LESSON ASSIGNMENT SHEET

LESSON 2	--Introduction to Solution Mathematics.
LESSON ASSIGNMENT	--Paragraphs 2-1 through 2-17.
LESSON OBJECTIVES	--After completing this lesson, you should be able to: Perform computations related to percent concentration of solutions.
SUGGESTIONS	--After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives. --Before studying this lesson, please read Appendix A, General Rules for Solving Solution Problems. These are useful guidelines and strategies that will help you throughout the rest of this review.

INTRODUCTION TO SOLUTION MATHEMATICS

Section I. PARTS OF A SOLUTION

2-1. INTRODUCTION

In order to discuss a solution, one first needs a definition of the term. A solution is a homogeneous mixture of gases, solids, or liquids in which the individual molecules of two or more substances are evenly dispersed throughout the medium (solution). For example, if one dissolves sucrose in water, the sugar granules will break down into individual molecules. This is to say, if one were to sample any two sections of the solution, the same number of sugar molecules would be found per unit volume. Solutions are not always liquids; e.g., if liquid mercury is rubbed on solid gold, the solid gold will dissolve the liquid mercury resulting in a solid solution.

2-2. SOLVENT

A solution consists of two parts. The first part is the solvent, which is defined as that portion of the solution that is either in greatest concentration or the portion of the solution that is doing the dissolving. Water is usually considered to be the universal solvent, no matter what proportion of the solution it is.

2-3. SOLUTE

The solute is the second part of a solution. One can define the solute as the substance that is being dissolved or the substance that is in lower concentration.

2-4. EXAMPLES

If one were to take 5 grams of sodium hydroxide and dissolve it in 100 milliliters of deionized water, what would be the solvent and what the solute? If you selected sodium hydroxide as the solute and water as the solvent, you were correct. The reason the sodium hydroxide is the solute is because it is present in the lower concentration and it is also the substance being dissolved. Water is the solvent because it is (1) the universal solvent; (2) present in the greatest concentration; and (3) the substance that is doing the dissolving.

Section II. TYPES OF MIXTURES

2-5. INTRODUCTION

As stated, a solution is a homogeneous mixture of gases, liquids, or solids in which the molecules of two or more substances are evenly dispersed throughout the medium. This can be more specifically defined as a true solution because the substances are mixed on a molecular basis. There are two other types of mixtures with which one should be familiar--the colloidal dispersion and the emulsion.

2-6. COLLOIDAL DISPERSION

A colloidal dispersion is not a true solution since the individual molecules are not mixed on a molecular basis; hence, the dispersion is not homogeneous throughout. This type of mixture contains aggregates of molecules with each individual aggregate being denoted as a colloid or as a colloidal particle. The number of molecules in each aggregate may be from several hundred to a few thousand. The size of each colloidal particle is usually in the range of from 1 to 200 nm in diameter. This range has been arbitrarily set since particles with a diameter of less than 1 nm do not scatter light and particles greater than 200 nm can be seen with the light microscope. As was mentioned above, there is no homogeneity of particles in this type of mixture. The particles are actually suspended in the dispersion phase. A colloidal dispersion is broken down into two parts (1) the dispersed phase (analogous to the solute of a true solution) and (2) the dispersion medium (analogous to the solvent of a true solution). The most important colloidal systems are those involving a solid dispersed in a liquid and are commonly denoted as colloidal dispersions. In some determinations of amylase, the starch substrate is a colloidal dispersion.

2-7. EMULSIONS

Emulsions are colloidal dispersions in which the dispersed phase and the dispersion medium are immiscible. If one mixes water and oil together and then shakes the container, the oil will break into very small particles that will disperse within the water. Upon standing, the oil droplets (dispersed phase) will tend to coalesce, forming larger and larger droplets. These droplets eventually become too large to remain within the dispersion medium (water) and the two liquids will separate. If one wishes to stabilize an emulsion, an emulsifying agent such as a bile salt must be added.

2-8. SATURATED SOLUTIONS

The laboratory specialist may on occasion be required to prepare a saturated solution. This type of solution is defined as a solution in which the dissolved solute is in equilibrium with undissolved solute. At a given temperature, most solutions can dissolve (hold) only a given number of solute particles. Once this solution contains all the solute particles that it can "hold," any additional solute will settle to the bottom of the container.

Once this point has been reached, the solution is said to be saturated. As stated, there is an equilibrium between dissolved and undissolved solute. More clearly, this is to say that dissolved solute is continuously leaving the solution and entering into the crystal lattice of the undissolved solute. At the same time, undissolved solute is leaving the crystalline state and entering into solution.

2-9. UNSATURATED SOLUTIONS

An unsaturated solution is one that does not contain all the solute molecules that the solution could possibly "hold."

Section III. PERCENT CONCENTRATION

2-10. DISCUSSION

The simplest solution to prepare in the laboratory is the percent solution. The main reason that this type of solution is commonly used is the ease in calculating the amount of solute needed in its preparation. The term percent is a shortened form of percentage which means parts per 100 total parts. This method is used with all three of the basic comparisons of percent concentration statements, that is, weight/weight, weight/volume, and volume/volume. The percent weight/weight is not commonly used in the clinical laboratory.

2-11. WEIGHT/VOLUME PERCENT SOLUTIONS (w/v)

a. The weight per unit volume system of percent concentration is the most frequently used method in the clinical laboratory. This method is used when a solid solute is mixed with a liquid solvent. Since percent is parts per 100 parts of total solution, then a w/v unit would be grams of solute per 100 milliliters of total solution (g/100 mL). In the clinical laboratory and related situations, any time a w/v solution is described by a number followed by a percent symbol (%), the concentration of the solution is expressed as grams per 100 mL (g/100 mL). Since 100 milliliters is equal to one deciliter, then a percent w/v concentration can be expressed as grams per deciliter (g/dL).

b. Another expression of w/v percent concentration used in the laboratory involves the use of fractional parts of the gram while retaining the unit of volume of solution. Examples of this kind would be milligram per deciliter or milligram percent. These may be expressed as mg/dL, mg/100 mL, or mg%.

c. The formulas used in this section have been derived from ratio and proportion based on the definition of a percent solution. For example, if a 5.0 g/dL solution of NaCl is to be prepared with a volume of 50 mL, how much NaCl would be required?

<u>NOTE</u>: In this review text math problems will be worked with an appropriate formula derived from definitions of terms, with the use of dimensional analysis or both.

d. Based on the definition, if one deciliter of solution (100 parts) contains 5.0 grams, then how many grams are in 50.0 mL (0.50 dL)?

By ratio and proportion, we would solve as follows:

(1) $\frac{5.0\text{ g}}{1\text{ dL}} = \frac{x\text{ g}}{0.50\text{ dL}}$

(2) $x\text{ g} = \frac{5.0\text{ g} \times 0.50\text{ dL}}{1\text{ dL}}$

(3) $x\text{ g} = 2.5\text{ g}$

(4) The formulas used for solving w/v percent problems are:

g = (g/dL) (dL) and mg = (mg/dL) (dL)

e. The problem stated above may be solved using **dimensional analysis** (see Appendix E).

Solution. By dimensional analysis, we would solve as follows:

After reading the problem carefully it should be evident that the desired quantity is the amount of solute expressed in grams.

Express the volume in dL

$$50.0\text{ mL} \times \frac{1\text{ dL}}{100\text{ mL}} = 0.500\text{ dL}$$

Multiply the volume expressed in deciliters times the percent concentration to determine the amount of solute contained in the specified amount of total solution.

$$0.500\text{ dL} \times \frac{5.0\text{ g}}{\text{dL}} = 2.5\text{ g}$$

f. Examining the solution reveals that the given volume in milliliters is first converted to deciliters, using the appropriate conversion factor. The volume of solution expressed in deciliters is then multiplied by the weight per volume concentration to yield the desired quantity, mass of solute expressed in grams per given volume. Notice that if the correct factor is used the unwanted units cancel out.

2-12. SOLVING WEIGHT/VOLUME PROBLEMS

The first step in solving any solution problems is to carefully read the problem. Remember that a unit of concentration consists of two components a weight (or volume) and a volume, thus w/v. Also notice that in reading the problem, the wording will suggest that a solution is to be prepared. Words such as "prepare" or "make" will be used in this type of problem. When making a percent solution, three things are necessary, that is, mass of solute needed, concentration of solution to be prepared, and total volume of solution.

Look at the formulas and see that all three of these requirements are met. Mass of solute is grams (or milligrams). Concentration of the solution is g/dL (or mg/dL). Total volume of solution is deciliters. In selecting a formula, find the unit of concentration that the solution is to be prepared in (g/dL or mg/dL) and use the formula containing that unit of concentration.

a. **Example.** How much NaCl is needed to make 2.0 liters of a 3.0 g/dL NaCl solution?

Solution. The first step of any problem is to read the problem carefully. Determine what the problem is asking for. You should then be able to select and write the correct formula based primarily upon unit of concentration. The unit of concentration is g/dL, therefore:

$$g = (g/dL)\ (dL)$$

Substitute the given information.

$$g = (3.0\ g/dL)\ (2.0\ L)$$

Make any necessary conversions.

$$g = (3.0\ g/dL)\ (20.0\ dL)$$

Solve for the unknown quantity.

$$\underline{60\ g} = (3.0\ g/dL)\ (20.0\ dL)$$

Solution using dimensional analysis. Determine what the problem is asking for.

Grams of solute (NaCl)

Express the volume in deciliters

$$2.0\ L \times \frac{10\ dL}{1\ L} = 20\ dL$$

Multiply the volume expressed in deciliters times the percent concentration to determine the grams of NaCl contained in 2.0 liters of a 3.0 g/dL solution.

$$20\ dL \times \frac{3.0\ g}{dL} = 60\ g$$

b. **Example.** How many milliliters of solution can be prepared from 62.5 mg of K_2SO_4 if the desired concentration is 12.5 mg/dL?

Solution. Read the problem carefully and determine what the problem is asking for, then based upon the unit of concentration, select the formula that will allow you to solve for the unknown quantity.

$$mg = (mg/dL)\ (dL)$$

Substitute the given information and solve for the unknown quantity.

$$62.5\ mg = (12.5\ mg/dL)\ (dL)$$

$$\frac{62.5\ mg}{12.5\ mg/dL} = 5.00\ dL$$

Convert deciliters to milliliters.

$$5.00\ dL \times \frac{100\ mL}{1\ dL} = 500\ mL$$

Ratio and proportion is also well suited for solving this type of problem.

$$\frac{12.5\ mg}{1\ dL} = \frac{62.5\ mg}{x\ dL}$$

Solve for the unknown quantity.

$$(12.5\ mg)\ (x\ dL) = (62.5\ mg)(1\ dL)$$

$$\frac{(62.5\ mg)(1\ dL)}{12.5\ mg} = x\ dL = 5.00\ dL$$

To completely satisfy the problem, convert deciliters to milliliters.

$$5.00\ dL \times \frac{100\ mL}{1\ dL} = 500\ mL$$

c. **Example.** What is the % concentration of a solution that was prepared by adding 50.0 g $CaCO_3$ to a 250.0 mL flask and adjusting the volume to the mark?

Solution. Read the problem carefully and determine what the problem is asking for. Then, based upon the unit of concentration, select the formula that will allow you to solve for the unknown quantity.

$$g = (g/dL)\ (dL)$$

Substitute the given information.

$$50.0\ g = (g/dL)\ (250.0\ mL)$$

Make the necessary conversions.

$$50.0\ g = (g/dL)\ (2.500\ dL)$$

Solve for the unknown quantity.

$$\frac{50.0\ g}{2.500\ dL} = g/dL$$

g/dL = 20.0 g/dL or equivalently, 20.0% (w/v)

Solution using dimensional analysis. Determine what the problem is asking for.

Percent (%) concentration. Solving this type of problem involves expressing the mass of solute per unit volume.

Since the unit volume is deciliters the first step in problem solving would be to convert the given volume in milliliters to deciliters.

$$250\ mL \times \frac{1\ dL}{100\ mL} = 2.50\ dL$$

The most direct approach to conclude solving the problem would be to simply express the given information as weight per volume and to evaluate the numerical data as follows.

$$\frac{50.0\ g}{2.50\ dL} = 20.\ g/dL \text{ or equivalently, } 20.0\ \%$$

Ratio and proportion could also be used to determine the concentration of the solution obtaining the same results.

$$\frac{50.0\ g}{2.50\ dL} = \frac{x\ g}{1\ dL}$$

$$(50.0\ g)(1\ dL) = (2.50\ dL)(x\ g)$$

$$x\ g = \frac{(50.0)(1\ dL)}{2.50\ dL} = 20.0\ g$$

Substituting for x in the original expression yields the desired results.

$$\frac{x\ g}{1\ dL} = \frac{20.0\ g}{1\ dL} = 20.0\ g/dL$$

2-13. HYDRATES

Some salts come in several forms, such as the anhydrous form (no water) and in the form of one or more hydrates. In a hydrate, a number of water molecules are attached to each molecule of salt. The water that is attached to the salt contributes to the molecular weight. Thus, if we were to weigh out equal amounts of a desired chemical and one of its hydrates, the hydrate would not yield as much of the desired chemical, per unit weight, as the anhydrous form, since some of the weight is attributable to the water molecules. In some cases, the prescribed form of a salt may not be available for the preparation of a solution. One must be able to determine how much of the available form is equivalent to the quantity of the form prescribed. To do this, we must first determine the amount of the prescribed form that is needed. Then, using the molecular weights of both substances involved, use ratio and proportion to determine the amount of available form needed.

a. **Example.** A procedure requires that 100 mL of a 10.0% $CuSO_4$ solution be prepared. Only $CuSO_4 \cdot H_2O$ is available. How much of the hydrate is needed to prepare this solution?

Solution. Read the problem carefully and determine which formula generates the desired quantity.

$$g = (g/dL)\ (dL)$$

Calculate the amount of the anhydrous form needed.

$$g = (10.0\ g/dL)\ (100\ mL)$$
$$g = (10.0\ g/dL)\ (1.00\ dL)$$
$$g = 10.0\ g$$

Dimensional analysis may also be used to calculate the amount of the anhydrous form needed.

$$100\ mL \times \frac{1\ dL}{100\ mL} \times \frac{10.0\ g}{1\ dL} = 10.0\ g$$

Calculate the gram molecular weight of each substance. (NOTE: You will learn more about gram molecular weights and moles in Lesson 3.)

(1) List each element in a column.

(2) Write the atomic weight of each element. (See Appendix C.)

(3) Multiply the weight of each element by the number of that element in the formula. For example, if there are 2 atoms of hydrogen present in the formula, multiply the weight of hydrogen by two.)

(4) Add the sum of the weights to obtain the total weight, and express the total weight in grams/mole.

$CuSO_4$ (anhydrous)

$$\begin{array}{llll} Cu & 63.5 \times 1 = & 63.5 \\ S & 32.1 \times 1 = & 32.1 \\ O & 16.0 \times 4 = & +\ 64.0 \\ \hline & & 159.6 \text{ g/mole} \end{array}$$

$CuSO_4 \cdot H_2O$ (hydrate)

$$\begin{array}{llll} Cu & 63.5 \times 1 = & 63.5 \\ S & 32.1 \times 1 = & 32.1 \\ O & 16.0 \times 4 = & 64.0 \\ H & 1.0 \times 2 = & 2.0 \\ O & 16.0 \times 1 = & +\ 16.0 \\ \hline & & 177.6 \text{ g/mol} \end{array}$$

If the amount of anhydrous salt needed is now multiplied by the ratio of the molecular weights of the hydrate to anhydrate the desired results will be obtained.

$$10.0 \text{ g } CuSO_4 \times \frac{177.6 \text{ g/mol } CuSO_4.H_2O}{159.6 \text{ g/mol } CuSO_4} = 11.1 \text{ g } CuSO_4.H_2O$$

Ratio and proportion may also be used to determine the amount of hydrate needed.

$$\frac{159.6 \text{ g/mol anhydrous}}{177.6 \text{ g/mol hydrate}} = \frac{10.0 \text{ g anhydrous}}{x \text{ g hydrate}}$$

Solve for x.

$$x \text{ g hydrate} = \frac{(177.6 \text{ g/mol hydrate})\ (10.0 \text{ g anhydrous})}{159.6 \text{ g/mol anhydrous}}$$

x = <u>11.1 g</u> of $CuSO_4 \cdot H_2O$ are needed to prepare the solution.

<u>NOTE</u>: Notice in this example that you needed a larger weight of the hydrated form to prepare a solution of equal strength. This is because a hydrate molecule weighs more than its anhydrous counterpart. The key is that the solution using a hydrate of a different form from the prescribed form will still react in the same manner in solution if it is prepared properly. Therefore, care must be taken when performing the calculation to ensure the proper amount is used.

b. **Example.** How much $Fe_2(SO_4)_3 \cdot 4H_2O$ is needed to prepare 500.0 mL of a 200.0 mg/dL $Fe_2(SO_4)_3$ solution?

Solution. Read the problem carefully and select the formula that generates the unknown quantity.

$mg = (mg/dL)\ (dL)$

Calculate the amount of the anhydrous form needed.

$mg = (200.0\ mg/dL)\ (500.0\ mL)$
$mg = (200.0\ mg/dL)\ (5.000\ dL)$
$mg = 1000\ mg$

Dimensional analysis may also be used to calculate the amount of the anhydrous form needed.

$$500.0\ mL \times \frac{1\ dL}{100\ mL} \times \frac{200.0\ mg}{1\ dL} = 1000\ mg$$

Calculate the gram molecular weight of each substance. (See Appendix C.)

$Fe_2(SO_4)_3$

Fe	55.8 X 2 =	111.6	
S	32.1 X 3 =	96.3	
O	16.0 X 12 =	+ 192.0	
		399.9	g/mol

$Fe_2(SO_4)_3 \cdot 4H_2O$

Fe	55.8 X 2 =	111.6	
S	32.1 X 3 =	96.3	
O	16.0 X 12 =	192.0	
H	1.0 X 8 =	8.0	
O	16.0 X 4 =	+ 64.0	
		471.9	g/mol

Use ratio and proportion to determine the amount of hydrate needed.

$$\frac{399.9\ g/mol\ anhydrous}{471.9\ g/mol\ hydrate} = \frac{1000\ mg\ anhydrous}{x\ mg\ hydrate}$$

$$x\ mg\ hydrate = \frac{(1000\ mg\ anhydrous)\ (471.9\ g/mol\ hydrate)}{399.9\ g/mol\ anhydrous}$$

$x\ mg\ hydrate = 1180\ mg$

c. **Example.** How many grams of $CaCl_2 \cdot 2H_2O$ are needed to make 1.00 liter of a 20.0 mg/dL $CaCl_2$ solution?

Solution. Read the problem carefully and select the formula that generates the unknown quantity.

$mg = (mg/dL)\ (dL)$

Calculate the amount of the anhydrous form needed.

$$mg = (20.0\ mg/dL)\ (1.00\ L)$$
$$mg = (20.0\ mg/dL)\ (10.0\ dL)$$
$$mg = 200\ mg \text{ or equivalently, } 0.200\ g$$

Dimensional analysis may also be used to calculate the amount of the anhydrous form needed.

$$1.00\ L \times \frac{10\ dL}{1\ L} \times \frac{20.0\ mg}{1\ dL} = 200\ mg$$

Calculate the gram molecular weight of each substance. (See Appendix C.)

$CaCl_2$

Ca	40.1	X 1 =	40.1	
Cl	35.5	X 2 =	+ 71.0	
			111.1	g/mol

$CaCl_2 \cdot 2H_2O$

Ca	40.1	X 1 =	40.1	
Cl	35.5	X 2 =	71.0	
H	1.0	X 4 =	4.0	
O	16.0	X 2 =	+ 32.0	
			147.1	g/mol

Use ratio and proportion to determine the amount of hydrate needed.

$$\frac{111.1\ g/mol\ \text{anhydrous}}{147.1\ g/mol\ \text{hydrate}} = \frac{0.200\ g\ \text{anhydrous}}{x\ g\ \text{hydrate}}$$

$$x\ g\ \text{hydrate} = \frac{(147.1\ g/mol\ \text{hydrate})\ (0.200\ g\ \text{anhydrous})}{111.1\ g/mol\ \text{anhydrous}}$$

$$x\ g\ \text{hydrate} = \underline{0.265\ g}$$

2-14. VOLUME/VOLUME PERCENT SOLUTION PROBLEMS (v/v)

When a solution has a liquid solute in a liquid solvent, percent concentration is expressed as volume per unit volume (v/v). When a number expressing a liquid solute in a liquid solvent is followed by a percent symbol (%), then the concentration is a v/v concentration.

a. **Formula.** mL = (mL/dL) (dL).

b. **Problem Solving.** Methods developed earlier for solving weight per volume solutions may be applied to volume per volume solutions.

c. **Example.** How much alcohol is required to make 100 mL of a 20.0 mL/dL alcohol solution?

Solution. Read the problem carefully and select the formula that generates the unknown quantity.

mL = (mL/dL) (dL)

Substitute the given values.

mL = (20.0 mL/dL) (100 mL)

Make any necessary conversions.

mL = (20.0 mL/dL) (1.00 dL)

Solve for the unknown quantity.

<u>20.0 mL</u> = (20.0 mL/dL) (1.00 dL)

Use **dimensional analysis:** Determine the unknown quantity.

Milliliters of alcohol.

Express the volume in deciliters

$$100 \text{ mL} \times \frac{1 \text{ dL}}{100 \text{ mL}} = 1.00 \text{ dL}$$

Multiply the volume expressed in deciliters times the percent concentration to determine the volume of solute needed to prepare the solution.

$$1.00 \text{ dL} \times \frac{20.0 \text{ mL}}{\text{dL}} = 20.0 \text{ mL}$$

d. **Example.** What is the concentration of a solution that was prepared by adding 75 mL of alcohol to enough water to make 250 mL total volume?

Solution. *Read the problem carefully and select the formula that* generates the unknown quantity.

<u>NOTE</u>: 75 mL of alcohol was added to enough water to yield a total volume of 250 mL. This is a volume-per-volume problem.

mL = (mL/dL) (dL)

Substitute the given values.

75 mL = (mL/dL) (250 mL)

Make any necessary conversions.

$$75 \text{ mL} = (\text{mL/dL})\ (2.50 \text{ dL})$$

Solve for the unknown quantity.

$$\text{mL/dL} = \frac{75 \text{ mL}}{2.5 \text{ dL}}$$

$\text{mL/dL} = \underline{30 \text{ mL/dL}}$ *or equivalently, 30%*

Use dimensional analysis to solve the problem

Since the unit volume is deciliters, convert the given volume in milliliters to deciliters.

$$250.0 \text{ mL} \times \frac{1 \text{ dL}}{100 \text{ mL}} = 2.50 \text{ dL}$$

To conclude solving the problem express the volume of solute per unit volume and evaluate the numerical data as follows.

$$\frac{75 \text{ mL}}{2.50 \text{ dL}} = 30 \text{ mL/dL or equivalently } 30\ \%$$

2-15. WEIGHT/WEIGHT PERCENT SOLUTIONS (w/w)

This type of percent solution is usually expressed as (w/w), where "w" denotes weight (usually grams) in both cases. An example of a correct designation for this type of solution is as follows: 10 g/100 g (w/w), which indicates to the technician that there are 10 grams of solute for every 100 grams total solution. The (w/w) denotes that the solution is a "weight in weight" percent solution. This type of solution is rarely if ever prepared in the clinical laboratory since it is easier to measure volumes of liquids rather than weigh the liquid on an analytical balance. When one is dealing with acids or bases, one must be familiar with w/w solutions because the common laboratory acids and bases are manufactured on a weight-in-weight basis.

2-16. PERCENT COMPOSITION PROBLEMS

At times it may be necessary to prepare a percent solution that requires only part of the entire molecule to be considered in the preparation of the solution. For example, you may wish to prepare a 2.5 g/dL sodium (Na^+) solution from NaCl. Since the entire molecule is used in the preparation of the solution, ratio and proportion will have to be used, based on the molecular weight of the entire molecule versus the molecular weight of the portion of the molecule being considered.

a. **Example.** How much NaCl is required to prepare 500 mL of a 2.5 g/dL sodium solution?

Solution. Read the problem carefully and select the formula that generates the desired quantity.

$$g = (g/dL)\ (dL)$$

Calculate the amount of the prescribed form needed.

$$g = (2.5\ g/dL)\ (500\ mL)$$
$$g = (2.5\ g/dL)\ (5.00\ dL)$$
$$g = 12.5\ g$$

Use **dimensional analysis:** Read the problem carefully and determine the desired quantity.

Grams of NaCl

Calculate the amount of sodium needed.

$$500\ mL \times \frac{1\ dL}{100\ mL} \times \frac{2.5\ g}{1\ dL} = 12.5\ g$$

Calculate the gram molecular weight of each substance. (See Appendix C.)

Na	23.0	Na 23.0 g/mol
Cl	+ 35.5	
	58.5 g/mol	

Use **ratio and proportion** to determine the amount of available form needed.

$$\frac{23.0\ g/mol\ Na}{58.5\ g/mol\ NaCl} = \frac{12.5\ g\ Na}{x\ g\ NaCl}$$

$$x\ g\ NaCl = \frac{(12.5\ g\ Na)\ (58.5\ g/mol\ NaCl)}{23.0\ g/mol\ Na}$$

$$x\ g\ NaCl = \underline{31.8\ g}$$

b. **Example.** How many milligrams of Na_2CO_3 are needed to prepare 100 mL of a 10.0 mg/dL sodium standard?

Solution. Read the problem carefully and select the formula that generates the unknown quantity.

$$mg = (mg/dL)\ (dL)$$

Calculate the amount of the prescribed form needed..

$$mg = (10.0\ mg/dL)\ (1.00\ dL)$$
$$mg = 10.0\ mg$$

Dimensional analysis may also be used to calculate the amount of sodium needed.

$$100 \text{ mL} \times \frac{1 \text{ dL}}{100 \text{ mL}} \times \frac{10.0 \text{ mg}}{1 \text{ dL}} = 10.0 \text{ mg}$$

Calculate the gram molecular weight of each substance.

Na 23.0 X 2 =	46.0	Na 23.0 X 2 =	46.0
C 12.0 X 1 =	12.0		46.0 g/mol
O 16.0 X 3 =	+ 48.0		
	106.0 g/mol		

Use ratio and proportion to determine the amount of available form (Na_2CO_3) needed.

$$\frac{46.0 \text{ g/mol Na}}{106.0 \text{ g/mol } Na_2CO_3} = \frac{10.0 \text{ mg Na}}{x \text{ mg } Na_2CO_3}$$

$$x \text{ mg } Na_2CO_3 = \frac{(106.0 \text{ g/mol NaCl})\ (10.0 \text{ mg Na})}{46.0 \text{ g/mol Na}}$$

$$x \text{ mg } Na_2CO_3 = \underline{23.0 \text{ mg}}$$

NOTE: 23.0 mg of Na_2CO_3 are needed to make a 10.0 mg/dL sodium standard.

2-17. ADVANTAGES AND DISADVANTAGES OF PERCENT SOLUTIONS

The main advantage of percent solutions is the ease in calculations. There are, however, two distinct disadvantages associated with percent solutions: (1) the technician does not know the number of molecules or ions that are present in the solution, and (2) the technician has no idea of the reacting strength of the solution.

EXERCISES, LESSON 2

REQUIREMENT. The following exercises are to be answered by writing the answer in the space provided at the end of the question. After you have completed all the exercises, turn to "Solutions to Exercises," at the end of the lesson and check your answers with the review solutions.

1. Which type of mixture is not homogenous throughout?

____

2. What amount of Na_2SO_4 is needed to make 2000 mL of a 30.0% Na_2SO_4 solution?

____

3. How many milligrams of NaCl are present in 5.0 mL of a 20.0 mg/dL NaCl solution?

____

4. How much HCl is needed to prepare 1.0 L of a 0.50 mL/dL HCl solution?

____

5. How many mL of water must be added to 30.0 mL of toluene in order to prepare a 10.0 mL/dL toluene solution?

____

6. How many mL of 5.0% tungstic acid can be prepared from 40.0 grams of acid?

____

7. A solution was prepared by adding 920 mg of KCl to a 250-mL flask. The flask was then filled to the mark with water. What is the % concentration of the solution?

____

8. How many grams of $Mg_3(PO_4)_2$ are needed to prepare 500 mL of a 4.0 mg/dL Mg standard?

____

9. What amount of $Na_2SO_4 \cdot 4H_2O$ is needed to make 2.0 liters of a 25.0 mg/dL Na_2SO_4 solution?

____

10. How many grams of $MgCl_2 \cdot 8H_2O$ are needed to make 250 mL of a 3.00 g/dL $MgCl_2$ solution?

____

11. You are asked to make the following solutions. How much solute would you need for each?

a. 600 mL of a 2.0% (w/v) solution.

____

b. 1900 mL of a 0.80 % (w/v) strength.

____

c. 770 mL of a 0.60 g/dL solution.

____

d. 16.0 mg/dL solution of 250 mL volume.

____

e. 140 mL of a 3.0 mg/dL strength.

____

f. 1300 mL of 30.0% HCl (v/v).

____

12. How much $Fe_2(SO_4)_3$ is needed to make 5000 mL of a 0.500 g/dL iron standard?

____

13. How much KCl is needed to prepare 250 mL of a 4.5 g/dL potassium standard?

____

SOLUTIONS TO EXERCISES, LESSON 2

1. Colloidal dispersion (paras 2-6)
2. 600 g (paras 2-11, 2-12)
3. 1.0 mg (paras 2-11, 2-12)
4. 5.0 mL (paras 2-11, 2-14)

5. 270.0 mL (para 2-14)

(NOTE: First calculate total volume (300 mL). This includes both the water and the toluene. Subtract 30 mL (amount of solute) to get the volume of water needed.)

6. 800.0 mL (paras 2-11, 2-12)

7. .368% (para 2-11, 2-12)

8. .072 g (para 2-16)

9. 0.75 g (para 2-13)

10. 18.8 g (para 2-13)

11. a. 12.0 g (paras 2-11, 2-12)
    b. 15.2 g (paras 2-11, 2-12)
    c. 4.6 g (paras 2-11, 2-12)
    d. 40.0 mg (paras 2-11, 2-12)
    e. 4.2 mg (paras 2-11, 2-12)
    f. 390.0 mL (paras 2-14)

12. 89.6 g (paras 2-16)

13. 21 g (paras 2-16)

NOTE: When preparing a solution in which acid is diluted, always fill the volumetric flask approximately half full with deionized water, then slowly add the acid. This is an exothermic reaction (heat is produced), and the solution must be cooled to room temperature before adjusting the volume to the mark.