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CHAPTER No. 10.

SOLUTIONS AND COLLOIDS

Solution :-

Homogeneous mixture of two or more then two components having uniform composition and physical properties is called solution. Solution may exist in solid, liquid or in gaseous phase.

Phase :-

A sample of matter having fixed composition and uniform properties throughout is called a phase.

Solute:-

Component of solution which is present in smaller quantity is called solute.

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Solvent :-

Component of solution which is present in larger quantity is called solvent.

For example: When NaCl is dissolve in water solution is form. In this case NaCl is solute and water is solvent.

Hydrophilic and Hydrophobic molecules.

Hydrophilic molecules :-

Hydro means water and philic means loving. So hydrophilic means water loving.

Molecules that are miscible

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with water are called hydrophilic molecules.

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

Hydrophobic molecules :-

Phobic means disliking therefore hydrophobic literally mean water disliking.

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

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

Nature of solution in liquid phase.

Solutions of 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 liquids.

For example;

(i) Water and methanol.
(ii) Acetone and water.
(iii) Benzene and cyclohexane.

they are all completely miscible pairs of liquids.

Explanation:-

(i) 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.

(ii) Benzene and cyclohexane are completely miscible because the molecules in the pure liquids and their mixtures interact through London dispersion forces. These dispersion forces b/w benzene and cyclohexane are about the same as those in pure liquids.

(b) **Partially miscible liquids:-**

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Liquids that dissolve in eachother to a very small extent are called 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.

Typical examples of such systems are:

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

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Explanation:-

Phenol-water system:-

(i) When equal volumes of phenol and water are mixed into eachother, two liquid layers are formed. The lower layer consists of a small amount of

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water dissolved in phenol, while the upper layer consists of small amount of phenol dissolved in water.

(ii) It is observed that at 25C° upper layer is 5% solution of phenol in water and the lower layer is 30% water in phenol. This means water is solute in lower layer and phenol is solute in upper layer. Such solutions are called conjugate solutions.

(iii) As the temperature increases, the mutual solubility of two liquids increases. Water starts moving form upper to the lower layer and phenol from lower layer to the upper layer. Thus composition of both the layers changes.

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(iv) When temperature finally reaches 65.9C° the composition of both the layers becomes identical. Each layer contains 34% phenol and 66% water. Above this temperature two solutions merge into one another and two liquids becomes completely miscible in all proportions.

Critical solution temperature:- OR
Upper consolute temperature:-

The temperature at which two conjugate solutions merge into one another is called critical solution temperature or upper consolute temperature.

For example: Critical temperature for water-aniline system is 167C° with 15% water and that for aniline-hexane

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is 59.6C° with 52% aniline. And that for water-phenol is 65.9C° with 34% phenol.

(C) **Immiscible liquids:-**

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

For example: water and benzene, carbon disulphide and water, cyclohexane and water.

Explanation:-

(i) Benzene, carbon disulphide or cyclohexane are non-polar in nature. The only forces of attraction b/w their molecules are dispersion forces.

(ii) 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.

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-: Dissolution process -

Process of dissolving solid into liquid is called dissolution process.

Explanation:-

(i) In the formation of a solution three types of interactions are involved. These are solute-solute, solute-solvent and solvent-solvent interactions.

(ii) A solution forms only when the interactions b/w solute-solvent molecules are equal to or greater than the interactions b/w solute-solute and solvent-solvent molecules.

(iii) Four factors influence the rate at which substances dissolve:

(i) Particle size.
(ii) Temperature.
(iii) Solution concentration.
(iv) Stirring.

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Solvation of ion and molecular substances.

The process in which solvent molecules interact and surround solute ions or molecules is known as solvation. When water is the solvent, this process is known as hydration.

Explanation:-

(i) Ionic solids are soluble only in solvents having polar molecules. When an ionic compound is dissolved in a polar solvent, it splits up into its ions.

For example: when NH_4NO_3 dissolves in water the resulting solution contains NH_4^+ and NO_3^- ions floating around independently. Solvent molecules surround these ions by directing their negative poles towards positive ions and their positive poles towards negative ions. This interaction is called **ion-dipole** interaction.

(ii) Molecular solids are held together by dispersion forces, dipole-dipole forces and sometimes hydrogen bonds. Such solids dissolve readily in solvents with similar types of intermolecular forces.

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Daily life applications of heat of solution.

(i) Instant hot and cold packs are in common use today.

(ii) Cold packs are used for the treatment of injuries and reduction of swelling.

(iii) Hot packs are used for instant warmth for hikers and skies and treatment of pulled muscles.

(iv) These packs are excellent examples of basic science producing a technologically useful product.

(v) These packs are based on heat of solutions.

(vi) These packs contains two separate compartments. One contains water and the other contains a salt, NH_4NO_3 for cold packs and $CaCl_2$ or $MgSO_4$ for hot packs.

(vii) When required these packs are kneaded, the wall b/w the compartments breaks, allowing the salts to mix with water.

(viii) Heat is absorbed in cold packs and released in hot packs. Gradually these packs attain room temperature.

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.**

For example: (i) $CuSO_4 \cdot 5H_2O$

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(ii) $BaCl_2 \cdot 2H_2O$ (iii) $MgSO_4 \cdot 7H_2O$

(iv) $(COOH)_2 \cdot 2H_2O$ (v) $Na_2CO_3 \cdot 10H_2O$

$$\% \text{ water in hydrate} = \frac{\text{mass of wate in hyd.}}{\text{mass of hydrate}} \times 100.$$

Q:- How to determine the percentage of water in hydrate?

Ans:- The percentage of water in a hydrate can be determined. For this purpose

(i) A known mass of hydrate is heated to expel water completely.

(ii) Mass of anhydrous solid is determined. Difference in the two masses gives the mass of water present.

(iii) From these masses, percentage of water in hydrate is determined by using the following formula.

$$\% \text{ water in a hydrate} = \frac{\text{mass of water in hydrate}}{\text{mass of hydrate}} \times 100$$

(iv) An ion having higher charge density has greater ability to attact water molecules.

(vi) In hydrates, although new bonds b/w ions and water molecules are formed but no hydrogen oxygen bond of water is booken.

Concept of Solubility:-

1- Solubility:-

The maximum amount of solute that dissolves in the given quantity of a solvent under given conditions is called solubility.

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Units:- Solubility commonly expressed in:

(i) Number of grams of solute per cm^3 of solution. or

(ii) Number of moles of solute per dm^3 of solution.

2- **Unsaturated solution:-**

A solution which can dissolve more solute under given conditions is called unsaturated solution.

3- **Saturated solution:-**

A solution which contains maximum amount of dissolve solute under existing conditions is called saturated solution.

Explanation:-

(i) A general rule useful for predicting solubilities is "like dissolve like".

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(ii) Substances which have similar structures and intermolecular forces tend to be soluble.

(iii) Substance which have dissimilar structures and intermolecular forces are insoluble.

For example: (i) Molecules of benzene, C_6H_6 and carbon tetrachloride CCl_4 are non-polar and have London dispersion forces b/w their molecules. When these two liquids are mixed, their molecules attract each other with London dispersion forces, thus these are miscible liquids.

(ii) Ionic solids have a crystal lattice structure composed of oppositely charged ions. When an ionic

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solid e.g. **NaCl** is placed in water which is a polar solvent. These ions are attracted by polar molecules. Water molecules break the crystal lattice of **Na^+Cl^-** and then surround the resulting **Na^+** and **Cl^-** ions. These ions are called **hydrated** ions.

(iii) When **NaCl** crystals are placed in **CCl_4** or **C_6H_6**. Non-polar molecules of these liquids are unable to attract ions in **Na^+Cl^-** and cannot break apart the crystal lattice. Thus **NaCl** is insoluble in these solvents.

Effect of Temperature on Solubility:-

(i) Generally, an increase in temperature increases solubility of a solid in a liquid.

(ii) At higher temperature greater masses of solutes dissolve in a fixed mass of water then at lower temperature.

(iii) A curve drawn b/w solubility and temperature is called **solubility curve.**

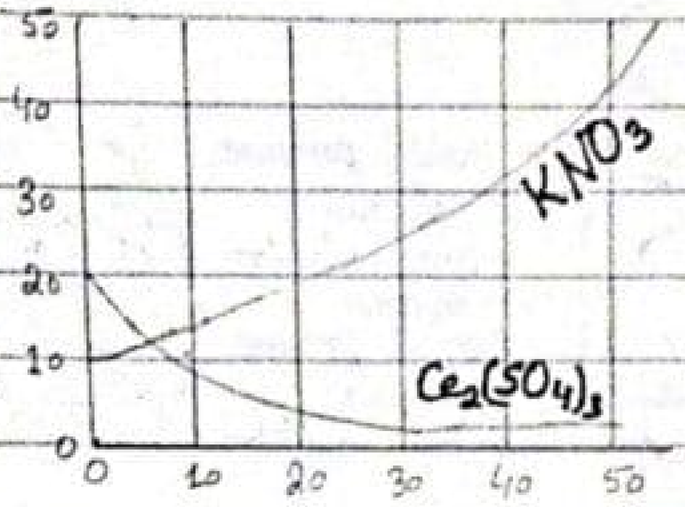
Solubility prediction from enthalpy of solution:-

The variation of solubility with temperature can be predicted from the enthalpy of solution.

(i) If ΔH°_{soln} is negative, the solubility of solute decreases as the temperature increases.

(ii) If ΔH°_{soln} is positive, the solubility of solution increases with temperature.

For example:



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(i) Solubility of $Ce_2(SO_4)_3$ decreases with increasing temperature because its solubility solution is exothermic.

(ii) Solubility of KNO_3 rapidly increases with increase in temperature, this is because it has large positive value of ΔH°_{soln} (+36 KJ/mole).

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For gases:-

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

(a) The condensation of gases is exothermic.

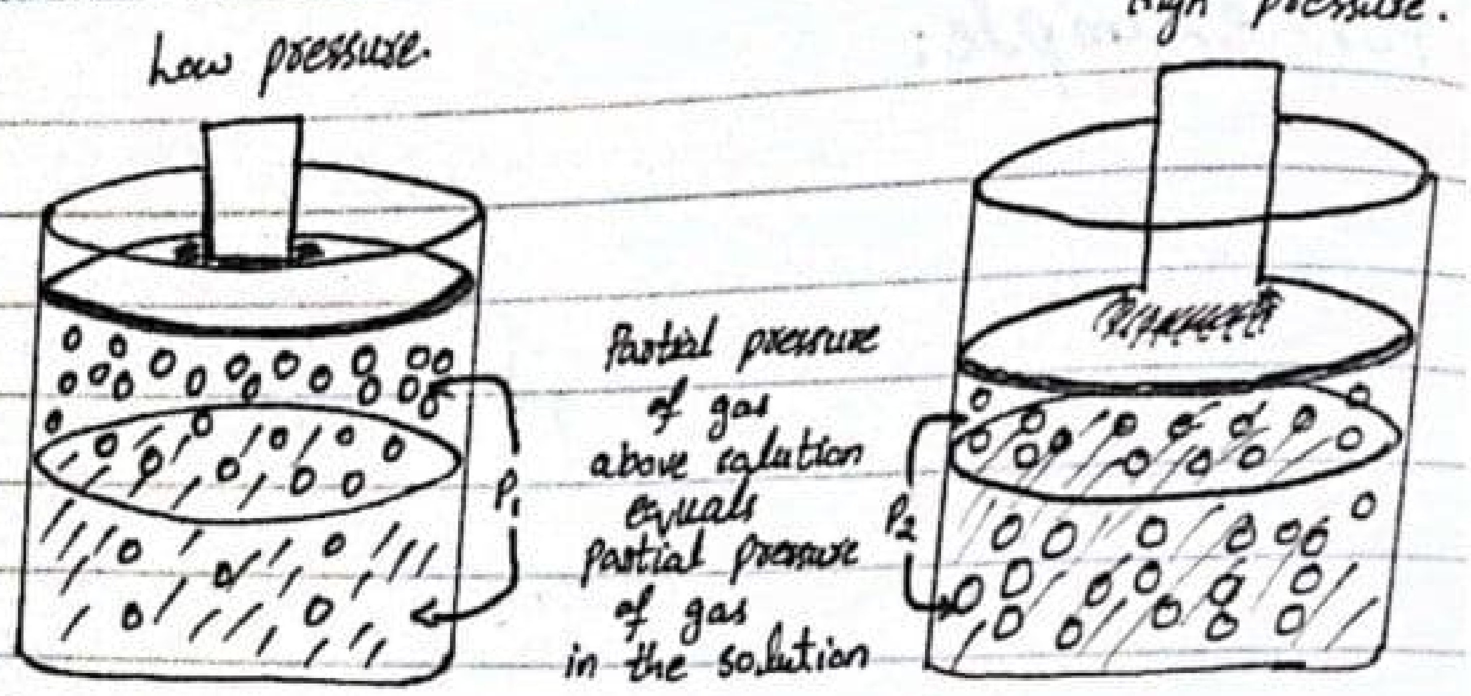
(b) The creation of holes in the liquid to accommodate the condensed gas molecules, is endothermic.

Effect of pressure on solubility:-

Pressure has negligible effect on solubility of solids or liquids.

Henry's Law:-

Solubility of a gas in solution increases as the partial pressure of the gas above the solution increases.



Applications:-

(i) Carbonated drinks are bottled at hight pressure of carbon dioxide.

(ii) When cap is removed, the effervescences results from the fact that the partial pressure of carbon dioxide in the atmosphere is much less than used in the bottling process.

(iii) As a result, the equilibrium quickly shifts to one of the lower gas solubility. This causes effervescence.

-: Concentration Units :-

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1. Mass Percent:-

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

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

For example: 15% NaCl solution means 15g of NaCl dissolved per 100 g of solution or 85g of water.

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2- Percent weight by volume:-

It is the mass of solute dissolved per 100 part(cm^3) by volume of solution. In this case volume of solvent is not exactly known.

$$\text{Percent } w/v = \frac{\text{Mass of solute (g)}}{\text{Vol. of solution } (cm^3)} \times 100.$$

3- Percent volume by volume:-

It is the volume of solute dissolved per 100 parts by volume of solution. In such solutions volumes of solute and solvent may not be necessarily equal to the volume of solution.

$$\text{Percent } V/v = \frac{cm^3 \text{ of solute}}{cm^3 \text{ of solution}} \times 100$$

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4- Molarity (M):-

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

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

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

5- Percent volume by weight:-

The volume of solute dissolved per 100g of solution is called percent volume by weight. In this case total volume of solution is not known.

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$$\% \ \frac{V}{w} = \frac{\text{volume of solute} (cm^3)}{\text{Mass of solution} (g)} \times 100$$

6- **Molality (m) :-**

It is defined as the number of moles of solute dissolved per kilogram of solvent.

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

7- **Mole fraction (X) :-** It has no units.

It is defined as ratio of moles of given component to the total no. of moles of solution.

Suppose a solution contains n_A and n_B moles of two components A and B. Moles fraction of each component is given by:

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

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

Sum of all components is unity ($X_A + X_B = 1$).

8- **Parts per million (ppm) :-**

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

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

9- **Parts per billion (ppb) :-**

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

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weight (or volume) of solution.

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

10- **Parts per trillion (ppt):-**

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

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

RAOULT'S LAW :-

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It states that when a nonvolatile solute is dissolved in a solvent, the vapour pressure of solution (P) is directly proportional to the mole fraction of solvent (X_1).

$$P \propto X_1$$

$$P = P^\circ X_1 \text{ ------ } (1)$$

Where, P° is constant of proportionality and is the vapour pressure of the pure solvent.

As $X_1 + X_2 = 1$

$\therefore X_1 = 1 - X_2$

where X_2 = mole fraction of solute.

Putting value of X_1 in eq. (1), we get

$$P = P^\circ(1 - X_2)$$

$$P = P^\circ - P^\circ X_2$$

$$P - P^\circ = -P^\circ X_2$$

$$P^\circ - P = P^\circ X_2 \text{ ------- } (2)$$

$$\Delta P = P^\circ X_2$$

where, $P^\circ - P$ = lowering in vapour of salvent (ΔP).

Therefore, Raoult's law can also be stated as the lowing in vapour pressure is directly proportional to the mole fraction of solute.

Rearranging eq. (2) we get another form of Raoult's law.

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

$$\frac{\Delta P}{P^\circ} = X_2$$

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$\frac{\Delta P}{P^\circ}$ is relative lowing in vapour pressure of the solvent. Raoult's law can also be stated as the relative lowering in vapour pressure is equal to the mole fraction of salute. Lowering in vapour pressure depends on temperature whereas relative lowing in vapour pressure in independent of temperature.

Raoult's law for ideal salution of two volatile components (Liquids).

(i) Raoult's law also governs the vapour pressure of mixture of two or more volatile components.

(ii) The vapour pressure of each component is determined by its mole fraction

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and the vapour pressure of pure component.

(iii) The total vapour pressure always lies b/w the vapour pressure of the pure components, and is determined by the mixture composition.

Colligative properties of solution containing non-electrolyte solutes.

Properties which depend upon numbers of solute and solvent particles not on the nature of particles, are called **colligative properties**

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For example:

(i) Vapour pressure lowering.
(ii) Boiling point elevation.
(iii) Freezing point depression.
(iv) Osmotic pressure.

Conditions for colligative properties:-

(i) Solution should be dilute.
(ii) Solution should be nonvolatile.
(iii) Solution should be nonelectrolyte.

Lowering of vapour pressure:-

When a nonvolatile, nonelectrolyte solute is added to volatile solvent vapour pressure of solution is less then as compaired to pure solvent this is called **lowering of vapour pressure.**

According to Raoult's law relative lowering of vapour pressure is equal to mole fraction of solute.

$$\frac{\Delta P}{P^\circ} = X_2$$

If n_1 and n_2 are the number of moles of the solvent and solute respectively, then

$$X_2 = \frac{n_2}{n_1 + n_2}$$

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$$\frac{\Delta P}{P^\circ} = \frac{n_2}{n_1 + n_2}$$

Since for dilute solution $n_2 << n_1$, n_2 can be ignored in the denominator

$$\frac{\Delta P}{P^\circ} = \frac{n_2}{n_1}$$

If W_1 and W_2 are masses of solvent and solute while M_1 and M_2 are their molecular masses respectively, then

$$\therefore n_1 = \frac{W_1}{M_1} \quad \text{and} \quad n_2 = \frac{W_2}{M_2}$$

$$\text{So} \quad \frac{\Delta P}{P^\circ} = \frac{W_2/M_2}{W_1/M_1}$$

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

$$\text{or} \quad M_2 = \frac{W_2 \times M_1 \times P^\circ}{W_1 \times \Delta P}$$

Thus molecular mass of a non-volatile solute can be calculated from this equation.

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Causes of boiling point elevation and freezing point depression.

Boiling point elevation:- OR Elevation of boiling point:-

When non-volatile nonelectrolyte solution is added to volatile solvent vapour pressure of solution is less then as compaired to pure solvent but boiling point of solution is greater then as compaired to pure solvent this is called elevation of boiling point. It is denoted by ΔT_b.

Mathametically:- The magnitude of the boiling point elevation is directly proportional to the molality of solution.

$$\Delta T_b \propto m$$

$$\Delta T_b = K_b m \ldots\ldots (1)$$

The constant K_b is called molal boiling point elevation constant or ebullioscopic constant. For one molal solution.

$$\Delta T_b = K_b$$

The molality m of the solution containing W_2g of solute of molecular mass M_2 dissolved in W_1g of the solvent is given by

$$m = \frac{W_2 \times 1000}{M_2 \times W_1}$$

Putting the value of m in eq. (1)

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

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

This eq. is used to determine the molecular mass of solute.

Explanation:-

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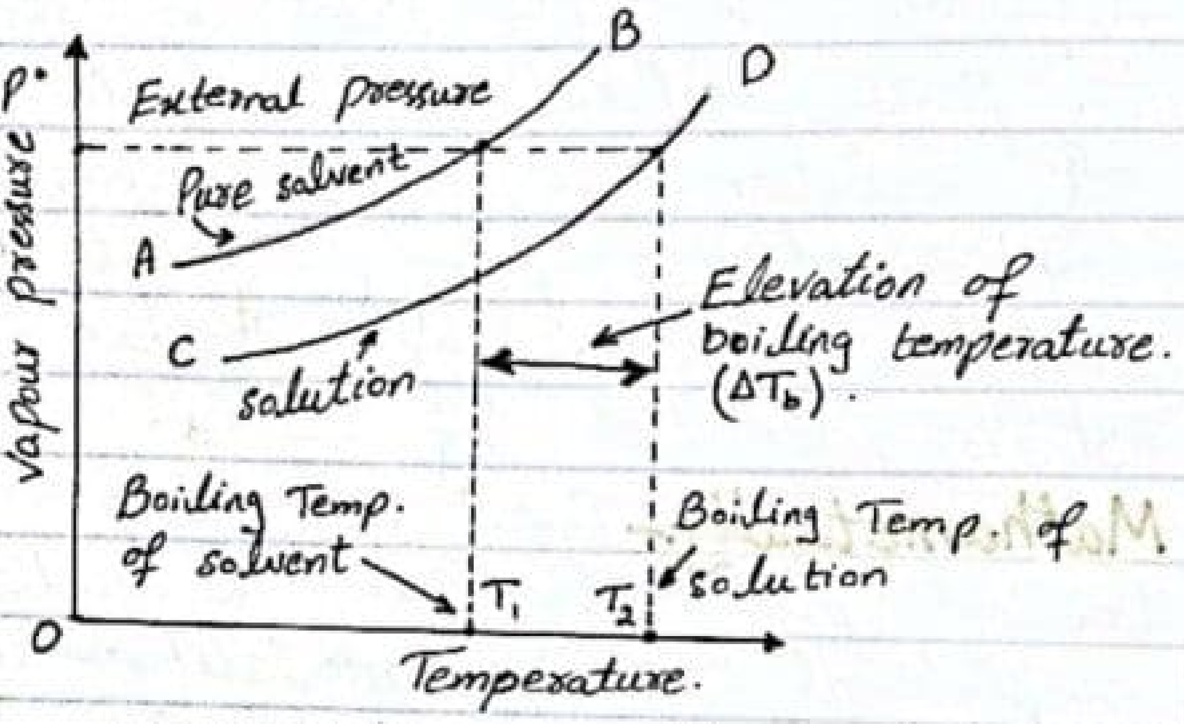

(i) Curve AB represents variation in vapour pressure of pure solvent with temperature.

(ii) The solvent boils at temperature T_1 when its vapour pressure becomes equal to external pressure. P°.

(iii) The curve CD represents variation in vapour pressure of solution with temperature

(iv) This curve must lies below that of pure solvent. This is because the vapour pressure of solution at all temperatures is lower than that of the pure solvent.

(v) The solution will boil at higher temperature T_2. to equalize its vapour pressure to external pressure P°.

(vi) The differences of two boiling points give the elevation of boiling point (ΔT_b).

$$\Delta T_b = T_2 - T_1 .$$

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Measurement of Boiling Point Elevation.

Lands Berger's Method:-

Apparatus:-

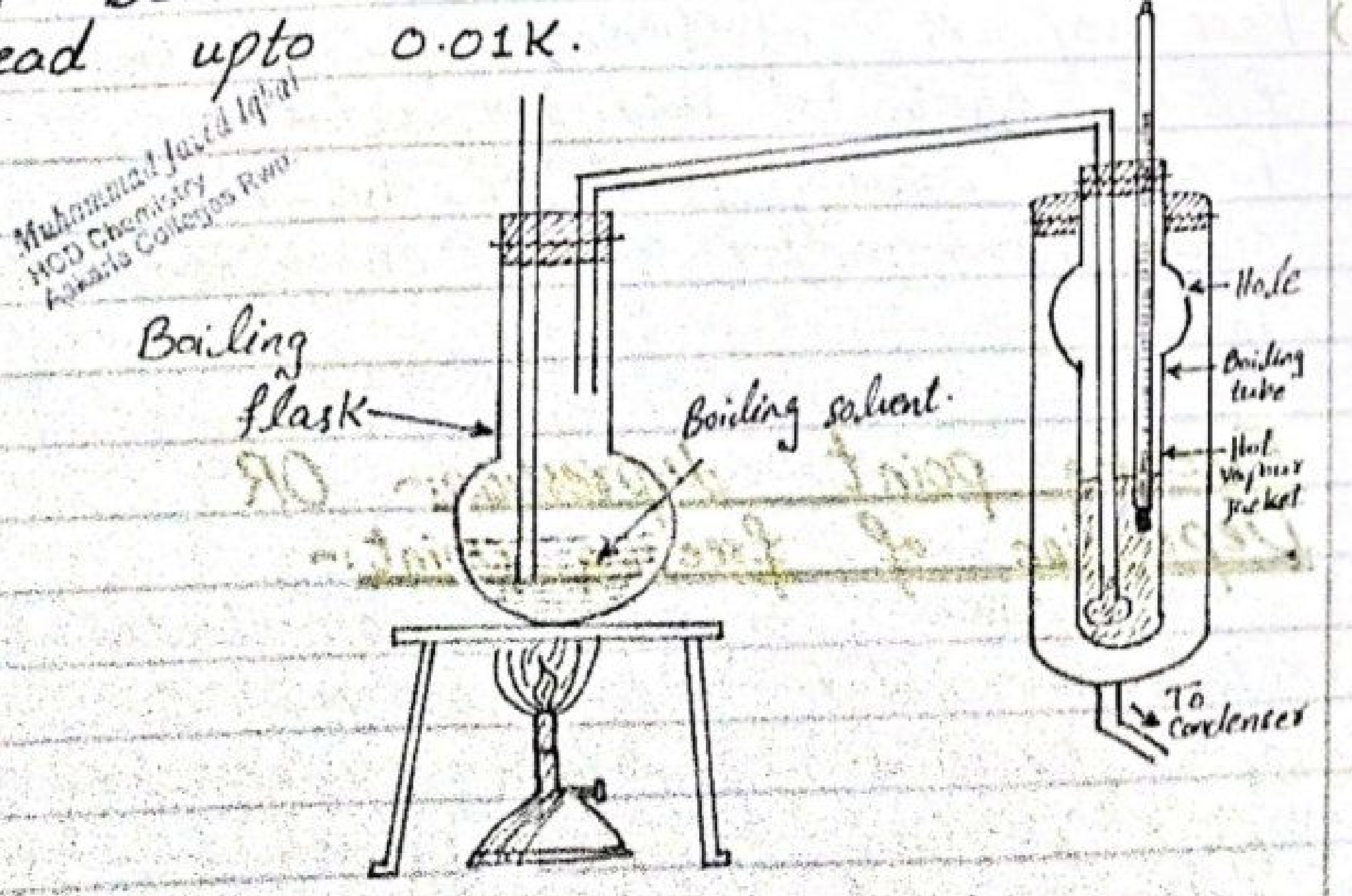
Apparatus consists of four major parts:

(a) A graduated inner tube with a hole in its side.

(b) A boiling flask which sends the solvent vapours into the inner tube through a rosehead.

(c) A outer tube, which receives solvent vapours coming out from the side hole of the inner tube.

(d) A Beckmann thermometer which can read upto 0.01K.



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Proceedure:-

(i) Cholesterol is an important compound in our body. Its excess has been implicated as a cause of heart disease.

(ii) Take volume in cm^3 of pure benzene (solvent) in the inner tube.

(iii) Boil benzene in the boiling flask and pass its vapours through the benzene in the inner flask.

(iv) These vapours will boil benzene in the inner tube by its latent heat of condensation.

(v) Record the temperature at which benzene is boiled in the inner tube. It will boil at T_1.

(vi) Now stop the supply of vapours temporarily.

(vii) Drop few grams of cholesterol in the inner tube.

(viii) Pass vapours of benzene from boiling flask again to boil the solution.

(ix) Record boiling point of the solution. Now Thermometer will show temperature T_2.

Freezing point depression:- OR Depression of freezing point:-

When non-volatile, non-electrolyte solute is added to valatile solvent vapour pressure of solution is less than vapour pressure of pure solvent. Similarly, freezing point of solution is less than

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as compaired to pure solvent this is called depression of freezing point. It is denoted by ΔT_f.

Mathametically:-

$$\Delta T_f \propto m$$

$$\Delta T_f = K_f m \text{ ----- } (1)$$

Where K_f = molal freezing point constant or the cryoscopic constant.

For 1 molal solution.

$$\Delta T_f = K_f$$

The value of K_f depends upon the nature of solvent and is independent of the solute used. The nature of solute does not effect the freezing point depression as long as the solute doesn't ionize.

The molality m of the solution containing W_2g of solute of molecular mass M_2 dissolved in W_1g of the solvent is give by

$$m = \frac{W_2 \times 1000}{M_2 \times W_1}$$

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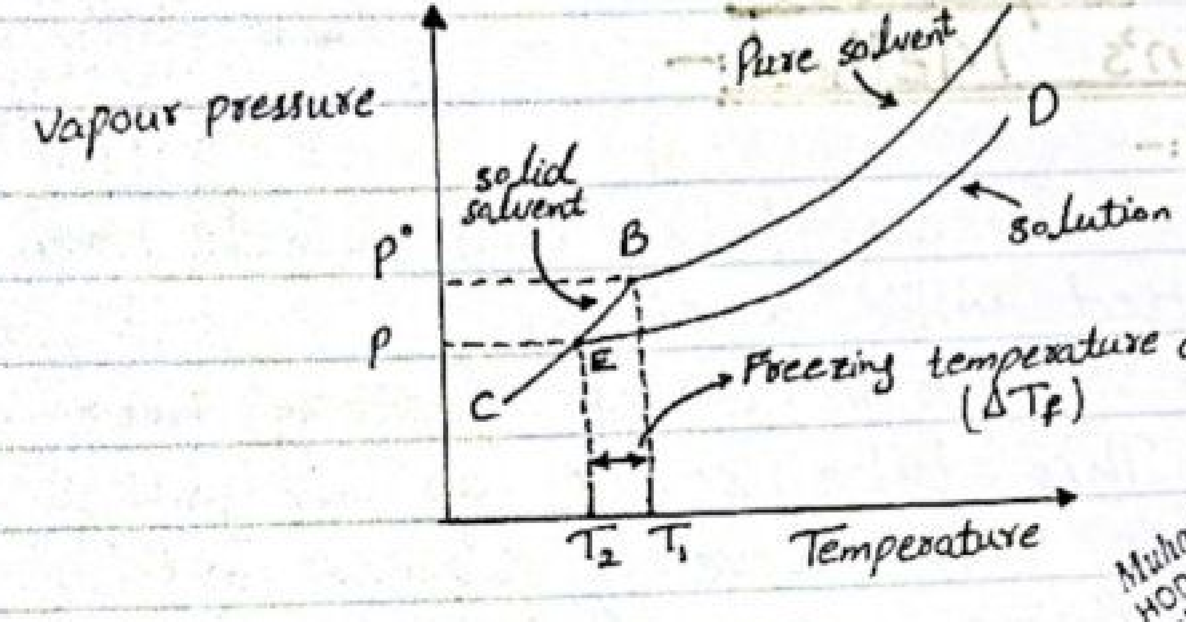
putting the value of m in eq ①

$$\Delta T_f = K_f \times \frac{W_2 \times 1000}{M_2 \times W_1}$$

$$M_2 = \frac{K_f \times W_2 \times 1000}{\Delta T_f \times W_1}$$

This equation is used to determine the molecular mass of solute.

Explanation:-



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(i) The curve DEC is for the solution.

(ii) It meets curve BC at point E which is freezing point of solution T_2 when its vapour pressure is P which is lower than P°. This is because vapour pressure of solution is always less than that of the pure solvent.

(iii) The curve ABC is for the pure solvent.

(iv) The solvent freezes at temperature T_1 corresponding to the point B when its vapour pressure is P°.

(v) The portion of the curve BC is for the solid solvent.

(vi) Greater slope of curve BC indicates a rapid change of vapour pressure with temperature.

(vii) The difference b/w freezing point of solvent and solution gives the depression of the freezing point. ΔT_f.

$$\Delta T_f = T_1 - T_2$$

Measurement of Freezing Point Depression.

Beckmann's Method:-

Apparatus:-

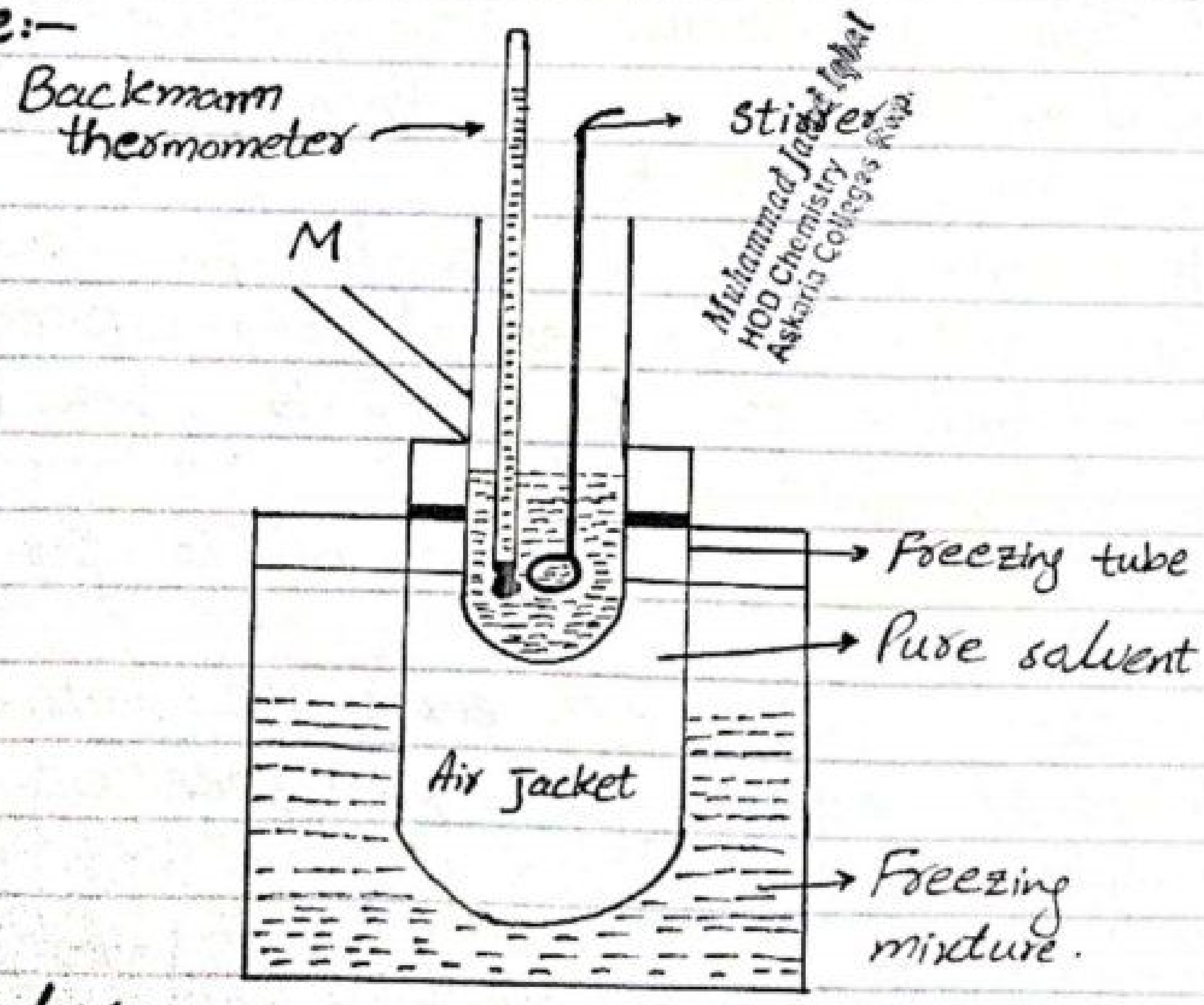
(a) An inner freezing tube with a side arm. It is fitted with a stirrer.

(b) An outer tube in which freezing tube adjusted. This tube serves as air jacket and helps to achieve a slower and more uniforms rate of cooling.

(c) A large vessel containing a freezing mixture.

(d) A Beckmann thermometer which can read upto 0.01K.

Figure:-



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Proceedure:-

(i) In large quantities, the nicotine is a deadly poison.

(ii) Take few grams of pure water (solvent) in freezing tube.

(iii) Now fix thermometer in it, such that the bulb of the thermometer immerse in the solvent.

(iv) Place freezing tube in air jacket in the large vessel containing a freezing mixture.

(v) Record accurate freezing point of solvent. T_1.

(vi) After remove this freezing tube from the air jacket and re-melt the solvent.

(vii) Add few grams of nicotine in the solvent through the side arm.

(viii) Place freezing tube again in the air jacket and record freezing point of solution constantly. Thermometer will show T_2 temperature.

(ix) Find the difference of two freezing points. This will give the value of ΔT_f.

Daily Life Applications of Depression of Freezing point and Elevation of Boiling Point.

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(i) Ethylene glycol is used as an antifreeze. It is nonvolatile in character and completely miscible with water. When mixed with water it lowers the freezing point but also raises the boiling point.

(ii) In winter ethylene glycol protects a car by preventing the liquid from freezing whereas in hot summer it protects the radiator from over heating.

(iii) The principle of freezing point depression is also used to prepare a freezing mixture for use in an ice cream machine. For this purpose NaCl or $NaNO_3$ is used to lower melting point of ice.

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-:Osmotic pressure:-

It is the pressure which needs to be applied to a solution to prevent the inward flow of water across a semipermeable membrane **OR**

It is the minimum pressure needed to nullify osmosis.

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Morse Equation:-

The osmotic pressure of an ideal solution with low concentration can be approximated using the Morse equation (named after Harmon North-rope Morse).

$$\pi = MRT$$

where

π = Osmotic pressure
M = malarity
R = General gass constant
T = Absalute temperature.

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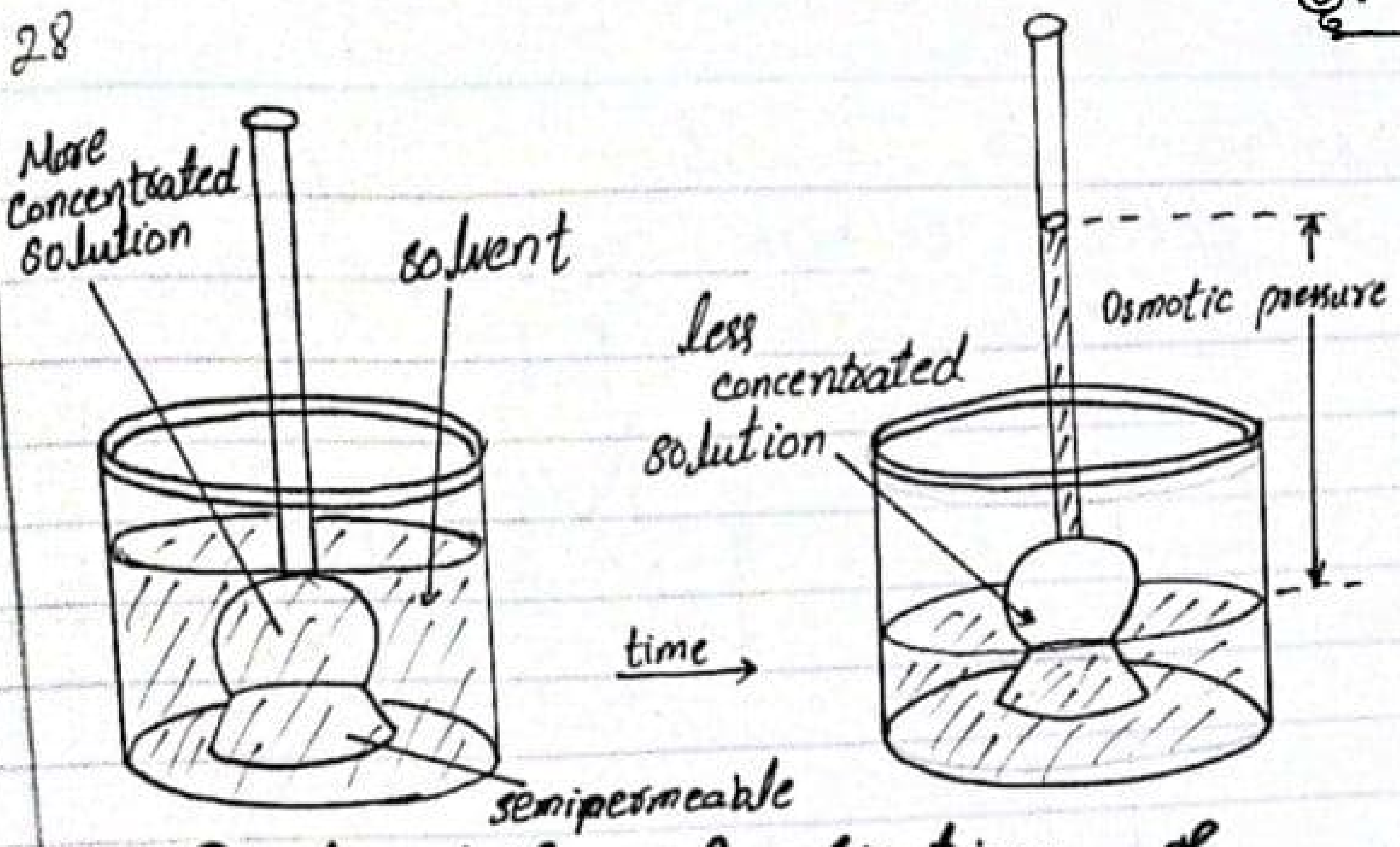

Daily Life Applications of Omosis.

(i) Biochemists use a technique called hemolysis to study the contents of red blood cells. These cells are protected from the external environment by a semipermeable membrane.

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(ii) Osmosis is the major mechanism for transporting water upward in plants.

(iii) A large quantity of sugar is assential to preserve jam and jelly.

(iv) 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 cell water.

-Reserve Omosis:-

If external is greater than solution's osmotic pressure, it will force solvent to flow from

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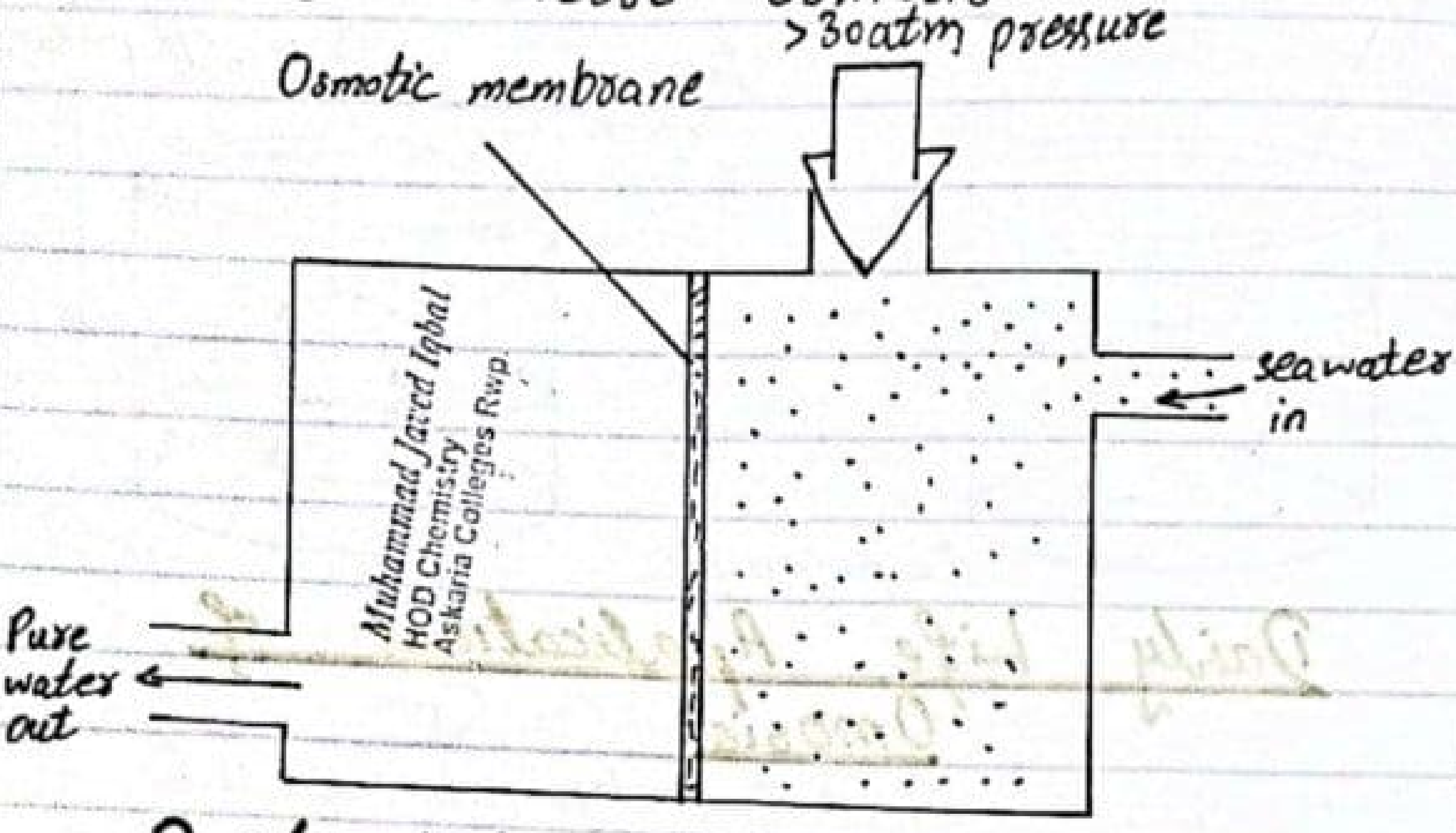
solution to the solvent. This process is called reverse osmosis.



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Daily Life Applications of Reverse Omosis-

(i) The sea water is highly hypertonic to body fluids. Thus it is not drinkable.

(ii) It can be desalinated by reverse osmosis to make it drinkable.

(iii) A desalination plant removes large amounts of dissolved salts from sea water.

(iv) The sea water is pumped under higher pressure (>30 atm) through the semipermeable membrane. It allows water molecules to pass through the membrane and stop the movement of ions.

Desalination of water

The process of removal of salts from water is called desalination of water.

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-: Colloids :-

A heterogeneous mixture of tiny particles of a substance dispersed through a medium is called colloidal dispersion or a colloid. The particles are called colloidal particles or the dispersed phase and the medium is called dispersion medium or continous phase (solvent).

Size of the colloidal particles:-

The dispensed or suspended particles are singal large malecules or aggregates of molecules or ions ranging in size from 1 to 10^3nm.

Lyophilic malecules:-

Colloidal dispersions in which dispersed phase shows an affinity or attraction for the dispersion medium are called lyophilic (means solvent loving). The malecules of dispersed phase are called lyophilic molecules.

Lyophobic malecules:-

A calloid which cannot be made by spontanous dispersion is called lyophobic (means solvent hating). The molecules of dispersed phase of such colloids have very little or no attraction for the dispersion medium, are called lyophobic molecules or particles.

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For Example; sulphur, gold, iron (III) hydroxide in water.

-: Properties of Colloids :-

(i) Most colloids are cloudy or opaque, but some are transparent to the naked eye.

(ii) When light passes through colloids, it scattered by the dispersed particles because their sizes are similar to the wavelength of visible light.

(iii) Colloidal particles exhibit Brownian motion. This can be seen under low magnification.

(iv) Colloidal particles do not coagulate into larger particles and settle out.

(v) Temperature changes effect colloids. This means increase in temperature causes coagulation. e.g; heating milk causes coagulation of casein in milk.

(vi) Colloidal particles have little power of diffusion.

(vii) Colloidal particles can pass through ordinary filter paper but cannot pass through ultra-filter papers.

(viii) Colloidal particles have high ratio of surface area to volume as compared to the particles of true solutions.

(ix). Calloidal particles do not settle under the influence of gravity.

Types of Calloids

Calloidal type (Common Name)	Nature and Composition	Example
Sol	Solid particles dispersed through a liquid	Milk of megnesia, strach dispersed in water, paints, coloured glasses gems
Gel	Continuous network of solid through out the liquid medium	Halwa, jellies, gelatin
Aerosal	Either a solid or a liquid dispersed in a gas.	Smoke, fog
Emulsion	Liquid dispersed in an another liquid	Milk, mayonnaise
Foam	Bubbles of a gas suspended in a liquid or a solid.	Canned shaving cream, soap leather, whipped cream

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~: Suspensions:~

A dispersions in which particles of the dispersed substance are visible to the naked eye are called suspensions. Sizes of these particles are greater than 10^3 nm. This means these particles are bigger than these of colloids.

Comparison of Calloids, suspensions and true solutions-

Sr. No	Properties	Calloids	Suspensions	True solutions
1.	Size of Particles	$1-10^3$ nm	$>10^3$ nm	0.1 - 1 nm
2.	Phase	Heterogenous	Heterogenous	Homogenous
3.	Aggregates	Particles are composed of 10^3 to 10^9 atoms	Particles are composed of more than 10^9 atoms	Particles are composed of 1 to 10^3 atoms
4.	Charge on the particles	Positive or negative	Positive or negative or may be neutral	Both positive and negative or may be neutral
5.	Visibility of particles	Invisible by naked eye and ordinary microscope but visible	Visible by the naked eye and in ordinary microscope	Indivisible by the naked eye, ordinary microscope as well as electron

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

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CHAPTER No. 10

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SOLUTIONS AND COLLOIDS...

EXERCISE...

Q2- Determine the molality of the following solutions.

i) 3.5% (w/w) glucose (aq).

Given data:

glucose = 3.5 % w/w.

Molality = ?

Solution:-

Mass of glucose (solute) = 3.5g.

Mass of solution = 100g.

Mass of solvent (water) = 100 - 3.5

= 96.5g

= 0.096 kg.

Mole of glucose ($C_6H_{12}O_6$) = $\frac{3.5}{180}$

= 0.019 moles.

Molality = m.

$$m = \frac{\text{No of moles of solute.}}{\text{Mass of solvent in Kg}}$$

$$m = \frac{0.019}{0.096}$$

m = 0.2 molal.

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

Mass of $NaNO_3$ (solute) = 9.9g.
Mass of water (solvent) = 940g
= 0.94 kg.

Molality = ?
Molar Mass ($NaNO_3$) = 23 + 14 + 16 X 3 = 85.
Moles of $NaNO_3$ = $\frac{9.9}{85}$
= 0.116 moles.

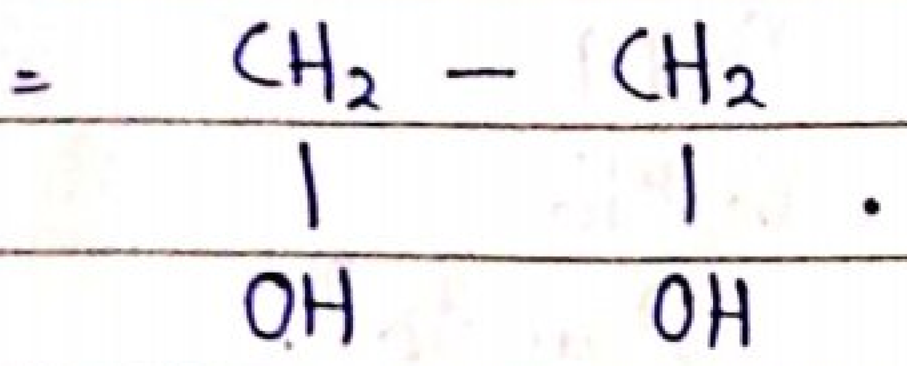
$$\text{Molality} = \frac{\text{No. of moles of solute}}{\text{Mass of solvent in kg}}$$

$$m = \frac{0.116}{0.94}.$$

$$m = 0.123 \text{ molal.}$$

Q3- What are the freezing and boiling points of a solution prepared by dissolving 13.3g of ethylene glycol in 100g of water.

Formula of ethylene glycol :-



$$= \underset{OH}{\underset{|}{CH_2}} - \underset{OH}{\underset{|}{CH_2}}.$$

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Mass of ethylene glycol = 13.3 g (solute).
Mass of water = 100 g (solvent).

Boiling Point of solution (T_2) = ?
Freezing Point of solution (T_2) = ?
Value of "$K_b = 0.52\,°C$" and
"$K_f = 1.86\,°C$."

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

M_2 = Molar Mass of solute = 62 g/mole.

$$\Delta T_b = \frac{0.52}{62} \times \frac{13.3}{100} \times 1000$$

$$\Delta T_b = 1.115\,°C.$$

$$\Delta T_b = T_2 - T_1$$
$$T_2 = \Delta T_b + T_1$$
$$T_2 = 1.115 + 100$$
$$T_2 = 101.115\,°C.$$

ΔK_f OR ΔT_f = ?

$$\Delta T_f = \frac{K_f}{M_2} \times \frac{W_2}{W_1} \times 1000.$$

$$\Delta T_f = \frac{1.86}{62} \times \frac{13.3}{100} \times 1000$$

$$\Delta T_f = 3.99\,°C.$$

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

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$T_2 = -3.99°C$.

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Q4- Concentrated sulphuric acid is 98% (W/w) H_2SO_4 (aq). Its density is 1.84 $g.cm^{-3}$. Calculate.

i) The molality of the solution.

H_2SO_4 (solute) = 98% w/w.
density of H_2SO_4 = 1.84 $g.cm^{-3}$.
Molality = ?

Mass of H_2SO_4 (solute) = 98g = 1 mole.
Mass of solution = 100g.
Mass of solvent = 100 − 98
= 2g = 0.002 kg.

molality = m = ?

$$m = \frac{\text{No. of moles of solute.}}{\text{Mass of solvent in kg}}$$

$$m = \frac{1}{0.002}$$

m = 500 molal.

ii) What quantity of conc. H_2SO_4 is required to prepare 500 cm^3 of 0.1M H_2SO_4.

density of H_2SO_4 = 1.84 $g.cm^{-3}$.
M_2 = 0.1M
$V_2 = 500\,cm^3 = \frac{500}{1000} = 0.5\,dm^3$.

$M_1 = 18.4$
$V_1 = ?$

$$M_1V_1 = M_2V_2$$
$$V_1 = \frac{M_2V_2}{M_1}.$$
$$V_1 = \frac{0.1 \times 500}{18.4}$$
$$V_1 = 2.717\ cm^3.$$

Thus, $2.717\ cm^3$ of $18.389\ M$ H_2SO_4 will be taken in $500\ cm^3$ flask and the volume is made up to mark. This is required to make $0.1M$ H_2SO_4 solution.

Q5- What would you expect potassium chloride KCl, an ionic solid to be more soluble in H_2O or CCl_4? Explain your prediction.

Solubility principle is "Like dissolve like". KCl is an ionic solid. Water is polar solvent. When $K^+ \cdot Cl^-$ is placed in water the ions are attracted by polar water molecules. The water molecule break the crystal lattice of $\overset{+}{K}Cl^-$. These then sorrounds the K^+ and Cl^- and thus KCl become soluble. However when KCl crystals are placed in CCl_4. Non-polar molecules of these liquid cannot attract ions of K^+ Cl^-. These cannot break the crystal lattice. Hence KCl is insoluble in CCl_4.

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Q6- List four factors that accelerate the dissolution process-

See Notes Page No. 6.

Q7- Express the solution concentration in term of mass percent, molality, molarity, parts per million, parts per billion and parts per trillion also mole fraction-

See Notes Page No. 12-15.

Q8- Distinguish between the solution of ionic species and molecular substances-

See Notes Page No. 6.

Q9- Explain the role of solvation in the dissolving process-

See Notes Page No. 5 and 6.

Q10- Define the term hydration-

See Notes Page No. 7 and 8.

Q11- What are colligative properties?

See Notes Page 17- 27

Q12- Define hydrophylic and hydrophobic molecules-

See Notes Page 1 and 2.

Q13- Describe on a particle basis why a solution has a lower vapour pressure than the pure solvent-

See the Notes Page 17 - 18.

Colligative Property.

- The lowering of vapour pressure-

Date:

Q14- Explain osmotic pressure, reverse osmosis and give their daily life applications.

See Notes Page No. 27 -29.

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Q15- Define heat of solution and apply this concept to the hydration of ammonium nitrate crystals.

Heat of solution:-

The amount of heat released or absorbed when a solute dissolve in a solvent is called heat of solution.

Explanation:-

The heat of hydration increases with increase in charge on the basi ions and decreases with increase in size of ions. Heat of a solution includes both the energy needed to move solvent molecules apart and energy release when they sorrounds solute particles. Thus, heat of solution $\Delta H_{solution}$ is the difference in $\Delta H_{lattice}$ and ΔH_{Hyd}.

$$\Delta H_{solution} = \Delta H_{lattice} - \Delta H_{Hyd}.$$

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It is because of different attractive forces in both solute and solution heat, heat of solution vary from significantly exothermic to significantly endothermic. If the crystal binds solute particle more tightly then the solution, solute must absorb energy as it dissolves and we have endothermic solution process. When this $\Delta H_{solution}$ is vary large the solute is unlikely to be soluble. But if this $\Delta H_{solution}$ moderately positive then solute dissolve. For example.

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

$$NH_4NO_3(s) + xH_2O(l) \longrightarrow NH_4^+ + NO_3^-$$

$$\Delta H_{solution} = 25.7 \text{ KJ } mole^{-1}$$

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

Q16- What is the effect of temperature on solubility?

See Notes Page No. 10+11.

Q17- Explain the following:

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

It is because molar solutions are based upon volume which changes with temperature, hence molarity changes. But molal solutions are based upon mass which is not changed with temperature.

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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.

One molal aqueous solution of glucose is dilute as compared to its one molar solution. It is because in one molal solution, 1 kg of water (i.e. 1 dm^3) is present.

In one molar solution same volume is occupied by the solute particles. Since the total volume of the solution is 1 dm^3. Since amount of water will be less than 1 dm^3.

However, one molal and one molar solutions contain one mole of solute particles. Thus, both solutions contain same number of particles (i.e. 6.022×10^{23}).

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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?

During ideal solution formation volume is not changed since intermolecular forces remains same. However, alcohol and water develop forces of attraction for each other. These forces are stronger than water - water and ethanol - ethanol forces. So the molecules of ethanol and water come closer. together and volume of solution is decreased. Hence, total volume of solution prepared by mixing $50cm^3$ of H_2O and $50cm^3$ of ethanol is less than $100cm^3$.

d) NaCl and $NaNO_3$ are used to lower the melting point of ice.

When NaCl and $NaNO_3$ is added to H_2O, its vapour pressure is lowered. Due to lowering of vapour pressure solution freezes below the freezing point of H_2O. Hence, this mixture is used as freezing mixture. e.g. in an ice-cream machine.

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

Antifreeze solution consists of solution of ethylene glycol in H_2O. Since ethylene glycol is less volatile, therefore, vapour pressure of this solution is lowered

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and boiling point is increased. In summer due to large heat in engine H_2O may boil over in radiator. However due to lower vapour pressure of solution, it requires much greater heat to boil. Hence this mixture prevents boiling over of H_2O.

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f) **One molal and two molal solution of urea boil at different temperatures.**

When a non-volatile solute is dissolved in a solvent, the vapour pressure of the solution is decreased. So its boiling point is increased. Elevation of boiling point is a colligative property which depends upon number of particles. Generally the magnitude of colligative properties increases with increase in number of particles. Since one molal urea solution contains one mole urea particles, while two molal urea solution contains two mole urea particles. Since two molal urea solution boils at higher temperature than one molal urea solution.

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g) relative lowering of vapour pressure is independent of the temperature.

According to the Raoult's law Relative lowering of vapour pressure is equal to the mole fraction of solute

$$\frac{\Delta P}{P^o} = X_2.$$

Where,

$\Delta P/P^o$ = relative lowering of vapour pressure.

X_2 = mole fraction of solute.

It is calculated from the number of moles of solute (n_2) and solvent (n_1). Since number of moles are not changed with temperature. Hence, relative lowering of vapour pressure is independent of temperature.

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

Consider a solution of two components A and B. Let number

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of moles of A and B are n_A and n_B, then their mole fractions are given by.

$$X_A = \frac{n_A}{n_A + n_B} \quad \text{——} \quad ①$$

$$X_B = \frac{n_B}{n_A + n_B} \quad \text{——} \quad ②$$

The sum of mole fractions will be

$$X_A + X_B . \quad \text{——} \quad ③$$

Put eq ① and ② in eq ③

$$\frac{n_A}{n_A + n_B} + \frac{n_B}{n_A + n_B}$$

$$\cancel{\frac{n_A + n_B}{n_A + n_B}} = 1$$

Hence, sum of mole fractions of different components in a solution is equal to one.

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Q18- 1.89g of an organic compound, A dissolves per 85cm³ of water ($d = 0.998\ gcm^{-3}$). The boiling point under one atmospheric pressure of this solution is increased to 100.106°C. What is the molecular weight of A?

Mass of organic compound $(W_2) = 1.89g.$
Volume of H_2O $= 85cm^3.$
density $= 0.998\,gcm^{-3}.$

$$d = \frac{W}{V} \quad \text{or} \quad W = d \times V.$$

$$W = 0.998\,g\cancel{cm^{-3}} \times 85\cancel{cm^3}$$
$$W = 84.83\,g.$$

Mass of water $(W_1) = 84.83g.$
$T_2 = 100.106°C$
$M_2 = ?$
" $K_b = 0.52°C$ "
$\Delta T_b = T_2 - T_1$
$= 100.106 - 100$
$\Delta T_b = 0.106°C.$

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

$$M_2 = \frac{0.52}{0.106} \times \frac{1.89}{84.83} \times 1000$$

$$M_2 = 109.297\ g/mol.$$

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Q19- What freezing point do you expect for water in which 17.9g sucrose $C_{12}H_{22}O_{11}$ is dissolved per 47.6g of H_2O.

Mass of Sucrose $(W_2) = 17.9g.$
Mass of H_2O $(W_1) = 47.6g.$
Freezing point of solution = ?

" $K_f = 1.86°C$ "

Molar Mass of $C_{12}H_{22}O_{11} = 342 g/mol.$

$$M_2 = \frac{K_f}{\Delta T_f} \times \frac{W_2}{W_1} \times 1000.$$

$$\Delta T_f = \frac{K_f}{M_2} \times \frac{W_2}{W_1} \times 1000$$

$$\Delta T_f = \frac{1.86}{342} \times \frac{17.9}{47.6} \times 1000$$

$$\Delta T_f = 2.045°C.$$

$$\Delta T_f = T_1 - T_2$$

$$T_2 = T_1 - \Delta T_f$$

$$T_2 = 0°C - 2.045°C$$

$$\therefore T_2 = -2.045°C.$$

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Q20- 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?

Vapour Pressure of Pure water = $(P°) = 23.756$ torr.

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Mass of H_2O (W_1) = 100g.
Vapour Pressure of solution = P = 23 torr
Mass of glucose (W_2) = ?

$$\Delta P = P^\circ - P$$
$$= 23.756 - 23.00$$
$$\Delta P = 0.756 \text{ torr.}$$

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

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

$$W_2 = \frac{0.756}{23.756} \times \frac{100}{18} \times 100.$$

$$W_2 = 31.82g.$$

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Q21- An aqueous solution of a compounds boil at 102.4°C. At what temperature will this solution freeze?

Boiling point of solution (T_2) = 102.4°C.
Freezing point of solution = ?

"$K_b = 0.52°C$" or "$K_f = 1.86°C$".

$$\Delta T_b = K_b \cdot m$$

$$m = \frac{\Delta T_b}{K_b} \quad \text{——} \ ①$$

$$\Delta T_f = K_f \cdot m$$

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$$m = \frac{\Delta T_f}{K_f} \quad \text{———} \; ②$$

$$\Delta T_b = T_2 - T_1$$
$$\Delta T_b = 102.4 - 100$$
$$\Delta T_b = 2.4°C.$$

Comparing eq ① and ②

$$\frac{\Delta T_b}{K_b} = \frac{\Delta T_f}{K_f}.$$
$$\Delta T_f = \frac{\Delta T_b \times K_f}{K_b}.$$
$$\Delta T_f = \frac{2.4}{0.52} \times 1.86.$$
$$\Delta T_f = 8.58°C.$$

$$\because \Delta T_f = T_1 - T_2.$$
$$T_2 = T_1 - \Delta T_f.$$
$$T_2 = 0 - 8.58°C$$
$$T_2 = -8.58°C$$

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Q22- 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. Explain this

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behaviour on the basis of your knowledge of intermolecular forces.

Solubility principle is " Like Dissolve Like ". I_2 is non-polar, therefore it better dissolve in non-polar solvents like CCl_4. It does not readily dissolve in polar solvents like H_2O. Thus, when an aqueous solution of I_2 is shaken with CCl_4, it enters into the CCl_4 layer because it can better form intermolecular forces with the non-polar CCl_4 molecules.

Q23- A Cucumber placed in concentrated brine (concentrated NaCl solution in water) shrivels into a pickle. Explain?

This is due to the process of Osmosis. In this process, solvent molecules move through a semi-permeable membrane from less concentrated to more concentrated solution. The skin of Cucumber acts as a semi-permeable membrane. The concentration of NaCl is less inside cucumber

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and more in brine solution. So, when it is placed in concentrated brine solution, water flows out of its cell into the brine solution. Thus, it shrinks into a pickle.

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