

Binary solutions

Binary solution is a mixture of two liquids that are completely miscible one with another. The boiling point of binary solution depends upon the solution composition and there can be three cases:

1. The boiling points of solutions of all compositions lie between the boiling points of clean liquids
2. The boiling points of solutions of any composition lie above the boiling points of clean liquids
3. The boiling points of solutions of some compositions lie below the boiling points of clean liquids

e.g 10% ethanol solution in water

Polar and non polar solvents

Polar solvent are those solvents which are constituted of polar molecules. e.g. Water, HCl Non polar solvents are those solvents which are made up of non polar molecules. e.g. Carbon Disulphide, Carbon tetrachloride

Aqueous Solution

An aqueous solution is a solution in which the solvent is water.

e.g. salt-water solution

Non-aqueous Solution

A non-aqueous solution is a solution in which the solvent is other than water.

e.g. ammonia as a solvent

Intensive properties

Intensive properties (such as density and concentration) are characteristic properties of the substance; they do not depend on the size of the sample being studied.

Extensive properties

An extensive property is a property that changes when the size of the sample changes. Examples are mass, volume, length, and total charge.

Importance of solutions

1. Most chemical reactions, both in nature and in the laboratory, take place in a solution.
2. For ionic chemicals, it is the polarity of the solvent (usually water) which allows the separation of the ions so that the reaction can take place.
3. For non-polar chemicals, the solvent (often a non-polar one) allows for the chemicals to come into contact with one another and to regulate the speed at which the reaction takes place.
3. All biological chemistry depends upon reactions which take place in water (as a solvent). This is especially true of reactions involving enzymes.

SuperSaturated Solution

It is a state of a solution that contains more solute than could be dissolved by the solvent under normal circumstances.

e.g. Honey is supersaturated solution of sugars.

Concentration of a solution

The amount of solute dissolved in an unit amount of solvent.

Percentage by Mass

The fraction of a solute in a solution multiplied by 100.

Percentage by mass = $(\text{mass of solute} / \text{mass of solution}) \times 100$

Molality

Number of moles of solute dissolved in 1 kg of a **solvent**.

Molality = $(\text{moles of solute} / \text{mass of solvent in kg})$

Molarity

Numbers of moles of solute in 1 liter of a **solution**.

Molarity = (number of moles of solute/ volume of solution in liter)

Solubility

The property of a solute(air, water or gas) to dissolve in a solvent(air, water or gas).
e.g. salt in water,honey in water, oxygen in water.

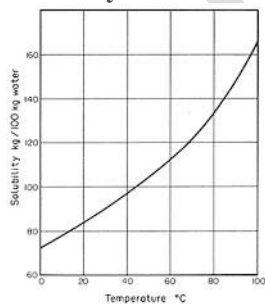
Factors which affect solubility

1. Increase in temperature increases the solubility and vice-versa.
2. Surface area affects solubility.
3. Concentration also affect solubility.
4. Pressure affect solubility if it increases, solubility increases and vice-versa.

Determine the solubility of a solute at room temperature

1. Solubility is the ability of a solute to dissolve in a solvent.
2. Temperature plays a very important role in deciding the solubility of solutes. Increase in temperature decreases the solubility of gases in liquids.
3. The solubility of solids increases with increase of temperature.

Solubility curve



1. A solubility curve is a graphical representation of the solubility of a particular solute in a given solvent with respect to varying temperatures.

2. Generally, temperature is directly proportional to solubility, as temperature increases, solubility also increases. Conversely, as temperature decreases, solubility also decreases.

Qualitative effect of temperature on solubility

Temperature plays a very important role in deciding the solubility of solutes. Increase in temperature decreases the solubility of gases in liquids. The solubility of solids increases with increase of temperature.

Solubility of solid in gas

The solubility of a solid in liquid is defined as the maximum amount of the solid in grams which can dissolve in 100 g of the liquid to form the saturated solution at that particular temperature.

Factors affecting the solubility of a solid in a liquid

The important factors on which the solubility of a solid in a liquid depends are:

1. Nature of the solute and the solvent
2. Temperature

Solubility of ionic solids in polar solvents

For ionic compounds, being dissolved in polar solvents, the solubility is on account of the fact that there are strong electrostatic forces of attraction between the ions of the crystals and the polar solvent molecules. Opposite charges get attracted towards each other. The water molecules pull the ions of the crystal apart and the electrostatic forces of attraction existing between the ions of the crystal are cut off. A substance dissolves if the hydration energy is greater than the lattice energy.

Effect of lattice energy on solubility

When an ionic compound dissolves in water, the water molecules surround the individual ions. Since water is very polar, when water surrounds an ion there is a decrease in overall energy.

However, to pull the ions apart in the first place, there has to be an energy increase to overcome

the lattice energy. If the lattice energy (cost) is larger than the energy of solvation of the ions (gain) the compound won't dissociate and it will be insoluble.

There is a large grey area where lattice energy and solvation energy are close, and for those compounds temperature has a big influence on solubility.

Solubility of non-polar solids in non-polar solvents

The solubility is due to similar solute-solute, solute-solvent and solvent-solvent interactions. Non-polar solid do not have any electronegative power to attract electron hence it get dissolved in non-polar solvent easily.

Effect of temperature on solubility of solids in liquids

On the basis of effect of temperature on solubility in water, the various ionic substances are divided into three categories:

Those whose solubilities increases continuously with increase of temperature.

Those whose solubilities continuously decrease with increase in temperature

Those whose solubilities do not change with increase in temperature

Solubility of a gas in liquid

The solubility of any gas in a particular liquid is the volume of the gas in cc that can dissolve in unit volume of the liquid to form the saturated solution at the temperature of the experiment and under a pressure of one atmosphere.

Solid solution

A solid mixture containing a minor component uniformly distributed within the crystal lattice of the major component.

Factors affecting solubility of gas in liquid

Nature of the gas and the solvent

Effect of temperature (Decreases with increase in temperature)

Effect of pressure

Characteristics of Henry's constant

It is the function of the nature of the gas

Greater the value of K_H , lower is the solubility of the gas at the same partial pressure at particular temperature

The value of K_H increases with the increase of temperature implying that the solubility decreases with the increase of the temperature at the same pressure.

Limitations of Henry's law

The pressure should be low and the temperature should be high i.e the gas should behave like an ideal gas

The gas should not undergo compound formation with the solvent or association or dissociation in the solvent

Applications of Henry's law

In the production of carbonated beverages

In the deep sea diving

In the function of lungs

For climbers or people living at higher altitudes

Vapour pressure of liquid or solution

Vapor pressure or equilibrium vapor pressure is defined as the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases (solid or liquid) at a given temperature in a closed system. The equilibrium vapor pressure is an indication of a liquid's evaporation rate.

Factors affecting vapour pressure

Nature of the liquid

Temperature(Directly proportional)

Raoult's law

It states that the partial vapor pressure of each component of an ideal mixture of liquids is equal to the vapor pressure of the pure component multiplied by its mole fraction in the mixture.

Expression of Raoult's law for non-volatile solutes

Vapour pressure of the solvent=[Mole fraction of the solvent in the solution]×[Vapour pressure of the pure solvent].

Now if the solute is non-volatile and non-electrolyte, it will not contribute to the total vapour pressure of the solution. Thus, the vapour pressure of the solution will be the vapour pressure due to solvent in the solution only.

$V.P = [\text{Mole fraction of the solvent in the solution}] \times [\text{Vapour pressure of the pure solvent}]$

Similarities and Dissimilarities of Raoult's law and Henry's law

Similarities:

Both apply to the volatile component of the solution

Both state that the vapour pressure of any component in the solution is proportional to the mole fraction of that component in the solution

Dissimilarities

The two laws differ in the proportionality constant. In Raoult's law, it is equal to the vapour pressure of pure component while in Henry's law, it is equal to an experimentally determined value of Henry's constant

Ideal solution

1. An ideal solution or ideal mixture is a solution with thermodynamic properties analogous to those of a mixture of ideal gases.

2. The enthalpy of mixing is zero as is the volume change on mixing; the closer to zero the enthalpy of solution is, the more "ideal" the behavior of the solution becomes.

e.g Benzene+Toluene

Conditions of ideal solutions

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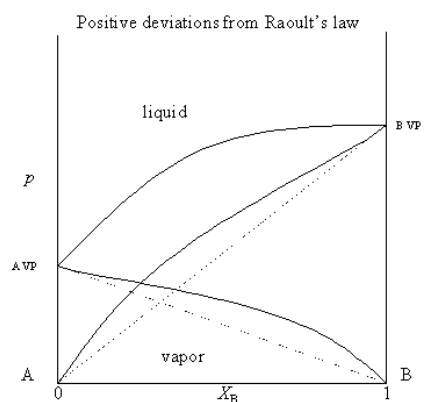
Types of Non-ideal solutions

Non-ideal solutions can occur two ways:

When intermolecular forces between solute and solvent molecules are less strong than between molecules of similar (of the same type) molecules.

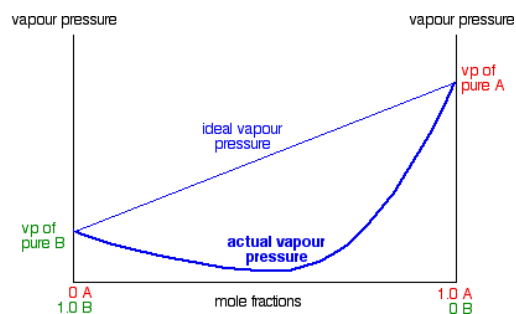
When intermolecular forces between dissimilar molecules are greater than those between similar molecules.

Non-ideal solutions of positive deviation



In mixtures showing a positive deviation from Raoult's Law, the vapor pressure of the mixture is always higher than you would expect from an ideal mixture. The deviation can be small - in which case, the straight line in the last graph turns into a slight curve.

Non-ideal solutions of negative deviation



Mixtures with vapor pressures which are less than would be expected by Raoult's Law. In some cases, the deviations are small, but in others they are much greater giving a minimum value for vapor pressure lower than that of either pure component. These are cases where the molecules break away from the mixture less easily than they do from the pure liquids. New stronger forces must exist in the mixture than in the original liquids. You can recognize this happening because heat is evolved when you mix the liquids - more heat is given out when the new stronger bonds are made than was used in breaking the original weaker ones.

Maximum boiling point azeotropes

For the solutions with negative deviations there is an intermediate composition for which the vapour pressure of the solution is minimum and hence, boiling point is maximum. At this composition the solution distills at constant temperature without the change in composition. This type of solutions are called maximum boiling azeotrope. e.g $H_2O + HClO_4$

Plot for ideal and non-ideal solutions

The solution which obey Raoult's law over the entire range of concentration are known as ideal solutions. When a solution does not obey Raoult's law it is called as non-ideal solution.

Ideal and Non-ideal solutions

Ideal solutions	Non-ideal solutions	
	Positive deviation from Raoult's law	Negative deviation from Raoult's law
1. Obey Raoult's law at every range of concentration.	1. Do not obey Raoult's law.	1. Do not obey Raoult's law.
2. $\Delta H_{\text{mix}} = 0$; neither is evolved nor absorbed during dissolution.	2. $\Delta H_{\text{mix}} > 0$. Endothermic dissolution; heat is absorbed.	2. $\Delta H_{\text{mix}} < 0$. Exothermic dissolution; heat is evolved.
3. $\Delta V_{\text{mix}} = 0$; total volume of solution is equal to sum of volumes of the components.	3. $\Delta V_{\text{mix}} > 0$. Volume is increased after dissolution.	3. $\Delta V_{\text{mix}} < 0$. Volume is decreased during dissolution.
4. $P = p_A + p_B = p_A^0 X_A + p_B^0 X_B$ i.e., $p_A =$	4. $p_A > p_A^0 X_A$; $p_B > p_B^0 X_B$ $\therefore p_A + p_B > p_A^0 X_A + p_B^0 X_B$	4. $p_A < p_A^0 X_A$; $p_B < p_B^0 X_B$ $\therefore p_A + p_B < p_A^0 X_A + p_B^0 X_B$
5. A–A, A–B, B–B interactions should be same, i.e., 'A' and 'B' are identical in shape, size and character.	5. A–B attractive force should be weaker than A–A and B–B attractive forces. 'A' and 'B' have different shape, size and character.	5. A–B attractive force should be greater than A–A and B–B attractive forces. 'A' and 'B' have different shape, size and character.
6. Escaping tendency of 'A' and 'B' should be same in pure liquids and in the solution.	6. 'A' and 'B' escape easily showing higher vapour pressure than the expected value.	6. Escaping tendency of both components 'A' and 'B' is lowered showing lower vapour pressure than expected ideally.

Azeotropic Mixtures

An azeotrope or a constant boiling mixture is a mixture of two or more liquids whose proportions cannot be altered by simple distillation. This happens because, when an azeotrope is boiled, the vapour has the same proportions of constituents as the unboiled mixture.

Colligative Properties

Colligative properties are the physical changes that result from adding solute to a solvent. Colligative Properties depend on how many solute particles are present as well as the solvent amount, but they do not depend on the type of solute particles. Eg. elevation in boiling point, depression in freezing point

Semi-permeable membrane

They are of two types:

1. Natural semipermeable membrane: Vegetable membranes and animal membranes which are found just under the outer skin of the animals and plants.
2. Artificial semi permeable membrane: e.g parchment paper, cellophane and certain freshly prepared inorganic membrane.

They only allow certain particles to pass through it.

Types of semi-permeable membrane

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They only allow certain particles to pass through it.

Osmosis

Osmosis is the process in which a liquid passes through a membrane whose pores permit the passage of solvent molecules but are too small for the larger solute molecules to pass through.

Exosmosis

The passage of a fluid through a semipermeable membrane toward a solution of lower concentration, especially the passage of water through a cell membrane into the surrounding medium. Eg. grapes placed in NaCl solution.

Endosmosis

Passage through a membrane from a region of lower to a region of higher concentration.
Movement of water in a cell when it is placed in hypotonic solution

Osmosis and diffusion

OSMOSIS	DIFFUSION
It involves movement of solvent molecules	It involves movement of solute molecules
Molecules move from lower concentration of solute to higher concentration of solute	Molecules move from higher concentration of solute to lower concentration of solute
It occurs only across a semi-permeable membrane	It does not require semi-permeable membrane
Example: Shrinking of Potato slice when kept in concentrated sucrose solution	Example: Spreading of ink when a drop of it is put in a glass of water.

Osmotic pressure

Osmosis is the diffusion of a fluid through a semipermeable membrane under concentration gradient. When a semipermeable membrane (animal bladders, skins of fruits and vegetables) separates a solution from a solvent, then only solvent molecules are able to pass through the membrane. The osmotic pressure of a solution is the pressure difference needed to stop the flow of solvent across a semipermeable membrane. The osmotic pressure of a solution is proportional to the molar concentration of the solute particles in solution.

Reverse osmosis

A process by which a solvent passes through a porous membrane in the direction opposite to that for natural osmosis when subjected to a hydrostatic pressure greater than the osmotic pressure.

Application of reverse osmosis in desalination of seawater

On applying pressure greater than osmotic pressure, pure water can be made flow through a semi permeable membrane and this water can be used for drinking purposes.

Berkeley and Hartley's method of experimental measurement of osmotic pressure

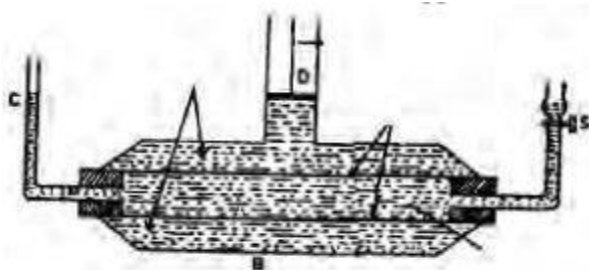


Fig. Berkeley - Hartley apparatus

The osmotic pressure of a solution can be measured by Berkeley - Hartley method. The apparatus consists of two concentric tubes. The inner tube (a) is made of semipermeable membrane(c) with two side tubes. The outer tube (b) is made of gun metal which contains the solution. The solvent is taken in the inner tube. As a result of osmosis, there is fall of level in the capillary indicator (d) attached to the inner tube. The external pressure is applied by means of a piston (e) attached to the outer tube so that the level in the capillary indicator remains stationary at (d). This pressure is equal to the osmotic pressure (p) and the solvent flow from inner to outer tube is also stopped.

Isotonic solutions

An isotonic solution refers to two solutions having the same osmotic pressure across a semipermeable membrane. This state allows for the free movement of water across the membrane without changing the concentration of solutes on either side.

Importance of osmosis

Osmosis and dialysis are of prime importance in living organisms, where they influence the distribution of nutrients and the release of metabolic waste products.

Hypotonic solutions

A hypotonic solution is any solution that has a lower osmotic pressure than another solution. In the biological fields, this generally refers to a solution that has less solute and more water than another solution. An example of a hypotonic solution is 0.45% sodium chloride (0.45% NS), commonly called half normal saline.

Hypertonic solution

A hypertonic solution is a solution with a higher concentration of solute (dissolved substance) than some other, specified solution (and which therefore has a higher osmotic pressure than the other solution). A solution of 5% dextrose (sugar) and 0.45% sodium chloride is an example of a hypertonic solution - so is a solution of 5% dextrose and 0.9% sodium chloride.

Examples of osmosis

If you ever placed your contacts in pure water you will notice how uncomfortable it is the next day, or if you fail to rinse out your contact case it will get too salty. Saline solution for contact lenses is the same concentration of salt water as your eye.

Making french fries - more salt makes the french fries more crispy and less soggy. This is done by pre soaking the potatoes in salt water before frying.

The different salt ratios in cells explain why salt water fish cannot go in fresh water and vice versa.

Osmotic pressure

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

Boiling point

The boiling point of a substance is the temperature at which the vapor pressure of the liquid equals the pressure surrounding the liquid and the liquid changes into a vapor. The boiling point of a liquid varies depending upon the surrounding environmental pressure.

Molal elevation constant

It is defined as the elevation in boiling point when the molality of the solution is unity i.e 1 mole of the solute is dissolved in 1 kg of the solvent. The units are degree/molality i.e K/m

Elevation in boiling point

Boiling Point Elevation

$$\Delta T_b = K_b \times m \times i$$

Change in boiling point

Molal boiling point constant
(0.51 °C/m for water)

Molality of solution

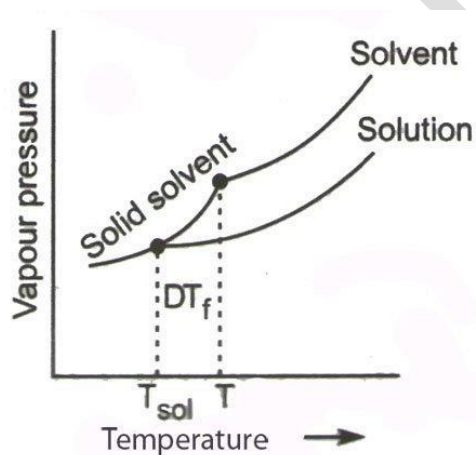
Van't Hoff factor

Elevation in boiling point is calculated from above formula.

Freezing point of a substance

Freezing point, temperature at which a liquid becomes a solid. As with the melting point, increased pressure usually raises the freezing point. The freezing point is lower than the melting point in the case of mixtures and for certain organic compounds such as fats.

Depression in freezing point



Freezing-point depression describes the process in which adding a solute to a solvent decreases the freezing point of the solvent. Examples include salt in water, alcohol in water, or the mixing of two solids such as impurities in a finely powdered drug.

Molal depression constant

It is defined as the depression in freezing point when the molality of the solution is unity i.e one mole of the solute is dissolved in 1 kg of the solvent. The units of K_f are degrees/molality i.e K/m.

Applications of depression in freezing point

In making antifreeze solutions

In melting of ice on the road

Abnormal molar mass of substances

When the molecular mass of a substance as determined by studying any of the colligative properties is different than the theoretically expected value, then the substance will have abnormal molecular mass.

Conditions for abnormal molecular mass

When the solution is non-ideal i.e the solution is not dilute

When the solution undergoes association in the solution

When the solution undergoes dissociation in the solution

State the significance of van't Hoff factor

The value of van't Hoff factor used to evaluate the degree of dissociation of electrolyte dissolved in the given solution.

Define and give example of van't Hoff factor

It is defined as the ratio of observed colligative property produced by a given concentration of electrolyte solution to the property observed for the same concentration of non electrolyte solution.

Degree of dissociation

Degree of dissociation is the fraction of a mole of the reactant that underwent dissociation. It is represented by α .

Definition of solution with Examples

A solution is a homogeneous mixture of two or more pure substances.

e.g. Salt in water, alcohol in water, are examples of solutions because they form a homogeneous mixture.

Saturated and Unsaturated solution

Unsaturated solution: The solution is unsaturated when it can still dissolve more solute.

Saturated solution: The solution is saturated when it can not dissolve further more solute.

Types of solutions

Solution can be of two types : Homogeneous solution and Heterogeneous solution.

Homogeneous solutions : When the solution contain single layer of components, it is called as Homogeneous solution.

Heterogeneous solution : When the solution contain more than one layer of components, it is called as heterogeneous solution.

True solution

True Solution is a homogeneous mixture of two or more substances in which substance dissolved (solute) in solvent has the particle size of less than 10^{-9} m or 1 nm.

Homogeneous solutions

Homogeneous solutions have the same uniform composition and appearance throughout their entire system.

Heterogeneous solutions

A heterogeneous mixture is a combination of two or more pure substances in which the original substances retain their chemical properties but they exist in different phases or a heterogeneous mixture is a mixture that consists of some visibly different substances or phases.

Solid as a Solvent

Gas in solid: e.g. hydrogen dissolves in palladium

Liquid in solid: e.g. mercury in gold forms amalgam, water in solid salt-moist solids

Solid in solid: e.g. steel, alloys like bronze, brass

Gas as a solvent

If the solvent is a gas, only gases are dissolved under a given set of conditions.

e.g. Air

Liquid as a solvent

Gas in liquid: e.g. oxygen and carbon dioxide in water

Liquid in liquid: e.g. ethanol in water

Solid in liquid: e.g. salt or sugar in water

Properties of a Solution

The constituents exhibit individual chemical characteristics but the physical properties of a solution is different from its constituents, like, boiling and melting points.