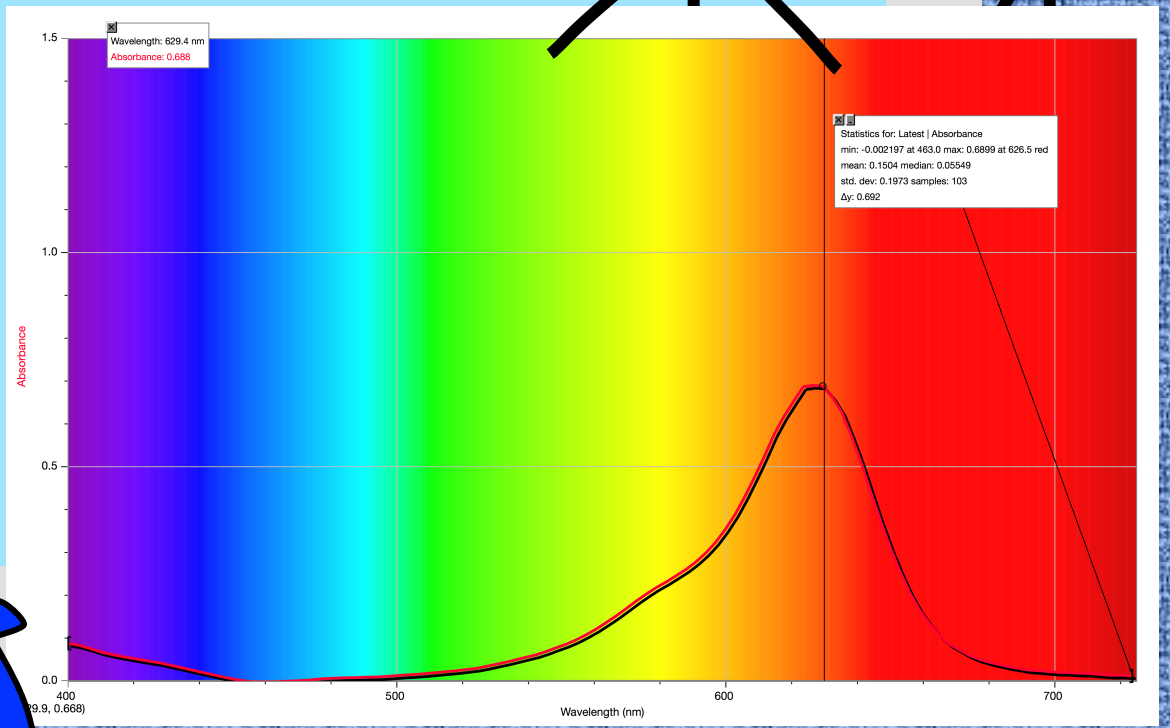
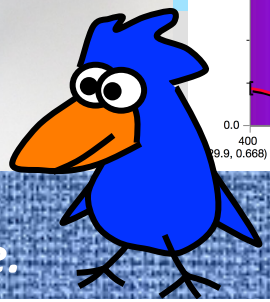
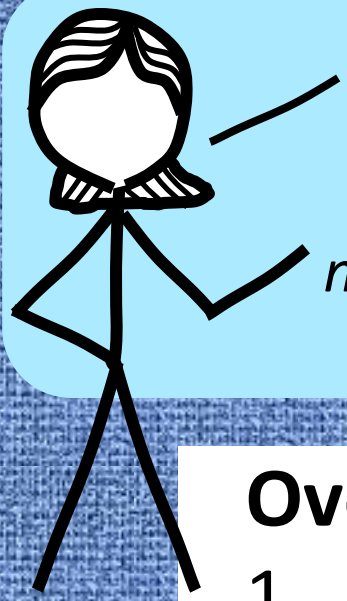
# Beer's Law
# 30 January 2020

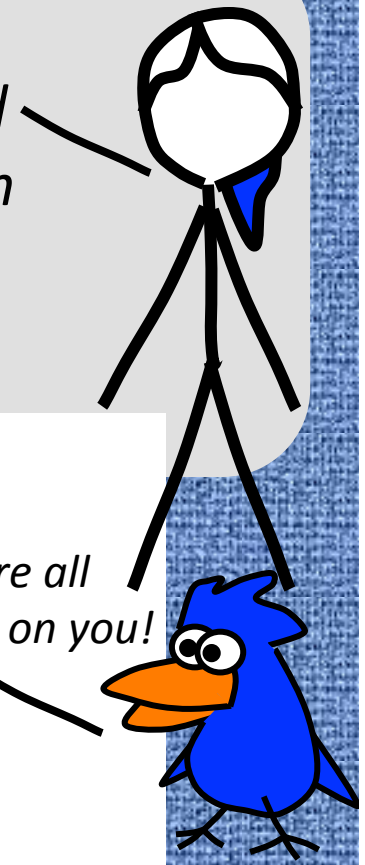
*I like blue.*

Objectives: To learn more about the visible spectrum of a colored solution and how concentration and color intensity are related.



*So Beer's law sounds sort of funny… but has nothing to do with beer*

*We will learn about visible spectroscopy and Beer's law. We will each contribute to a classroom data set.*



*We are all counting on you!*

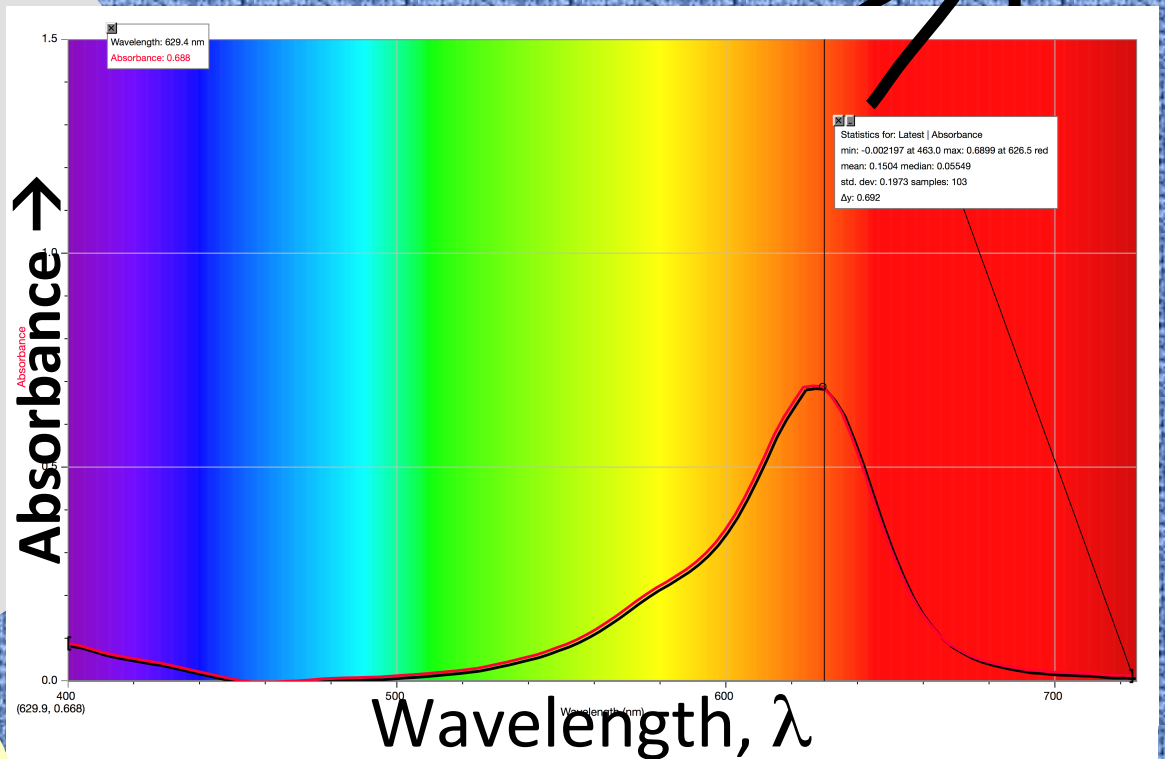
**Overview:**

1. The visible spectrum
2. Beer's law
3. Making a solution by dilution
4. Procedure: What we do today
5. Your lab report

# 1. The visible spectrum

*Here we have a cup of blue food coloring.*

*And here is the visible spectrum of blue food coloring.*




400 nm . . . . . 700 nm

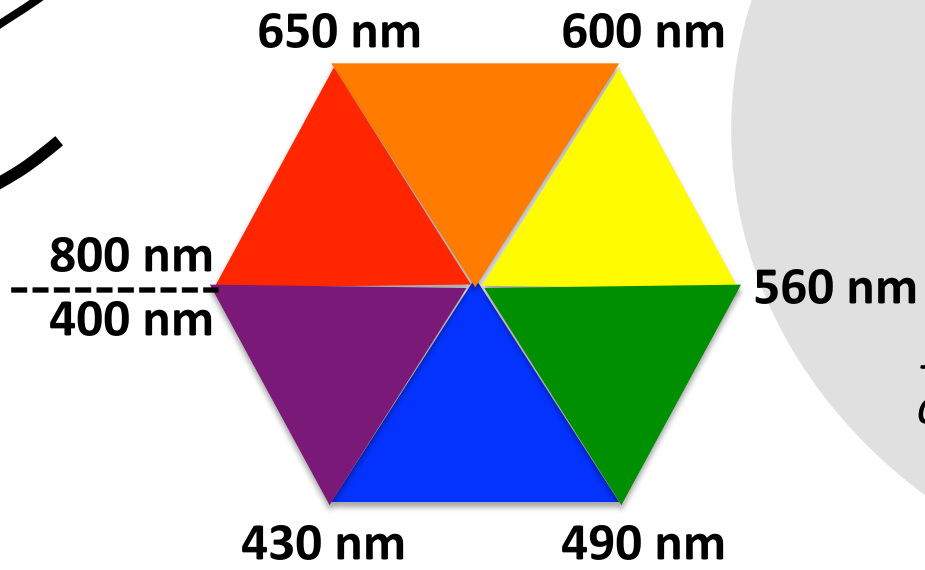
High energy . . . . → . . . . Low energy

*LoggerPro displays the visible colors on the spectrum. It's cute. See how blue food coloring absorbs orange?*

**Info for Introduction**

# 1. The visible spectrum

*Here is my version of the color wheel – sort of a color hexagon, but whatever…*



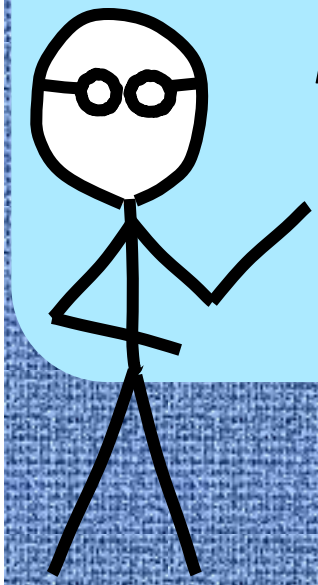

*Colored solutions absorb part of the visible spectrum and transmit the rest. So a solution that absorbs red, for example, will transmit all the other colors, but frequently looks the color wheel opposite of red – green!*

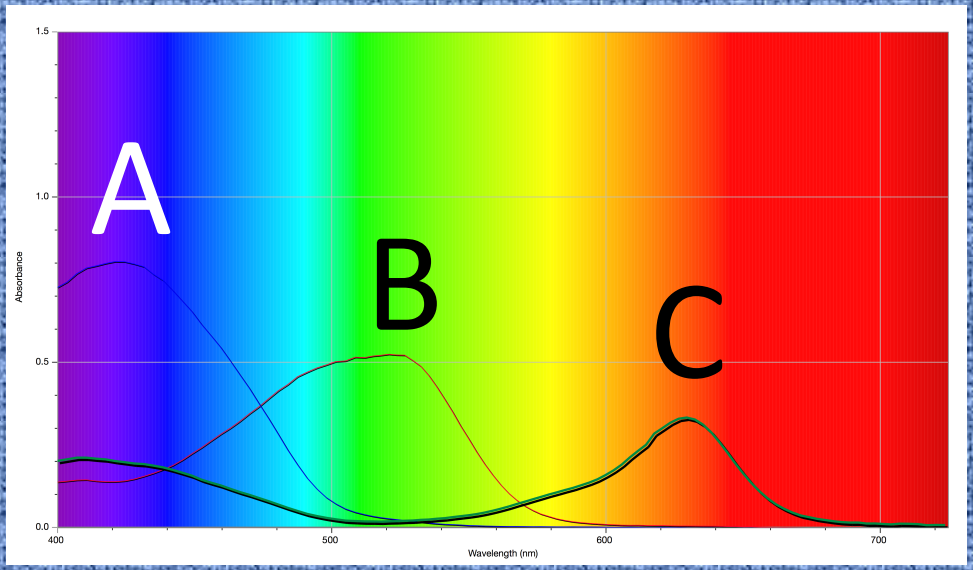
*Anyone else smell a quiz question?*

**Info for Introduction**

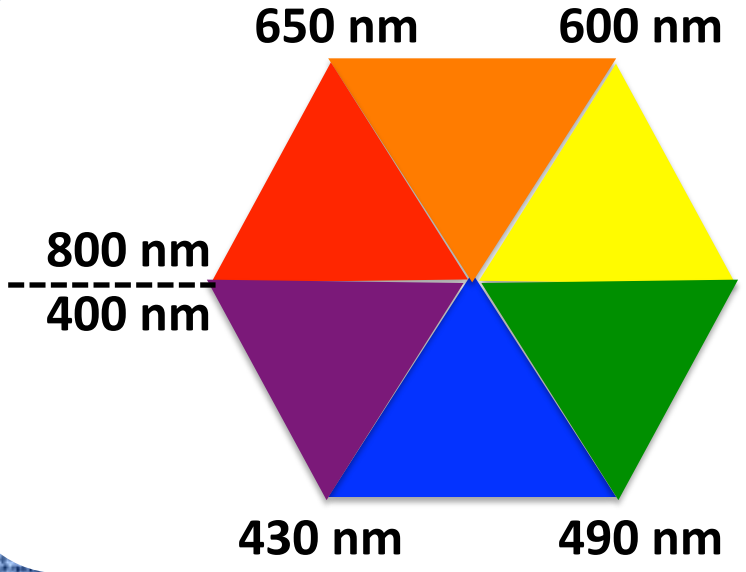
# 1. The visible spectrum

*Today you will record the visible spectrum for three food colorings as shown here and labeled A, B, and C. What food color gave Spectrum A? Spectrum B? Spectrum C?*



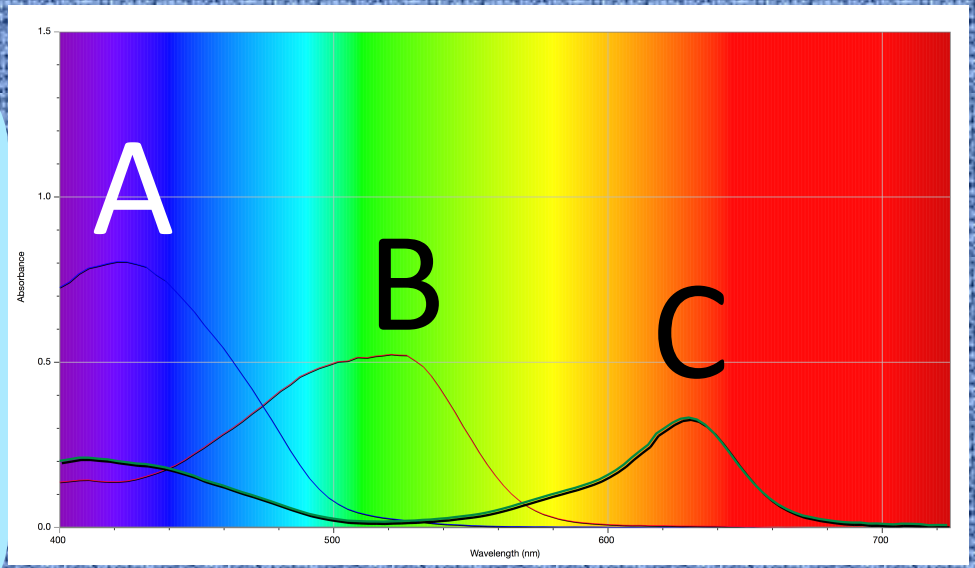




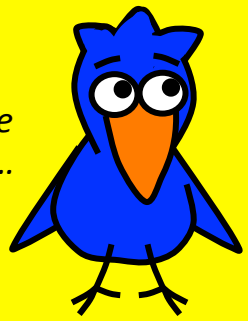


# 1. The visible spectrum

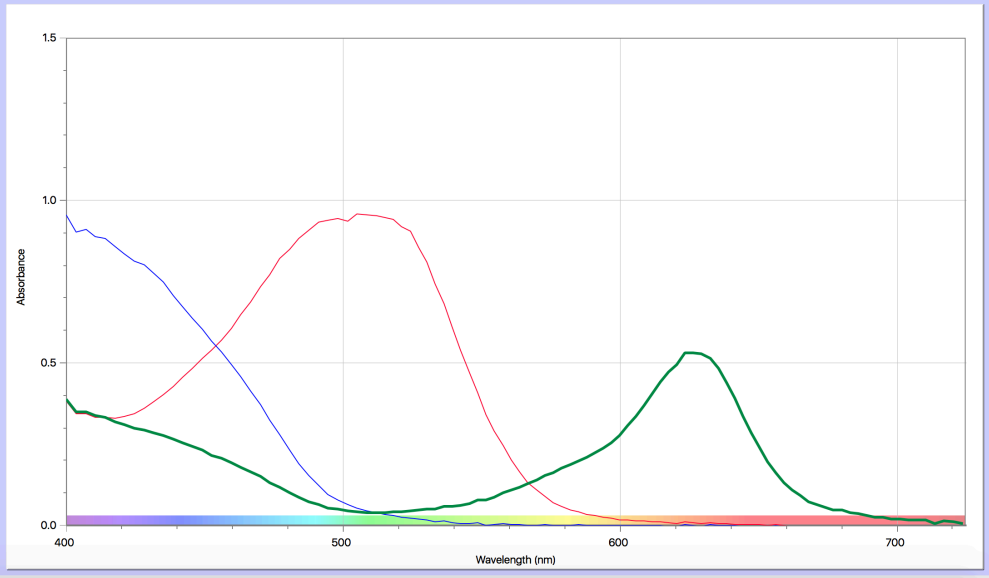
*LoggerPro has an option to show the spectrum without the full rainbow, like you see below. Here is how: From the LoggerPro pull-down menu, pick Preferences, then click Graph spectrum as narrow strip.*



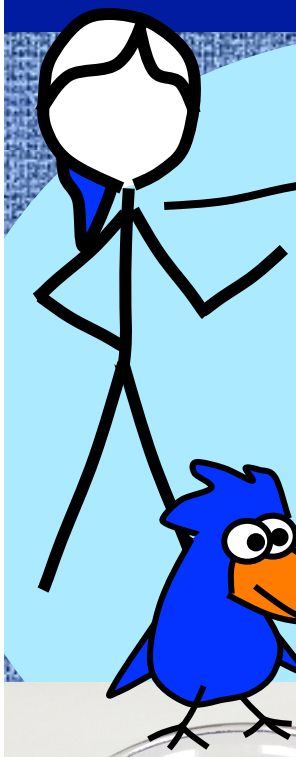

*I kinda like rainbows…*



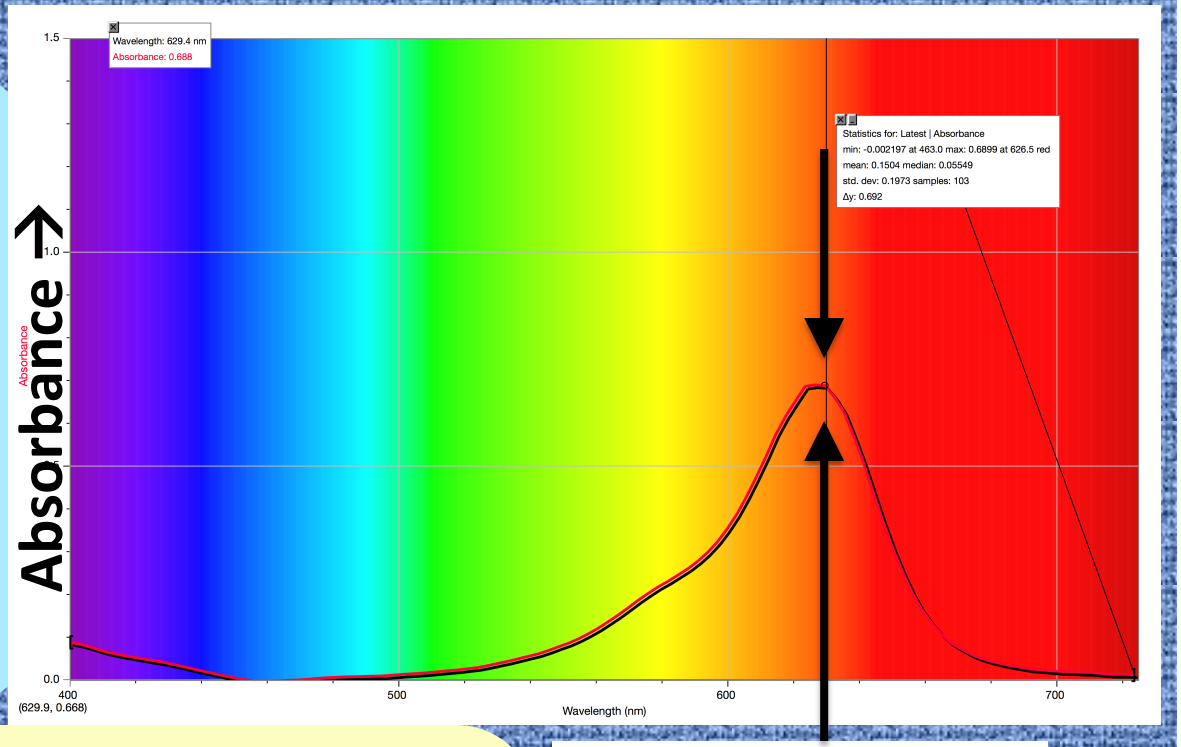
| | Latest | |
|---|---|---|
| | λ (nm) | Abs |
| 1 | 400.0 | 0.387 |
| 2 | 403.5 | 0.349 |
| 3 | 407.0 | 0.349 |
| 4 | 410.5 | 0.339 |
| 5 | 414.0 | 0.333 |
| 6 | 417.5 | 0.318 |
| 7 | 421.0 | 0.311 |
| 8 | 424.5 | 0.300 |
| 9 | 428.0 | 0.293 |
| 10 | 431.5 | 0.285 |
| 11 | 435.0 | 0.277 |
| 12 | 438.5 | 0.265 |
| 13 | 442.0 | 0.255 |
| 14 | 445.5 | 0.243 |
| 15 | 449.0 | 0.232 |
| 16 | 452.5 | 0.216 |
| 17 | 456.0 | 0.205 |
| 18 | 459.5 | 0.192 |
| 19 | 463.0 | 0.179 |
| 20 | 466.5 | 0.163 |
| 21 | 470.0 | 0.149 |
| 22 | 473.5 | 0.132 |
| 23 | 477.0 | 0.118 |
| 24 | 480.5 | 0.099 |
| 25 | 484.0 | 0.085 |
| 26 | 487.5 | 0.072 |
| 27 | 491.0 | 0.063 |
| 28 | 494.5 | 0.054 |
| 29 | 498.0 | 0.050 |
| 30 | 501.5 | 0.044 |
| 31 | 505.0 | 0.042 |



# 1. The visible spectrum



*The wavelength with the largest absorbance is called $\lambda_{max}$, and spoken as lambda-max*

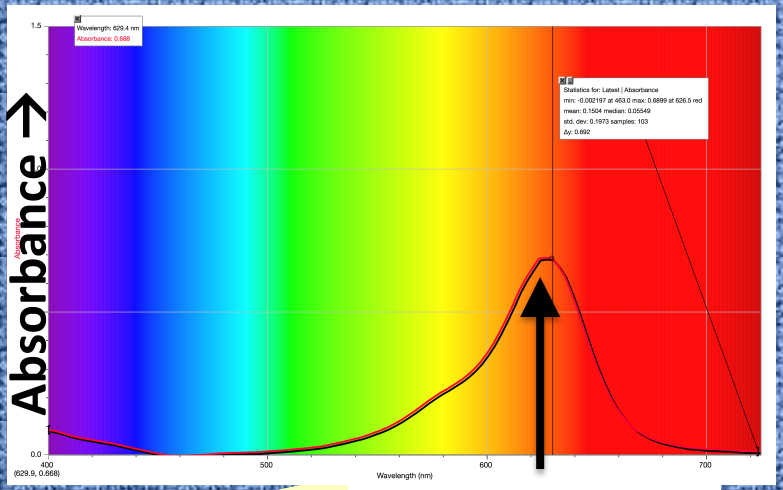


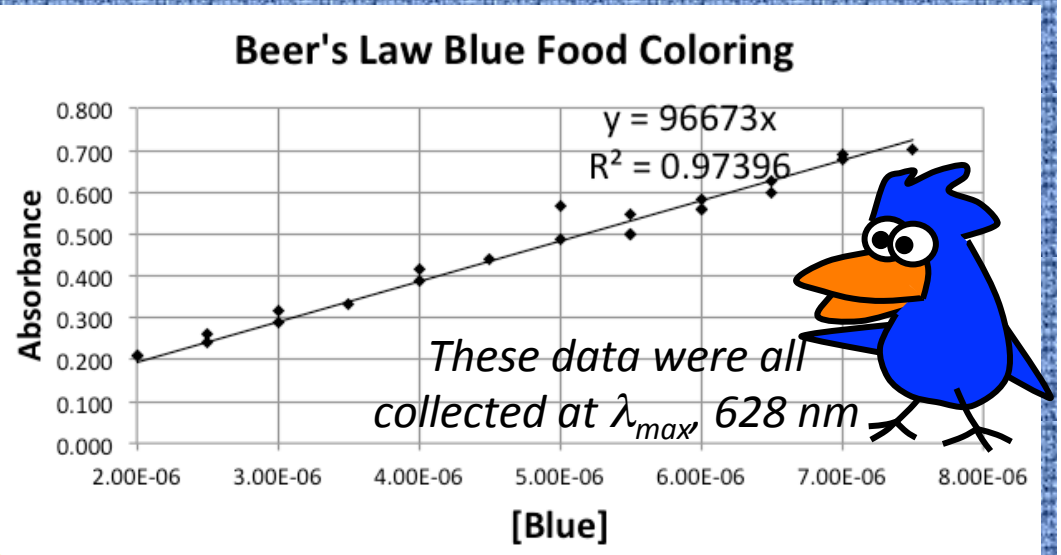

*We would say that $\lambda_{max}$ = 628 nm. In the second part of our experiment, we will collect new data, all at $\lambda_{max}$.*

$\lambda_{max}$~628 nm

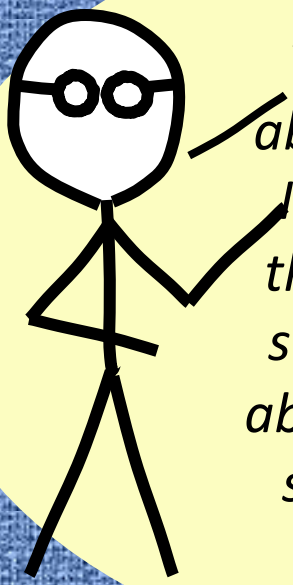
**Info for Introduction**

# 2. Beer's law




$\lambda_{max}$~628 nm



*The y-axis in the spectrum above is labeled Absorbance. It is a measure of how blue the solution is. A very dilute solution would have small a absorbance and a darker blue solution would have larger absorbance value.*

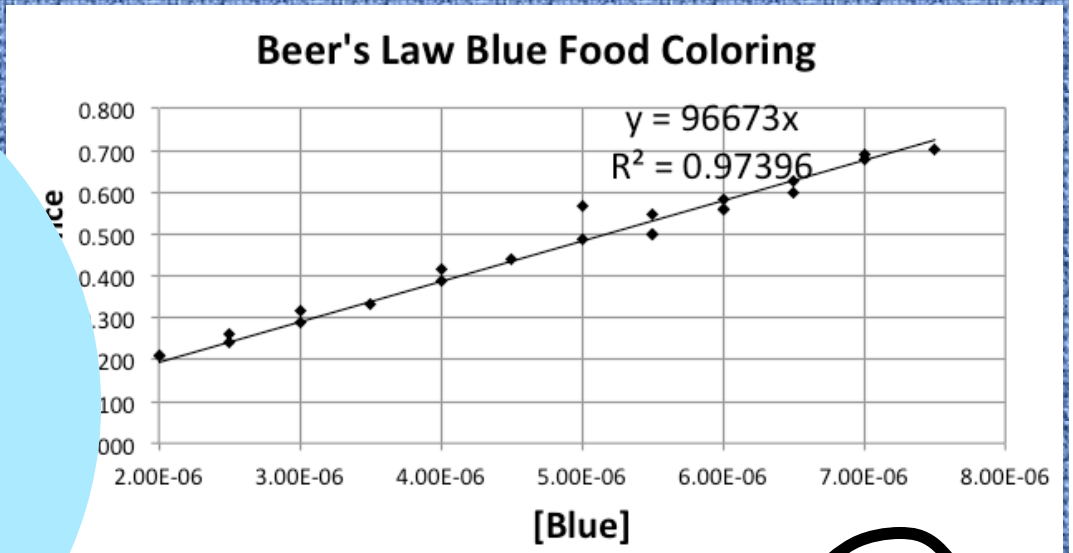
*The relationship between concentration and absorbance is linear! The graph above features Concentration of Blue on the x-axis and Absorbance on the y-axis.*

# 2. Beer's law

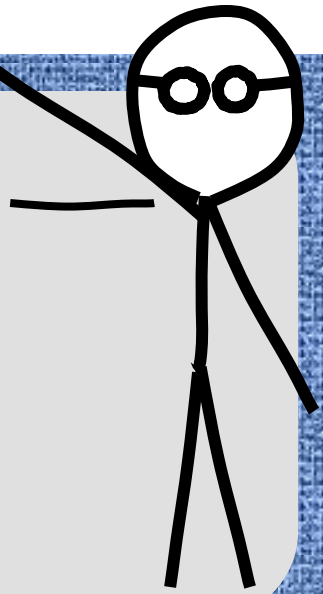
*So the relationship between concentration and absorbance is linear. The formula is A = k[Blue], where A is absorbance, k is the slope of the line and [Blue] is the molar concentration of Blue in moles per liter.*

**A = k[Blue]**

*See how A = k[Blue] looks just like y = mx + b, where b = 0?*



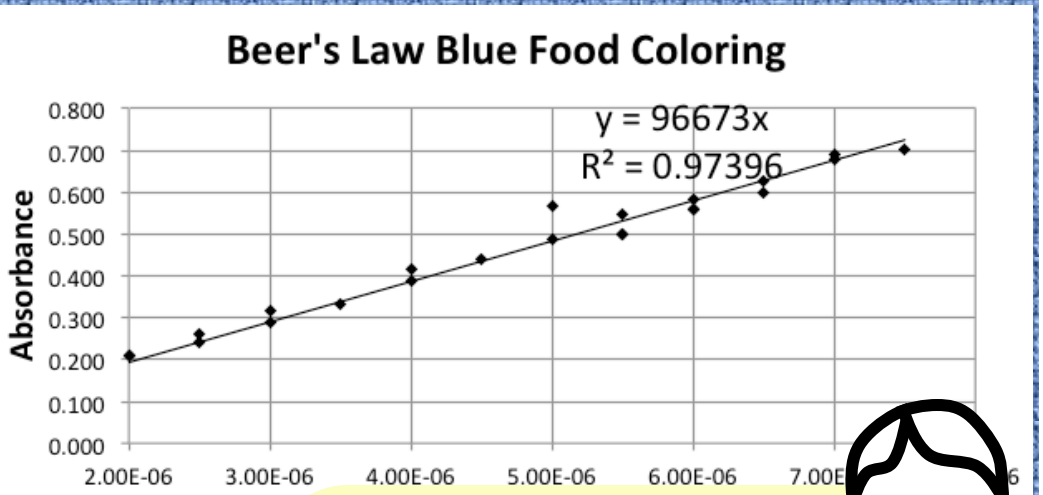

*This is a real Beer's law chart created from a collection of student data. You and your lab partner will contribute one point to a graph like this.*

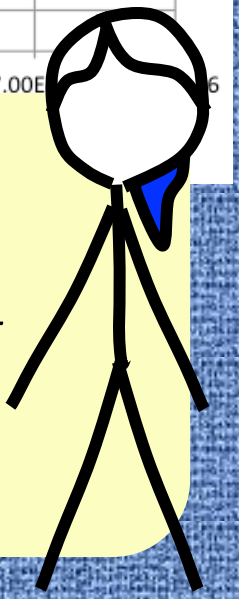


# 2. Beer's law

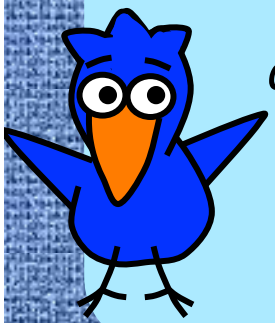
**A = k[Blue]**

*The slope, **k**, is actually equal to two constants, **b** and **ε** (epsilon). The **b** is the cell path length in centimeters and has a value of 1.00 cm. The **ε** is called the molar absorptivity.*



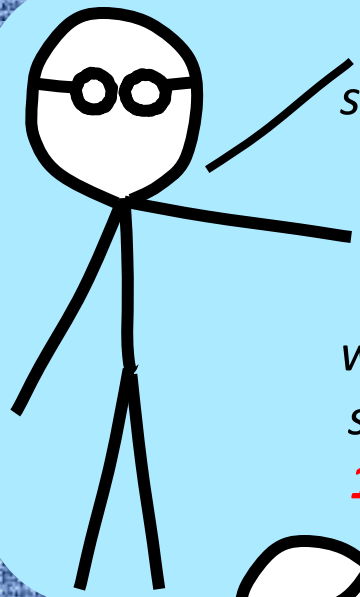
*When this chart was made, they did this: They chose Add Trendline, Options, Set intercept = 0, Display equation and R2 value on chart.*



*Absorbance has no units, and concentration is mol/L. That leaves **k** to have units of L/mol. Because **k** = **bε**, and b has units of cm, ergo **ε** has units of L $mol^{-1}$ $cm^{-1}$.*

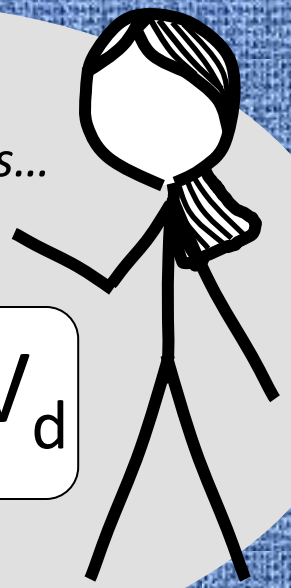
*How many birds do you know who say things like ergo?*

# 3. Making a solution by dilution

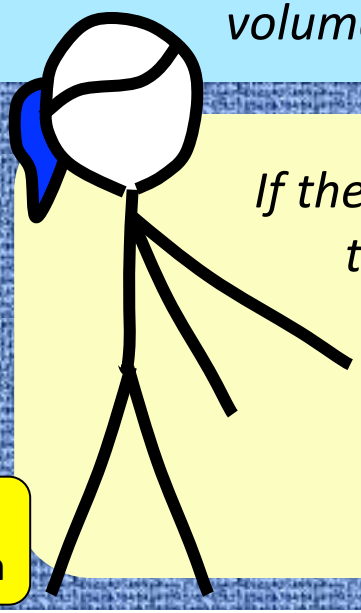


*You'll be assigned a solution to make today – to contribute to the Beer's law chart. For example, suppose you were assigned to make a solution that* ***was 8.00 x $10^{-6}$ M*** *using a* ***50.00 mL*** *volumetric flask…*

*The dilution formula is…*



$$M_c V_c = M_d V_d$$



*If the stock solution were 7.5 x $10^{-5}$ M, the math would look like this:*

$$7.5 \times 10^{-5} \times V_c = 8.00 \times 10^{-6} \times 50.00 \text{ mL}$$

$$V_c = 5.3 \text{ mL}$$

*Yup.*

**Info for Introduction**

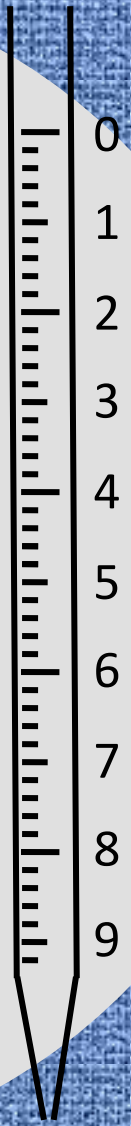
# 3. Making a solution by dilution

*By now you've watched the Mohr pipet YouTube video.*

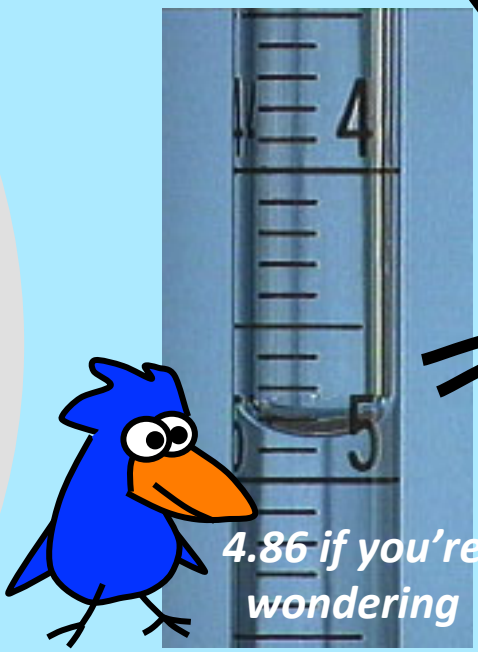
*We always start with the thing filled to the 0 mark.*

*And then deliver to the calculated volume.*

*The rest is extra.*




*Reading the volumes is tricky. The numbers get bigger going down.*




***4.86 if you're wondering***

*Pipet image credit: allpipettes.com/Use-Mohr-Pipettes.html*

# 3. Making a solution by dilution

*Suppose we wanted 4.86 mL. Start with it filled to the 0.00 mark.*

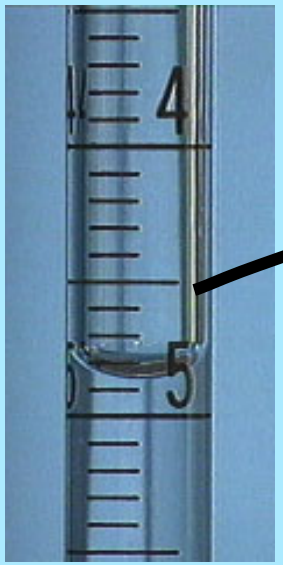
*… and deliver the liquid down to 4.86 mL*

*… and the rest goes back in the beaker.*

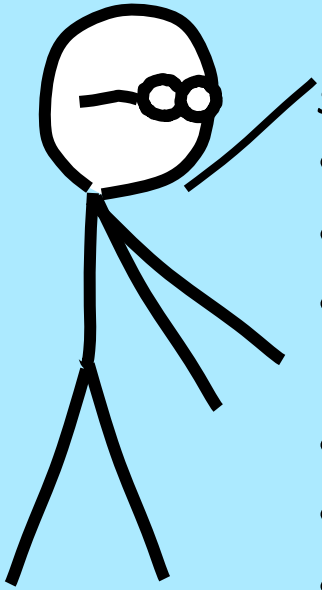
***See how the Mohr pipet gets weird before it gets to 10?***

*This is the part you need – from 0.00 down to 4.86 mL*

*You can read two places past the decimal with this Mohr pipet*



# 4. Procedure: What we do today

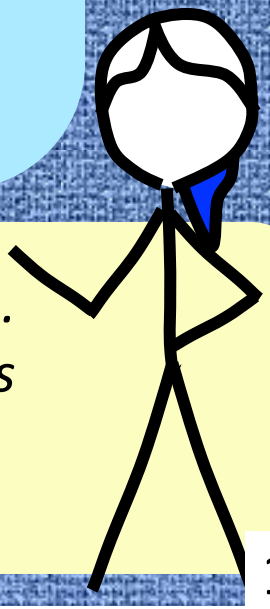


*We will be using cuvettes today with the spectrometer. Here is how to use them:*

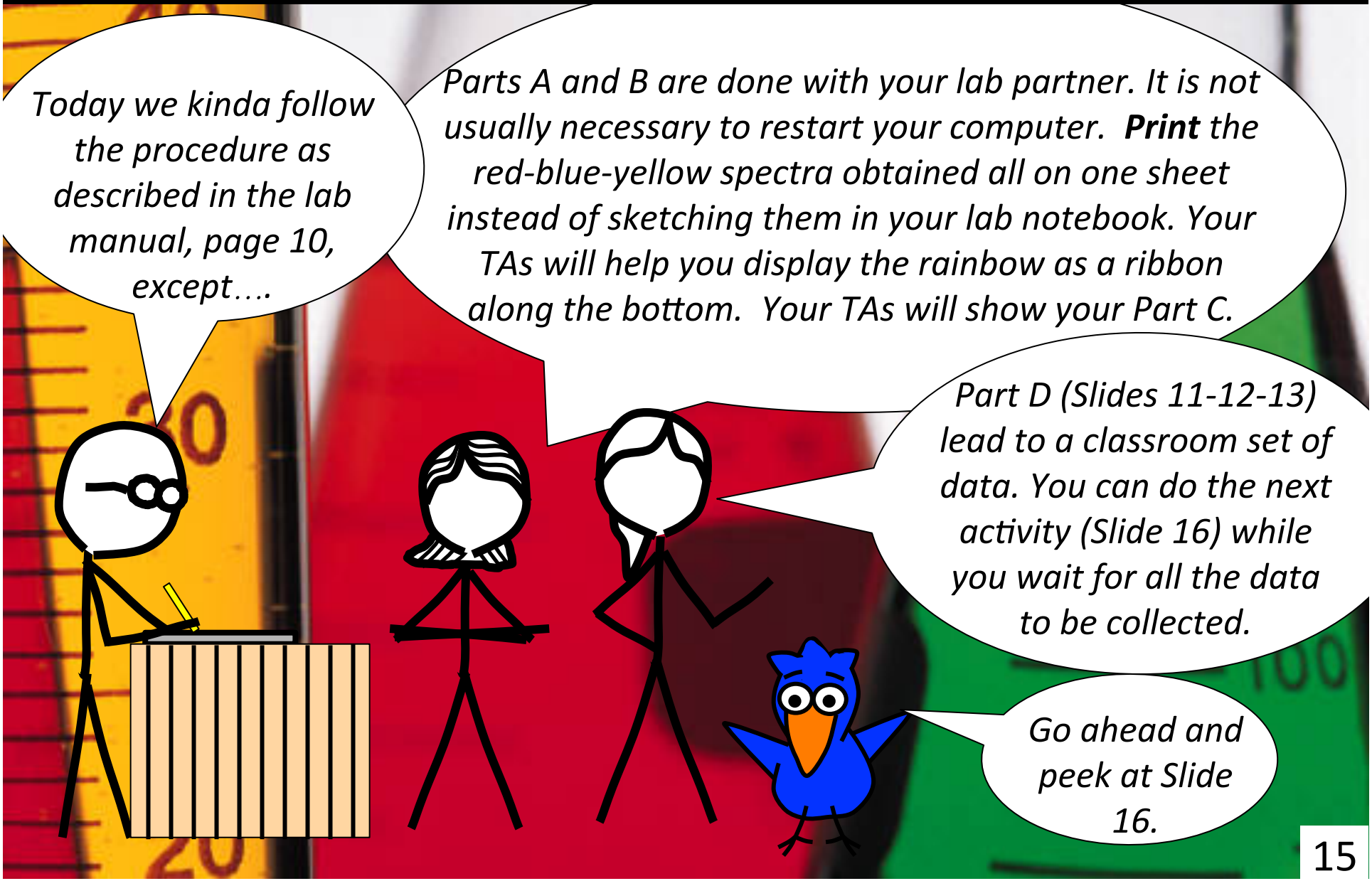
- *Rinse with the stock solution*
- *Fill cuvette ~$^{3}/_{4}$ full*
- *Make sure the light goes through the clear, not the "frosted" sides (**line up the arrows**)*
- *Make sure there are no bubbles*
- *Wipe it clean*
- *At end of lab, rinse and leave at your table upside down on a paper towel so it can drain.*

*Only this one way will work!*

*You'll be entering data into a Google form. Exponential numbers are entered as in this example: 8.00 x $10^{-6}$ would be entered as* ***8.00E-6*** *– note there are no spaces!*

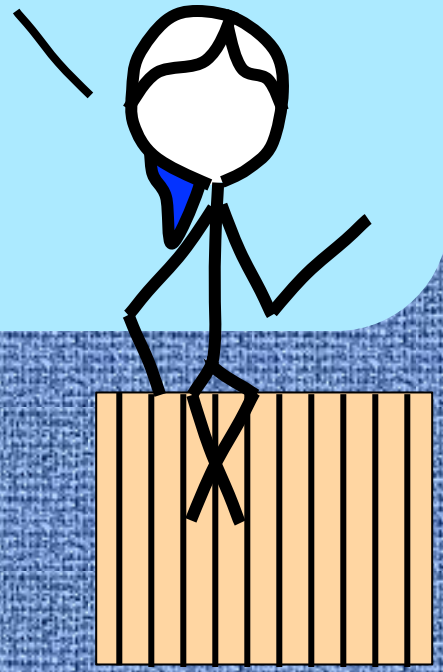


# 4. Procedure: What we do today



# 4. Procedure: What we *also* do today

*There is a Mohr pipet activity on the back of your cover sheet that is part of your on-line report. It is not in the lab manual. You can do it before or after the experiment in the lab manual.*



## Using the Mohr pipet

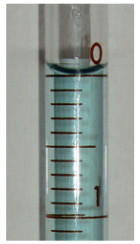
1. Watch the YouTube video linked from the lab website, under Experiment 2. Watch this particular video. Especially note how the instructor uses her index finger to control the flow of the solution. When you practice this, try easing up ever-so-slightly with your finger on the far side of the pipet top – allowing the solution to drain slowly. You can quickly stop the delivery by pushing down firmly on the pipet top. *IMPORTANT: Delivering solutions with the Mohr pipet is different from the volumetric pipet: with the Mohr pipet, you do not drain the pipet into the destination flask!* The delivered volume is calculated by difference ($V = V_f - V_i$).

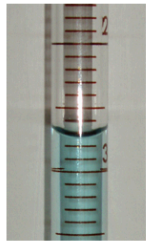
2. Before you use a Mohr pipet, you will need to calculate how much of a liquid you wish to use. In the example below, we see how to transfer 2.72 mL.

   a. Rinse the pipet as per the Youtube video.

   b. First, the pipet is filled past the 0.00 mL mark and then slowly drained to the 0.00 mark (left figure) into a waste container.

   c. Now you are ready to transfer the 2.72 mL to the flask in which you want the solution. Allow the pipet to drain from 0.00 mL to your goal, 2.72 mL as shown in the figure at right. Note the numbers increase going down, the opposite of a thermometer, but like a buret. Slow down as you get close.




   d. The remaining solution (the pipet is still mostly full) is transferred back to the solution from which it came. Clean the pipet with distilled water.

**Optional (not required): Test yourself:** Obtain a medium-sized weighing dish and a 10.00 mL Mohr pipet. Pick a volume between 1.0 and 4.0 mL. Write that number here: _____. It should be to the hundredths place, such as 3.24 mL

Transfer this volume of water to the weighing dish. A TA will test this for you.

### Mohr Pipet Test with the Orange Solution (not in lab manual).

At the middle station in lab you will find a small beaker of orange solution. This solution contains NaCl(aq) and orange food coloring. Your assignment is to measure out an assigned volume of the solution. Your TA will measure its mass and you will report volume and mass with your on-line data.

Your assigned volume is…

| Station | Group A | Group B |
|---|---|---|
| 1 | 3.60 mL | 8.80 mL |
| 2 | 4.20 mL | 8.20 mL |
| 3 | 4.70 mL | 7.50 mL |
| 4 | 5.30 mL | 7.20 mL |
| 5 | 5.70 mL | 3.70 mL |
| 6 | 3.20 mL | 6.40 mL |

| Station | Group A | Group B |
|---|---|---|
| 7 | 6.40 mL | 3.20 mL |
| 8 | 3.70 mL | 5.70 mL |
| 9 | 7.20 mL | 5.30 mL |
| 10 | 7.50 mL | 4.70 mL |
| 11 | 8.20 mL | 4.20 mL |
| 12 | 8.80 mL | 3.60 mL |

*They'll never find me here.*

# 4. Procedure: What we do today

① *Wearing your safety glasses is always prudent, but today we will not be enforcing it. No special attire needed today. We are not making a mess.*

② *Take time writing an introduction in your own words before lab.*

③ *Each pair of students performs Part A and B and attaches spectra as part of your lab report today. This is different from the lab manual.*

④ *Record observations and details as carefully as possible. Show your calculations with formulas, units, and significant figures!*

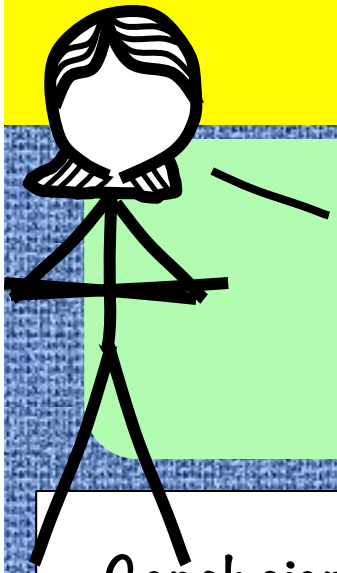
⑤ *Do Part C anytime. One of our TAs will assist.*

⑥ *Make sure you can correctly use the Mohr pipet before you do Part D. In Part D – you and partner will contribute one point to the class Beer's law plot.*

⑦ *Complete Mohr pipet activity with the orange solution before you submit on-line data.*

⑧ *You will use class data to produce a Beer's law plot in Excel. Class data will be available at the Chm 206 website one hour after lab.*

# 5. Your lab report



*In the conclusion we can summarize what we've learned. Why did we do this experiment? Review the Objectives from Slide 2 and see if we did what we set out to do. We read your conclusions carefully. Be sure to write it in your own words and not copy it from anyone.*

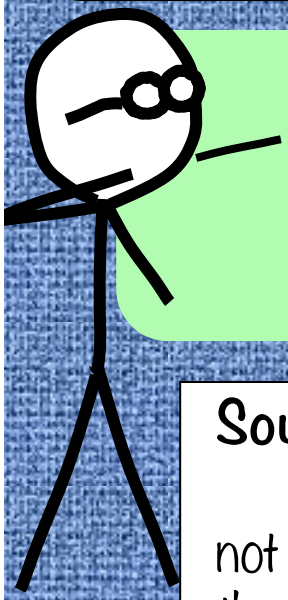
**Conclusion.**

In this experiment we worked together as a class to create a Beers law chart for Blue Food Coloring. This involved each pair of us making a specific dilution and measuring its absorbance using a visible spectrometer.

The Beers law chart created plotted absorbance on the y-axis and concentration on the x-axis, so the equation of the line is Absorbance = Slope X Concentration. We set the y-intercept to zero because if the solution were 0.00 molar, the absorbance would be zero. The slope of the line lets us calculate the concentration of any unknown solution from it abso reading.

# 5. Your lab report

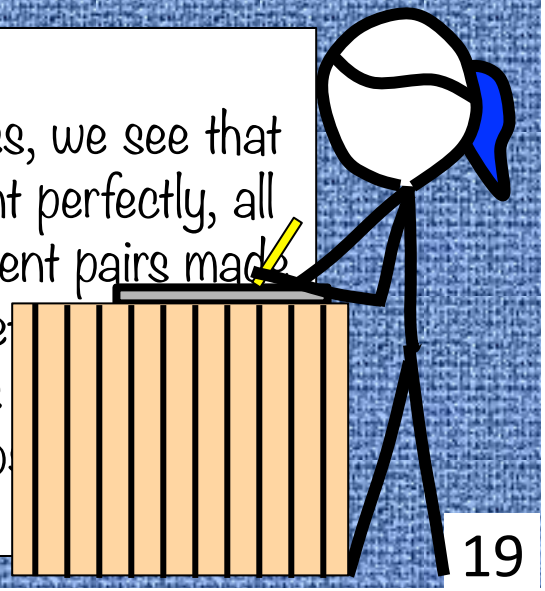
| Reasonable | Not too likely | Unreasonable |
|---|---|---|
| Errors with reading the Mohr pipet | Spectrometer wasn't working correctly | Laws of physics suspended. Sabotaged by TAs |



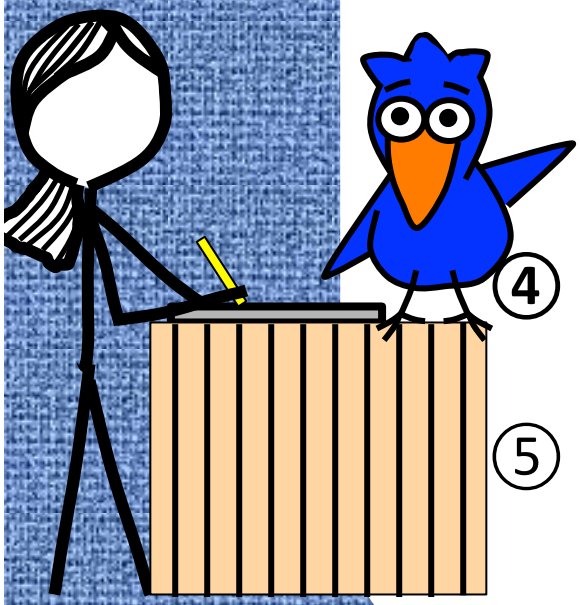
*We also address sources of errors. Sometimes there aren't any obvious ones and other times there are plenty. We need to only worry about the more plausible ones. Looking over the continuum of possible errors for this experiment, we will stick with the reasonable ones only.*

**Sources of error.**

Looking at the data contributed by the entire class, we see that not all points are on the line. If everyone did the experiment perfectly, all the points would be on the line. This means that some student pairs mad some sort of error. Because correctly using the Mohr pipe challenging, this is the most likely sourse of error. Perhaps used incorrectly or read incorrectly. Our data point was clo the line, so we probably didn't experience an error.



# 5. Your lab report



① First, the cover page with TA initials.

② Next, the trimmed copy pages from your lab notebook stapled together. Staple all together.

③ **On-line results** due at the end of class today. Remember the required format for exponentials: **8.00E-6** (and no spaces). Late submissions are not graded – see the syllabus.

④ **Two attachments:** Your visible spectrum and your Beer's law plot

⑤ Turn in lab report ***before*** the start of class tomorrow. You will need data available one hour after lab. Late labs may not be graded – see the syllabus.

Stick people inspired by xkcd cartoons by Randall Munroe (www.xkcd.com)

***Chem Lab with the Stick People and Bird*** *was created and produced by Dr. Bruce Mattson, Creighton Chemistry. Enjoy it and share it if you wish.*