

## SECTION 11.1

### AMOUNT AND CONCENTRATION ARE NOT SYNONYMS

One of the most important applications of laboratory math is in making laboratory solutions and reagents. The preparation of aqueous solutions containing the proper components to support the biological system of interest is the first step in nearly every biological laboratory procedure. A **solution** can be defined as a homogeneous mixture in which one or more substances is (are) dissolved in another. **Solutes** are the substances that are dissolved in a solution. The substance in which the solutes are dissolved is called the **solvent**. In biological applications, the solutes are solids or liquids and the solvent is a liquid, most often, water.

This is the first of four chapters relating to the preparation of laboratory solutions. This chapter introduces the concept of **solute concentration**. Each successive chapter delves more deeply into calculations relating to the concentration(s) of solute(s) in a solution. Throughout these chapters you will find that proportions often provide a tool for solving a laboratory problem.

**Concentration** is the amount of a particular substance (solute) in a stated volume (or mass) of a solution or mixture. Concentration is a ratio where the numerator is the amount of the material of interest and the denominator is usually the volume (or sometimes mass) of the entire mixture. Observe that the terms “**amount**” and “**concentration**” are not synonyms. **Amount** refers to how much of a component is present. For example, 10 grams, 2 cups, and 30 mL are amounts, while concentration is a ratio.

In Figure 1, six “solutions” are sketched. The stars represent solute molecules. Observe that solutions *a* and *b* have different numbers of “stars” and different volumes, but their concentration of “stars” is the same. Solutions *c* and *d* have the same numbers of “stars”, yet the concentration of “stars” is different in the two solutions; stars are more concentrated in solution *d* than they are in *c*. Solutions *e* and *f* have the same volumes but different concentrations of “stars”.

FIGURE 1



a. Total volume =  $\underline{10 \text{ mL}}$   
Amount of solute =  $\underline{10 \text{ "stars"}}$   
Concentration =  $\underline{10 \text{ "stars"} / 10 \text{ mL} = 1 \text{ "star"} / \text{mL}}$



b. Total volume =  $\underline{5 \text{ mL}}$   
Amount of solute =  $\underline{5 \text{ "stars"}}$   
Concentration =  $\underline{5 \text{ "stars"} / 5 \text{ mL} = 1 \text{ "star"} / \text{mL}}$



c. Total Volume =  $\underline{10 \text{ mL}}$   
Amount of solute =  $\underline{10 \text{ "stars"}}$   
Concentration =  $\underline{10 \text{ "stars"} / 10 \text{ mL} = 1 \text{ "star"} / \text{mL}}$



d. Total volume =  $\underline{5 \text{ mL}}$   
Amount of solute =  $\underline{10 \text{ "stars"}}$   
Concentration =  $\underline{10 \text{ "stars"} / 5 \text{ mL} = 2 \text{ "stars"} / \text{mL}}$



e. Total volume =  $\underline{10 \text{ mL}}$   
Amount of solute =  $\underline{5 \text{ "stars"}}$   
Concentration =  $\underline{5 \text{ "stars"} / 10 \text{ mL} = 0.5 \text{ "star"} / \text{mL}}$



f. Total volume =  $\underline{10 \text{ mL}}$   
Amount of solute =  $\underline{5 \text{ "stars"}}$   
Concentration =  $\underline{5 \text{ "stars"} / 10 \text{ mL} = 0.5 \text{ "stars"} / \text{mL}}$

**Figure 1. AMOUNT AND CONCENTRATION ARE NOT THE SAME.** Concentration is a ratio where the numerator is the amount of the substance of interest and the denominator is usually the volume of the entire mixture. Solutions a and b have different numbers of “stars” and different volumes, but their concentration of “stars” is the same. Solutions c and d have the same numbers of “stars”, yet the concentration of “stars” is different in the two solutions; stars are more concentrated in solution d than they are in c. Solutions e and f have the same volumes but different concentrations of “stars”.

### PRACTICE PROBLEMS

1. State whether each of the following expressions is a concentration or an amount:
 

a. 1 g enzyme	b. 1 mL solution	c. 1 g NaCl/mL	d. 1 pound of salt
e. 1 mg of salt	f. 1 mg KCl/mL	g. 15 µg of NaCl	h. 18 picograms NaCl
i. 1 pg NaCl/L			
  
2. 4 g of KCl is dissolved in water to a volume of 1 L. What is the solute? What is the solvent? What is the concentration of KCl in this solution?
  
3. You have a solution of NaCl at a concentration of 15 mg/L. What is the solute? What is the solvent? What is the concentration of NaCl in this solution?
  
4. Express each of the following as a concentration.
  - a. 1 mg of enzyme out of 10 mL total solution
  - b. 1 gram of NaCl in water for a total of 1000 mL
  - c. 4 mL of ethanol dissolved in water for a total of 1 L
  
5.
  - a. If you take 5 g of solute and dissolve it in water to get a total volume of 10 mL, what is the concentration of solute in the solution? What is the amount of the solute in the solution?
  - b. If you take 5 g of solute and dissolve it in water to get a total volume of 100 mL, what is the concentration of solute in the solution? What is the amount of the solute in the solution?

### ANSWERS

1. State whether each of the following expressions is a concentration or an amount:
 

a. 1 g enzyme, amount	b. 1 mL solution, amount
c. 1 g NaCl/mL, concentration	d. 1 pound of salt, amount
e. 1 mg of salt, amount	f. 1 mg KCl/mL, concentration
g. 15 µg of NaCl, amount	h. 18 picograms NaCl, amount
i. 1 pg NaCl/L, concentration	
  
2. KCl is the solute and water is the solvent. The concentration of KCl is 4 g/L.
  
3. NaCl is the solute and water is (assumed to be) the solvent. The concentration of NaCl is 15 mg/L.
  
4.
 

a. 1mg enzyme/10 mL	b. 1 g NaCl/1000 mL	c. 4 mL ethanol/1 L
---------------------	---------------------	---------------------
  
5.
 

a. The <i>concentration</i> of solute in the solution is:	$\frac{5 \text{ g}}{10 \text{ mL}}$
The <i>amount</i> of solute in this solution is 5 g.	

b. The concentration of solute in the solution is:  $\frac{5 \text{ g}}{100 \text{ mL}}$

The amount of solute in this solution is 5 g.

(Observe that the amount of solute, 5 g, is the same in a and b, but the concentrations are different.)

## SECTION 11.2

### PREPARING A SOLUTION WITH THE RIGHT CONCENTRATION OF SOLUTE

Recall the following problem from Chapter 6:

*If it requires 1 teaspoon of baking soda to make one loaf of bread, how many teaspoons of baking soda are required for 33 loaves?*

Answer: ? = amount of baking soda for 33 loaves

$$\frac{1 \text{ tsp}}{1 \text{ loaf}} = \frac{?}{33 \text{ loaf}}$$

$$? = \frac{1 \text{ tsp} (33 \cancel{\text{ loaf}})}{\cancel{\text{ loaf}}} \qquad ? = 33 \text{ tsp}$$

The same sort of logic applies to problems where we need to calculate the amount of solute to make a solution at a particular concentration. For example:

*If it requires 1 g of enzyme to make 1 L of a particular solution, then how many grams of enzyme are required to make 3 L of this solution at the same concentration? (The enzyme is the solute.)*

Answer: ? = amount of enzyme for 3 L of this solution

$$\frac{1 \text{ g enzyme}}{1 \text{ L}} = \frac{?}{3 \text{ L}}$$

$$? = \frac{1 \text{ g enzyme} (3 \cancel{\text{ L}})}{\cancel{\text{ L}}} \qquad ? = 3 \text{ g enzyme}$$

#### EXAMPLE PROBLEM:

How could you make 300 mL of a solution at a concentration of 10 g NaCl per 100 mL?

#### ANSWER:

The solute is NaCl. To answer the question you must calculate how much solute is required to make a solution at the right volume and with the right concentration of the solute. This is easily solved with proportions:

$$\frac{10 \text{ g NaCl}}{100 \text{ mL total solution}} = \frac{?}{300 \text{ mL total solution}}$$

$$? = 30 \text{ grams}$$

30 g of NaCl in 300 mL is the same concentration as 10 g of NaCl in 100 mL.

To prepare this solution, weigh out 30 g of NaCl and dissolve it in less than 300 mL of water. After the solute is dissolved, bring the solution to a final volume of 300 mL by adding water until a volume of exactly 300 mL is reached. The 30 g is NOT added to 300 mL of water because then the final volume (NaCl + water) would be more than 300 mL. The process of bringing a solution to the correct final volume is called: "bringing to volume", or **BTV**.

### PRACTICE PROBLEMS

1.
  - a. How would you make 10 mL of a solution of NaCl at a concentration of 1 mg/mL?
  - b. How would you make 20 mL of a solution of NaCl at a concentration of 1 mg/mL?
  - c. How would you make 100 mL of a solution of NaCl at a concentration of 1 mg/mL?
  - d. How would you make 5 mL of a solution of NaCl at a concentration of 1 mg/mL?
2.
  - a. How would you make 1 L of a solution of KCl at a concentration of 4 g/L?
  - b. How would you make 0.5 L of a solution of KCl at a concentration of 4 g/L?
  - c. How would you make 2 L of a solution of KCl at a concentration of 4 g/L?
  - d. How would you make 10 mL of a solution of KCl at a concentration of 4 g/L?
3.
  - a. How would you make 100 mL of a solution of KCl at a concentration of 10  $\mu\text{g/mL}$ ?
  - b. How would you make 200 mL of a solution of KCl at a concentration of 10  $\mu\text{g/mL}$ ?
  - c. How would you make 50 mL of a solution of KCl at a concentration of 10  $\mu\text{g/mL}$ ?
  - d. How would you make 1 L of a solution of KCl at a concentration of 10  $\mu\text{g/mL}$ ?

### ANSWERS

1. a. To make 10 mL of a solution of NaCl at a concentration of 1 mg/mL:

$$\frac{1 \text{ mg NaCl}}{1 \text{ mL total solution}} = \frac{?}{10 \text{ mL total solution}} \quad ? = 10 \text{ mg}$$

So you would weigh out 10 mg of NaCl, dissolve it in water, and bring it to a volume of 10 mL.

- b. To make 20 mL of a solution of NaCl at a concentration of 1 mg/mL:

$$\frac{1 \text{ mg NaCl}}{1 \text{ mL total solution}} = \frac{?}{20 \text{ mL total solution}} \quad ? = 20 \text{ mg}$$

Weigh out 20 mg of NaCl, dissolve it in water, and bring it to a volume of 20 mL.

- c. To make 100 mL of a solution of NaCl at a concentration of 1 mg/mL:

$$\frac{1 \text{ mg NaCl}}{1 \text{ mL total solution}} = \frac{?}{100 \text{ mL total solution}} \quad ? = 100 \text{ mg}$$

Weigh out 100 mg of NaCl, dissolve it in water, and bring it to a volume of 100 mL.

- d. To make 5 mL of a solution of NaCl at a concentration of 1 mg/mL:

$$\frac{1 \text{ mg NaCl}}{1 \text{ mL total solution}} = \frac{?}{5 \text{ mL total solution}} \quad ? = 5 \text{ mg}$$

Weigh out 5 mg of NaCl, dissolve it in water, and bring it to a volume of 5 mL.

2. a. To make 1 L of a solution of KCl at a concentration of 4 g/L:

$$\frac{4 \text{ g KCl}}{\text{L}} = \frac{?}{1 \text{ L}} \quad ? = 4 \text{ g}$$

Weigh out 4 g of KCl, dissolve it in water, and bring it to a volume of 1 L.

- b. To make 0.5 L of a solution of KCl at a concentration of 4 g/L:

$$\frac{4 \text{ g KCl}}{\text{L}} = \frac{?}{0.5 \text{ L}} \quad ? = 2 \text{ g}$$

Weigh out 2 g of KCl, dissolve it in water, and bring it to a volume of 0.5 L.

- c. To make 2 L of a solution of KCl at a concentration of 4 g/L:

$$\frac{4 \text{ g KCl}}{\text{L}} = \frac{?}{2 \text{ L}} \quad ? = 8 \text{ g}$$

Weigh out 8 g of KCl, dissolve it in water, and bring it to a volume of 2 L.

- d. To make 10 mL of a solution of KCl at a concentration of 4 g/L:

The units of volume must match; either convert 1 L to units of mL, or convert 10 mL to units of L.

$$1 \text{ L} = 1000 \text{ mL}$$

$$\frac{4 \text{ g KCl}}{1000 \text{ mL}} = \frac{?}{10 \text{ mL}} \quad ? = 0.04 \text{ g}$$

Weigh out 0.04 g of KCl, dissolve it in water, and bring it to a volume of 10 mL.

3. a. To make 100 mL of a solution of KCl at a concentration of 10 µg/mL:

$$\frac{10 \text{ µg}}{1 \text{ mL}} = \frac{?}{100 \text{ mL}} \quad ? = 1000 \text{ µg} = 1 \text{ mg}$$

Let's also use a unit canceling strategy for this problem:

$$\frac{10 \text{ µg}}{1 \text{ mL}} \times 100 \text{ mL} = 1000 \text{ µg} = 1 \text{ mg}$$

This means you would weigh out 1 mg of KCl, dissolve it in water, and bring it to a volume of 100 mL.

- b. To make 200 mL of a solution of KCl at a concentration of 10 µg/mL:

$$\frac{10 \text{ µg}}{1 \text{ mL}} \times 200 \text{ mL} = 2000 \text{ µg} = 2 \text{ mg}$$

Weigh out 2 mg of KCl, dissolve, bring to a volume of 200 mL.

