“EEWWWW…. CHEMISTRY!!”
Or, “dumb math problems Dr. Moss says I gotta know how to do for lab….”

I’m not going to collect these assignments and grade them. However, there WILL be at least one “math question” on each exam. To answer it you'll need to master the skills displayed here. So I do suggest you practice these problems, and others like them, until you’re comfortable with them!

Definitions you’ll need:
SOLUTE: The molecule or molecules in solution that you care about, such as DNA, a protein, or a salt.
SOLVENT: The liquid that the solute is dissolved in.

IMPORTANT NOTE ON UNITS:
Often beginning science students will do calculations writing down only numbers in their notebooks, without the units. This is a terrible idea, and will cause you to make lots of mistakes! KEEP YOUR UNITS! Every number you write down should have some units written with it! Imagine you’re taking a trip, and you ask the driver how far you are from your destination. The driver responds, “Six”. Does that really help? Six miles? Six minutes? Six hours? Six kilometers? Or six yards?

IMPORTANT NOTE ON CHECKING YOUR ANSWERS:
Whenever you do any kind of quantitative problem, you should calculate the answer, AND then check to see if it makes sense. For instance, if you are “diluting” a 1 molar solution by adding water, and yet you calculate that the final solution is GREATER than 1 molar, you should be able to notice that you must have made an error. If you calculate that you are going to make a solution by adding a kilogram of solute to a milliliter of water, you must have made an error… You should be able to “picture” a kilogram of solute, and a milliliter of water, and know that you couldn’t dissolve the former in the latter.

1. **CONCENTRATION OF A SOLUTION:** This is the amount of solute present in a given volume of solution. The concentration can be expressed in many different ways, such as moles per liter, mass per liter, or %. But most commonly solutions are given in molarity (M), or “molar” [moles per liter]. This is the number of moles of solute per liter of solution:

\[
\text{Molarity} = \frac{\text{moles solute}}{\text{liters of solution}}
\]

or

Concentration in % (w/v) = 100 x (mass solute in g) / (volume solution in mL)

Sample problems:
A. What’s the concentration of a solution containing 0.1 moles of NaCl in 0.25 liters of water?

B. Vinegar is about 3% acetic acid (weight/volume). How many grams of acetic acid are there in 100 ml of vinegar?

2. **MASS FROM CONCENTRATION**
Sometimes you need at extremely small mass of a molecule, such as 1 µg of DNA. We don’t have scales capable of measuring such small masses. So instead, we have the molecule in solution, and calculate what volume we need that will contain that mass.

\[
\text{Volume} = \frac{\text{Mass}}{\text{Concentration}}
\]

**Volume = Mass / Concentration**

You don’t need to memorize this; I never remember it. Just check your units:
[liters]= [grams] / [grams/liter]

SAMPLE PROBLEMS:
A. You need 1 µg of DNA. You have a stock that is 50 µg/ml. How much will you use?
B. Mercury has a density of 13.5 g/mL. How many grams of mercury does 50 mL weigh?

3. **CHANGING UNITS:**
Whenever a problem has two different units for mass, or for volume for instance, you will need to convert one to the other.

There are many ways to change units. If you’re comfortable with the method you use, stick with it.
You may be used to multiplying by a conversion factor for instance, such as 1000 mg/g. If that works with you, stick with it!
I believe the easiest method for beginners is to change all units to “scientific notation”. For example, altering the previous problem slightly:
You need 4 µg of DNA. You have a stock that is 2 mg/mL. How much will you use?
The formula is “V = Mass/Concentration”
Yet here, mass is in micrograms; and concentration is in MILLIGRAMS per mL. So let’s convert both mass terms into scientific notation and fill in the formula:
V = 4 x 10^{-6} g / (2 x 10^{-3} g/mL) = 2 x 10^{-3} mL = 2 x 10^{-6} liters

**UNITS YOU’LL FREQUENTLY SEE IN BIOLOGY:**
- Mass: g grams
- Volume: L liter
- Length: m meter
- Concentration: M molar

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<tr>
<th>Prefix</th>
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<td>Femto</td>
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<td>10^{-15}</td>
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**SAMPLE PROBLEMS:**
A. You’ve measured a molecule that is 0.0001 cm long. How many meters long is this molecule?
B. The mass of a molecule is 0.000000002 mg. Determine its mass in picograms.
C. Convert 155 nanoliters into liters.

4. **MAKING A “MOLAR” SOLUTION FROM SOLID SOLUTE:**
You need to calculate the weight of solute to add to the solvent. There is one formula you need to know for mixing up any solution from solid solute:

\[ \#g = M \times V \times MW \]

Always check your units to make sure you’ve remembered the equation correctly:
- Molarity = moles/liter; MW = grams/mole, and Volume = Liters.
So the formula becomes:

\[ \#g = (\text{moles/liter}) \times (\text{grams/mole}) \times \text{liters} \]

Moles/moles cancel, as do liters/liters. So you end up with
\[ \#g = \#g; \text{ the formula is correct.} \]

When figuring out the problems, don’t forget to keep your units!!
Sample problems:

A. How would you make a 100 mL of a 0.1M NaCl solution [MW=58 g/mole]

Use the formula. The only “trick” here is that the volume isn’t in liters; it’s in milliliters. You need to convert the 100 mL to 0.1 liters first [see the ‘UNIT CONVERSIONS” section if you need help with that]

B. You have 3 g of NaCl [MW=58]. You need a 1M solution. How much solution can you make?

Use the formula. This time, you’re solving for V.

5. MAKING A % SOLUTION FROM A SOLID SOLUTE:
Sometimes in biology, rather than using molarity, we’ll make solutions that are a certain “percent” of solute. Here, we generally refer to what chemists would call a “weight-volume” solution. That is, the % represents the portion of the weight of a certain volume of solution that will be solute.

That sounds complicated, but it’s not, once you get the hang of it. By definition, at standard conditions, 1 mL of water weighs one gram. So pure water is 100% water. But if we now have 10 mg of NaCl in a mL [1 gram] of solution, that 10 mg represents 1% of the weight of the solution [ignoring any change in the density of the solution]. So:

weight/volume % = (grams of solute)/(volume of solution) [x 100 to make it a percent]

Put another way,

weight/volume % = (grams of solute)/(100 mL of solution)

Sample Question: How much NaCl is in a 100 mL of a 5% solution?

6. DILUTIONS:
Whenever you need to go from a more concentrated solution [“stock”] to a less concentrated one, you add solvent [usually water] to “dilute” the solution. No matter what the units of concentration are, you can always use this one formula:

\[ C_s V_s = C_f V_f \]

[Concentration of the stock] x [Volume of the stock] = [Concentration of the final solution] x Volume of the final solution

It doesn’t matter what the units of C and V are; but of course they’ll have to be the same on each side of the equation. Keep your units!

Sample problem:
A. You have a DNA solution that is 50 µg [micrograms] / mL. You need 1 mL of 10 µg /mL. How would you make this?

Use the formula. \( C_s = 50 \text{ µg/mL}; \ C_f = 10 \text{ µg/mL}; \ V_f = 1 \text{ mL} \)

C. You measure 5 mL of 1M acetic acid, add it to a 100 ml graduated cylinder, and add water until it reaches the 100 ml mark. What’s the concentration of acetic acid in the final solution?

Use the same formula. \( C_s = 1\text{M}; \ V_s = 5 \text{ mL}; \ V_f = 100 \text{ mL} \)

D. Now using the diluted acetic acid you just made, you want to make a second dilution, to create 50 mL of a 0.03 M acetic acid solution. How would you do this?

Use the formula again, using the “final” solution from the previous problem as the new “stock”. So \( C_s = 0.05 \text{ M}; \ C_f = 0.03 \text{ M}; \ V_f = 50 \text{ mL} \).
7. MORE SAMPLE PROBLEMS:
   a. What is the molarity of a solution containing 15 g of NaCl [MW=58] in 200 mL?
   b. You need to administer 10 mg [milligrams] of epinephrine to a patient to save her life. The bottle reads 200 µg /mL [micrograms per milliliter]. How much will you administer?
   C. A 10 mL sample of water was found to have 30 mg of NaCl. What’s the concentration of NaCl [MW=58], in moles per liter?
ANSWERS:

SECTION 1:
A. 0.4 molar
B: $3 = \frac{100 \times \text{grams}}{100 \text{ mL}}$
   $3 = \text{grams}$

SECTION 2:
A. Volume = (1 µg)/(50 µg/ml)
   0.02 mL
B: Use the formula: 50 mL = mass / (13.5 g/mL)
   mass = 50 mL x (13.5 g/mL) = 675 g

SECTION 3:
A. $10^{-4} \times 10^{-2} \text{ m} = 10^{-6} \text{ meters, or 1 µm.}$
B. $2 \times 10^{-9} \times 10^{-3} \text{ g} = 2 \times 10^{-12} \text{ g; 2 picograms.}$
C. $155 \times 10^{-9} \text{ liters, better expressed as } 1.55 \times 10^{-7} \text{ liters.}$

SECTION 4:
A. 0.58 g NaCl plus enough water to bring volume to a liter.
B. 52 mL.

SECTION 5: 5 g.

SECTION 6:
   a. 200 µL of stock, plus 800 µL of water, to give a final volume of 1 mL
   b. 0.05 M acetic acid.
   c. 30 mL of the previous “stock”, plus 20 mL of water.

SECTION 7:
   a. $15 \text{ g} / (58 \text{ g/mole}) = 0.26 \text{ moles}$
   $0.26 \text{ moles} / 0.2 \text{ liters} = 1.3 \text{ molar}$
   b. 50 mL
   c. 0.052 moles/liter