Al-Rasheed University College
Department of Dentistry
1st Stage

MEDICAL CHEMISTRY

lecture 2
Solution & Concentration

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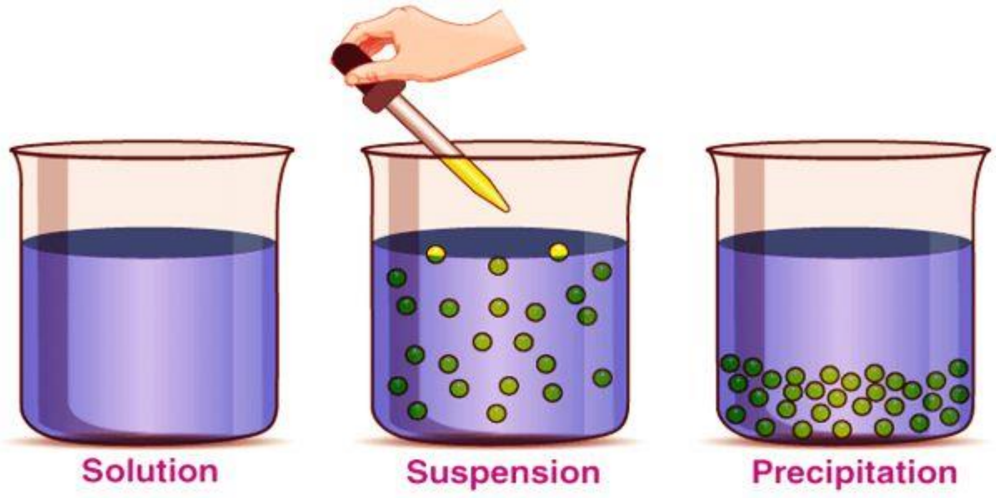


Introduction

In the previous lecture, we have concentrated primarily on pure substances—elements, covalent compounds, and ionic compounds. Most matter with which we come into contact, however, is a mixture composed of two or more pure substances. The air we breathe is composed of nitrogen and oxygen, together with small amounts of argon, water vapor, carbon dioxide, and other gases. Seawater is composed largely of sodium chloride and water. A mixture may be **heterogeneous** or **homogeneous**.

- A mixture may be heterogeneous or homogeneous.

❖ ***A heterogeneous mixture*** does not have a uniform composition throughout a sample.

❖ ***A homogeneous mixture*** has a uniform composition throughout a sample.

A pepperoni pizza is a heterogeneous mixture, while a soft drink is a homogeneous solution.

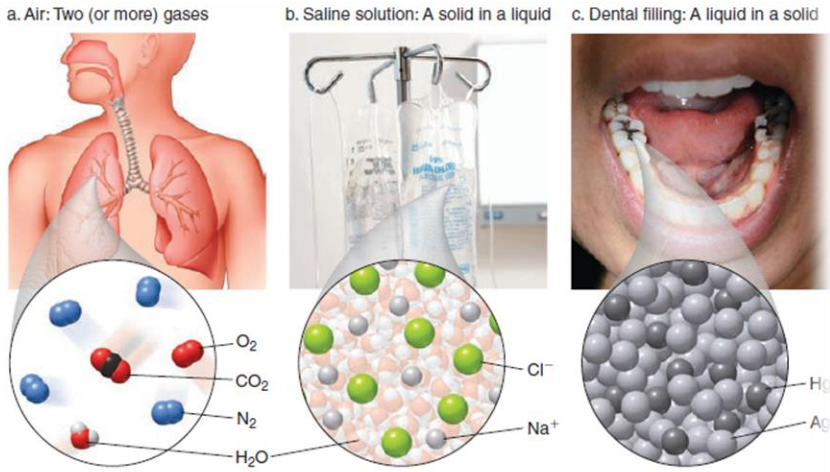
Amalgam filling is a silver dissolve in Hg as homogenous mixture.

Types of Mixture

A. **solution** is a homogeneous mixture that contains small particles. Liquid solutions are transparent.

When two substances form a solution, the substance present in the lesser amount is called **the solute**, and the substance present in the larger amount is the **solvent**. A solution with water as the solvent is called an aqueous solution.

Figure 7.1
Three Different Types of Solutions



a. Air is a solution of gases, primarily N_2 and O_2. The lungs contain significant amounts of H_2O and CO_2 as well.
b. An IV saline solution contains solid sodium chloride (NaCl) dissolved in liquid water.
c. A dental filling contains a liquid, mercury (Hg), dissolved in solid silver (Ag).

B. Colloid is a homogeneous mixture with larger particles, often having an opaque appearance.

- The particles in a colloid generally cannot be filtered from its order components, and they do not settle out on standing.
- By addition, **a colloid contains particles that are 1nm-1µm in diameter**. Milk is a colloid. Homogeneous milk is an opaque homogeneous mixture contains large protein and fat molecules that do not dissolve in water.

C. Suspension is a heterogeneous mixture that contains large particles suspended in a liquid.

- **A suspension contains particles greater than 1µm in diameter.**
- The particles are so large that they do not dissolve in a liquid, and they can filter away from the liquid, or separated using a centrifuge.

Health Note

- ✓ Blood is a suspension containing blood cells that can be separated from liquid blood plasma by centrifugation.
- ✓ Zinc oxide eugenol (ZOE) is a material created by the combination of zinc oxide and eugenol contained in oil of cloves. Mixed at a powder-to-liquid ratio of 1:3 to achieve a homogeneous mix. (colloid type)

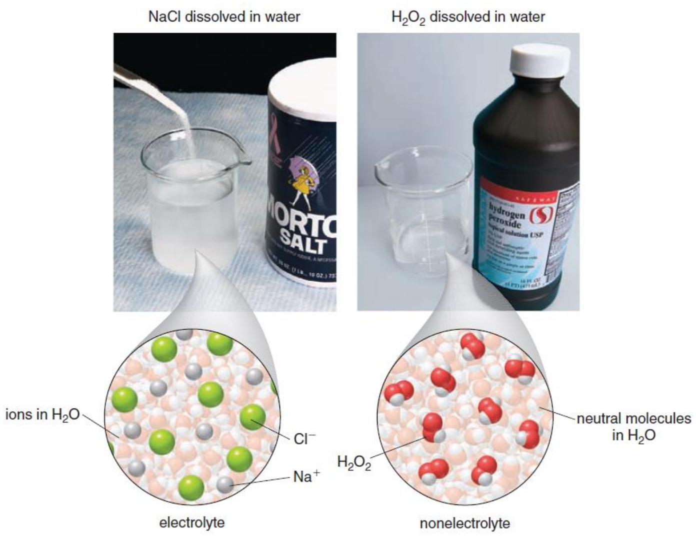
This table summarizes the properties of solutions, colloids, and suspensions.

Properties of Solutions, Colloids, and Suspensions

Property	System		
	Solution	**Colloid**	**Suspension**
Particle type	Ions, atoms, small molecules	Large molecules or particles	Large particles or aggregates
Particle size	0.1–1 nm	1–1000 nm	1000 nm and larger
Effect of light	No scattering	Exhibits Tyndall effect	Exhibits Tyndall effect
Effect of gravity	Stable, does not separate	Stable, does not separate	Unstable, sediment forms
Filtration	Particles not retained on filter	Particles not retained on filter	Particles retained on filter
Uniformity	Homogeneous	Homogeneous	Heterogeneous

Electrolytes and Nonelectrolytes

- A solute that dissolve in water to from ions conducts electricity, whereas a solute that contains only neutral molecules does not. Thus, an aqueous solution of sodium chloride, NaCl, contains Na^+ cations and Cl^- anions and conducts electricity. An aqueous solution of hydrogen peroxide, H_2O_2, contains only neutral H_2O_2 molecules in H_2O, so it does not conduct electricity.
- A substance that conducts an electric current in water is called ***an electrolyte***. NaCl is an electrolyte.
- A substance that does not conduct an electric current in water is called ***a nonelectrolyte.*** H_2O_2 is a nonelectrolyte.



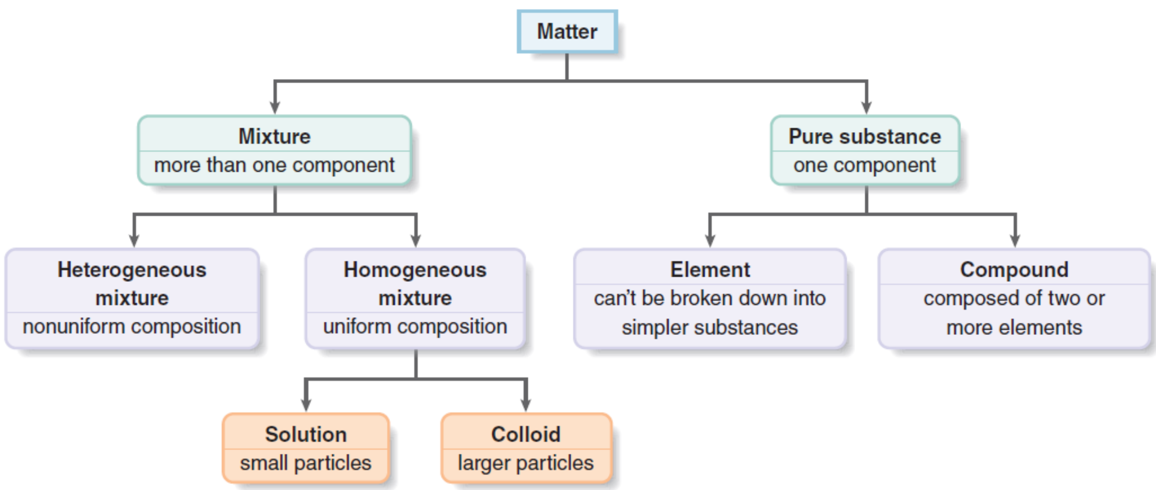
Classification of Electrolytes

Electrolytes are substances which, when dissolved in water, break up into cations (positive-charged ions) and anions (negative-charged ions). We say they ionize. Strong electrolytes ionize completely (100%), while weak electrolytes ionize only partially (usually on the order of 1–10%). That is, the principal species in solution for strong electrolytes are ions, while the principal specie in solution for weak electrolytes is the un-ionized compound itself.

Electrolytes can be classified as **strong** or **weak**, on the extent that the compound dissociates (forms ions).

- ***A strong electrolyte*** dissociates completely to form ions when it dissolves in water. Like NaCl.
  - ✓ strong acids HCl, HBr, HI, HNO_3, $HClO_3$, $HClO_4$, and H_2SO_4
  - ✓ strong bases NaOH, KOH, LiOH, $Ba(OH)_2$, and $Ca(OH)_2$
  - ✓ salts NaCl, KBr, $MgCl_2$, and many, many more
- ***A weak electrolyte*** dissolves in water to yield largely uncharged molecules, but small fraction of the molecules form ions. Like ammonia NH_3
  - ✓ weak acids HF, $HC_2H_3O_2$ (acetic acid), H_2CO_3 (carbonic acid), H_3PO_4 (phosphoric acid), and many more
  - ✓ weak bases NH3 (ammonia), C_5H_5N (pyridine), and several more, all containing "N"

Figure 7.2 Classification of Matter



	Electrolytes	Nonelectrolytes
Definition	Electrolytes are substances that produce ions when dissolved in a solvent	Nonelectrolytes are substance that cannot produce ions when dissolved in a solvent
Production of Ions	Dissociate into ions	Cannot dissociate into ions
Polarity	Polar compounds	Nonpolar compounds
Electrical Conductivity	Can conduct electricity when dissolved in a solvent	Cannot conduct electricity

Saliva as Electrolyte

Saliva is essential to all aspects of oral health. Among its important functions are cleansing, provision of antimicrobial characteristics via enzymes (e.g., lysozyme and lactoferrin), and the remineralization of the dental enamel surface.

The primary component of saliva, amounting to 99 % of the total, is water. The other constituents are electrolytes and organic substances such as enzymes and proteins. The pH of saliva falls in the range of 6.0–7.5.

Calcium and phosphate ions are especially important in the natural remineralization process.

Substance	**Concentration in mmol/L**
Calcium (Total)	1.43
Phosphate (Total)	5.10
Chloride	23.2
Sodium	10.1
Potassium	22.7
Ammonium	4.35
Magnesium	0.21

Concentrations Units

In using a solution in the laboratory or in administering the proper dose of a liquid medication, we must know its concentration—how much solute is dissolved in a given amount of solution. Concentration can be measured in several different ways that use mass, volume, or moles. Two useful measures of concentration are reported as percentages—that is, the number of grams or milliliters of solute per 100 mL of solution.

1. ***Weight/Volume Percent***

   One of the most common measures of concentration is weight/volume percent concentration, (w/v)%—that is, the number of grams of solute dissolved in 100 mL of solution. Mathematically, weight/volume percent is calculated by dividing the number of grams of solute in a given number of milliliters of solution, and multiplying by 100%.

Weight/volume percent concentration

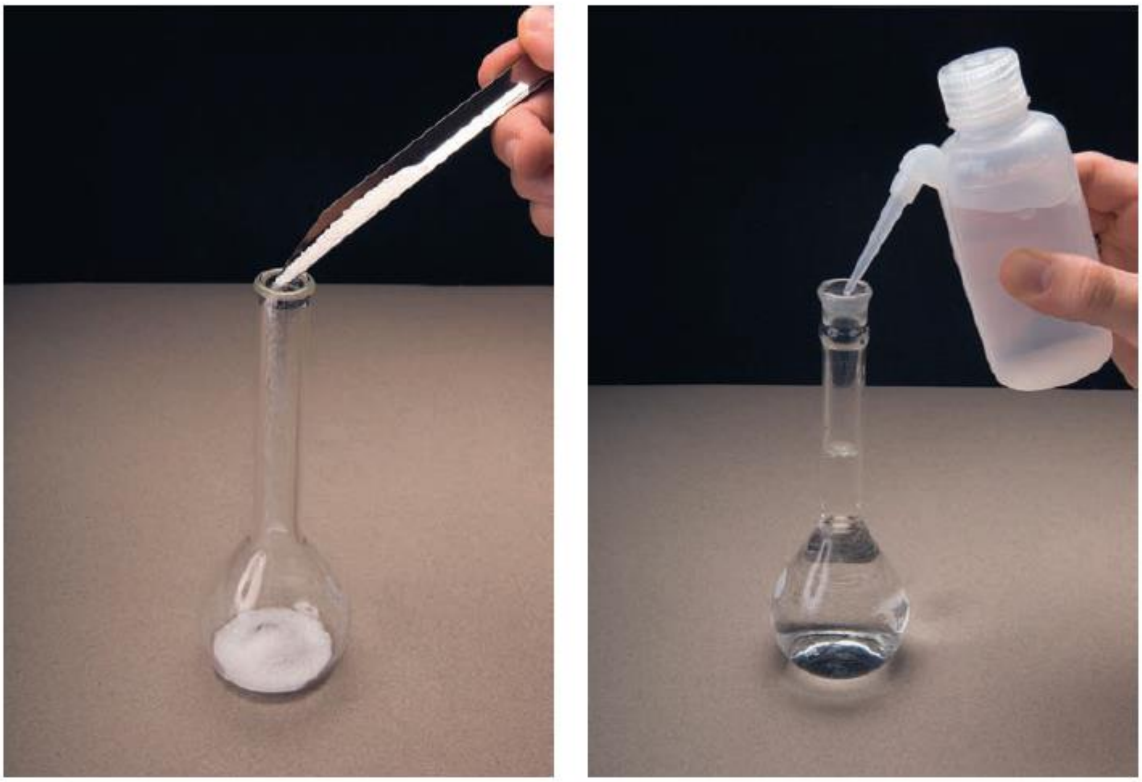
$$(w/v)\% = \frac{\text{mass of solute (g)}}{\text{volume of solution (mL)}} \times 100\%$$

For example, vinegar contains 5 g of acetic acid dissolved in 100 mL of solution, so the acetic acid concentration is 5% (w/v).

$$(w/v)\% = \frac{\text{5 g acetic acid}}{\text{100 mL vinegar solution}} \times 100\% = 5\%\ (w/v)\ \text{acetic acid}$$

Note that the volume used to calculate concentration is the final volume of the solution, not the volume of solvent added to make the solution. A special flask called a volumetric flask is used to make a solution of a given concentration . The solute is placed in the flask and then enough solvent is added to dissolve the solute by mixing. Next, additional solvent is added until it reaches a calibrated line that measures the final volume of the solution.

a. Add the solute. b. Add the solvent.



To make a solution of a given concentration: (a) add a measured number of grams of solute to a volumetric flask; (b) then add solvent to dissolve the solid, bringing the level of the solvent to the calibrated mark on the neck of the flask.

Example: Chloraseptic sore throat spray contains 0.35 g of the antiseptic phenol dissolved in 25 mL of solution. What is the weight/volume percent concentration of phenol?

Solution:

Use the formula (w/v)% = (grams of solute)/(mL of solution) × 100%.

$$(w/v)\% = \frac{0.35 \text{ g phenol}}{25 \text{ mL solution}} \times 100\% = 1.4\% \text{ (w/v) phenol}$$

Answer

2. ***Volume/Volume Percent***

   When the solute in a solution is a liquid, its concentration is often reported using volume/volume percent concentration, (v/v)%—that is, the number of milliliters of solute dissolved in 100 mL of solution. Mathematically, volume/volume percent is calculated by dividing the number of milliliters of solute in a given number of milliliters of solution, and multiplying by 100%.

$$\text{Volume/volume percent concentration} \quad (v/v)\% = \frac{\text{volume of solute (mL)}}{\text{volume of solution (mL)}} \times 100\%$$

For example, a bottle of rubbing alcohol that contains 70 mL of 2-propanol in 100 mL of solution has a 70% (v/v) concentration of 2-propanol.

$$(v/v)\% = \frac{\text{70 mL 2-propanol}}{\text{100 mL rubbing alcohol}} \times 100\% = \text{70\% (v/v) 2-propanol}$$

3. *Using a Percent Concentration as a Conversion Factor*

Percent concentration can be used as a conversion factor to relate the amount of solute (either grams or milliliters) to the amount of solution. For example, ketamine, an anesthetic especially useful for children, is supplied as a 5.0% (w/v) solution, meaning that 5.0 g of ketamine are present in 100 mL of solution. Two conversion factors derived from the percent concentration can be written.

$$\text{5.0\% (w/v) ketamine} \qquad \frac{\text{5.0 g ketamine}}{\text{100 mL solution}} \quad \text{or} \quad \frac{\text{100 mL solution}}{\text{5.0 g ketamine}}$$

weight/volume percent concentration

We can use these conversion factors to determine the amount of solute contained in a given volume of solution, or to determine how much solution contains a given number of grams of solute.

Example: A saline solution used in intravenous drips for patients who cannot take oral fluids contains 0.92% (w/v) NaCl in water. How many grams of NaCl are contained in 250 mL of this solution?

Solution:

1. Identify the known quantities and the desired quantity.

   0.92% (w/v) NaCl solution

250 mL	? g NaCl
known quantities	desired quantity

2. Write out the conversion factors.

   • Set up conversion factors that relate grams of NaCl to the volume of the solution using the weight/volume percent concentration.

$$\frac{\text{100 mL solution}}{\text{0.92 g NaCl}} \quad \text{or} \quad \frac{\text{0.92 g NaCl}}{\text{100 mL solution}}$$

Choose this conversion factor to cancel mL.

3. Solve the problem.
   • Multiply the original quantity by the conversion factor to obtain the desired quantity.

$$250\ \text{mL} \times \frac{0.92\ \text{g NaCl}}{100\ \text{mL solution}} = 2.3\ \text{g NaCl}$$

Answer

4. ***Parts Per Million (ppm)***

   When a solution contains a very small concentration of solute, concentration is often expressed in parts per million (ppm). Whereas percent concentration is the number of parts per million is the number of "parts" in 1,000,000 parts of solution. The "parts" may be expressed in either mass or volume units as long as the same unit is used for both the numerator and denominator.

Parts per million

$$\text{ppm} = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 10^6$$

or

$$\text{ppm} = \frac{\text{volume of solute (mL)}}{\text{volume of solution (mL)}} \times 10^6$$

A sample of seawater that contains 1.3 g of magnesium ions in 10^6 g of solution contains 1.3 ppm of magnesium.

$$\text{ppm} = \frac{1.3\ \text{g magnesium}}{10^6\ \text{g seawater}} \times 10^6 = 1.3\ \text{ppm magnesium}$$

Parts per million is used as a concentration unit for very dilute solutions. When water is the solvent, the density of the solution is close to the density of pure water, which is 1 g/mL at room temperature. In this case, the numerical value of the denominator is the same no matter if the unit is grams or milliliters. Thus, an aqueous solution that contains 2 ppm of MTBE (tert-butyl methyl ether), a gasoline additive and environmental pollutant, can be written in the following ways:

$$\frac{2\ \text{g MTBE}}{10^6\ \text{g solution}} \times 10^6 = \frac{2\ \text{g MTBE}}{10^6\ \text{mL solution}} \times 10^6 = 2\ \text{ppm MTBE}$$

10^6 mL has a mass of 10^6 g.

Example: What is the concentration in parts per million of DDT (Dichlorodiphenyltrichloroethane) in the tissues of a seabird that contains 50 mg of DDT in 1,900 g of tissue? DDT, a nonbiodegradable pesticide that is a persistent environmental pollutant, has been banned from use in the United States since 1973.

Solution:

- Use the formula ppm = (g of solute)/(g of solution) × 10^6.

1. Convert milligrams of DDT to grams of DDT so that both the solute and solution have the same unit.

$$50.\ \cancel{mg}\ \text{DDT} \times \frac{1\ \text{g}}{1000\ \cancel{mg}} = 0.050\ \text{g DDT}$$

2. Use the formula to calculate parts per million.

$$\frac{0.050\ \text{g DDT}}{1900\ \text{g tissue}} \times 10^6 = 26\ \text{ppm DDT}$$

Answer

5. ***Molarity and Normality***

The most common measure of concentration in the laboratory is molarity—the number of moles of solute per liter of solution, abbreviated as M.
A solution that is formed from 1 mol (58.4 g) of NaCl in enough water to give 1 L of solution has a molarity of 1 M. A solution that is formed from 2.50 mol (146 g) of NaCl in enough water to give 2.50 L of solution is also a 1 M solution. Both solutions contain the same number of moles per unit volume.

$$M = \frac{\text{Moles of } Solute\ (mol)}{V(L)} \qquad M = \frac{Weight(wt.)}{M.Wt}\ x\ \frac{١٠٠٠}{V(ml)}$$

$$N = \frac{Equivelents\ of\ Solute\ (Eq)}{V(L)} \qquad N = \frac{Weight(wt.)}{Eq.Wt}\ x\ \frac{١٠٠٠}{V(ml)}$$

Molarity is a conversion factor that relates the number of moles of solute to the volume of solution it occupies. Thus, if we know the molarity and volume of a solution, we can calculate the number of moles it contains. If we know the molarity and number of moles, we can calculate the volume in liters.

- To calculate the volume of solution… …rearrange the equation for molarity (M):

$$V(L) = \frac{\text{Moles of } Solute\ (mol)}{M}$$

- To calculate the moles of solute… …rearrange the equation for molarity (M):

$$\text{Moles of } Solute\ (mol) = \text{M x V(L)}$$