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Understanding Solution Chemistry the "Southern Way" With Sweet Tea

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Solution chemistry is one of the most important and most confusing aspects of biology. In many labs outside academia, understanding concentration units such as M, % and X is critical. Thus, students need the ability to manage several different ways to think about and calculate solution concentrations. A first lab in biochemistry is often the time to introduce topics including solution chemistry. This lab exercise requires each student to make a different M solution of tea with sucrose, i.e. sweet tea. We then do a blind taste test to how various concentrations of sucrose correlate to tasting "sweet."

Keywords: solution chemistry, biochemistry lab, molarity

Introduction

This laboratory exercise was developed for a Biochemistry course at the junior/senior level, and is used as part of the first week of lab along with safety, attendance, our schedule, etc. This lab takes 2-3 hours to complete depending on how much background information is included and how many times the students do the taste-testing.

Solution chemistry is important but a confusing aspect of biology. While students usually have made M calculations many times, especially in chemistry labs, the knowledge often does not "translate" to biology labs. In addition, biologists are often confronted with %, as in Ringers or 0.9% saline, and X, stock solutions that come 50X, etc. Thus, students need the ability calculate various solution concentrations. In order to put solution chemistry in "context" for the students, we discuss how they might have used X concentration when making juice from frozen concentrate without even realizing that they were making a solution! As we move through this lab exercise, each student must make a different M solution of tea with sucrose, i.e. sweet tea. We then do a blind taste test to how various concentrations of sucrose correlate to tasting "sweet." Students practice a number of thought processes and skills in this lab experience including: 1) review of solution chemistry; 2) dilutions; 3) making solutions; 4) writing a hypothesis; 5) writing lab methods; and 6) excel graphing. Informally, students have reported that this lab is fun while making them work on solution chemistry, a topic they have dreaded in the past.

The set of plastic graduated cylinders used in the lab are kept separate from all other lab supplies so they can safely be used to drink the tea they contain. However, if students were concerned about the "look" of making tea to drink in graduated cylinders, simply purchase measuring cups at a local retail shop that have metric measurements. Use new plastic cups and sample cups every year. Any student who has concerns about drinking sweet tea must participate in making the tea but does not have to drink anything. A legal waiver form is not used in this lab, but diabetic students are discouraged from drinking the solutions.

While the intention in this lab is to work on solution chemistry, scientific method and graphing, this lab could be used in physiology to explore the same topics while adding more details on taste. Human ability to detect sweetness is actually quite poor, at about 1 in 200 parts sucrose in solution. In contrast, humans are fairly adroit at detecting bitter, since we can sense about 1 part in 2 million for a quinine solution (McAleer, 1985).

Students usually make highly concentrated sugar solutions, so in a first taste-test, all of them will be able to taste sugar (not much fun but interesting to them!). Students are then asked to either make dilutions or new solutions to make much less "sweet tea." In the past, students typically had what looks like a saturation curve for tasting sucrose (see Fig. 1 and 2.) Spend some time explaining "saturation" as a biological phenomena since this class will work on enzyme kinetics, which also brings up saturation. Usually at 0.01 M most students cannot taste sweet, and it is important to have a glass of water for them to "clear their palate" during the taste test(s). In order to make the taste-test blind, keep the samples for them to taste in another room and just transport small sample cups over while they work on problems. Then they taste-test, they take notes on the procedure, and then graph the data.

This lab has been conducted using students with a fairly wide range of academic abilities. For this reason students are not provided with a protocol for the lab, but instead are asked to take careful notes and draft up a protocol. The in-

structor collects the protocols and carefully analyzes them for accuracy. Students earn a few points for including the protocol in their write-up. Students who do a poor job with the protocol are contacted for appointments because this is a key moment in an upper division course to provide feedback on the importance of note-taking and the ability to put into writing a series of directions. A student sample protocol has been included, though, for faculty who teach larger lab sections this writing exercise may not be feasible. In addition, a key to the questions at the start of this lab is also included.

To intrigue students and engage them in the applications of this content, the instructor may reference the serious human medical complications that occurred when a lab erroneously made dilutions with sterile water rather than sterile ringers' solution to use for injections (Kravath, 1998) or the death of 21 horses in spring 2009 from a Venezuela-based polo team due to a compounding pharmacy making a mistake in the mixture given to the horses (Segal, 2009.)

Student Outline

Biochemistry Lab Handout – Solution Chemistry and Biochemistry

Biologists learn chemistry for a reason! Biochemists know all of life is delicately controlled chemical reactions. We need to understand how molecules are built out of atoms, pH chemistry, etc. Quite often, biologists need to exactly measure the amount of a chemical or biochemical analyte or solute. For example, knowing the exact amount of glucose in the bloodstream before and after eating can be an indication how well a human processes sugar and if they are at risk for diabetes. Most analytical measurements rely on instruments that depend on a host of factors, such as room temperature, humidity, and the condition of electrical components. A major part of a clinical chemist's job (med tech program) is to understand how their instruments work!

In the lab, you may see up to three different ways of expressing concentrations, molarity (M), percent (%) and times concentration(X). The only one you might see in daily life is the X – and if you have followed the directions to dilute frozen OJ, you have diluted a 4-5X stock to 1X to drink! Percentages are based on a weight to volume or volume to volume measure based on 100 ml of solvent (typically water). So, a 95% ethanol solution is 95 ml of ethanol (solute) with 5 ml of water (solvent). Finally, we get to molarity. This is the most important concentration expression in molecular labs since it allows us to work with precise numbers of moles or molecules in solution (1M= 1FW / 1L). Once we know the concentration of a stock, we can also dilute knowing this relationship:

$$M_1V_1 = M_2V_2$$

M_1 is the concentration of the stock solution, V_1 is the aliquot volume of the stock solution that we use, M_2 is the diluted concentration of the new solution, and V_2 is total volume of the diluted solution.

Some other miscellaneous definitions you will need this semester:

- Observations are records of quantitative or qualitative data. In other words, data are things that a person can see or measure, for example concentration via the spectrophotometer.
- Independent variable(s) are factors that the investigator deliberately changes or manipulates graphed on the X axis.
- A negative control treatment can be no treatment at all, or a treatment that gives data near to or at zero.
- A positive control treatment is when the level of the factor is a known amount or a treatment that is known to have an effect under standard conditions.
- The dependent variable is measured in the experiment (graphed on the Y axis). As the biologist changes a given independent variable, those factors that depend on the independent variable will change. Thus, the biologist measures the dependent variables in the attempt to understand the relationship of independent and dependent variables.
- Standardized variables are those variables that may cause changes in the dependent variables but which a scientist attempts to keep equal across all treatments. In other words, this is something the investigator is not experimenting with at this time. For example, in a plant growth experiment, a biologist might need to standardize the amount of water given to plants while investigating how amounts of light affect growth.

Questions/Problems on Solutions:

1. Explain in YOUR OWN language what X, M and % mean as designations for solutions.
2. Frozen lemonade is a 5X solution. Calculate how to make 37 ml of 1X lemonade.
3. If you bought concentrated sports drink at 14X, how would you make 2 L of 1X drink for your team?

Table 1. Molecular Weights of Common Sweeteners

Chemical	Formula or Molecular Weight
Aspartame	294.3
Saccharine	205.17
Sodium chloride	58.44
Sucrose	342.3

All of the chemicals in the table are solids under normal conditions!

4. How would you make 50 ml of a 2% saccharine solution? 150 ml of a 30% saccharine solution?

5. How would you make 75 ml of an 8% sucrose solution? 250 ml of a 33% sucrose solution?

6. How do you make 500 ml of a 1 M sodium chloride solution? What about 500 ml of a 5 M sodium chloride solution? What about 300 ml of a 2 M sodium chloride solution?

7. A packet of saccharine weighs 1.2 g. You like to add 1 packet per 100 ml of tea or coffee. What M and mM solution of saccharine are you drinking?

8. One packet of aspartame (NutraSweet) weighs 2.34 g. You like one packet of aspartame per 250 ml of coffee. Your friend likes it much sweeter and puts three packets in! What M and mM aspartame is in your coffee and your friend's coffee?

Student Experiment

We can all taste sweet and have varying tolerances for sweet foods. So, at what point in a series of M solutions can we (meaning our lab) cease to detect sweet?

Write your hypothesis below. Remember this is just your best guess:

Write the experimental design here:

Table 2. Personal Data

Sample	I tasted…

Describe any other observations here:

Table 3. Section Data

Sample	Sugar Concentration	# of Tasters
1		
2		
3		
4		
5		
6		
7		
8		

Graphing

Presenting data is a very important part of science. You need to attach to your completed lab a graph of the section data. The first part of doing an effective graph is to decide what is the independent variable which is on the X axis? A quick hint, this is the variable you deliberately manipulate in the experiment.

Now, what is the dependent variable that goes on the Y axis? This is what you measured in your experiment!

Finally, you need to select what type of graph you want to do. Bar graphs can be useful ways to present information, but so can scatter plots with an added curve. In this lab, use both graph types to present your data. Which one gives THE READER (not you!) more or more accurate information and why? Which one do you prefer as the reader?

Do you accept or reject your hypothesis? Explain:

Materials

- 1 - 5 lb bag white sugar
- potable water, approximately 2 gallons
- tea bags – 1 box family size (decaffeinated)
- Balances – milligram and gram
- Pitcher to make tea
- Graduated cylinders not used with chemicals or measuring cups with milliliters on the side
- Package of new plastic cups – 12-16 oz for making tea samples and dilutions
- Box of plastic spoons
- 1 oz sample cups for sipping tea for taste
- Laptop or computer with Excel or other graphing software – you can have students do this as part of lab or on their own time

Notes for the Instructor

Sample Results

See Figures 1 and 2 below.

Sample Protocol

In these areas are notes for a professor or TA that should be removed from the protocol or edited before giving to students

Before lab prepare a weak solution of decaffeinated tea

1. Give each student a clean 12-16 oz. plastic cup.
2. Each student should write on their lab the M concentration of sucrose they intend to make as part of lab. That concentration should be written on the side of the cup in sharpie.

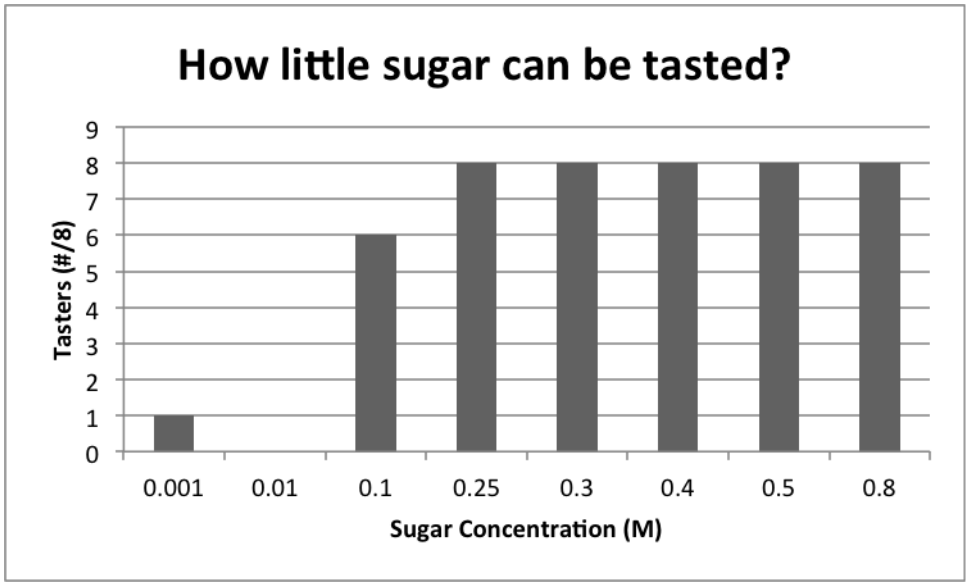

Figure 1.
Bar graph of student results, Spring 2009.

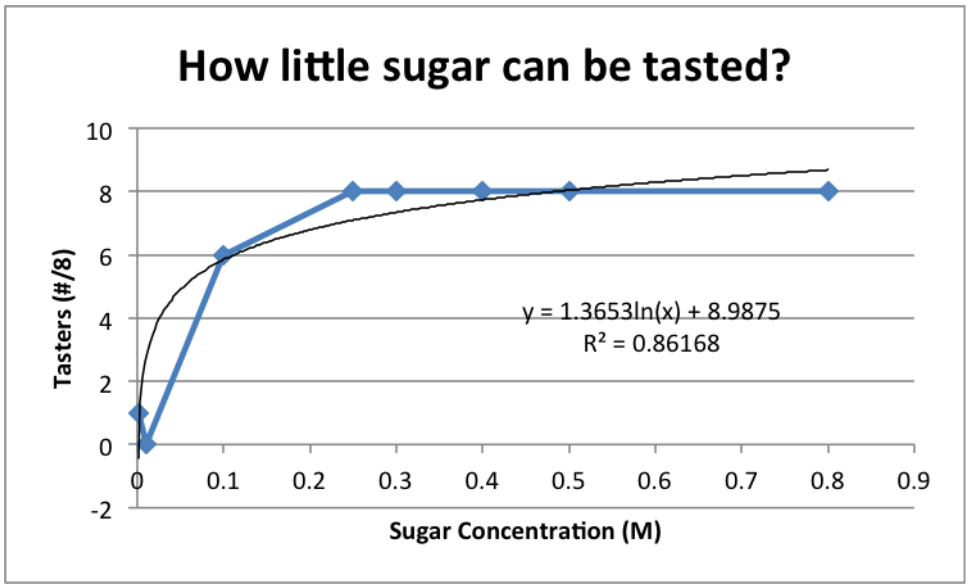

Figure 2.
Scatter-plot of student results, Spring 2009.

3. Students should make a calculation to solve for the amount in grams of sucrose it will take to make 1 L and 100 ml of their sucrose solution (M from step 2).

*** Instructors may want to check calculations before proceeding***

4. Have students weigh out the sucrose on the appropriate balance.

5. Dissolve the sucrose in about 50 ml of tea in plastic cups. Once the sucrose is in solution, bring the volume of tea to 100 ml.

6. Give the cup of tea to the professor or TA.

7. The lab instructor should take the tea cups on a cart with sample cups to another room or hallway.

8. The instructor needs to aliquot the tea samples plus a ZERO M sucrose (just tea!) sample. The M solutions should be in a random order.

*** Make sure to keep CAREFUL notes on what M of sucrose is in each sample. I put out sample cups in rows and put a piece of paper with numbers on it to show the direction we are to taste (see Fig. 3)***

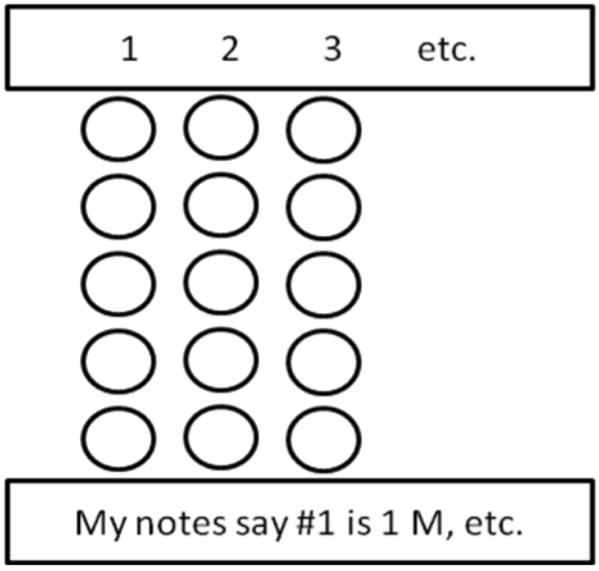

Figure 3. How to arrange the cups for tasting!

9. Bring the cart of samples back to the lab and have students get a second plastic cup of water.

10. Now have students taste the tea one sample at a time. Students should immediately write on their lab if they taste sweet (1) or not (0).

*** Make sure the students "clean their palates" with a sip of water each time.

*** Instructors should feel free to change the scale for the taste/no taste – I want a saturation curve so this 1 or 0 scale works***

*** After all the tasting is done, check if students all made high M solutions and if everyone tasted sweet in every sample. If this is true, have students dilute their original solutions and repeat the taste test again. Most students stop tasting sweet at 0.01 M***

11. Students should now graph their data, the class data and analyze the results.

Questions/Problems on Solutions KEY

1. Explain in YOUR OWN language what X, M and % mean as designations for solutions.

2. Frozen lemonade is a 5X solution. Calculate how to make 37 ml of 1X lemonade.

$M_1V_1 = M_2V_2$
$5X * V_1 = 37 \text{ ml} * 1X$
$V_1 = 7.4 \text{ ml}$

So, to make the solution, take 7.4 ml of the 5X stock and add it to 29.6 ml of water.

3. If you bought concentrated sports drink at 14X, how would you make 2 L of 1X drink for your team?

$M_1V_1 = M_2V_2$
$14X * V_1 = 2 \text{ L} * 1X$
$V_1 = 143 \text{ ml or } .143 \text{ L}$

So, to make the solution, take 143 ml of the 14X stock and add it to 1857 ml of water.

Table 1. Molecular Weights of Common Sweeteners

Chemical	Formula or Molecular Weight
Aspartame	294.3
Saccharine	205.17
Sodium chloride	58.44
Sucrose	342.3

All of the chemicals in the table are solids under normal conditions!

4. How would you make 50 ml of a 2% saccharine solution? 150 ml of a 30% saccharine solution?

2.0 g of saccharine would make 100 ml of 2%, so use 1 g of saccharine for 50 ml.

30 g of saccharine would make 100 ml of 30%, so use 45 g of saccharine for 150 ml.

5. How would you make 75 ml of an 8% sucrose solution? 250 ml of a 33% sucrose solution?

   You need 6 g of sucrose for 75 ml of an 8% solution.

   You need 82.5 g of sucrose for 250 ml of a 33% solution.

6. How do you make 500 ml of a 1 M sodium chloride solution? What about 500 ml of a 5 M sodium chloride solution? What about 300 ml of a 2 M sodium chloride solution?

   You need 29.22 g of sodium chloride in 500 ml of water for 1M.

   You need 146.1 g of sodium chloride in 500 ml of water for 5M.

   You need 34.93 g of sodium chloride in 300 ml of water for 2M.

7. A packet of saccharine weighs 1.2 g. You like to add 1 packet per 100 ml of tea or coffee. What M and mM solution of saccharine are you drinking?

   1.2 g/100 ml * 1000 ml/ 1 L = 12 g/L /205.17 g/FW =

   0.0584 M or 58.4 mM

8. One packet of aspartame (NutraSweet) weighs 2.34 g. You like one packet of aspartame per 250 ml of coffee. Your friend likes it much sweeter and puts three packets in! What M and mM aspartame is in your coffee and your friend's coffee?

   2.34 g/250 ml * 1000 ml/ 1 L = 9.36 g/L /294.3/FW =

   0.0318 M or 31.8 mM (for me with 1 packet!)

   Friend with 3 packets is 0.096 M or 96 mM

Literature Cited

Biello, David (August 16, 2007). Strange but True: Cats Cannot Taste Sweets. *Scientific American.* **http://www.scientificamerican.com/article.cfm?id=strange-but-true-cats-cannot-taste-sweets**. Retrieved July 28, 2009.

Kravath, R.E. 1998 More on Dangerous Dilution of 25 Percent Albumin. *New England Journal of Medicine* 339(9): 634-635.

Li X, Staszewski L, Xu H, Durick K, Zoller M et al. 2002. Human receptors for sweet and umami taste. *Proc Natl Acad Sci* USA 99: 4692–4696 **http://www.pnas.org/cgi/content/abstract/99/7/4692**

McAleer, N. 1985. *The Body Almanac: Mind-boggling facts about today's human body and high-tech medicine.* New York: Doubleday & Co.

Nofre, C., J. M. Tinti and D. Glaser. 1995. Evolution of the Sweetness Receptor in Primates. I. Why Does Alitame Taste Sweet in all Prosimians and Simians, and Aspartame only in Old World Simians? *Chemical Senses* 20: 573-584.

Segal, K. (2009). Florida pharmacy says it wrongly prepped horse meds before match. CNN. April 22, 2009. **http://www.cnn.com/2009/US/04/23/polo.pony.deaths/index.html**

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