

(xii) Aerosol are colloids which contain

- (a) A solid dispersed in a liquid
- (b) A solid dispersed in a gas
- (c) A liquid dispersed in a gas
- (d) A liquid in another liquid

Answers

i. c	ii. d	iii. d	iv. d	v. c	vi. b	vii. b
viii. d	ix. c	x. d	xi. c	xii. c		

2. Determine the molality of the following solutions

i) 3.5% (W/W) glucose (aq) (Ans: 0.2 g dm^{-3})

ii) 9.9g $NaNO_3$ dissolved in 940g of water (Ans: 0.124 g dm^{-3})

Solution: 1 3.5% (W/W) glucose (aq)

Mass of Glucose = 3.5g

Molar mass of Glucose ($C_6H_{12}O_6$) = 180

Mass of Water = 100 - 3.5 = 96.5g

Molality is given by

$$\text{Molality} = \frac{\text{moles of solute}}{\text{kg. of solvent}}$$

$$\text{molality} = \frac{\text{mass of solute}}{\text{molar mass of solute}} \times \frac{1000}{\text{mass of solvent in gram}}$$

$$\text{Molality} = \frac{3.5}{180} \times \frac{1000}{96.5} = 0.20m$$

ii) 9.9g $NaNO_3$ dissolved in 940g of water

Mass of water = 940 g

Mass of $NaNO_3$ = 9.9g

Formula Mass of $NaNO_3$ = 23 + 14 + 48 = 85 g mole⁻¹

$$\text{Molality} = \frac{\text{moles of solute}}{\text{kg. of solvent}}$$

$$\text{molality} = \frac{\text{mass of solute}}{\text{molar mass of solute}} \times \frac{1000}{\text{mass of solvent in gram}}$$

$$\text{Molality} = \frac{9.9}{85} \times \frac{1000}{940} = 0.124\text{m}$$

3. What are the freezing and boiling points of a solution prepared by dissolving 13.3g of ethylene glycol in 100g of water.

(Ans: F.P = -3.99°C, B.P = 101.115°C)

Solution:

Mass of Solute (ethylene glycol) = $W_2 = 13.3\text{g}$

Molar mass of Solute = 62 g mole^{-1}

Mass of solvent (water) = $W_1 = 100\text{g}$

Molar mass of solvent (water H₂O) = 18 g mole^{-1}

Molal F.P constant, K_f for water = $1.86\text{ }^\circ\text{C}$

Mol. Elevation B. P constant, K_b for water = 0.52 C

Freezing point of Solution = ?

$$\begin{aligned} \Delta T_b &= \frac{K_f \times W_2 \times 1000}{M_2 \times W_1} \\ &= \frac{1.86 \times 13.3 \times 1000}{62 \times 100} = 3.99^\circ\text{C} \end{aligned}$$

Let Freezing point of pure water = $T_1 = 0^\circ\text{C}$

Freezing point of solution = $T_2 = ?$

$$\Delta T_f = T_2 - T_1$$

$$T_2 = T_1 - \Delta T_f = 0 - 3.99$$

$$= -3.99^\circ\text{C}$$

Boiling point of Solution = ?

As

$$\Delta T_b = K_b \times K_b \times 1000 = 0.52 \times 13.3 \times 1000$$

Let Boiling point of pure water = $T_1 = 100^\circ\text{C}$

Boiling point of solution = $T_2 = ?$

$$\Delta T_f = T_2 - T_1$$

$$T_2 = T_1 - \Delta T_f = 100 + 1.116^\circ = 101.116^\circ\text{C}$$

4. When cooking, what effect does add salt to water have on the time required to boil food?

Ans: When the salt is added, a phenomenon known as "boiling point elevation" take place. Boiling point elevation happens when a non-volatile solute (or a dissolvable substance in this case, the salt) is added to a pure solvent (or a substance that dissolves a solute in this case, the water itself) to create a solution (the salt water)

By adding salt, the vapour pressure of water decreases due to which its boiling point increases. Hence salt water requires more exposure to the heat in order to boil than water alone, so the boiling point is elevated and more time is required to boil food.

5. Concentrated sulphuric acid is 98% (W/W) H_2SO_4 (aq). Its density is 1.84g.cm^{-3} .

Calculate

i) The molarity of the solution **(Ans: 18.4 M)**

ii) The molality of the solution **(Ans: 10 molal)**

iii) What quantity of conc. H_2SO_4 is required to prepare 500 cm^3 of $0.1\text{M } \text{H}_2\text{SO}_4$.

Solution: (i) Molarity of Solution:

98% (W/W) solution means 98 g H_2SO_4 is dissolved in 100 g of solution

Mass of $\text{H}_2\text{SO}_4 = 98\text{g}$

Density of $\text{H}_2\text{SO}_4 = 1.84\text{g.cm}^{-3}$.

Molar mass of $\text{H}_2\text{SO}_4 = 2 + 32 + 64 = 98\text{g mole}^{-1}$

$$\text{Number of moles} = \frac{\text{given mass}}{\text{molar mass}}$$

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Volume} = \frac{\text{mass}}{\text{density}} = \frac{100}{1.84} = 54.3478 \text{ cm}^3$$

54.3478 cm^3 contains $\text{H}_2\text{SO}_4 = 1$ mole

$$1000 \text{ cm}^3 \text{ contains } \text{H}_2\text{SO}_4 = \frac{1}{54.3478} \times 1000 = 18.4 \text{ moles}$$

So molarity of $\text{H}_2\text{SO}_4 = 18.4$ moles

(ii) The molality of the solution:

98% (W/W) solution means 98 g H_2SO_4 is dissolved in 100 g of solution

Mass of $\text{H}_2\text{SO}_4 = 98\text{g}$

Mass of Solution = 100 g

Mass of Solvent = 100 g - 98 g

= 2 g = 0.002 kg

Molar mass of $\text{H}_2\text{SO}_4 = 98\text{g mole}^{-1}$

As

$$\text{Molality} = \frac{m_{\text{solute}}}{M_{\text{solute}}} \times \frac{1}{W_{\text{solvent}} (\text{kg})}$$

$$\text{Molality} = \frac{98}{98} \times \frac{1}{0.002} = 500\text{m}$$

What quantity of Concentrated H_2SO_4 is required to prepare 500 cm^3 of 0.1M

H_2SO_4

Molarity of H_2SO_4 present = $M_1 = 18.4$ M

Volume of H_2SO_4 required = $V_1 = ?$

Molarity of H_2SO_4 prepared $M_2 = 0.1$ M

Volume of H_2SO_4 prepared $V_2 = 500 \text{ cm}^3$

As we know that

$$M_1V_1 = M_2V_2$$

$$V_1 = \frac{M_2V_2}{M_1} = \frac{0.1 \times 500}{18.4} = 2.717 \text{ cm}^3$$

made up to the mark. This is required 0.1M H_2SO_4 solution

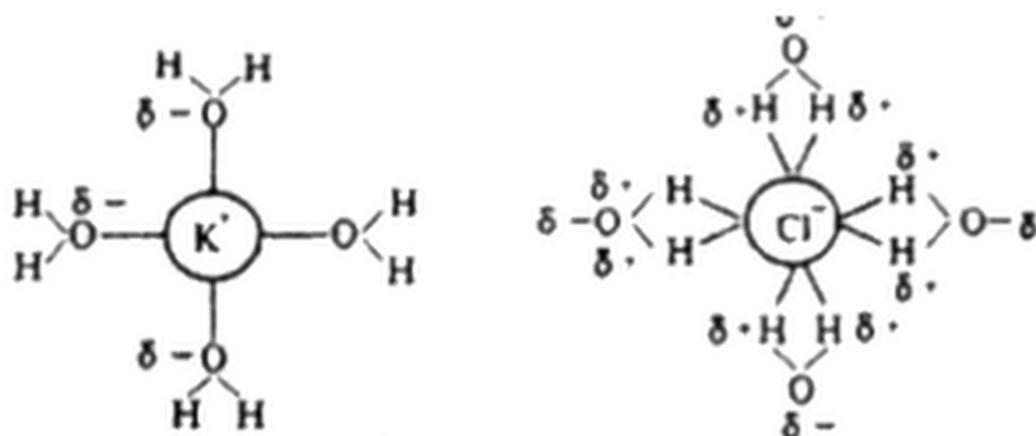
6. What would you expect potassium chloride, KCl, an ionic solid to be more soluble in H_2O or CCl_4 ? Explain your prediction.

Ans: The basic principle of solubility is "Like dissolves like". KCl is an ionic solid. Ionic solids have a crystal lattice structure composed of oppositely charged ions.

Examples:

i. When an ionic solid e.g. KCl is placed in water which is a polar solvent These ions are attracted by polar molecules. Water molecules break the crystal lattice of K^+Cl^- and then surrounds the resulting K^+Cl^- ions

These ions are called hydrated ions



ii. When KCl crystals are placed in CCl_4 , Non-polar molecules of these liquids are unable to attract ions in NaCl and cannot break apart the crystal lattice Thus KCl is insoluble in these solvents

7. List three factors that accelerate the dissolution process.

Ans: Following are the three factors that accelerate the dissolution process

(1) Particle size:

When a sugar cube is placed into water, it dissolves slowly than does an equal amount of finely granulated sugar. A sugar cube exposes less surface area to the water molecules than do the tiny particles of granulated sugar. Inner regions of cube dissolve only after the outer layers are in solution.

There are fewer unexposed particles when sugar is granulated, so it dissolves

(2) Temperature:

Temperature is another factor which changes the rate at which solutes dissolve in solvent. At higher temperature, increased molecular motion increases the interaction of solute and solvent particles which increases the dissolving rate.

(3) Stirring:

Stirring a solution increases the rate at which a solid dissolves decreasing the concentration of solute in the immediate region surrounding the solid solute. Stirring also increases the amount of exposed solute surface to the solvent.

8. Explain the nature of solutions in liquid phase giving examples of completely miscible, partially miscible and immiscible liquid-liquid solutions.

Ans: Nature of Solution in Liquid phase:

Solutions of liquids in liquids may be divided into three classes.

(a) Completely miscible **(b)** Partially miscible **(c)** Immiscible.

(a) Completely Miscible Liquids:

Liquids which are miscible in all proportions are called completely miscible

Examples:

Water and methanol, Acetone and water. Benzene and cyclohexane are completely miscible liquid pairs. Substances that dissolve in each other possess similar types of inter-molecular interactions.

Water and methanol:

Water and methanol are miscible because molecules in the pure liquids and their mixtures form hydrogen bonds. The degree of hydrogen bonding in the solution is same as that in the pure liquids.

Benzene and cyclohexane:

Benzene and cyclohexane are completely miscible because the molecules in the pure liquids and their mixtures interact through London dispersion forces. These dispersion forces between benzene and cyclohexane are about the same as those in pure liquids

(b) Partially Miscible Liquids:

On mixing such liquids two layers are formed. Each layer is a saturated solution of the other liquid.

For example ether and water are partially miscible liquids. The mutual solubilities of these solutions change by temperature changes.

Examples:

Typical examples of such systems are:-

- (i) Phenol-water
- (ii) Aniline-water
- (iii) Aniline-n-hexane
- (iv) Nicotine-water

(c) Completely Immiscible Liquids:

Liquids which do not dissolve into each other in any proportion at any temperature are called completely immiscible.

Examples:

For instance water and benzene, carbon disulphide and water, cyclohexane.

For instance, water and benzene, carbon disulphide and water, cyclohexane and water are completely immiscible in one another.

Benzene, carbon disulphide or cyclohexane:

Benzene, carbon disulphide or cyclohexane are non-polar in nature. The only forces of attraction between their molecules are dispersion forces. In water hydrogen bonds are much stronger than dispersion forces. Since hydrogen bonds cannot be disrupted by the molecules of benzene, carbon disulphide or cyclohexane, these liquids are immiscible with water.

9. Express solution concentration in terms of mass percent, molality, molarity, parts per million, parts per billion and parts per trillion and mole fraction.

Ans: Mass Percent:

It is defined as the mass of solute present in 100g of solution. It is also referred as percent weight / weight

$$\text{Mass Percent} = \frac{\text{grams of solute}}{\text{grams of solution}} \times 100$$

15% NaCl solution means 15g of NaCl dissolved per 100 g of solution or 85g of water

Molarity (M):

i. It is defined as the number of moles of solute dissolved per dm^3 of solution.

Molarity is moles of solute per liter of solution.

ii. Molarity is expressed as the moles per Liter/s of solution.

$$\text{iii. } M = \frac{\text{moles of solute}}{dm^3 \text{ of solution}}$$

$$\text{iv. } M = \frac{\text{grams of solute}}{\text{molar mass of solute} \times dm^3 \text{ of solution}}$$

Example:

When 58.5g NaCl (1 mole) is dissolved in one kilogram of water, the resulting solution would be one molal or 1m NaCl solution

Parts per million (ppm):

It is defined as the number of parts by weight (or volume) of a solute per million parts by weight (or volume) of the solution

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

Parts per billion (ppb):

It is defined as the number of parts by weight (or volume) of a solute per billion parts by weight (or volume) of the solution

$$\text{ppb} = \frac{\text{Mass or volume of solute}}{\text{Mass or volume of solution}} \times 10^9$$

Parts per trillion (ppt):

It is defined as the number of parts by weight (or volume) of a solute per trillion

$$\text{ppt} = \frac{\text{Mass or volume of solute}}{\text{Mass or volume of solution}} \times 10^{12}$$

Mole Fraction (X):

It is defined as the ratio of the number of moles of a given component to the total number of moles of solution.

Examples:

Suppose a solution contains n_A and n_B moles of two components A and B

Mole fraction of each component is given by

$$\text{Mole fraction of component A} = X_A = \frac{n_A}{n_A + n_B}$$

$$\text{Mole fraction of component B} = X_B = \frac{n_B}{n_A + n_B}$$

Note:

Rare components of a solution are expressed by ppm, ppb and ppt. A pollutant concentration of 1 ppm in the atmosphere means that out of one million molecules of air there is one molecule of the pollutant, whereas 1 ppb concentration of it means that out of one billion molecules of air there is one molecule of that pollutant.

10. Distinguish between the solvation of ionic species and molecular substances.

Ans: Similarities:

The process of solvation of ionic and molecular substances is similar in the sense in that both the cases the process of solvation involves the disruption of solute particles from the crystal lattice. Then these particles are surrounded by solvent molecules.

Differences:

The heat of solvation in both the cases is much different since ion-dipole interactions are much stronger than dipole-dipole or dispersion forces, heat of solvation for ionic species is generally larger than those for molecular solvents

Ans: Role of Solvation in the Dissolving Process:

- i. Solution making process is accompanied by either the absorption or evolution of heat.
- ii. Energy change in the formation of a solution depends upon three types of interactions between solute-solute solvent and solute-solvent particles
- iii. In the formation of solution, interactions between solute particles are broken. At the same time solvent molecules also move apart to accommodate the solute particles
- iv. Since energy is needed to break interactions. Therefore, both these processes are endothermic.
- v. Simultaneously interactions between the particles of solute and solvent are established i.e. solvation occurs
- vi. Solvent molecules surround solute particles from all sides.
- vii. in these interactions energy is released, so it is exothermic.

Result:

Thus the strength of these two types of interactions determines whether the process of dissolution is endothermic or exothermic.

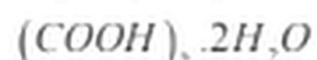
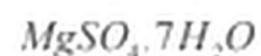
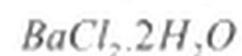
12. Define the term water of hydration.**Ans: Hydrate:**

A crystalline substance which has associated with each formula unit a definite number of water molecules is called a hydrate

Such water molecules are called water of crystallization or water of hydration

Water of Hydration:

The water molecules that combine with compounds as they are crystallized from aqueous solution are called water of crystallization or water of hydration

Example:

13. Define the term colligative.

Ans: The properties of solutions which depends only on number of solute particles and not on their nature. Those properties are called as colligative properties

Examples:

- (i) Lowering of Vapour pressure
- (ii) Elevation of Boiling point
- (iii) Depression of Freezing point
- (iv) Osmotic pressure

14. List the characteristic of colloids and suspensions.

Ans: Characteristic of colloids and suspensions:

Sr. No.	Properties	Colloids	Suspensions
1.	Size of particles	$1 - 10^3$ nm	$> 10^3$ nm
2.	Phase	Heterogeneous	Heterogeneous
3.	Aggregates	Particles are composed of 10^3 to 10^9 atoms	Particles are composed of more than 10^9 atoms
4.	Charge on the particles	Positive or negative	Positive or negative or may be neutral
5.	Visibility of particles	Invisible by naked eye and ordinary micro-scope	Visible by the naked eye and in ordinary

		electron microscope	
6.	Filterability	Particles can pass through ordinary filter, but cannot pass through ultra filter paper	Particles cannot pass through ordinary as well as ultra filter paper
7.	Dispersion of light	Scatter light	Scatter light
8.	Effect of gravity	Particles do not settle under the influence of gravity	Particles settle under the influence of gravity

15. Define hydrophilic and hydrophobic molecules.

Ans: Hydrophilic molecules:

Hydro mean water, philic means loving. So hydrophilic literally means water loving.

Molecules that are miscible with water are known as hydrophilic molecules. Such molecules can form hydrogen bond with water molecules

Example:

For example, molecules of methanol, acetone, acetic acid etc. are called hydrophilic molecules

Hydrophobic molecules.

Molecules that do not dissolve in water are known as hydrophobic molecules.

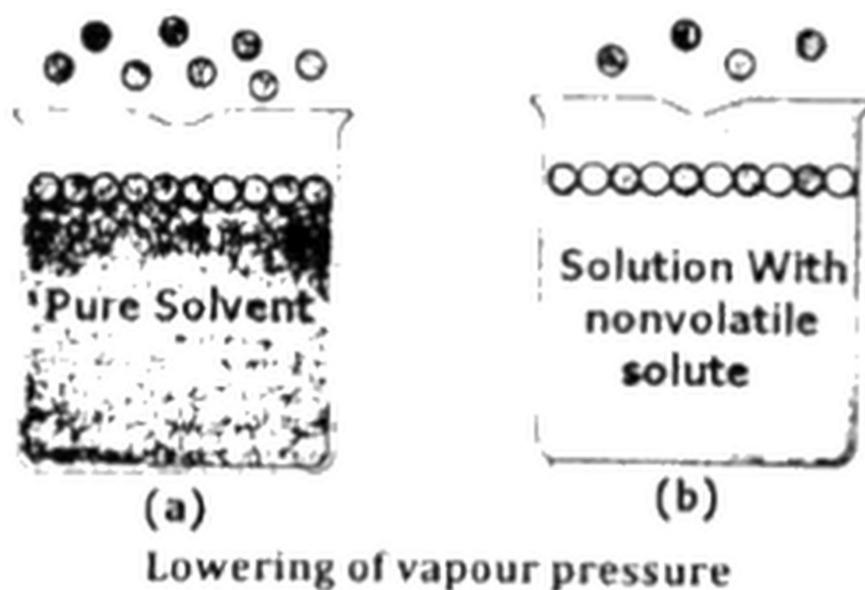
Example:

For example, molecules of organic fats and oils are called hydrophobic molecules.

16. Describe on a particle basis why a solution has a lower vapour pressure than the pure solvent.

Ans: Causes of Lowering in Vapour Pressure:

- i. Every liquid has a definite vapour pressure at a particular temperature,
- ii. In a pure liquid, all the surface particles are that of the Liquid,
- iii. But in a solution containing a non volatile solute, both solute and solvent particles occur on the surface.
- iv. The solute particles decrease the number of solvent surface particles



- v. Decreasing the number of surface solvent particles decreases the rate of evaporation of the solvent, which decreases the vapour pressure.

Conclusion:

Thus the vapour pressure of a solution containing a nonvolatile solute is always less than the vapour pressure of the pure solvent

17. Explain osmotic pressure, reverse osmosis and give their daily life

Ans: Osmotic Pressure:

Osmotic pressure is the pressure which needs to be applied to a solution to prevent the inward flow of water across a semipermeable membrane.

It is also defined as the minimum pressure needed to nullify osmosis. The osmotic pressure of an ideal solution with low concentration can be approximated using the Morse equation (named after Harmon Northrop Morse)

$$\pi = MRT$$

Where

M is the molarity

R = 0.08205746 L atm $K^{-1}mol^{-1}$ is the gas constant

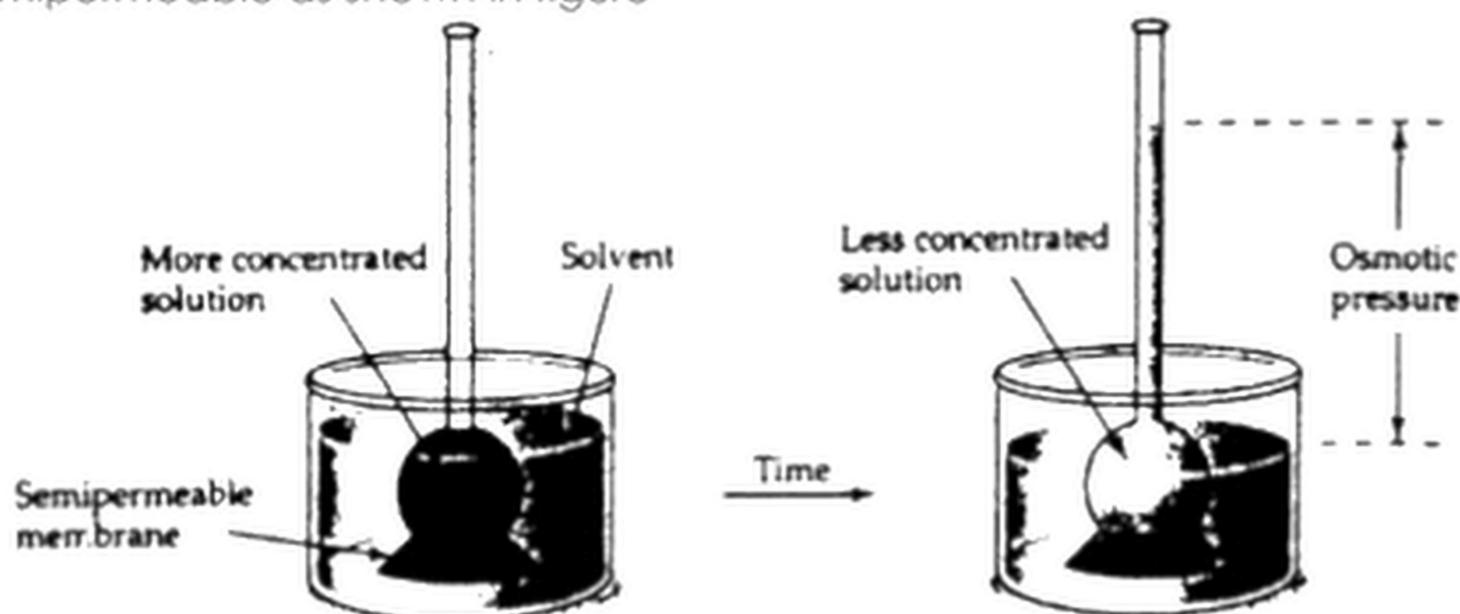
T is the thermodynamic (absolute) temperature

Examples:

- i. Certain animal membranes such as that of bladder or outer covering of intestines are semipermeable. They allow the passage of water but not any solute dissolved in the water.
- ii. A man made material such as cellophane can be used as semipermeable membrane.

Explanation:

A solution inside the bulb is separated from pure solvent in the beaker by a semipermeable as shown in figure



The phenomenon of osmosis

As time passes the volume of solution increases and that of solvent decreases. The process continues until the hydrostatic pressure due to the extra height of

is defined as the pressure, which must be applied above the solution to prevent passage of solvent through a semipermeable membrane into the solution,

Daily Life Applications of Osmosis:

The osmosis phenomenon manifests itself in many interesting daily life applications.

1. Biochemists use a technique called hemolysis to study the contents of red blood cells. These cells are protected from the external environment by a semi permeable membrane. Red blood cells are placed in a hypotonic solution. Since hypotonic solution is less concentrated than the interior of the cell, water moves into the cells. The cells swell and eventually bursts releasing hemoglobin and other molecules.

2. Osmosis is the major mechanism for transporting water upward in plants. Because leaves constantly lose water to the air by a process called transpiration. As a result, leaf fluids become more concentrated than the ground water. Thus water enters membranes in the roots and rises into the tree. It can create an osmotic pressure that can exceed 20 atm in the tallest trees

3. A large quantity of sugar is essential to preserve jam and jelly. This is because the sugar helps to kill bacteria that may cause botulism. When a bacterial cell is in a hypertonic solution. The intracellular water tends to move out of the bacterial cell to the more concentrated sugar solution by osmosis. This causes the bacterial cell to shrink and eventually to cease functioning

4. Food is preserved by coating with salt, which produces hypertonic solution. Thus food coated with salt causes microbes on the surface to shrivel and die from loss of cell water

Reverse Osmosis:

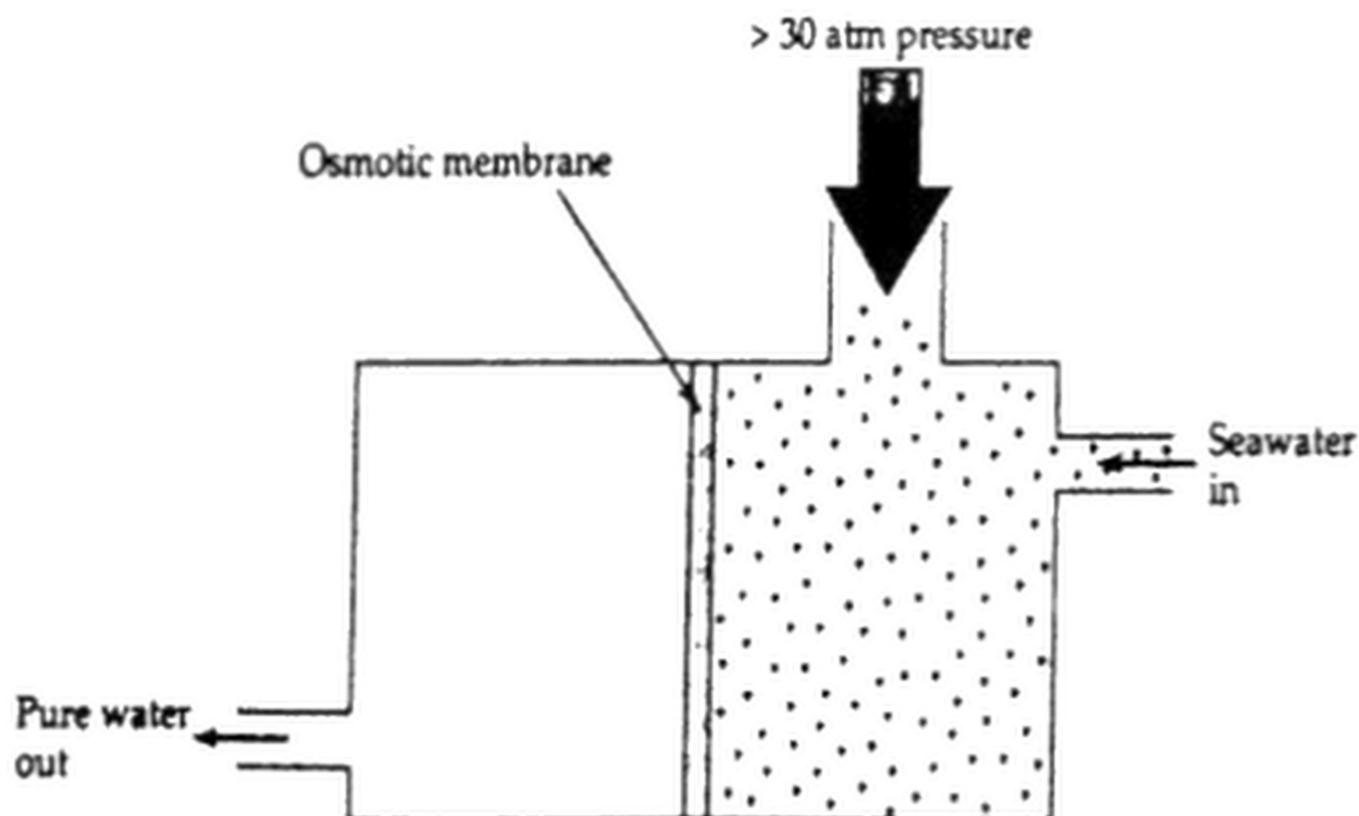
If a solution in contact with pure solvent across a semipermeable membrane is subjected to an external pressure equal to osmotic pressure, it stops osmosis. If external pressure is greater than solution's osmotic pressure, it will force solvent to flow from solution to the solvent. This process is called reverse osmosis

ii. By reverse osmosis it is subjected to desalination (removal of dissolved salts) to make it drinkable.

iii. Desalination plant (as shown in figure), remove large amounts of dissolve salts from sea water

Working:

The sea water is pumped under high pressure (20 atm) through the semi permeable membrane, which allow water molecules to pass and stop ions



A schematic for the desalination of seawater by reverse osmosis

18. Define heat of solution and apply this concept to the hydration ammonium nitrate crystals.

Ans: The enthalpy of solution, enthalpy of dissolution or heat of solution is the enthalpy change associated with the dissolution of a substance in a solvent at constant pressure resulting in infinite dilution.

Unit:

The enthalpy of solution is most often expressed in kJ/mol at constant temperature.

Explanation:

i. When a solute dissolves in water, attractive forces among these solute particles must be overcome to break solute particles from the solid lattice.

iii. Therefore, heat of solution measures the net energy flow that occurs as a substance dissolves.

iv. The energy needed to break solute particles is equal to lattice energy of solute ($\Delta H_{\text{lattice}}$) On the other hand the energy released when solute particles bind to the water molecules in the solution is called heat of hydration (ΔH_{hyd}).

Heat of hydration increase with increasing charge on the ions and decreases with increasing size of ions.

v. For other solvents (except water) this energy is known as heat of solvation.

vi. Heat of solution includes both the energy needed to move solvents molecules, move apart and energy release when they surround solute particles.

Thus, heat of solution $\Delta H_{\text{solution}}$ is the difference in a $\Delta H_{\text{lattice}}$ and ΔH_{hyd}

$$\Delta H_{\text{solution}} = \Delta H_{\text{lattice}} - \Delta H_{\text{hyd}}$$

Because of the different attractive forces in both solute and solution heat, heats of solution vary from significantly exothermic to significantly endothermic.

vii. If the crystal binds solute particles more tightly than the solution, solute must absorb energy as it dissolves and we have endothermic solution process

viii. When this $\Delta H_{\text{solution}}$ is very large, the solute is unlikely to be soluble. But if this $\Delta H_{\text{solution}}$ moderately positive, then solute dissolves.

Examples:

Hydration of ammonium nitrate:

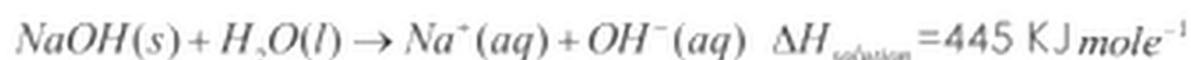
When ammonium nitrate dissolves in water $25.7 \text{ KJ mole}^{-1}$ energy is absorbed and the flask becomes cold. This is because crystal binds NH_4^+ and NO_3^- ions more tightly than the solution.



On the other hand, if solution binds solute particles more tightly than the crystal, energy is released as the solute dissolves and we have an exothermic solution process

Hydration of NaOH:

For example, when NaOH dissolves in water $44.5 \text{ KJ mole}^{-1}$ energy is released and



Thus solution process can be endothermic or exothermic depending upon the difference in the lattice energy for solute and heat of solvation for solute particles

Other examples are given below:



The values of standard enthalpies of solution of some ionic solids in water are given in table.

Enthalpies of Solutions of some ionic solids.

Substance	Enthalpy of Solution (KJ mole ⁻¹)
LiCl	-37.0
NaCl	+2.98
KCl	+17.2
KI	+20.3
NH ₄ NO ₃	+25.7
AlCl ₃	-321.0

19. Explain the phenomenon of freezing in a mixture of ice and salt.

Ans: Melting point is a property of solids. The melting point is simply the temperature at which the solid turns into a liquid. For example, the melting point of normal ice is 0°C at standard pressure.

Freezing point is a property of liquids. The freezing point is simply the temperature

The value of the melting and freezing points is the same (ie, both are 0°C for water).

When salt is added to ice it lowers the freezing point by decreasing the vapour pressure of the solution. Thus the solution will freeze at a lower temperature than that of the pure solvent. Therefore addition of a non-volatile solute causes a depression in freezing point of solution.

20. Explain how solute particles may alter the colligative properties.

Ans: Causes of Boiling Point elevation:

- i.** When a non-volatile and non-electrolyte solute is added to a solvent, its vapour pressure is decreased.
- ii.** This is because in solution both solute and solvent particles occur on the surface.
- iii.** Thus solute particles decrease the number of solvent surface particles.
- iv.** This decreases the rate of evaporation of solvent, which decreases the vapour pressure.
- v.** Therefore, a solution must be heated to a higher temperature than the boiling point of pure solvent to equalize its vapour pressure to the atmospheric pressure.

Conclusion:

Thus addition of solute to a pure solvent causes an elevation of the boiling point of solution.

Causes of Freezing Point Depression:

- i.** The decrease in vapour pressure of a pure solvent on the addition of a solute also affects the freezing point of the solution
- ii.** The solution will freeze at a temperature at which vapour pressure of both solution and solid solvent are the same.
- iii.** This means solution will freeze at a lower temperature than that of the pure solvent

Conclusion:

Thus addition of a non-volatile solute also causes a decrease or depression in

Moreover, the magnitude of colligative properties increases with increase in number of particles i.e., when concentration of solute is increased

21. Explain the effect of temperature on solubility.

Ans: Q. Describe the effect of temperature on solubility,

Ans: Effect of Temperature on Solubility:

Generally, an increase in temperature increases solubility of a solid in a liquid. At higher temperature greater masses of solutes dissolve in a fixed mass of water than at lower temperature

Solubility curve:

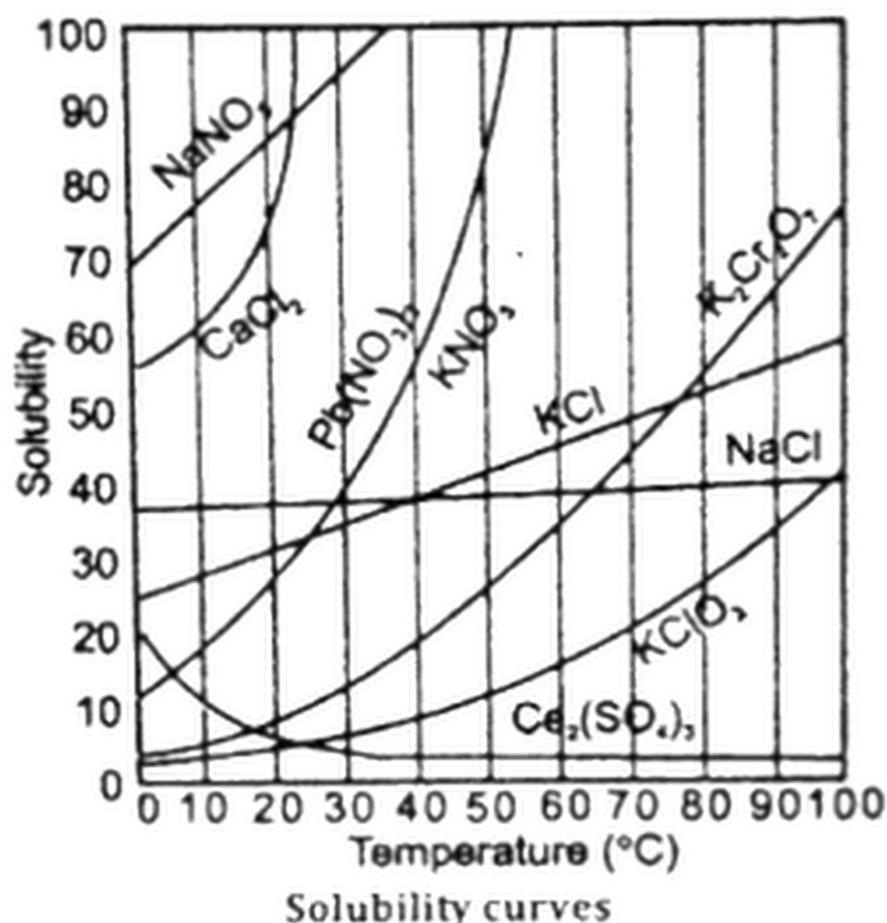
A curve drawn between solubility and temperature is called solubility curve

Exceptions:

- i. The solubilities of solid solutes generally increase with the increase in temperature. However this is not always the case.
- ii. The solubilities of some solids e.g. Na₂SO₄ and Ce₂(SO₄)₃, decrease with increasing temperature.
- iii. Some substances like NaCl have relatively constant solubility with increasing temperature

Prediction by enthalpy of solution:

- i. The variation of solubility with temperature can be predicted from a consideration of the enthalpy of solution.
- ii. If ΔH_{soln} is negative, the solubility of solute decreases as the temperature increases
- iii. If ΔH_{soln} is positive, the solubility increases with temperature



Explanation of Solubility curves:

Solubility of KNO₃ rapidly increases with increase in temperature, this is because it has large positive value of ΔH_{soln} (+36 KJ/mole) The solubility of NaCl does not vary much with temperature because of relatively small magnitude of ΔH_{soln} (+3 kJ/mole).

Solubility of gases:

It is generally observed that the solubility of a gas decreases with increasing temperature.

The dissolving of gases in liquids can be understood in terms of two processes

- The condensation of the gas which is exothermic.
- The creation of holes in the liquid to accommodate the condensed gas molecules, it is endothermic

Because of the open structure of water, little work is required to accommodate gas

molecules, this means dissolving process is exothermic. Thus solubilities of gases in water decrease with temperature.

Molal Solutions	Molar Solutions
i. A molal solution is a solution that contains 1 molecular weight of solute in a kilogram of solvent	Molar solution is an aqueous solution that contains 1 mole (gram-molecular weight) of solute in 1 liter of the solution,
ii. It is a concentration of a solution expressed in moles or molality (m)	ii. It is expressed in molarity (M).
iii. It is independent of temperature	iii. Its value depends upon temperature.
iv. 1 molal solution is dilute than 1 molar solution	iv. 1 molar solution is concentrated than 1 molal solution
Example: When 56.59 NaCl (1 mole) is dissolved in one kilogram of water the resulting, solution would be one molal or 1m NaCl solution	Example: if 0.5 mole of NaOH (20g) is dissolved in enough water to make one dm^3 of solution, 0.5 molar or 0.5 M NaOH solution is obtained

23. Explain the following

(a) Molality is independent of temperature but molarity depends on it.

(b) One molal solution of glucose in water is dilute as compared to one molar solution of glucose, but the number of particles of solute is the same.

(c) The total volume of solution by mixing 50 cm^3 of ethanol and 50 cm^3 of water may not be equal to 100 cm^3 , why?

- (f) One molal and two molal solutions of urea boil at different temperatures.
 (g) Relative lowering of vapour pressure is independent of the temperature.
 (h) The sum of mole fractions of all the components is always equal to one.

Ans:

(a) Molality is independent of temperature but molarity depends on it.

Molality:

In case of molality the concentration of solvent is expressed in terms of mass. The mass of substance is not affected by the change in temperature. Hence molality is independent of temperature.

$$m = \frac{\text{moles of solute}}{\text{kg. of solvent}}$$

Molarity:

In case of molarity the concentration of solution is expressed in terms of volume which change with the change of temperature. Hence molarity is temperature dependent.

$$M = \frac{\text{moles of solute}}{\text{dm}^3 \text{ of solution}}$$

$$M = \frac{\text{grams of solute}}{\text{molar mass of solute} \times \text{dm}^3 \text{ of solution}}$$

OR

Molality is independent of temperature but molarity depends on it is because volume of a solution changes with temperature and Molarity = no. of moles / volume of solution.

But Molality = Number of moles / mass of solvent and hence molality is not altered by temperature.

(b) One molal solution of glucose in water is dilute as compared to one molar solution of glucose, but the number of particles of solute is the same.

The molal aqueous solution of a solute say glucose is dilute in comparison to its molar solution

The reason is that in molal solution the quantity of the solvent is comparatively greater. While in molar in molar solution the quantity of the solute is comparatively greater.

or

Molarity:

Molarity is the measure of concentration of a solution in terms of moles solute per liter of solution.

Molality:

Molality is a measure of concentration in terms of moles solute per kg of solvent

Reason:

As the concentration of the solution increases, the volume of the solute will start to become appreciable and will start to take a measurable amount of space that would otherwise be taken by the water. Whereas in the case of molality, the denominator is always the mass of the solvent (not solvent plus solute) so it will remain unchanged regardless of the concentration.

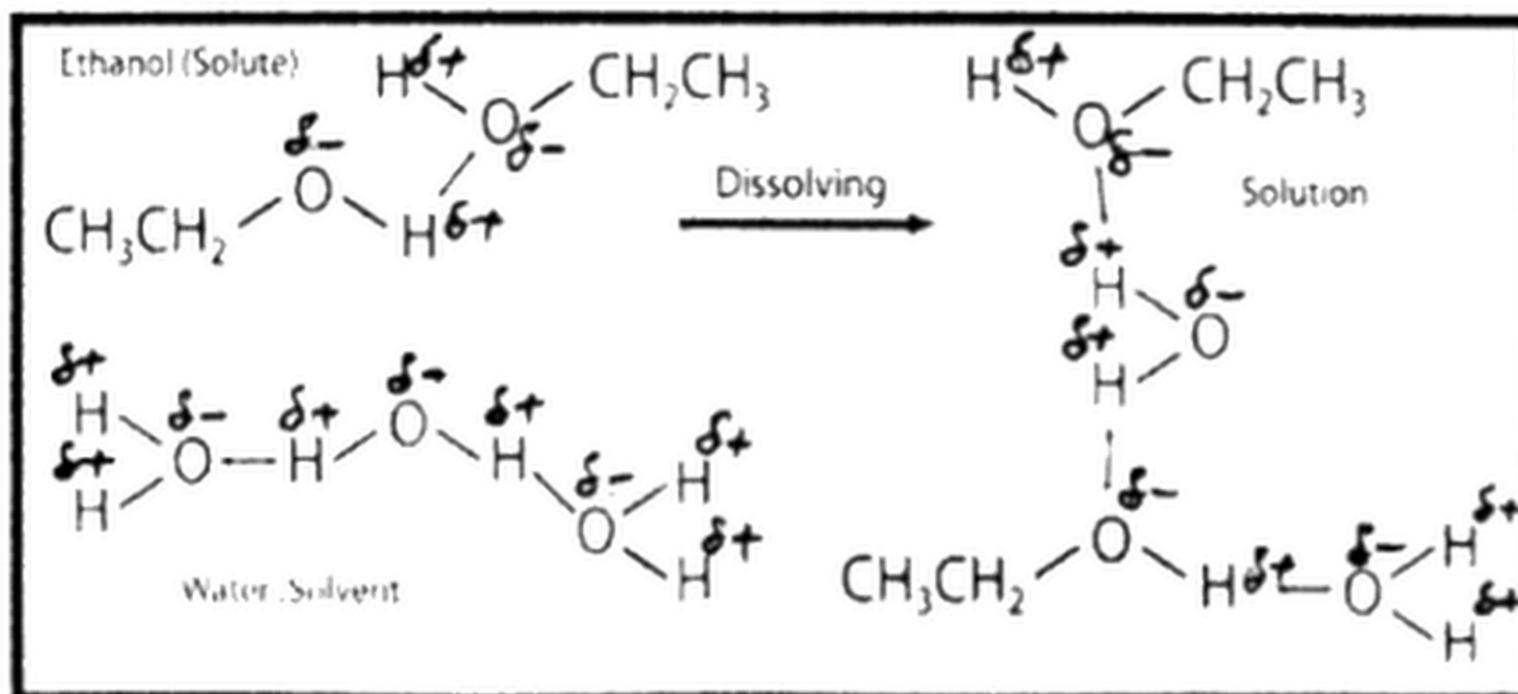
In practical terms:

In practical terms, dilute solutions in water will have the same value of molarity and molality since the density of water is 1 g/mL, thus 1 liter of water will weigh 1 kg.

(C) The total volume of solution by mixing 50 cm^3 of ethanol and 50 cm^3 of water may not be equal to 100 cm^3 , why?

The total volume of solution by mixing 50 cm^3 of ethanol and 50 cm^3 of water may not be equal to 100 cm^3

- i. It is because of the phenomenon of association or dissociation of solute particles in solvent.
- ii. Ethanol and water form strong hydrogen bonding due to which their molecules come closer and therefore the total volume of the solution decrease.



(d) NaCl and NaNO₃ are used to lower the melting point of ice.

The addition of NaCl and NaNO₃ decreases the vapour pressure of water. The addition of NaCl and NaNO₃ decreases the vapour pressure of water due to which the freezing point of water decreases.

OR

When salt is added to ice it lowers the freezing point by decreasing the vapour pressure of the solution. Thus the solution will freeze at a lower temperature than that of the pure solvent.

(e) In summer the antifreeze solutions protect the radiator from boiling over.

Antifreeze lowers the vapour pressure due to which freezing point decreases and boiling point increases. Thus in summer due to the increase in boiling point the

antifreeze solutions protect the radiator from boiling over.

(f) One molal and two molal solutions of urea boil at different temperatures.

As we know that colligative properties depend on the number of the solute particles and not on their nature.

As one molal solution contains one mole of particles and two molal solution contains two moles of particles, therefore one molal and two molal solutions of

Relative lowering of vapour pressure, depends upon mole fraction of solute in a solution

According to Raoult's law

$$\frac{\Delta P}{P} = \text{Relative lower of } V.P$$

And

$$\frac{\Delta P}{P} = X_2 \dots\dots\dots(i)$$

Where

X_2 = Mole fraction of solute

From equation (1) it is concluded that relative lowering of vapour pressure depends upon mole fraction and number of moles do not depend upon temperature. Thus relative lowering of vapour pressure is independent of the temperature.

(h) The sum of mole fractions of all the components is always equal to one.

Suppose a solution contains three components A, B and C with 5, 8 and 10 moles respectively

$$n_A = 5 \text{ mole}$$

$$n_B = 8 \text{ mole}$$

$$n_C = 10 \text{ mole}$$

$$\text{Total number of moles} = n_t = 23 \text{ moles}$$

$$\text{Mole fraction of component A} = X_A = \frac{n_A}{n_t} = \frac{5}{23} = 0.217$$

$$\text{Mole fraction of component B} = X_B = \frac{n_B}{n_t} = \frac{8}{23} = 0.347$$

$$\text{Mole fraction of component C} = X_C = \frac{n_C}{n_t} = \frac{10}{23} = 0.43$$

$$X_A + X_B + X_C = 0.217 + 0.347 + 0.43 = 1$$

24. 1.899 g of an organic compound, A was dissolved per 85 cm³ of water (d=0.998

(Ans: 109.2978.4)

Solution:

Density of water = $d = 0.998 \text{ g cm}^3$

Volume of water = $V = 85 \text{ cm}^3$

Mass of water = $W_1 = ?$

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Mass of water = $W_1 = 0.998 \times 85 = 84.83\text{g}$

Mass of an organic compound = $W_2 = 1.89\text{g}$

Mass of water (solvent) = $W_1 = 84.83\text{g}$

K_b for water = $K_b = 0.52^\circ\text{C}$

Boiling point of water = $T_1 = 100^\circ\text{C}$

Increase in the boiling point of water = $T_2 = 100.105^\circ\text{C}$

Elevation of boiling point = $\Delta T_b = T_2 - T_1 = 100.106^\circ\text{C} - 100^\circ\text{C} = 0.106^\circ\text{C}$

Molecular mass of organic compound = $M_2 = ?$

$$M_2 = \frac{K_b \times W_2 \times 1000}{\Delta T_b \times W_1}$$

$$= \frac{0.52 \times 1.89 \times 1000}{0.106 \times 84.83}$$

$$= 109.297 \text{ g mole}^{-1}$$

25. What freezing point do you expect for water in which 17.99 sucrose $C_{12}H_{22}O_{11}$ is dissolved per 47.69 of H_2O (Ans: -2°C)

Solution:

Mass of sucrose = $W_2 = 17.9\text{g}$

Mass of water = $W_1 = 47.6\text{g}$

K_f for water = $K_f = 1.86^\circ\text{C}$

Depression of freezing point = $\Delta T_f = ?$

As we know that

$$\Delta T_f = \frac{K_f \times W_2 \times 1000}{M_2 \times W_1} = \frac{1.86 \times 17.9 \times 1000}{342 \times 47.6} = 2.045^\circ\text{C}$$

Let

Freezing point of pure water = $T_1 = 0^\circ\text{C}$

Freezing point of solution = $T_2 = ?$

As we know that

$$\Delta T_f = T_1 - T_2$$

or

$$T_2 = T_1 - \Delta T_f$$

$$= 0 - 2.045$$

$$= -2.045^\circ\text{C}$$

26. The vapour pressure of pure water is 23.756 torr at 25°C. How much glucose would be added to 100g of water to bring the vapour pressure down to 23.00 torr?

(Ans: 31.829)

Solution:

Mass of glucose = $W_2 = ?$

Mass of water = $W_1 = 100 \text{ g}$

Vapour pressure of pure water = $P^* = 23.756 \text{ torr}$

Vapour pressure of solution = $P = 23 \text{ torr}$

Lowering of vapour pressure = $\Delta P = P^* - P = 23.756 - 23 = 0.756 \text{ torr}$

Molar Mass of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) = $M_2 = 12 \times 6 + 1 \times 12 + 16 \times 6 = 180 \text{ g mole}^{-1}$

Molar Mass of water (H_2O) = $M_1 = 18 \text{ g mole}^{-1}$

As we know that

$$\frac{\Delta P}{P} = \frac{M_1 \times W_2}{M_2 \times W_1}$$

$$W_2 = \frac{\Delta P}{P} = \frac{W_1 \times M_2}{M_1}$$

$$W_2 = \frac{0.756}{23.756} \times \frac{100 \times 180}{18} = 31.824\text{g}$$

27. You are provided 98%(W/W) H_2SO_4 having density 1.84 g cm^{-3} How much volume of this H_2SO_4 is required to obtain one dm^3 of 30% (W/W) H_2SO_4 which has density 1.25 g cm^{-3} . This solution is used in lead storage batteries as electrolyte.

Solution: For 98% sulphuric acid:

Density of sulphuric acid = 1.84 g/cm^3

Mass of 1 cm^3 of solution = 1.84 g

Mass of 1000 cm^3 of solution = $1.84 \times 1000 = 1840 \text{ g}$

Therefore,

100 g of solution contain sulphuric acid = 98 g

1840 g of solution contain sulphuric acid = $\frac{98}{100} \times 1840 = 1803.2\text{g}$

Hence, 1803.2 g of H_2SO_4 are present in 1000 cm^3 of solution.

Mass of $H_2SO_4 = M_{\text{solute}} = 1803.2\text{g}$

Molecular Mass of $H_2SO_4 = M_{\text{solute}} = 98 \text{ g mole}$

Volume of solution = $V = 1000 \text{ cm}^3 = 1 \text{ dm}^3$

Therefore, molarity is given by

$$\text{Molarity} = \frac{m_{\text{solute}}}{M_{\text{solute}}} \times \frac{1}{V} = \frac{1803.2}{98} \times \frac{1}{1} = 18.4\text{M}$$

For 30% sulphuric acid:

% of sulphuric acid = 30%

Density of sulphuric acid = 1.25 g/cm^3

Mass of 1000 cm^3 of solution = $1.25 \times 1000 = 1250 \text{ g}$

Therefore

100 g of solution contain sulphuric acid = 30 g

1250 g of solution contain sulphuric acid = $\frac{30}{100} \times 1250 = 375 \text{ g}$

Hence, 375g of H_2SO_4 are present in 1000 cm^3 of solution

Mass of $\text{H}_2\text{SO}_4 = m_{\text{solute}} = 375 \text{ g}$

Mol. Mass of $\text{H}_2\text{SO}_4 = M_{\text{solute}} = 98 \text{ g mole}^{-1}$

Volume of solution = $V = 1000 \text{ cm}^3 = 1 \text{ dm}^3$

Therefore, molarity is given by

$$\text{molarity} = \frac{m_{\text{solute}}}{M_{\text{solute}}} \times \frac{1}{V} = \frac{375}{98} \times \frac{1}{1} = 3.83 \text{ M}$$

To prepare 1 dm^3 (1000 cm^3) of 3.83 M H_2SO_4 from 18.4 M H_2SO_4 we have

Conc. H_2SO_4 Dil. H_2SO_4

$$M_1 V_1 = M_2 V_2$$

$$\text{or } V_1 = \frac{M_2 V_2}{M_1}$$

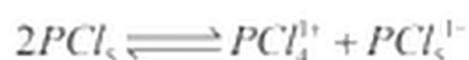
$$V_1 = \frac{3.38 \times 1000}{18.4} = 208.15 \text{ cm}^3$$

28. Caffeine is about 10 times more soluble in hot water than in cold water. Is

ΔH_{soln} of caffeine in water is positive or negative?

Ans: Caffeine is about 10 times more soluble in hot water than in cold water it means that it needs heat (energy) to dissolve. As an increase in temperature adding heat favours the endothermic processes therefore dissolve of caffeine in water is endothermic process.

Thus ΔH_{soln} of caffeine in water is positive.



The extent to which this reaction occurs depends on the solvent in which it is run. Predict whether a non polar solvent such as CCl_4 favours the product or the reactants of this reaction. Predict what would happen to this reaction if we use a polar solvent.

Ans: Principle:

The basic principle of solubility is "Like dissolves like"

Nature of reactant and products:

PCl_5 is a non-polar species, while PCl_4^{1+} and PCl_6^{1-} are polar ions.

Non polar solvent:

A non-polar solvent like CCl_4 will dissolve PCl_5 but it cannot dissolve ionic species, PCl_4^{1+} and PCl_6^{1-}

Polar solvent:

A polar solvent like water will dissolve ionic species, PCl_4^{1+} and PCl_6^{1-} But it cannot dissolve PCl_5

Conclusion:

Thus, in a non-polar solvent the equilibrium will be shifted towards reactant side. While in a polar solvent, the equilibrium will be shifted towards product side.

30. An aqueous solution of a compound boil at 102.4 °C. At what temperature will this solution freeze?

Solution:

According to relations of Elevation in Boiling point.

K_b

$$\text{molar mass} = \frac{\text{mass of solute}}{\text{Mass of Solvent}} \times \frac{K_b}{\Delta T_b} \times 1000 \dots\dots\dots (i)$$

According to relations of depression in Freezing point

$$\text{molarmass} = \frac{\text{mass of solute}}{\text{Mass of Solvent}} \times \frac{K_f}{\Delta T_f} \times 1000 \dots\dots\dots(\text{ii})$$

On comparing equation (i) and (ii)

$$\text{molarmass} = \frac{\text{mass of solute}}{\text{Mass of Solvent}} \times \frac{K_b}{\Delta T_b} \times 1000 = \text{molarmass} = \frac{\text{mass of solute}}{\text{Mass of Solvent}} \times \frac{K_f}{\Delta T_f} \times 1000$$

$$\frac{K_b}{\Delta T_b} = \frac{K_f}{\Delta T_f}$$

$$\Delta T_f = K_f \times \frac{\Delta T_b}{K_b}$$

$$= 1.86 \times \frac{2.4}{0.52} = 8.5^\circ\text{C}$$

Freezing point of solution = - 8.5°C

31. Water and carbon tetrachloride are not miscible. When mixed they form two layers. If an aqueous solution of iodine I_2 shaken with CCl_4 the iodine is extracted into the CCl_4 layer. Explain this behavior on the basis of your knowledge of intermolecular forces.

Ans: CCl_4 is a non-polar solvent while iodine (I_2) is a non-polar solute so they can dissolve in each other as we know that "like dissolves like". Water and carbon tetrachloride are not miscible. When mixed they form two layers. If an aqueous solution of iodine I_2 is shaken with CCl_4 the iodine is extracted into the CCl_4 layer. It is because both of them are non-polar.

32. A Cucumber placed in concentrated brine (concentrated NaCl solution in water) shrivels into a pickle. Explain?

Ans: This happens due to the process of osmosis

Reason:

The cucumber shrivels because the moisture (water) is extracted from it. This

removing water from the cucumber and adding salt from the solution. Thus the brine solution is hypertonic (more concentrated) relative to the cucumber cells.

OR

Cucumber cells membranes are semi permeable membranes. On placing that in concentrated brine process of Osmosis takes place and water start to flow from higher concentration (in cucumber) to lower concentration (in brine). As a result, the cucumber shrivels.

33. Two beakers are placed in a sealed bell jar. One beaker contains water and the other contained concentrated glucose solution. With time volume of water decreases and solution volume increases. Explain why?

Ans: As water is a pure solvent, so its rate of evaporation is high than that of glucose solution. Water vapours go into the atmosphere of bell jar (A bell jar is a sealed laboratory equipment). Therefore, the water vapours are transferred from high pressure area to low pressure area. Thus, volume of water decreases and that of solution increases.

34. Consider two aqueous solutions one is sucrose and the other of glucose. Both of these solutions boil at 101.52 °c. List some common properties of these solutions.

Ans: Both these solutions have

- i. Same number of particles
- ii. Same vapour pressure
- iii. Same freezing point
- iv. Same boiling point
- v. Same molality
- vi. Same osmotic pressure

