Notes on Basic Laboratory Mathematics, Laboratory Solutions & Some Practice Problems

I. Ratios & proportions

A. A ratio is the relationship between two quantities. For example a car is traveling at 50 miles per hour, which reflects the relationship between speed and time. A ratio can be expressed as a fraction: 30 miles/gallon or 10 ounces/1 cake.

B. A proportion is a statement that two ratios are equal. For example, if 10 oz of chocolate are required to make 1 cake, then 20 oz of chocolate are needed to make 2 cakes. Proportionally, 1 cake/10 oz chocolate = 2 cakes/20 oz chocolate.

C. To solve for unknowns in proportionalities:

1. If 3 cakes require 16 oz of chocolate then how many ounces are required for 5 cakes?

16 oz/3 cakes = ?/5 cakes

Solve for ?

16 oz/3 ~~cakes~~ x 5 ~~cakes~~ = ?

? = 27 oz of chocolate needed for 5 cakes

D. <u>Sample problems</u> (answers for all problems at end of document)

1. If there are about 1×10^{2} blood cells in a 1.0×10^{-2} mL (milliliter; milliliter = 1/1,000 of a liter) sample, then about how many blood cells would be in 1.0 ml of this blood?
2. 30 g (grams) of NaCl are needed to make 1 L (liter) of salt solution. How much NaCl is needed to make 250 ml of salt solution?

II. Density

A. Density is the ratio between the mass and volume of a material (density = mass/volume). For example, the density of benzene is 0.880 g/ml (grams/ml).

B. <u>Sample problem</u>

1. The density of glycerol at 20^{o}C is 1.26 g/ml. What is the volume of 20.0 g of glycerol

III. Concentration

A. Concentration is the amount of a substance in a specific volume (or sometimes mass) of a solution or mixture. The substance that is dissolved is called the solute and the liquid is called the solvent. Remember concentration and amounts are NOT synonymous. Amount is how much of a substance is present (e. g. 4 grams, 2 cups, or 1 teaspoon). Whereas concentration is a ratio with a numerator (amount) and a denominator (usually volume).

B. Since concentration is a ratio, problem solving for unknowns is the same as for proportions.

C. Sample problems
    1. If a solution requires a concentration of 3 g of NaCl in 250 ml, then how much NaCl is needed to make a solution of 1 L?
    2. If a solute has a concentration of 0.1 moles/L, how much solute is present in 1 µL (microliter = 1/1,000,000 of a L) of solution?
    3. If a solution contains 3 g/mL of compound A, how much compound A is present in 1 L of solution?
    4. A solution has 5 µg/L (microgram = 1/1,000 of a gram) of enzyme Q. How much enzyme Q is present in:
        a. 50 mL of solution
        b. 500 mL of solution
        c. 100 mL of solution

IV. Dilutions

A. A dilution is when one substance (often, but not always, water) is added to another to reduce the concentration of the first substance. The original substance being diluted may be called the Stock Solution, whereas the diluting substance is called the Diluent. For example, a 1 in 10 dilution is accomplished by adding 1 ml of stock solution to 9 ml of diluting solution.

B. The concepts of dilutions and proportions are related. A dilution can be written as a ratio, 1 ml/10 ml (1 in 10 dilution). A 1 in 10 dilution can be accomplished in a number of ways and are proportional: 1 ml/10 ml = 10 ml/90 ml.

C. Dilution terminology:
    1. 1 part of a stock solution diluted by 9 parts of diluent is 1 part in 10 ml total volume or a 1/10 dilution.
    2. An undiluted substance, by definition is called 1/1.
    3. When talking about dilutions, the symbol : means parts. 1 ml of stock in 10 ml diluent is written as 1:9 (1 part stock in 9 parts diluent). Additional examples, 1:2 means 1 part stock in 2 parts diluent (3 parts total), 1/2 means there are 2 parts total volume (1 part stock in 1 part diluent).

D. Many dilutions will involve concentrations, so remember to keep track of your concentrations when performing these types of dilutions. For example, a stock has a concentration of 2 mg (milligrams = 1/1,000 of a gram), a dilution is made by removing 1 ml stock and placing it in 14 ml of water. The dilution is 1:14 or 1/15. What is the concentration of the diluted solution?

    20 mg/L x 1/15 = 1.3 mg/L

    1. The concentration of a solution is determined by multiplying the concentration of the original solution times the dilution (expressed as a fraction).

E. Sample problems:
    1. Suppose you have 20 µL of a very expensive enzyme and you cannot afford to purchase more. Its concentration is 1000 Units/mL. You are performing an experiment that requires tubes

with a concentration of 1 Unit/mL of enzyme and each tube will have 5 mL total volume. How much does each tube require? How many tubes can you prepare before you run out of enzyme?

2. If you prepare a 1/40 dilution of a 50% solution, what is the final concentration of the solution?
3. If you prepare a 1/10 dilution of a 10 mg/mL solution, what is the final concentration of the solution?
4. How much 1/5 diluted solution can be made if you have 1 mL of original solution?

V. Solutions

A. Solutions always involve concentrations although such ratios are not readily evident in some cases. Recipes for solutions can express concentrations in a number of ways, for example weight per volume, molarity or percentage.

B. Weight per volume is the simplest manner of expressing a concentration. For example, 10 mg/mL of proteinase K.

C. Molarity is the number of moles of a substance dissolved in 1 L of solution. Of course, a mole of any element contains 6.02×10^{23} atoms (Avagadro's number). The weight of a mole of a given element is equal to its atomic weight in grams, or its gram atomic weight (more properly given as mass).

1. Compounds are composed of atoms of two or more different elements bonded together. The gram formula weight (FW) or gram molecular weight (MW) of a compound is the weight in grams of 1 mole of the compound.

D. Percents are always expressed with the numerator representing the amount of solute and the denominator is 100 units of total solution. There are generally two ways in which percentages are expressed.

1. Weight per volume (w/v) is the weight of the solute (in grams) in 100 mL of solution. For example, 20 g of NaCl in 100 mL of total solution is a 20% (w/v) solution.
2. Volume percent (v/v) is when both the amount of solute and total solution are expressed in volumes. For example, 10 mL of ethanol in a total solution of 100 mL is a 10% solution.

E. Sample problems:

1. How much proteinase K is needed to make up 250 µL of a 10 mg/mL solution?
2. How much solute is required to make 250 mL of a 1 M (molar) solution of KCl (FW = 74.55)?
3. How much solute is required to make up 600 mL of a 0.4 M solution of Tris buffer (FW of Tris = 121.10)?
4. How would you prepare 10 L of 0.3 M KH_2PO_4 (FW = 136.09)?
5. How would you prepare a 35 mL of a 95% (v/v) solution of ethanol?
6. How would you prepare 600 mL of a 15% (w/v) solution of NaCl?