I.9 Isotonicity

GOAL *To review the calculations needed to make solutions isotonic and compatible with body fluids.*

OBJECTIVES

This chapter equips students to:

- Distinguish between electrolyte and nonelectrolyte solutions regarding their effects on osmotic pressure and tonicity
- Calculate the dissociation constant of a molecule given its percent dissociation in solution
- Describe the importance of freezing point depression in determining tonicity of a solution
- Given the molecular weight (mw) of a nonelectrolyte or an electrolyte, use freezing point depression to calculate the amounts of either needed to prepare an isotonic solution
- Define the percent strength of normal saline solution
- Define sodium chloride (NaCl) equivalent
- Given the mw and dissociation constant of a substance, calculate its NaCl equivalent
- Given a prescription for compounding an isotonic solution, calculate the following:
    - The amount of ingredients needed
    - The amount of NaCl represented by the ingredients
    - The amount of NaCl when used alone that would make the required volume of solution isotonic
    - The amount of additional NaCl needed in addition to other ingredients to make the prescribed solution isotonic
    - The amount of an ingredient used in place of NaCl to make the prescribed solution isotonic

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Importance for Medical Math and Clinical Practice

Injectable solutions and products for use in the eye or other sensitive tissues must be compatible with body fluids to avoid pain and potentially irreversible damage to tissues. Creating these solutions and products requires knowledge of the physical chemistry of drug solutions as well as the therapeutic benefits expected. This is where understanding how terminology and calculations—some deriving from chemistry and some deriving from physiology—mesh to describe a solution or product that can be used safely to treat disease. To this end, study the **Basic Concepts** several times before learning how to prepare an isotonic solution. Chapter 9 focuses on making suitable solutions and products. Chapter 10 focuses on understanding the terminology most used in clinical practice when these solutions and products are administered to a patient.

Basic Concepts

- *Osmotic pressure:* pressure created when a dilute aqueous solution and a more concentrated solution are separated by a semipermeable membrane (membrane through which only water tends to pass). Water passes through the membrane from the dilute solution into the more concentrated solution until the concentrations are equal. The movement of water is the process of *osmosis*, and pressure occurs because the volume of the concentrated solution tends to increase.
    - *Nonelectrolyte solutions:* osmotic pressure is related to the concentration of the solute; that is, the number of molecules of a nonelectrolyte substance existing in solution after the substance dissolves.
    - *Electrolyte solutions:* osmotic pressure is also related to the concentration of solute (the

KEYWORDS:
Dissociation constant
Electrolyte
Freezing point depression
Hypertonic
Hypotonic
Isotonic
Nonelectrolyte
Osmotic pressure
Sodium chloride equivalent

number of molecules in solution), but electrolyte substances can break down (dissociate) into their component ions. *Ions* are charged particles that balance each other electrically to make a neutral molecule. This does not happen for nonelectrolyte substances. The degree of dissociation of those molecules into individual ions in solution contributes to osmotic pressure. The word *particles* refers to individual ions plus any molecules of electrolyte substance that remain intact in solution. Substances that dissociate will have a greater number of particles in solution than solutes that do not dissociate. Therefore, 1 g of an electrolyte in solution should exert greater osmotic pressure compared to 1 g of a nonelectrolyte.

- *Isotonic:* "of equal tone"; refers to a solution that has the same osmotic pressure as body fluids (blood, tears). A solution equivalent to 0.9% w/v NaCl in water.
- *Hypotonic:* solutions with a lower osmotic pressure than body fluids. A solution equivalent to less than 0.9% w/v NaCl in water.
- *Hypertonic:* solutions with a higher osmotic pressure than body fluids. A solution equivalent to greater than 0.9% w/v NaCl in water.
- The words *tonicity* (isotonic) and *osmolarity* (isosmotic) are often used interchangeably. Very generally, however, tonicity may refer only to the osmotic pressure exerted by electrolytes (crystalloid substances), and osmolarity may refer only to the osmotic pressure exerted by nonelectrolytes ("colloidal" substances) in aqueous solutions.
- In clinical practice, *tonicity* is most applicable in describing the composition and preparation of a drug product suitable for application into or onto body fluids, while *osmolarity* is most applicable to describing the normal chemical composition of body fluids.
- O*smo***lal***ity* (shown below): osmolarity and osmolality are virtually identical at ordinary room temperature and atmospheric pressure because of the only slight difference between 1 kg and the weight of 1 L of water.
- Note that a formula commonly used to estimate the osmolarity of blood plasma (the water fraction of whole blood) uses both electrolytes and nonelectrolytes in the calculation. This is why we have to speak using general definitions for words describing nonelectrolytes and electrolytes in solution.

These basic concepts are expanded in the next chapter's discussion of millimoles (mM), milliequivalents (mEq), and milliosmoles (mOsmol). The table below is an introduction to this next discussion that is valuable to understand the terminology.

- Note the use of the prefix *milli* for these concepts. This is because *moles, equivalents,* and *osmoles* are much too large as units of measure describing normal human biochemistry. Please remember that the prefix *milli* means 1/1,000th—for example 0.001 g is 1 mg and 0.001 mole is 1 mM.
- A *mole* represents the weight expressed in grams of a substance equal to the atomic weight or mw of that substance.