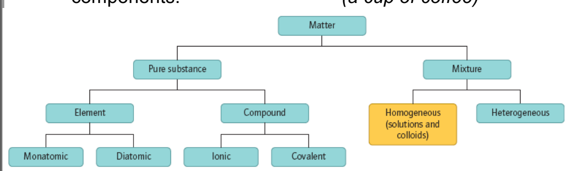
OUTLINE

- **5.1 Mixtures and Solutions**
- **5.2 Concentration of Solutions**
- ~~**5.3 Colloids and Suspensions**~~
- **5.4 Processes that Maintain Biochemical Balance in Your Body**

CHAPTER 5: Solutions, Colloids, and Membranes
W. H. FREEMAN

5.1 MIXTURES AND SOLUTIONS

- **Pure substances** are composed of a *single* element or compound.
- **Mixtures** contain *two or more* elements or compounds in any proportion, NOT covalently bound to each other:
  - **Heterogeneous mixtures** have an *uneven* distribution of components. *(a chocolate chip cookie)*
  - **Homogeneous mixtures** have an *even* distribution of components. *(a cup of coffee)*



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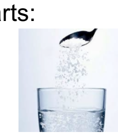
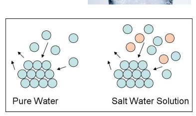
SOLUTIONS: DEFINITIONS & COMPONENTS

- **Solutions** are homogeneous mixtures.
  - May be solids, liquids, or gases.
- All solutions are composed of *two* parts:
  1. **Solvent**: the major component
  2. **Solutes**: minor components



Solutions containing water as the solvent are **aqueous solutions**



SOLUTIONS & PHYSICAL STATES

- **Solutions** can be composed of *any* of the three states: solid, liquid, or gas.
  1. *Solid solutions* include metal alloys
     - *Examples*: brass and dental amalgams
  2. *Liquid solutions* can contain solutes of all three states at the same time:
     - *Example: mixed drinks such as "rum-and-coke"*
       - Solids (sugar)
       - Liquids (alcohol)
       - Gases (CO_2)
  3. *Gas solutions*, such as air, can contain dissolved gases (O_2, CO_2), liquid (water droplets), and even some solids (some odors).

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SOLUBILITY RULES

- The simplest rule for determining solubility is that "**like-dissolves-like**":

  The polarity of solute & solvent typically match

  - *Polar* solvents dissolve *polar* or *ionic* solutes.
    - ***For example***: Water dissolves sugar or salt
  - *Non-polar* solvents dissolve *non-polar* solutes
    - ***For example***: Vegetable oil dissolves peanut butter
- Polar solvents will not dissolve non-polar solutes *(why oil and vinegar will not mix)*

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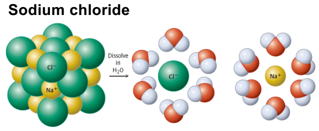
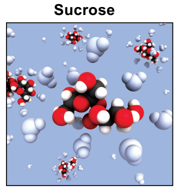
WHAT HAPPENS TO A DISSOLVED COMPOUND?

- The molecules uniformly disperse throughout the solution, *forming new intermolecular forces*:
  - **Ionic compounds** *dissociate* into individual ions

Sodium chloride



Sucrose



  - **Molecules** remain *intact*……
    (covalent bonds DO NOT break!)

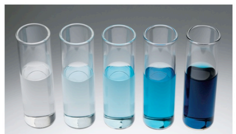
5.2 CONCENTRATION OF SOLUTIONS

- **Concentration** of a solution refers to the amount of solute that is dissolved into a solvent:

$$\text{Concentration} = \frac{\text{amount of solute}}{\text{amount of solution}}$$

** Note that the amount of the solution is the sum of solvent + solute*

- *Qualitative* words describe the amount of solute present in a given solution:
  - **Dilute** (low solute conc.)
  - **Concentrated** (high solute concentration)
  - **Saturated** (no more solute will dissolve)



QUANTIFYING CONCENTRATIONS

- A critical goal in chemistry is to **measure** (*quantify*) the amount of solute in a solution
- Concentrations of solutions can be measured in four distinct ways:
  1. **Mass concentration** = *grams/liter (g/L)*
  2. **Molar concentration** = *moles/liter (mol/L = M)*
  3. **Percent mass/volume**: $\% \frac{\text{mass}}{\text{volume}} = \frac{\text{g solute}}{\text{mL solution}} \times 100$
  4. **Equivalents of charge** = *equivalents/liter (eq/L)*

QUANTIFYING CONCENTRATIONS

- Concentrations in **chemistry** are typically measured either in **mass units** or in **molar units**
- Concentrations are a division of an amount of **mass** or **moles** by **volume**

$$\text{Concentration} = \frac{\text{amount of solute}}{\text{amount of solution}} = \frac{\text{mass}}{\text{volume}} \text{ or } \frac{\text{mols}}{\text{volume}}$$

- Measurements of concentration based on SI units may include **metric prefixes** of scale
  ("milli" [10^{-3}], "micro" [10^{-6}], "nano" [10^{-9}])

QUANTIFYING MOLECULES PER VOLUME

- In **chemistry**, ***molar concentration*** is abbreviated to its own "unit" of concentration:
  - **Molarity** (***M***) is defined as **moles** of a given solute per **liter** of solution:

$$M = \frac{\text{moles solute}}{\text{liters solution}}$$

  - *Molarity is a measure of how many molecules are present in a given volume of solution*
  - 1 *M* solution of *anything* contains 1 mole of solute in each liter; a 1 mM solution has 1/1000 this much.

CONVERTING CONCENTRATION UNITS

- Routine work in chemistry requires conversion between in **mass concentration** and **molar concentration** of solutions:

For example: You might need to know concentration in *M*, but the information is given in units of mass/volume (***g/L***)

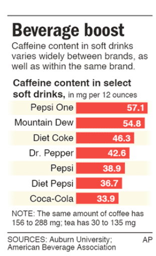
The key here is taking care of your units…make sure they cancel out to get the correct final value !!!

Starting units → **Conversion Factors** (molecular mass, volumes, dimensions, etc) → **Ending units**

QUANTIFYING MOLECULES PER VOLUME

What is the molarity (M) of caffeine in a 12 oz Diet Coke based on this data?

1. What are your starting & ending units?
2. What conversion factors do you need?
3. How will you set up the unit conversion?



PERCENT MASS CONCENTRATIONS

- Concentrations in **medicine** may be measured as a **percent mass** solution:

$$\% \frac{mass}{volume} = \frac{g\ solute}{mL\ solution} \times 100$$

  - *Units must always be **g/mL**, because the density of water is 1.00 g/mL; every mL of water weighs 1.00 g*
- *Example*:

  What is the percent mass of 5.93 grams of sodium chloride dissolved in a final volume of 1.3 liters?

EQUIVALENTS/LITER FOR IONIC COMPOUNDS

- The concept of **equivalents** (***eq***) is related to moles, but refers to electrical charge:
  - These units specifically apply to ***ionic compounds*** dissolved into a solvent (usually water)
  - *Remember: ionic compounds separate in solution!*
- Ions in biological fluids are often given in ***eq/L*** units
- **Equivalents** = **moles** (of ion) x **charge** (on each ion)
  - How many equivalents are in 1 M NaCl ?

    in 1 M Fe_2O_3 ?

    in Na_3PO_4 ?

DRUG DOSAGES & FLOW RATES

- An important **medical** application of understanding concentrations involves calculating *drug dosages*
  - A "dose" can be a single administered amount
  - A "dose" can be continuously infused by IV
- Drugs administered by IV are given at a specific dosage per unit of time, called the **flow rate**

$$\text{Flow Rate} = \frac{\text{dosage}}{\text{time}}$$

  - The units for flow rate can vary, but in medicine are typically in **"units"/hr** or **mL/hr**

CHAPTER 5: Solutions, Colloids, and Membranes

W. H. FREEMAN

FLOW RATE EXAMPLE PROBLEM

An order is given to infuse 500 units per hour of Heparin (an anticoagulant). The IV bag supplied contains 25,000 units in 250 mL. At what flow rate in mL per hour should the solution be infused into the patient?

1. What are the starting & ending units?
2. What conversion factors do we need?
3. How do we set up the unit conversion so that the units appropriately cancel out?

CHAPTER 5: Solutions, Colloids, and Membranes

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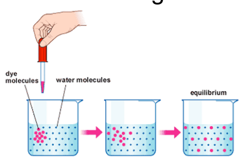
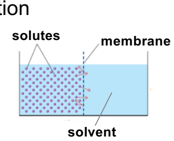
5.4 BIOCHEMICAL BALANCE OF SOLUTIONS

- **Diffusion** is the movement of *solute molecules* in solution from high-to-low concentration



Diffusion results in a *homogeneous* distribution of solute within the solution

- **Membranes** are *barriers* that prevent diffusion of molecules between the two environments



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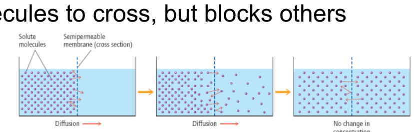
SEMIPERMEABLE & CELL MEMBRANES

- A **semipermeable membrane** allows certain molecules to cross, but blocks others



- Cells and organelles are surrounded by semipermeable membranes that maintain different concentrations of ions and molecules inside and outside the cells.
  - **Ions** and **large molecules** require special transport systems to carry them across the membrane as needed.

Table 5-7 Typical Concentrations of Electrolytes Inside and Outside a Blood Cell

Electrolyte	Concentration Inside the Cell (mmol/L)	Concentration Outside the Cell (mmol/L)
Na^+	10	140
Cl^-	4	100
K^+	140	4
Ca^{2+}	1×10^{-4}	2.5

OSMOSIS vs. DIALYSIS

- There are two ways by which molecules may cross **semipermeable membranes**:
  - **Osmosis**: _water_ can diffuse across the membrane, but not other substances.
  - **Dialysis**: _water_ or _small solutes_ (ions or sugars) may diffuse across the membrane, but not large molecules such as proteins.
- *Both are mechanisms that allow for equal molar concentration of solute on both sides of a semipermeable membrane*

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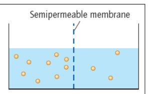
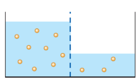
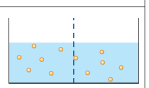
OSMOSIS vs. DIALYSIS

Process	Substance crossing membrane	How does it cross the membrane?	
			 Initial solutions
Osmosis	Water (solvent)	Simple diffusion of water from a region of lower solute concentration (higher water concentration) to a region of higher solute concentration (lower water concentration), across a semipermeable membrane.	 Osmosis: solvent crosses membrane
Dialysis	Solutes	Simple diffusion of solute from a higher concentration of solute to a lower concentration of solute, across a semipermeable membrane	 Dialysis: solute crosses membrane

Osmosis
Only water moves across the membrane *(e.g. laxatives)*

Dialysis
Water & solute moves across the membrane *(e.g. kidney dialysis)*

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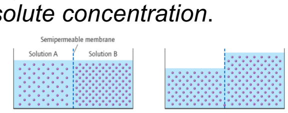
DIRECTION OF OSMOTIC DIFFUSION

- In **osmosis**, *water always moves from low solute concentration to high solute concentration*.

Water flow normalizes concentration in both compartments

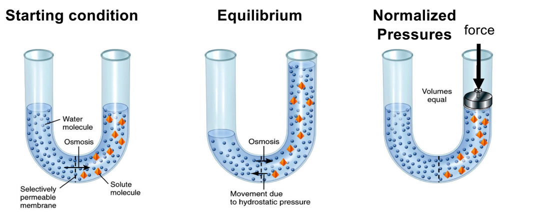


hypotonic **hypertonic** **isotonic**

- Three types of solutions relative to a membrane:
  - **Hypertonic** – solution with a higher solute concentration than inside cells.
  - **Hypotonic** – solution with the lower solute concentration compared with cells.
  - **Isotonic** – solutions have equal solute concentrations to cell contents.

OSMOTIC PRESSURE

- When osmosis occurs in a confined space, it exerts **pressure** on the walls of that space
  - The amount of pressure needed to overcome osmotic flow is called the **osmotic pressure**



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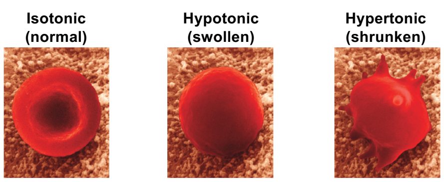
OSMOSIS IN LIVE CELLS

- **Osmotic pressure** is a biologically important problem!
- Cells placed in hypotonic or hypertonic solutions will swell or shrink due to osmosis across their membranes



- Red blood cells placed in water (hypotonic) solution will burst in a process called **hemolysis**

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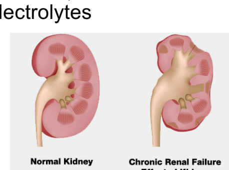
DIALYSIS

- **Dialysis** is useful for separating small solute molecules from larger particles.
  - Blood has both types of particles!
- ***Kidneys*** carry out a natural form of dialysis:
  - They remove small waste solutes (urea and creatinine) while retaining water and electrolytes
- ***Artificial dialysis*** can be used if kidneys are diseased or damaged



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ARTIFICIAL KIDNEY DIALYSIS