 10 mL of each is mixed and allowed to stand?

a) CCl_4 and C_6H_6
b) C_2H_5OH and CH_3OH
c) CCl_4 and CH_3OH
d) C_6H_{14} and C_5H_{12}

Answer: c) CCl_4 and CH_3OH

Explanation: According to the "like dissolves like" principle, polar solutes are more soluble in polar solvents and nonpolar solutes in nonpolar solvents.

Polar molecules: C_2H_5OH ,CH_3OH
Non polar molecules: C_6H_6,CCl_4,C_5H_{12},C_6H_{14}

Because CCl_4 is nonpolar and CH_3OH is polar, when 10 mL of each is mixed and allowed to stand, they will separate into two layers.

Q-4: What is the molecule mass of a compound with a concentration ,W= 1.2g/L, an osmotic pressure equal to 0.20 atm, and a temperature of T=300 K?

Answer: We know that Osmotic pressure, π = c×R×T

Substituting π = 0.20 atm, T = 300 K and R = 0.0821 Latm/mol K in the expression.

0.20 atm = c×0.0821 Latm/mol K × 300 K

This implies, c = 0.00812 mol/L

Molecule mass of compound = W/c = (1.2g/L)/(0.00812 mol/L) = 147.7 g/mol

Q-5: Which law states that "the mole fraction of solute equals the relative lowering in vapour pressure" for a dilute solution?

a) Dalton’s law
b) Raoult’s law

c) Henry's law
d) Avogados law

Answer: b) Raoult's law

Explanation: The equation for relative lowering in vapour pressure is given below:

$$\frac{\Delta P_1}{P_1^o} = \chi_2$$

As stated above, the expression on the left side of the equation is known as relative lowering of vapour pressure and is equal to the mole fraction of the solute.