Unit 1

Units of measurements of solutes in solution, e.g. normality, molarity, molality, ionic strength, millimoles, osmosis, osmotic pressure, osmolarity and its application. Concept of isotonic, hyper and hypotonic solution and its importance in biology**.**

Introduction

In biochemistry biochemical techniques are commonly used to qualitative and quantitative analysis of biomolecule such as protein, carbohydrates, lipids and nucleic acids with the help of instruments such as centrifugation a rapid spinning method used to separate plasma from blood and to calculate the molecular weight of proteins, electrophoresis movement of charge particles in electric field the separation of proteins and DNA have been done on the basis of electric charge, chromatography the separation of biomolecule depends upon the size of the molecules and isotopes are radioactive elements used in diagnostic purposes. Biochemical techniques are used to develop the skills required to design and interpret the data from scientific experiments, to learning of basic lab skills such as good pipetting technique, and good lab practices.

Units of weight

1 Kilogram = 1000 Gram

1 Gram = 1000 Milligram

1 Milligram = 1000 Microgram

1 Microgram = 1000 Nanogram

1 Nanogram = 1000 Picogram

1 Picogram = 1000 Femtogram

Units of liter

1 Liter = 1000 Milliliter

1 Milliliter = 1000 Microliter

1 Microliter = 1000 Nanoliter

1 Nanogram = 1000 Picoliter

1 Picoliter = 1000 Femtoliter

Standard solution

A standard solution contains accurately known concentration of solute. We can express the concentration in molality, molarity, normality, percentage solution and ppm.

Stock solution

Stock solution is one having a concentration many folds higher than that required in the experiment.

Saturated solution

To dissolve the solute in solution completely until the equilibrium, the solution is said to be saturated

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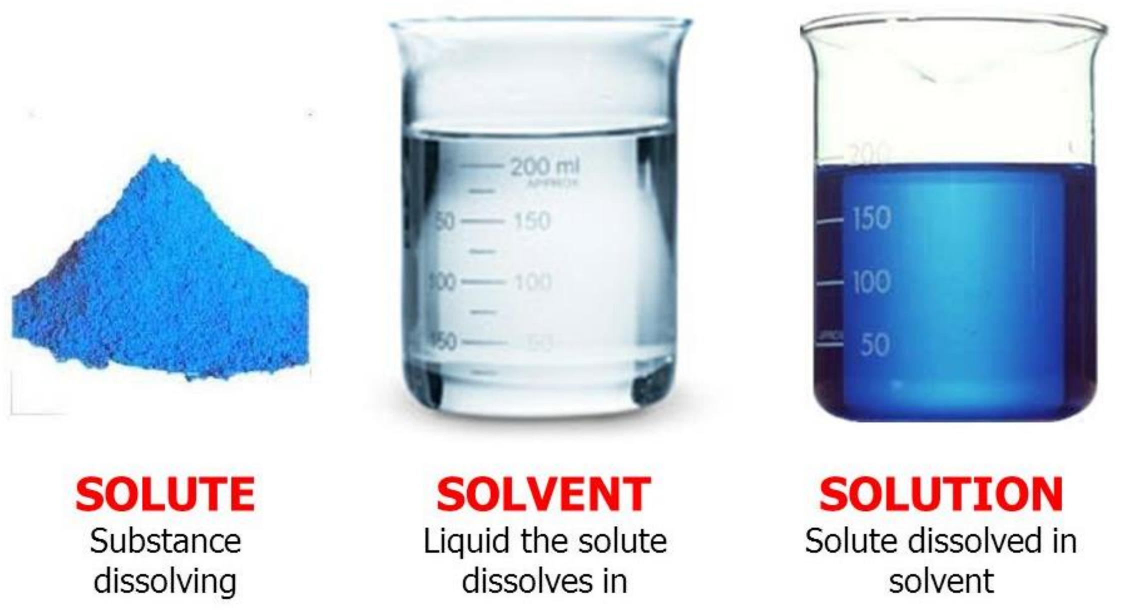
Solute solution and solvent

Solute is substance or chemicals which are going to dissolves in solvent to make solution. Solutes are in the form of gas, liquid and solid.

Solvent are substances which dissolves the solute to form a solution, in many cases the solvent will be liquid, but in some cases the solvent may be gases or solid.

Solution is the combination of solute dissolved in solvent.



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Molarity

This is the common method for expressing the concentration of a solution in biochemical studies. The molarity of a solution is defined as number of moles of the solute dissolved in one liter of the solution is called a molar solution. It is also used to calculate the amount of solvent or solute in the solution. The molarity can be represented by M.

Molarity of a solution can be calculated as follows

$$\text{Molarity} = \frac{\text{Wt. of a solute in g/L of solution}}{\text{Mol. wt. of solute}}$$

In other ways it also calculate by following formula

$$\text{Molarity} = \frac{\text{Required molar} \times \text{Required volume} \times \text{Molecular weight}}{1000}$$

Example

1. How to prepare 0.1 molar sodium hydroxide for one liter

   Therefore, for preparing 0.1 M NaOH

   Molecular weight of NaOH = 40
   Required molarity of solution = 0.1 M

   Amount of NaOH (g) per liter of solution = MW of NaOH × molarity
   = 40 × 0.1
   = 4g

2. How to prepare 0.2 molar sodium chloride for 250 ml

   Therefore for preparing 0.2 molar sodium chloride we need to know

   Molecular weight of sodium chloride = 58

   Volume required to prepare = 250ml

   Required molar = 0.2

   From the second equation

   $$\text{Molarity} = \frac{0.2 \times 250 \times 58}{1000}$$

   So the required gram to prepare 0.2M sodium chloride is = 2.9 gram

Normality

The normality of a solution is defined as number of gram equivalents of the solute per liter of the solution. In other words number of gram or mole equivalents of solute present in one liter of a solution. The normality can be represented by N. Equivalent weight is weight of the substance contains a reactive proton hydrogen ion or hydroxide ion.

Normality of a solution can be calculated as follows

$$\text{Normality} = \frac{\text{Gram equivalent weight}}{\text{liter of solution}}$$

In other ways it also calculate by following formula

$$\text{Normality} = \frac{\text{Required molar} \times \text{Required volume} \times \text{Equivalent weight}}{1000}$$

Example

1. How to prepare 0.1 normal solution of sodium chloride for 1 liter

Therefore for preparing 0.1 normal sodium chloride we need to know

Equivalent weight of sodium chloride = 58

Volume required to prepare = 1000ml

Required molar = 0.1

From the second equation

$$\text{Normality} = \frac{0.1 \times 1000 \times 58}{1000}$$

So the amount of sodium chloride required to prepare 0.1 N is 5.8 grams.

How to prepare 0.25 normal solution of sodium carbonate for 250ml

Equivalent weight of sodium chloride = 106

Volume required to prepare = 250 ml

Required molar = 0.25

From the second equation

$$\text{Normality} = \frac{0.25 \times 250 \times 106}{1000}$$

So the required gram to prepare 0.25N sodium carbonate is = 6.625gram

Molality

Molality is defined as one mole of solute dissolved in 1 kilogram of solvent, it is used to measure the concentration of the solution, molality can be represented by m, moles of the solute divided by kilograms of solvent. Molarity and molality can be differ in the liter and kilograms, molarity is based on liter and molality is based on kilograms, unlike molarity molality does not change with temperature but molarity changes when the temperature changes. As molality increases, the amount of solute present in the solution also increases. 1 molal solution is obtained by dissolving 1 mole of the solute in 1,000 mL (since Sp. gravity = 1) of water

The unit of molality is moles per kilogram (mol kg^{-1}). It also an SI unit. mol kg^{-1} is also called molal. In other words, 1 molal = 1 mol kg^{-1}.

Molality of a solution can be calculated as follows

$$\text{molality} = \frac{\text{Moles of solute}}{\text{kilograms of solvent}}$$

Example

How to calculate the molality of solution from 30 grams of sodium chloride dissolved in three grams of water

From the periodic table the atomic mass of sodium chloride is

Sodium =22.9g/m

Chloride =35.45

From this to calculate the molecular mass by adding two atomic masses

Molecular mass of sodium chloride = 22.9 + 35.45

=58.44g/mol

Moles of sodium chloride = 30/ 58.44

= 0.513 moles

From the equation

Molality = 0.51 / 3

= 0.17

So the molality of the sodium chloride solution is 0.17 molal

Ionic strength

Ionic strength was first defined by Lewis and Randall in 1921 based on the dissociation that suffers salts, acid and bases when are in an aqueous solution, ionic strength is a measure of the ions concentration ions solution. Each ions have positive or negative charge that can attract or repel each other, in ionic strength the interaction take place between the ions in the solution. It is used in theoretical chemistry for calculating dissociation of salts in heterogeneous systems such as colloids. It is also used in biochemistry and molecular biology for determining the strength of buffer solutions that should have concentrations similar to the found in nature.

It is expressed in concentration units, such as molar concentration (mol/L).

The ionic strength formula calculates the sum of each ion's molar concentration multiplied by the valence squared.

$$I = \frac{1}{2}\sum_{i=1}^{n} c_i z_i^2$$

From the equation

Half the term ½ is consider both the ions as cation and anion.

C refers to the concentration in molar units' mol/L.

Z refers to the charge of each ion.

For a solution of potassium chloride 3 M, calculate the ionic strength. First, it is needed to draw the dissociation

$$KCl \rightarrow K^+ + Cl^-$$

so, the concentration of each ion is the same as the concentration of the salt, 3 mol/L.

Then, the equation can be applied

$$I = 1/2\ [(3\ mol/L)(+1)^2 + (3\ mol/L)(-1)^2] = 3\ M$$

For a solution of potassium chloride 1 M and magnesium sulfate 0.2 M, calculate the ionic strength.

First, it is needed to draw the dissociation:

$$KCl \rightarrow K^{+} + Cl^{-} \text{ and } MgSO_4 \rightarrow Mg^{2+} + SO_4^{2-}$$

Then, the equation can be applied

$I = 1/2\ [(1\ mol/L)(+1)^2 + (1\ mol/L)(-1)^2 + (0.2\ mol/L)(+2)^2 + (0.2\ mol/L)(-2)^2\ ] = 3$

Osmosis

Osmosis is a diffusion process that involves the passive transport of water or solvent. In osmosis, solvent moves from higher concentration to lower concentration through a semipermeable membrane. Semipermeable membrane selectively allows the movement of solvent and which restricted the movement of solutes. For

\][poi example in plants the plasma membranes are selectively permeable not semipermeable membrane because they allow the movement of solvent and solutes. The lipid bilayer and the specific transport proteins produce selective permeability in plants. The process of osmosis was first studied by Wilhelm Pfeffer in 1877 and the term osmosis was introduced by Thomas Gragam in 1854.

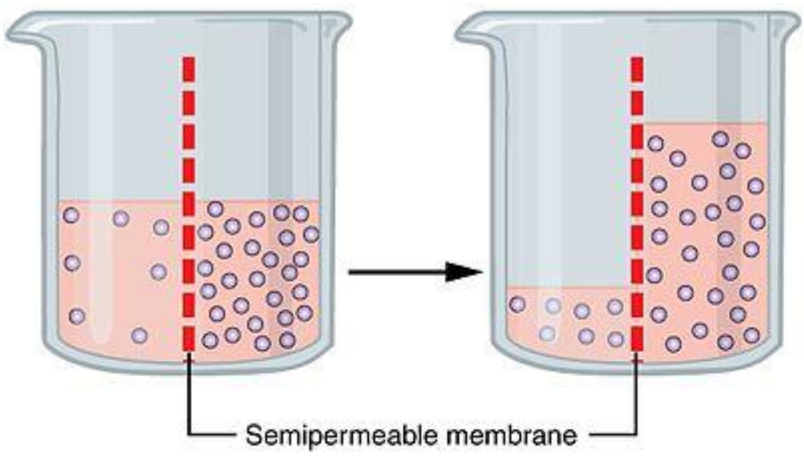


Image.ref.https://upload.wikimedia.org/wikipedia/commons/thumb/6/62/0307_Osmosis.jpg/400px0307_Osmosis.jpg

Application of osmosis

Osmosis plays vital role in power generation, desalination, wastewater treatment, food processing, medical product, drug release etc.,

Desalination

The process of removing salt from sea water it was obtained by forward osmosis movement of solvent in opposite direction in the presence of osmotic pressure by removing salt from water involves two major steps first to separate the pure water from sea water and then diluted the draw solution

Wastewater treatment

When compare with sea water wastewater usually has low osmotic pressure but much high fouling propensity. So forward osmosis shows greater advantage in treating of wastewater due to its low fouling tendency. Forward osmosis in both desalination and wastewater treatment. the process of forward osmosis acts as a pretreatment process, due to which the membrane fouling problem can be significantly reduced.

Food processing

To avoid food contaminations by placing food substances in sugar or salt solution which create tonicity in the solution leads to bacteria or fungi present will lose water in their cells to more concentrated solution, the cells will become shrivel and die.

Pharmaceutical application

In pharmaceuticals to increase the bioavailability, enhanced to reduce the side effects, drug release, dose frequency and drug delivery by using forward osmosis is commonly used

Osmotic pressure

Osmotic pressure can be defined as the minimum pressure required halting the flow of solvent molecules through a semipermeable membrane (osmosis). The property is dependent on the concentration of solute particles in the solution. In other words the selective diffusion of solvent is driven by the internal energy of the solvent molecules. It is defined as the pressure required to completely stop the entry of water into an osmotically active solution across a semipermeable membrane. It is also defined as the minimum pressure needed to stop osmosis. It is measured in atmospheres or bars. The osmotic pressure is directly proportional to the difference in the concentration of the total number of solute molecules on each side of the membrane.

Osmotic pressure was found in plants by transport water from root to different parts of the plant, used in purification of water by reverse osmosis process, desalination process for converting sea water to drinking water a force in applied to sea water to move through a semipermeable membrane and also used to determine the molecular weight of certain proteins.

Osmotic pressure can be calculated with the help of the following formula

$$\pi = iCRT$$

Where,

- π is the osmotic pressure
- i is the van’t Hoff factor
- C is the molar concentration of the solute in the solution

- R is the universal gas constant
- T is the temperature

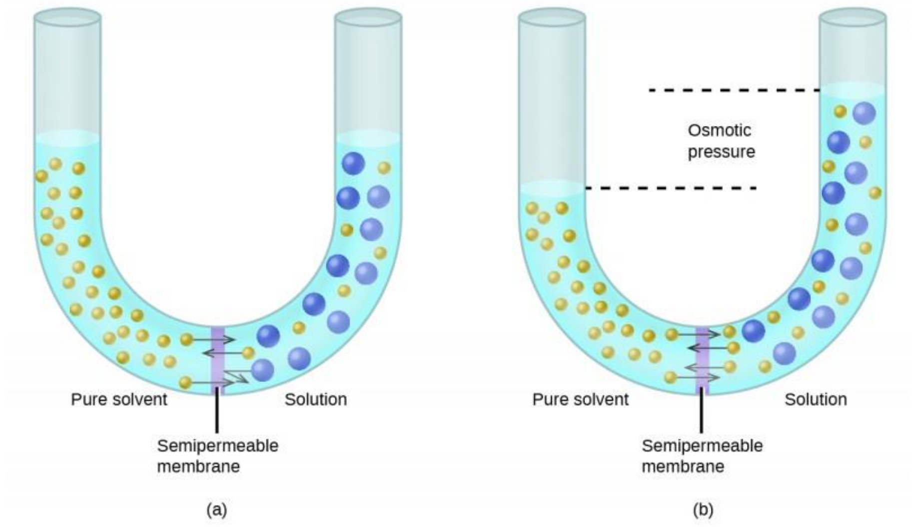


Image.ref https://nigerianscholars.com/assets/uploads/2018/08/CNX_Chem_11_04_osmosis.jpg

Osmolarity

Osmolarity, defined as the number of osmoles (Osm) of solute per litre (L) of solution (osmol/L or Osm/L) is the measure of solute concentration. The osmolarity of a solution is usually expressed as Osm/L (pronounced "osmolar"), Whereas osmolarity measures the number of *osmoles of solute particles* per unit volume of solution. This value allows the measurement of the osmotic pressure of a solution and the determination of how the solvent will diffuse across a semipermeable membrane (osmosis) separating two solutions of different osmotic concentration. NaCl dissolved in a liter of fluid, the fluid will be considered to have an osmolarity of 2 Osmolar (Osm) since NaCl dissolves into separate Na^+ and Cl^- ions.

Tonicity

A tonicity of the solution is directly linked with osmolarity of the solution. If a solution conatins greater number of water molecule having low osmolarity, a solution with high osmolarity has fewer water molecules. In a situation in which solutions of two different osmolarities are separated by a membrane permeable to water, though not to the solute, water will move from the side of the membrane with lower osmolarity to the side with higher osmolarity.

Isotonic Solution

When a cell is placed in isotonic solution the solute concentrations inside and outside are same in other words is equilibrium with its surroundings, (*iso* means *equal* in Latin). There is no concentration gradient and therefore, no large movement of water in or out.

Water molecules do freely move in and out of the cell, however, and the rate of movement is the same in both directions.

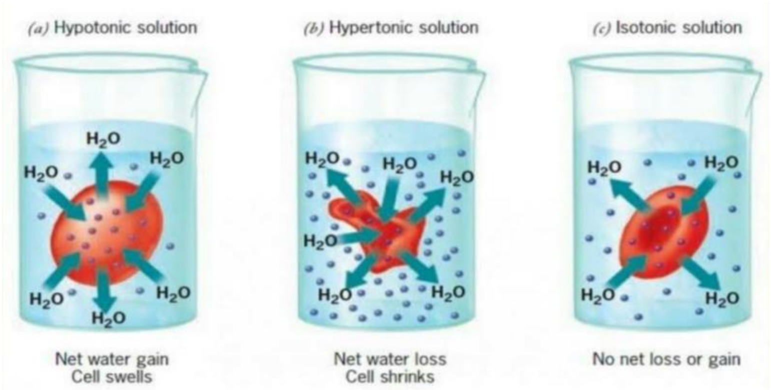
Best examples of isotonic solutions are 0.9% sodium chloride and 5% dextrose solution which is commonly used intravenously for humans during loss of large amount of water from body due to dehydration or diarrhea conditions.

Hypotonic solution

A hypotonic solution the concentration of solute inside the cell is higher when compare with outside (the prefix *hypo* is Latin for *under* or *below*). The difference in concentration between the cell and the surrounding cause movement of water into the cell leads to cell bust. When compare with human and animal cell Plant cells can tolerate this situation better than those cells because due to the presence of large central vacuole fills with water and water also flows into the intercellular space. The combination of these two effects causes turgor pressure which presses against the cell wall causing it to bulge out. The cell wall helps keep the cell from bursting. However, if left in a highly hypertonic solution, an animal cell will swell until it bursts and dies.

Hypertonic solution

Hypertonic solutions have a higher solute concentration when compare with inside the cell. This causes water to rush out from cell to became wrinkle or shrivel the prefix *hyper* means *over* or *above*.. Plant cells in a hypertonic solution can look like a pincushion because of what's going on inside. The cell membrane pulls away from the cell wall but remains attached at points called plasmodesmata. Plasmodesmata are tiny channels between plant cells that are used for transport and communication. When the inner membrane shrinks, it constricts the plasmodesmata resulting in a condition called plasmolysis. This is clearly seen in red blood cells undergoing a process called crenation



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Reference

1. R. Katoch, Analytical Techniques in Biochemistry and Molecular Biology, Springer Science Business Media DOI 10.1007/978-1-4419-9785-2_2, , LLC 2011.

2. Principles and Techniques of biochemistry and molecular biology Keith Wilson and John Walker, seventh edition.

3. Biochemistry laboratory modern theory and techniques Rodney Boyer.