Measurements and Solutions

Measuring specific amounts of liquids and solids and making solutions of chemicals at precise concentrations are skills you will use frequently in Biology labs. The outcome of your experiment can depend on how accurately you measure, so it's important that you take the time to develop these skills. This section will give you a brief overview of some of the types of measurement you will use most often.

Metric measurements

All scientific measurements are made using the metric system—which is also the system used for all everyday measurements in all but the most backward countries! You should already be familiar with metric measurements, but the tables below will help you if you get stuck.

Metric units of measure

length	meters	m
mass (weight)	grams	g
volume	liters	l
temperature	degrees Celsius	°C
atomic mass	Daltons	Da

Basic metric prefixes and symbols:

Mega-	M	1,000,000 x	10^{6}
kilo-	k	1,000 x	10^{3}
(basic unit)		1 x	10^{0}
centi-	c	0.01 x	10^{-2}
milli-	m	0.001 x	10^{-3}
micro-	μ	0.000001 x	10^{-6}
nano-	n	0.000000001 x	10^{-9}
pico-	p	0.000000000001 x	10^{-12}

Temperature scale

water freezes	0 °C
water boils	100 °C
human body	37 °C
room temp.	~25 °C
refrigerator	4 °C
freezer	-20 °C

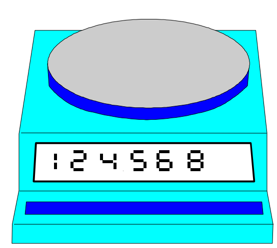
Conversions

1 inch = 2.54 cm
1 m = 39.4 inches
1 ounce (mass) = 28.3 g
1 kg = 2.2 pounds
1 ounce (fluid) = 29.6 ml
1 l = 1.06 quarts
1 Angstrom (Å) = 10^{-10} m
°C = 5/9 (°F - 32)
1 ml of water weighs 1 gram

How should I measure this?

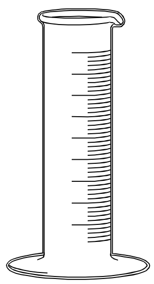
It doesn't matter how carefully you calculate the amount you need if you use the wrong measuring device! Your measurement won't be accurate if you use a small container to measure a large volume or a large container to measure a small volume. Some students just grab the first thing they think of and figure it'll be "close enough." Don't! Learn how to measure appropriately and how to use each instrument correctly.

Measuring mass. Mass (or weight) is measured with a balance. But different balances have different accuracies. Most of the digital balances in the department have readouts that show three decimal places. These could reasonably be used to weigh out as little as 10 mg (0.01 g) of a chemical. For more accuracy, the chemistry department has balances that display four decimal places and could be used to weigh out as little as 0.001 g.



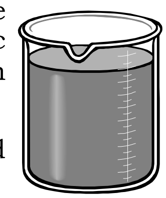
Never weigh a chemical directly on the pan of the balance. Weigh it into a beaker, a plastic weigh boat, or (for small amounts) a piece of weighing paper (folding the paper in half diagonally will provide a "spout" for easy pouring). The plastic weigh boats are expensive, so it's a good idea to use paper when you can. Place the boat or paper on the balance pan, press the "tare" or "zero" button, and wait for the balance to stabilize at zero before weighing the desired amount of the chemical. Don't cross-contaminate chemicals by using the same spatula without rinsing it. After you're done, clean up the balance thoroughly: chemicals left on the balance will corrode the balance and might create a hazard for the next user. If necessary, find out how to remove the pan and clean beneath it.

Measuring volume. Always *think!* and select an appropriate measuring device for the volume you are measuring. Rule of thumb: use the smallest measuring device that will still allow you to make only one measurement. If you have to measure more than once, the error increases with each measurement. The table below summarizes the accurate ranges for the three most common tools that you will use:



Volume Needed	Appropriate Tool
1 μl to 1 ml	micropipettor
1 ml to 10 ml	glass pipet
Greater than 10 ml	graduated cylinder

Of course, you still need to choose the most appropriate graduated cylinder or micropipettor for the specific job. For example, you wouldn't want to use a 500-ml graduated cylinder to measure 20 ml of a solution! Remember to read the *bottom* of the meniscus when making a volume measurement in a cylinder or pipette. Specific directions for using micropipettors (page ?) and glass pipettes (page 81) are given in separate sections of this guide.

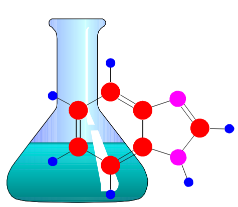


The lines on the sides of beakers and flasks are not accurate and should never be used for measuring volumes. They can be off by as much as 10%!

Making solutions

A solution which is not at the proper concentration can throw off your whole experiment! So you need to become very familiar with how to make a solution of a given concentration. Here are basic directions for making some commonly used types of solutions:

Molar concentrations. Recall from your chemistry classes that a **mole** is an amount of some molecule equal to its formula weight in grams. A concentration of **one molar** (**1 M**) is that amount dissolved in one liter of water. For example, the molecular mass of salt, NaCl, is 58 (you can check the periodic table or the label on the bottle), so 58 grams of NaCl is one mole, and a 1M solution is 58 grams dissolved in one liter of water. Notice that the terms 'mole' and 'molar' are not interchangeable! We often use rather dilute solutions in biology laboratories, so you will frequently be thinking in terms of **millimolar** (**mM**), which is 1/1000 (10^{-3}) molar. For example, a 100 mM solution of NaCl is the same as 0.1 M, or 5.8 grams per liter (0.1 × 58).



When making up a solution, remember that a solid chemical will add some volume to the solution. So, you would not want to measure 1000 ml of water and add 58 grams of salt to it—the total volume would then be a little more than a liter. Instead:

- Weigh out the solid and transfer it to a beaker of appropriate size
- Add about 80% of the final volume of water and stir to dissolve the solid
- Pour the solution into a graduated cylinder of appropriate size
- Add water carefully until the desired final volume is reached and mix

Percentage concentrations (w/v). Chemists will tell you there are several ways to make a solution based on percentage, but in biology, if we have a solid chemical, we always make percentage solutions based on weight per (total) volume (w/v). That is, a 1% solution means 1 gram of solid dissolved in a total volume of 100 ml.

We can determine the percent concentration by simply dividing the mass of the solid in grams by the final volume of the solution in ml (since for water, 1 ml = 1 g) and multiplying by 100. So, to make a 0.85% solution of NaCl (the same salinity as your blood), we'd dissolve 0.85 grams in 100 ml of water (pop quiz: what molarity would this be?).

Percentage concentrations (v/v). If you're adding a liquid to another liquid, then you would want to determine the percentage based on volume (v/v). This works the same way, except that you're dealing with a volume of solute instead of a mass. So, a 1% (v/v) solution is 1 ml of liquid diluted to a total volume of 100 ml. If you wanted to make a 70% ethanol solution (useful for disinfecting surfaces or skin), you would add 70 ml of ethanol to a 100-ml graduated cylinder and then add water to a total volume of 100 ml.

Absolute concentrations. Sometimes, you'll be given the desired concentration of a solution directly: for example, a 100 mg/ml solution of an amino acid. This means just what it says: for every ml of solution, add 100 mg of the solid. Again, remember that you want to deal with total volume, so to make 100 ml of this solution, you'd weigh out 10 g of powder (100 mg/ml × 100 ml), dissolve it in water and then bring the final volume to 100 ml.

Dilutions. A very common task that a biologist needs to perform in the lab is diluting a solution to a desired concentration. For example, you may want to make a concentrated "stock solution" of some chemical and then use it to make other solutions at different concentrations.

You have already learned how to do this in chemistry classes (yes, you are expected to remember what you learned in chem!). In fact, there's really only one key equation you have to remember for most routine dilutions:

$$\mathbf{C_1 V_1 = C_2 V_2}$$

In this equation, $\mathbf{C_1}$ is the concentration of the undiluted solution, $\mathbf{V_1}$ is the volume of the undiluted solution, $\mathbf{C_2}$ is the concentration after dilution and $\mathbf{V_2}$ is the volume after dilution. (Or, you may have learned this as $m_1v_1 = m_2v_2$; it's the same thing!) Usually, you will know the values of three of these variables and can easily solve for the fourth. This equation works for any kind of concentration—molar, percentage, etc.—but the only catch is that the concentration units on each side of the equation need to be the same, so you may have to do some conversions first. The same is true for volume: it can be l, ml, µl or any other unit, but there must be the same units on either side.

Let's look at an example. Say you are provided with a 5 M NaCl solution, but what you need is 100 ml of a 25 mM NaCl solution for today's experiment. How will you make this working solution (25 mM NaCl) from the stock solution (5 M NaCl)? Begin by assigning values to the variables that you can. The final concentration is 25mM, so that's C_2. Our final volume is 100 ml, so that's V_2. Our initial concentration (C_1) is 5 M, but those units don't match up with the 25 mM on the other side, so we'll just convert them: 5 M = 5000 mM. What we don't know is V_1: the amount of stock solution we should use. So, we have:

$$\mathbf{5000\ mM \times V_1 = 25\ mM \times 100\ ml}$$

With a little quick algebra abracadabra, we solve for V_1 and find that it is 0.5 ml (don't forget the units!). So to make our solution, we'll use 0.5 ml of the 5 M NaCl and bring it to our final volume of 100 ml with water.