Short Answer Questions-I

Short Answer Questions-I (PYQ)

Q.1. State Henry's law. Write its one application. What is the effect of temperature on solubility of gases in liquid?

[CBSE (F) 2016]

Ans. It states that the partial pressure of a gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution.

$p \propto x$ or $p = K_H\, x$ where K_H is the Henry's constant.

Application of Henry's law:

To increase the solubility of CO2 in soft drinks and soda water, the bottle is sealed under high pressure.

Effect of temperature on solubility:

As dissolution is an exothermic process, therefore, according to Le Chatelier's principle solubility should decrease with rise in temperature.

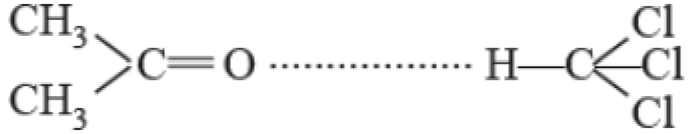
Q.2. State Raoult's law for a solution containing non-volatile solute. What type of deviation from Raoult's law is shown by a solution of chloroform and acetone and why?

[CBSE (F) 2017]

Ans. It states that the relative lowering of vapour pressure is equal to mole fraction of solute when solvent alone is volatile and is expressed as

$$\frac{P_A^o - P_{\text{Total}}}{P_A^o} = x_B$$

A solution of chloroform and acetone shows negative deviation from Raoult's law. This is because chloroform molecule is able to form H–bond with acetone molecule as shown below.



It decreases the escaping tendency of molecules of each component from the surface of solution and consequently the vapour pressure decreases resulting in negative deviation from Raoult's law.

Q.3. Answer the following question :

Q. Why is an increase in temperature observed on mixing chloroform and acetone?

Ans. The bonds between chloroform molecules and molecules of acetone are dipole–dipole interactions but on mixing, the chloroform and acetone molecules, they start forming hydrogen bonds which are stronger bonds resulting in the release of energy. This gives rise to an increase in temperature.

Q. Why does sodium chloride solution freeze at a lower temperature than water?

[CBSE (F) 2013]

Ans. When a non-volatile solute is dissolved in a solvent, the vapour pressure decreases. As a result, the solvent freezes at a lower temperature.

Q.4. Define an ideal solution and write one of its characteristics.

[CBSE Delhi 2014]

Ans. A solution which obeys Raoult's law over the entire range of concentration is called ideal solution. The important characteristics of an ideal solution are

- **i.** The enthalpy of mixing of pure components to form the solution is zero *i.e.*, $\Delta_{mix}H = 0$
- **ii.** The volume of mixing is zero *i.e.*, $\Delta_{mix}V = 0$

Q.5. Differentiate between molarity and molality of a solution. Explain how molarity value of a solution can be converted into its molality.

[CBSE (F) 2011]

Ans. Molarity (M) is the number of moles of solute dissolved in one litre of solution whereas molality (m) is the number of moles of the solute per thousand grams of solvent.

If MB is the molar mass of solute, d is the density of solution then molarity (M) value of a solution can be converted into its molality (m) by using the following formula.

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

Q.6. Define azeotropes. What type of azeotrope is formed by negative deviation from Raoult's law? Give an example.

[CBSE Delhi 2015]

Ans. Azeotropes are binary liquid mixtures having the same composition in liquid and vapour phase and boil at a constant temperature.

Maximum boiling azeotrope is formed by negative deviation from Raoult's law. A mixture of 68% nitric acid and 32% water by mass is an example of maximum boiling azeotrope.

Q.7. Define the term osmotic pressure. Describe how the molecular mass of a substance can be determined by a method based on measurement of osmotic pressure.

[CBSE Delhi 2012]

Ans. Osmotic pressure (π) is defined as the extra pressure that must be applied to the solution side in order to prevent the flow of solvent molecules into it through a semipermeable membrane.

According to van't Hoff equation

$$\pi = \frac{n_B}{V} RT$$

where π is the osmotic pressure, R is the gas constant and V is the volume of solution in litres containing n_B moles of the solute.

If W_B grams of the solute of molar mass, M_B is present in the solution, then

$$n_B = \frac{W_B}{M_B} \text{ and we can write}$$

$$\pi = \frac{W_B \times R \times T}{M_B \times V} \qquad \text{or } M_B = \frac{W_B \times R \times T}{\pi \times V}$$

Thus, knowing W_B, T, π and V, the molecular mass of the solute, M_B can be calculated.

Q.8. State Raoult's law for the solution containing volatile components. What is the similarity between Raoult's law and Henry's law?

[CBSE Delhi 2014]

Ans. It states that for a solution of volatile liquids, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction. According to Raoult's law, for a volatile component, A of the solution

$P_A \propto x_A$ or $P_A = P_A^0 x_A$, where P_A^0 is the vapour pressure of pure component A.

If one of the component is so volatile that it exist as a gas then according to Henry's law

$p = K_H x$, where K_H is the Henry law constant *i.e*., the partial vapour pressure of the volatile component (gas) is directly proportional to its mole fraction in the solution.

Thus the similarity between Raoult's law and Henry's law is that both state that the partial vapour pressure of the volatile component or gas is directly proportional to its mole fraction in the solution.

Q.9. State the following:

Q. Raoult's law in its general form in reference to solutions.

Ans. Raoult's law: It states that for any solution, the partial pressure of each volatile component in the solution is directly proportional to its mole fraction.

Q. Henry's law about partial pressure of a gas in a mixture.

[CBSE (AI) 2011]

Ans. Henry's law: It states that the partial pressure of a gas in vapour phase (P) is proportional to its mole fraction (x) in the solution.

Q.10. Answer the following question :

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

Ans. According to Henry's law, $p = K_H x$, *i.e.*, higher the value of K_H lower is the solubility of the gas in the liquid. Therefore, Gas *B* will have higher value of K_H than gas *A*.

Q. In non-ideal solution, what type of deviation shows the formation of maximum boiling azeotropes?

[*CBSE Central 2016*]

Ans. Negative deviation from Raoult's law.

Q.11. Write two differences between a solution showing positive deviation and a solution showing negative deviation from Raoult's law.

[CBSE East 2016]

Ans.

Solutions showing positive deviation from Raoult's law	**Solution showing negative deviation from Raoult's law**
(*i*)PA>P0AxAandPB>P0BxB	(*i*) PA<P0AxAandPB>P0BxB
(*ii*) $\Delta_{mix} H > 0$, $\Delta_{mix} V > 0$	(*ii*) $\Delta_{mix} H < 0$, $\Delta_{mix} V < 0$
(*iii*) Form minimum boiling azeotropes.	(iii) Form maximum boiling azeotropes.

Q.12. Define the following terms:

Q. Abnormal molar mass

Ans. When the molar mass of a substance determined by using any of the colligative properties comes out to be different than the theoretically expected molar mass, the substance said to show abnormal molar mass.

Q. van't Hoff factor (i)

[CBSE Delhi 2017]

Ans. van't Hoff factor (i) gives the extent of association or dissociation of the solute particles in the solution. It may be defined as the ratio of observed colligative property to calculated colligative property.

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

Q.13. What type of deviation is shown by a mixture of ethanol and acetone? What type of azeotrope is formed by mixing ethanol and acetone?

[CBSE (F) 2013]

Ans. A mixture of ethanol and acetone shows positive deviation.

The azeotrope formed is minimum boiling azeotropes.

Q.14. (i) On mixing liquid X and liquid Y, volume of the resulting solution decreases.What type of deviation from Raoult's law is shown by the resulting solution? What change in temperature would you observe after mixing liquids X and Y?

(ii) What happens when we place the blood cell in water (hypotonic solution)? Give reason.

[*CBSE Allahabad 2015*]

Ans. (i) ♦ The solution will show negative deviation from Raoult's law.
♦ Temperature will rise.

(ii) Due to osmosis water enters into the cell and blood cell will swell.

Q.15. State Raoult's law for the solution containing volatile components. Write two differences between an ideal solution and a non-ideal solution.

[*CBSE Panchkula 2015*]

Ans. Raoult's law states that for a solution of volatile liquids the partial vapour pressure of each component is directly proportional to its mole fraction.

Differences between Ideal and non-Ideal solutions

S.No.	Ideal solution	Non-Ideal solution
(*i*)	Obeys Raoult's law over entire range of concentration *i.e.,* $P_A = P_A^\circ x_A; P_B = P_B^\circ x_B$	Does not obey Raoult's law over entire range of concentration, *i.e.,* $P_A \neq P_A^\circ x_A; P_B \neq P_B^\circ x_B$
(*ii*)	$\Delta_{mix} H = 0; \Delta mix\ V = 0$	$\Delta_{mix} H \neq 0; \Delta_{mix} V \neq 0$
(*ii*)	Does not form azeotrope.	Forms azeotrope.

Q.16. A solution prepared by dissolving 8.95 mg of a gene fragment in 35.0 mL of water has an osmotic pressure of 0.335 torr at 25°C. Assuming that the gene fragment is a non-electrolyte, calculate its molar mass.

[*CBSE (AI) 2011*]

Ans.

$$M_B = \frac{W_B \times R \times T}{\pi \times V} \qquad ....(i)$$

Here, W_B = 8.95 mg = 8.95×10^{-3}g , R = 0.0821 L atm mol^{-1} K^{-1}

T = 25°C = $(25 + 273)$ K = 298 K, π = 0.335 torr = $\frac{0.335}{760}$ atm

V = 35 mL = 35×10^{-3} L

Substituting these values in the equation (i), we get

$$M_B = \frac{8.95 \times 10^{-3} g \times 0.0821\ L\ \text{atm}\ \text{mol}^{-1}\ K^{-1} \times 298 K \times 760}{0.335\ \text{atm} \times 35 \times 10^{-3}\ L} = 14193.3\ g\ \text{mol}^{-1}$$

Q.17. Henry's law constant (K_H) for the solution of methane in benzene at 298 K is 4.27×10^5 mm Hg. Calculate the solubility of methane in benzene at 298 K under 760 mm Hg.

[*CBSE (F) 2013*]

Ans.

Here, K_H = 4.27×10^5 mm H_g

p = 760 mm Hg

According to Henry's law, $p = K_H x_{CH_4}$

$$x_{CH_4} = \frac{p}{K_H} = \frac{760\ \text{mm}\ \text{Hg}}{4.27 \times 10^5\ \text{mm}\ \text{Hg}} = 1.78 \times 10^{-3}$$

Mole fraction of methane in benzene, x_{CH_4} **= 1.78×10^{-3}.**

Q.18. Derive the relationship between relative lowering of vapour pressure and molar mass of the solute.

[*CBSE Chennai 2015*]

Ans. From Raoult's law we have, $P = P_A + P_B$

If solute B is non-volatile, then

$$P = P_A \quad \text{or} \quad P = P_A^0 x_A$$

$$P = P_A^0\ (1 - x_B) = P_A^0 - P_A^0 x_B$$

$$P_A^0 x_B = P_A^0 - P$$

$$\frac{P_A^0 - P}{P_A^0} = x_B \quad \text{or} \quad \frac{\Delta P}{P_A^0} = \frac{n_B}{n_A + n_B}$$

For a dilute solution $n_B << n_A$, so n_B can be neglected in denominator in comparison to n_A.

$$\frac{\Delta P}{P_A^0} = \frac{n_B}{n_A} = \frac{W_B/M_B}{W_A\ /\ M_A} = \frac{W_B \times M_A}{M_B \times W_A}$$

$$M_B = \frac{P_A^0 \times W_B \times M_A}{\Delta P \times W_A}$$

Q.19. Calculate the freezing point depression expected for 0.0711 m aqueous solution of Na_2SO_4. If this solution actually freezes at – 0.320°C, what would be the value of van't Hoff factor?

(K_f for water is 1.86 K kg mol^{-1}).

[*CBSE Delhi 2009; (F) 2009*]

Ans.

$$\Delta T_f = [273.15 - (-0.320 + 273.15)]K = 0.320\ K$$

$$\Delta T_f = K_f\ .\ m = 1.86\ \text{K kg mol}^{-1} \times 0.0711\ \text{mol kg}^{-1} = \mathbf{0.132\ K}$$

$$i = \frac{Observed value of \Delta T_f}{Calculated value of \Delta T_f} = \frac{0.320\ K}{0.132\ K} = \mathbf{2.42}$$

Q.20. When 1.5 g of a non-volatile solute was dissolved in 90 g of benzene, the boiling point of benzene raised from 353.23 K to 353.93 K. Calculate the molar mass of the solute.

(K_b for benzene = 2.52 *K* kg mol^{-1})

[*CBSE Chennai 2015*]

Ans.

ΔT_b = 353.93 K – 353.23 K = 0.7 K

Substituting W_B = 1.5 g, W_A = 90g, ΔT_b = 0.7 K, K_b = 2.52 K kg mol^{-1} in the expression

$$M_B = \frac{K_b \times W_B \times 1000}{\Delta T_b \times W_A}, \text{ we get}$$

$$M_B = \frac{2.52\ K\ \text{kg mol}^{-1} \times 1.5\ g \times 1000\ g\ \text{kg}^{-1}}{0.7\ K \times 90\ g}$$

$$M_B = \mathbf{60\ g\ mol^{-1}}$$

Short Answer Questions-I (OIQ)

Q.1. Explain the solubility rule "like dissolves like" in terms of intermolecular forces that exist in solutions.

[NCERT Exemplar]

Ans. A substance (solute) dissolves in a solvent if the intermolecular interactions are similar in both the components; for example, polar solutes dissolve in polar solvents and non polar solutes in non polar solvents thus we can say "like dissolves like".

Q.2. CCl_4 and water are immiscible whereas ethanol and water are miscible in all proportions. Correlate this behaviour with molecular structure of these compounds.

Ans. CCl_4 is a non-polar covalent compound, whereas water is a polar compound. CCl_4 can neither form hydrogen bonds with water molecules nor can it break hydrogen bonds between water molecule, therefore, it is insoluble in water.

Ethanol is a polar compound and can form hydrogen bonds with water, which is a polar solvent, therefore it is miscible with water in all proportions.

Q.3. State Henry's Law. What is the significance of K_H?

Ans. Henry's law: It states that "the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution" and is expressed as:

$p = K_H\, x$

where, K_H is the Henry's law constant.

Significance of K_H: Higher the value of Henry's law constant K_H, the lower is the solubility of the gas in the liquid.

Q.4. State Raoult's law for a solution containing volatile components. How does Raoult's law become a special case of Henry's law?

Ans. For a solution of volatile liquids, Raoult's law states that the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution, *i.e.*,

$$P_A \propto x_A, \qquad \text{or} \qquad P_A = P_A^0 x_A$$

According to Henry's law, the partial pressure of a gas in vapour phase (p) is directly proportional to mole fraction (x) of the gas in the solution.

$p = K_H x$

On comparing it with Raoult's law it can be seen that partial pressure of the volatile component or gas is directly proportional to its mole fraction in solution, only the proportionality constant K_H differs from P_A^0

$p_A \propto x$

Thus, it becomes a special case of Henry's law in which $K_H = P_A^0$

Q.5. After removing the outer shell of two eggs in dil. HCl, one is placed in distilled water and the other in a saturated solution of NaCl. What will you observe and why?

Ans. Egg in water will swell whereas in NaCl solution it will shrink. This is because due to osmosis, the net flow of solvent is from less concentrated to more concentrated solution.

Q.6. When fruits and vegetables that have dried are placed in water, they slowly swell and return to the original form. Explain why. Would a temperature increase accelerate the process? Explain.

Ans. The cell walls of the fruits and vegetables act as semipermeable membrane. When they are dried, concentration inside becomes higher. On placing in water, the process of osmosis takes place. So, they swell and return to their original form. The process will be accelerated with increase of temperature because osmosis becomes faster with increase in temperature.

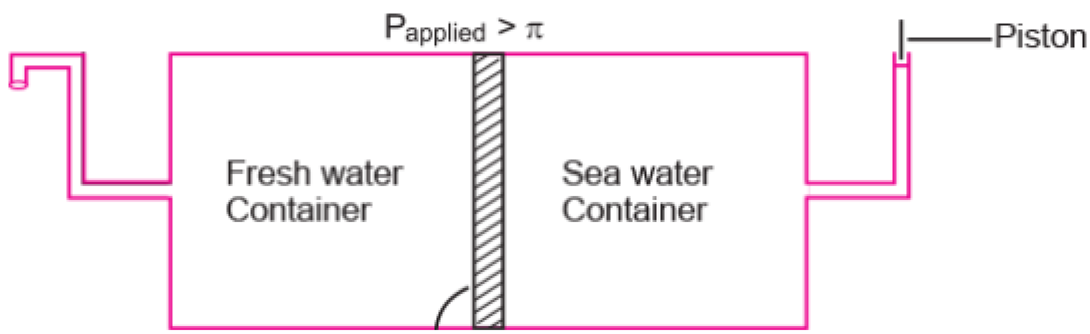
Q.7. Will the elevation in boiling point be same if 0.1 mol of sodium chloride or 0.1 mol of sugar is dissolved in 1 L of water? Explain.

[*CBSE Sample Paper 2016*] [HOTS]

Ans. No, the elevation in boiling point is not the same. NaCl, being an electrolyte, dissociates almost completely to give Na^+ and Cl^- ions whereas glucose, being non-electrolyte does not dissociate. Hence, the number of particles in 0.1 M NaCl solution is nearly double than 0.1 M glucose solution. Elevation in boiling point being a colligative property, is therefore, nearly twice for 0.1 M NaCl solution than for 0.1 M glucose solution.

Q8. Given alongside is the sketch of a plant for carrying out a process.

- **i. Name the process occurring in the given plant.**
- **ii. To which container does the net flow of solvent take place?**
- **iii. Name one SPM which can be used in this plant.**
- **iv. Give one practical use of the plant.**



Ans.

- **i.** Reverse osmosis.
- **ii.** Fresh water container.
- **iii.** Cellulose acetate placed on a suitable support.
- **iv.** Desalination of sea water.