I.10 Concentrations of Solutes and Osmolarity

GOAL *To describe calculations needed to find the osmolarity of solutions containing electrolytes and nonelectrolytes where concentrations are stated as millimoles, milliequivalents, and milliosmoles of substance per volume of solution.*

OBJECTIVES

This chapter equips students to:

- Define millimole, milliequivalent, milliosmole, osmolarity, and osmolality
- Given the atomic or molecular weight of an electrolyte, calculate its milliequivalent weight
- Convert milliequivalents per unit volume to weight per unit volume
- Convert milliequivalents per unit volume to percentage weight/volume strength
- Calculate the number of milliequivalents represented in an electrolyte solution given the atomic/molecular weight of the electrolyte, the quantity of electrolyte present in solution, the volume of solution and/or the percentage weight-in-volume strength of solution
- Given a patient-specific dosing guideline (milliequivalents per kg), calculate a patient-specific dose and the volume of electrolyte solution of known concentration to be administered to the patient
- Given the amount of electrolyte substance and its molecular weight, calculate the number of millimoles
- Given the number of millimoles of an electrolyte and its molecular weight, calculate its weight (grams or milligrams)
- Calculate the osmolarity of a solution, given the molecular weight of the solute and the weight of solute in solution

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Importance for Medical Math and Clinical Practice

In therapeutics it is sometimes important to ensure that water volumes and concentrations of electrolytes/nonelectrolytes in blood or tissue are normal before other drugs can have a desired effect. For example, a drug intended to restore low blood pressure may depend upon having adequate intravascular volume or a drug intended to restore the heart's rhythm may depend upon having normal electrolyte concentrations circulating in the blood. Restoration and maintenance of normal hydration and electrolytes is often accomplished by injecting aqueous solutions, which are themselves drugs, into a patient's vein. These solutions, of course, must be compatible with life in terms of not only composition but also sterility and absence of particulate contaminants. Remember that 0.9% NaCl solution is referred to as *normal* because it is compatible with physiologic fluids such as blood and tears.

Chapter 10 explores the nomenclature and calculations needed to define precisely the injectable solutions used for hydration and electrolyte balance in the body. The terms describing these are often—as is true for other examples of medical calculations—much more confusing than the arithmetic needed to dose them. The etymology of these terms derives from chemistry, physical chemistry, and physiology. In current usage, these terms have definite meanings for calculations contributing to precise therapy. With dedicated study of Chapter 10, a reader should be able to move easily from

KEYWORDS
Atomic weight
Electrolyte
Milliequivalent (mEq)
Millimole (mM)
Milliosmole (mOsmol)
Molar fraction
Molecular weight (mw)
Osmolality
Osmolarity
Valence

confusing words to understanding the concentrations of appropriate ingredients present in this important drug therapy.

Key Concepts

It's important to begin this chapter by summarizing a bit and ensuring students remember a few things about three key concepts: moles, equivalents, and osmoles. By way of summary, this chapter focuses on solutes in aqueous solutions so the description of percentage weight/volume (% w/v) used in previous chapters is appropriate in this chapter as well to describe the weight of substance dissolved in a volume of water. The three concepts are used in chemistry also to describe amounts or concentrations of substances; however, it is important to review the specialized language of chemistry surrounding these concepts.

1. We define the same amount (mass, weight) of a substance in terms of numbers of atoms or molecules (or, indeed, subatomic particles) of a substance. The *mole* is this basic unit of that amount in the International System (SI) of Units. A mole equals the number of atoms/molecules/etc. of a substance represented by 12 grams of pure carbon-12, meaning 1 mole contains 6.02×10^{23} (Avogadro's Number) atoms/molecules/etc.
2. We state an amount of substance by way of its chemical combining power. The *equivalent* represents this notion, meaning "equal valence"—when the positive and negative electrical charges represented by valences of individual combining atoms of an electrolyte (salt) sum to zero.
3. We define the amount of solute that contributes to the osmotic pressure of an osmotically active solution. This is represented by the *osmole*, meaning how many osmotically active particles are released by dissolution of a substance in a solution.

Concentrations such as moles or equivalents or osmoles per volume of solution are much too large to describe normal human physiology. Concentrations of solutes in physiologic solutions that are compatible with life are of the magnitudes millimoles (mM), milliequivalents (mEq), or milliosmoles (mOsmol) per volume of solution. That is, 1/1,000th of a mole, equivalent, or osmole per volume of solution is descriptive of normal human values. And, keep in mind that the volume 1,000 mL is commonly used as the reference volume for these statements of concentration, although we'll see in Chapter 11 that the volume 100 mL is important when using a formula to predict the kidney function of a patient. 1/1,000th of a mole of sodium chloride (mw 58.5), for example, is 1/1,000th of 58.5 g = 58.5 mg. So, the units of *milli-* simply express the numeric values of atomic or molecular weight of a substance as milligrams, rather than as grams—as would be the case for atomic or molecular (often referred to as gram-atomic or gram-molecular) weights.

Although in chemistry it is valid to describe amounts or concentrations of solutes in numerous different solvents, water is the solvent important for therapeutics. There may be some water-soluble solvents added to water to prepare a particular drug product.