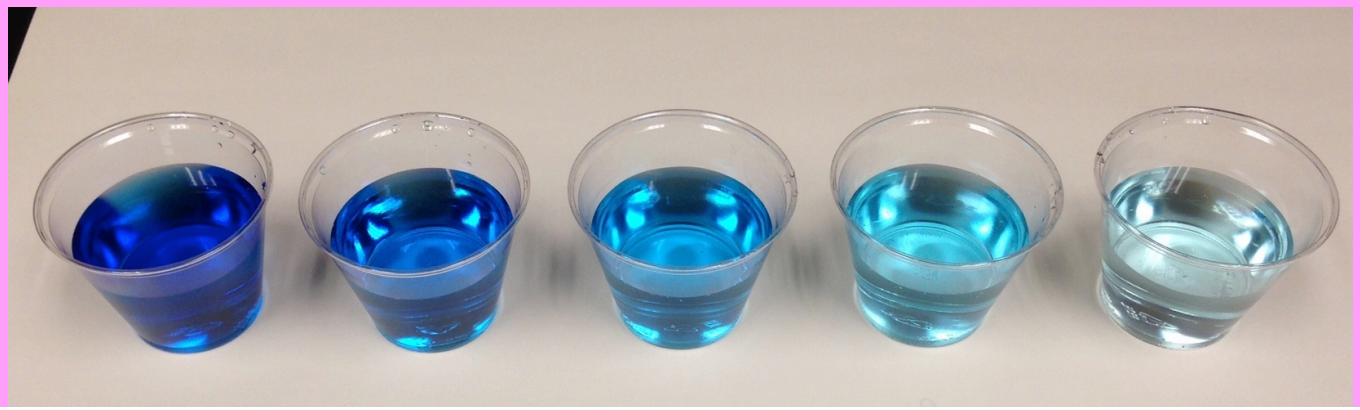
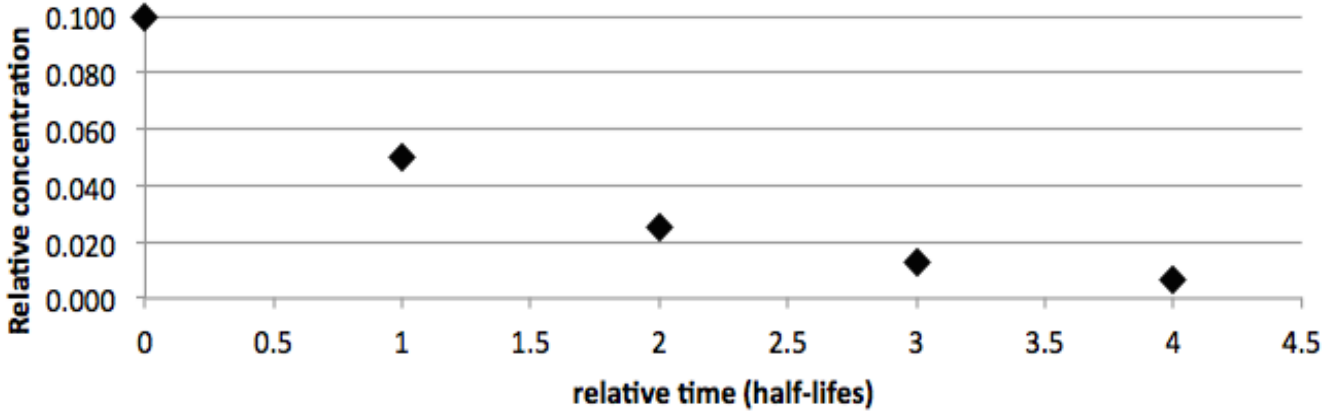
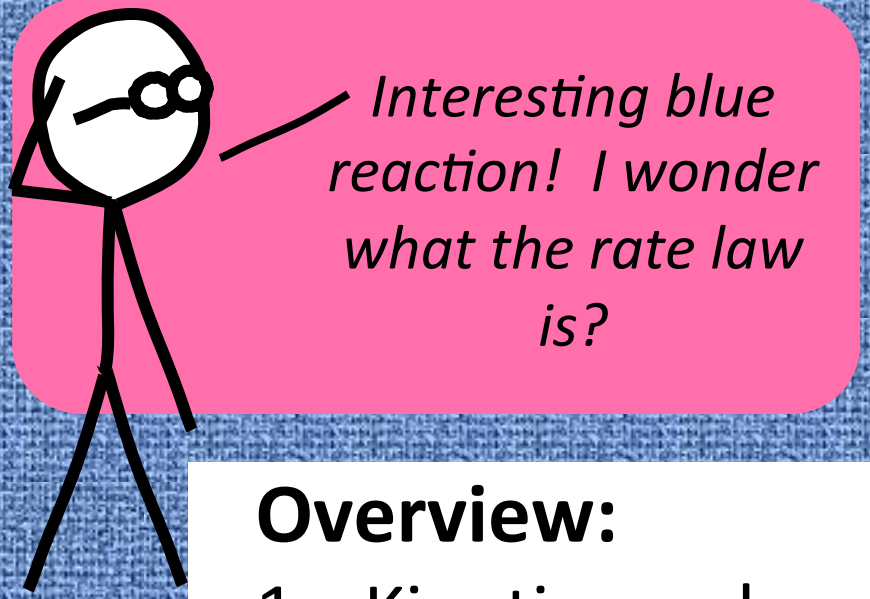
Experiment 3 Kinetics
6 February 2020



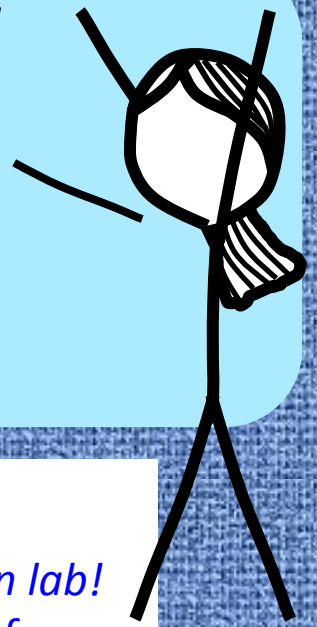


Objectives: To determine the order of a reaction and determine the rate law and rate constant.



Interesting blue reaction! I wonder what the rate law is?

We will figure that and more! We'll also figure out the rate constant using a single time-concentration study!

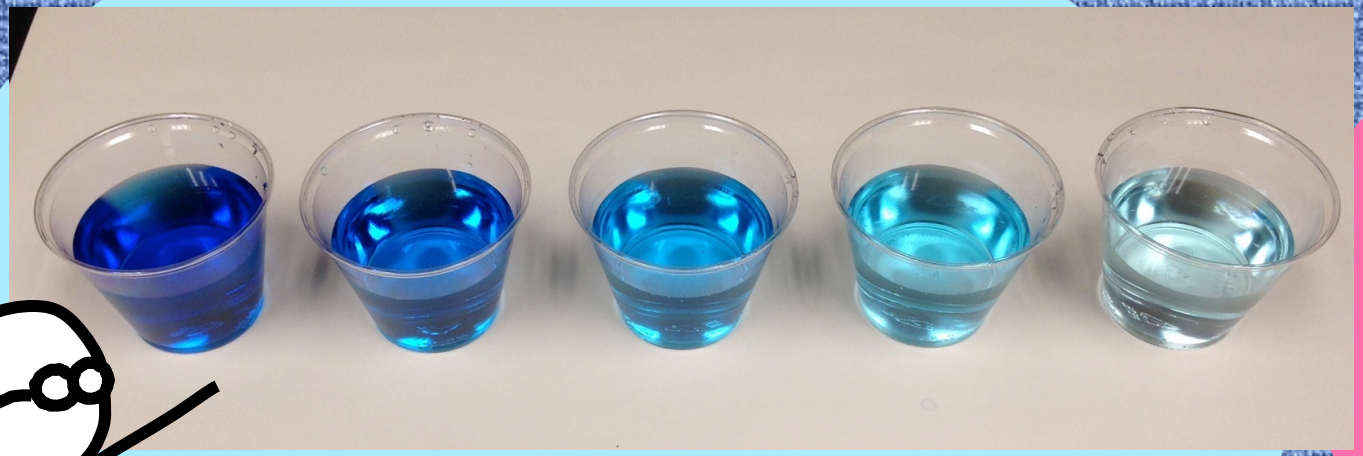


Overview:

1. Kinetics and reaction order
2. Collecting the data
3. Using Excel
4. Procedure: What we will do today
5. Your lab report

It's selfie day in lab! Send a selfie of you and your lab partner to Dr M for the lab website.

1. Kinetics and reaction order



Here we have a cup of blue food coloring undergoing the reaction. Each cup represents a certain period of time

*The formula for blue food coloring is complicated enough that we refer to it as **Blue**.*

$$Blue(aq) + OCl^-(aq) \rightarrow Colorless(aq) + Cl^-(aq)$$

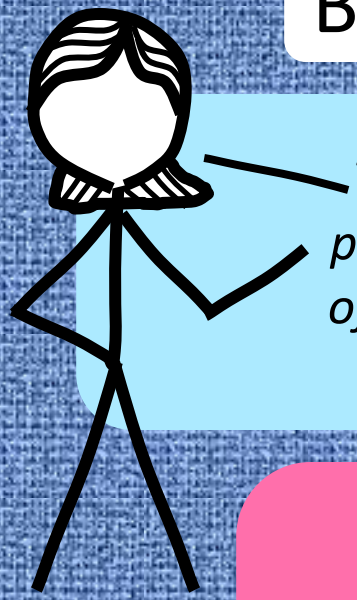
The Blue is blue food coloring.

The hypochlorite ion is the active ingredient in household bleach.

Info for Introduction

1. Kinetics and reaction order

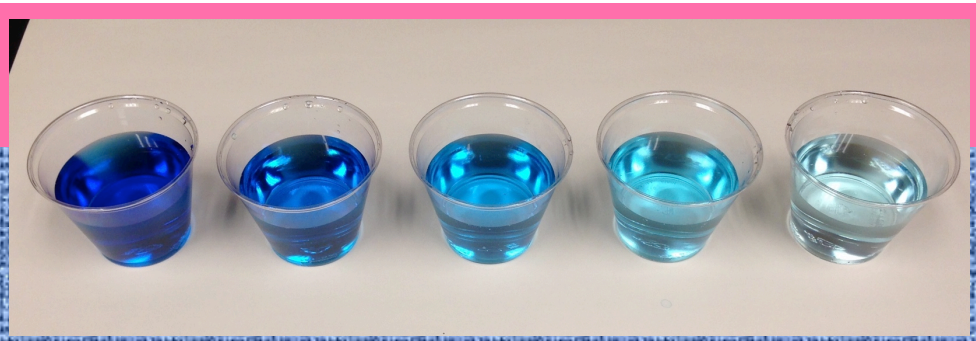
Blue + $OCl^-(aq)$ → Colorless(aq) + $Cl^-(aq)$



The experiment is designed so that there is plenty of hypochlorite throughout the course of the reaction, so our focus is on the kinetics of the reaction in terms of Blue.

We wish to determine the order in terms of Blue. In other words, what is x?

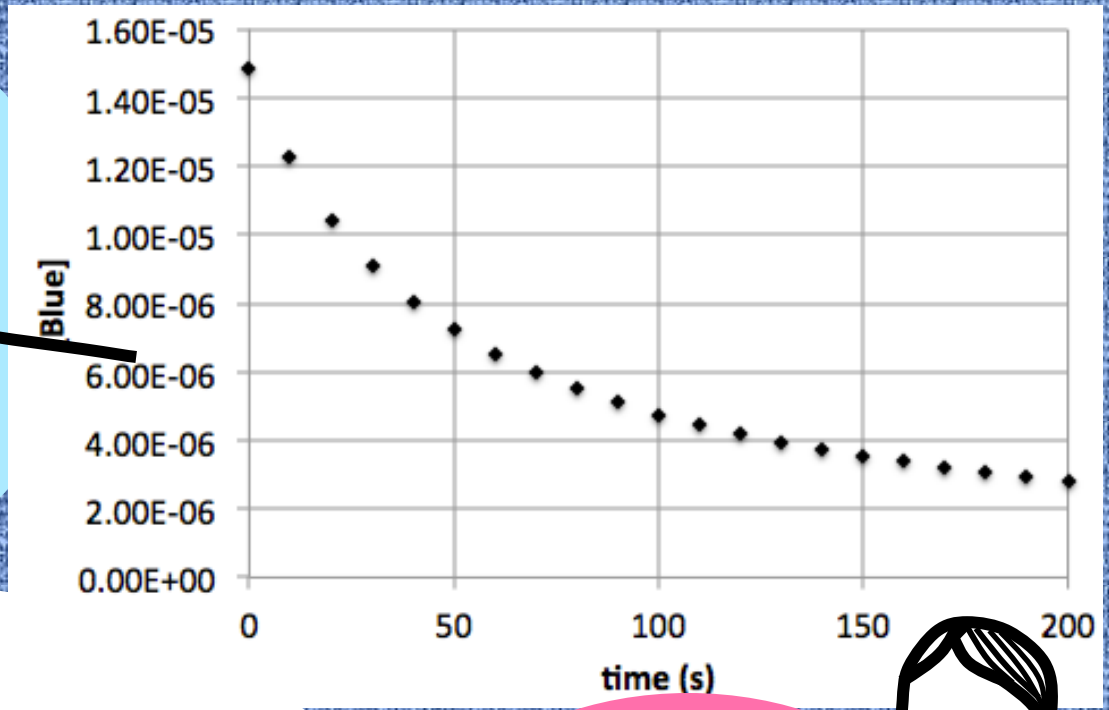
rate = $k[Blue]^x$, Is x = 0, 1 or 2?



Info for Introduction

1. Kinetics and reaction order

We'll make charts like this – three in all. On the x-axis we will always plot time.

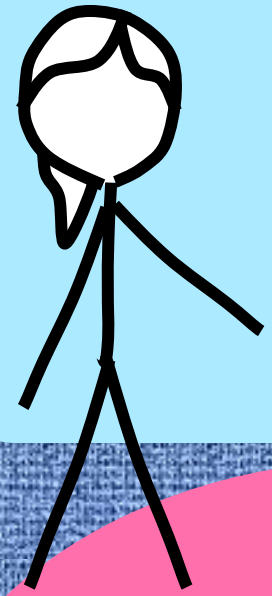


The three charts are: ***[Blue] vs time****,* ***ln[Blue] vs time****, and* ***1/[Blue] vs time*** *to test for zero, first, and second order, respectively.*

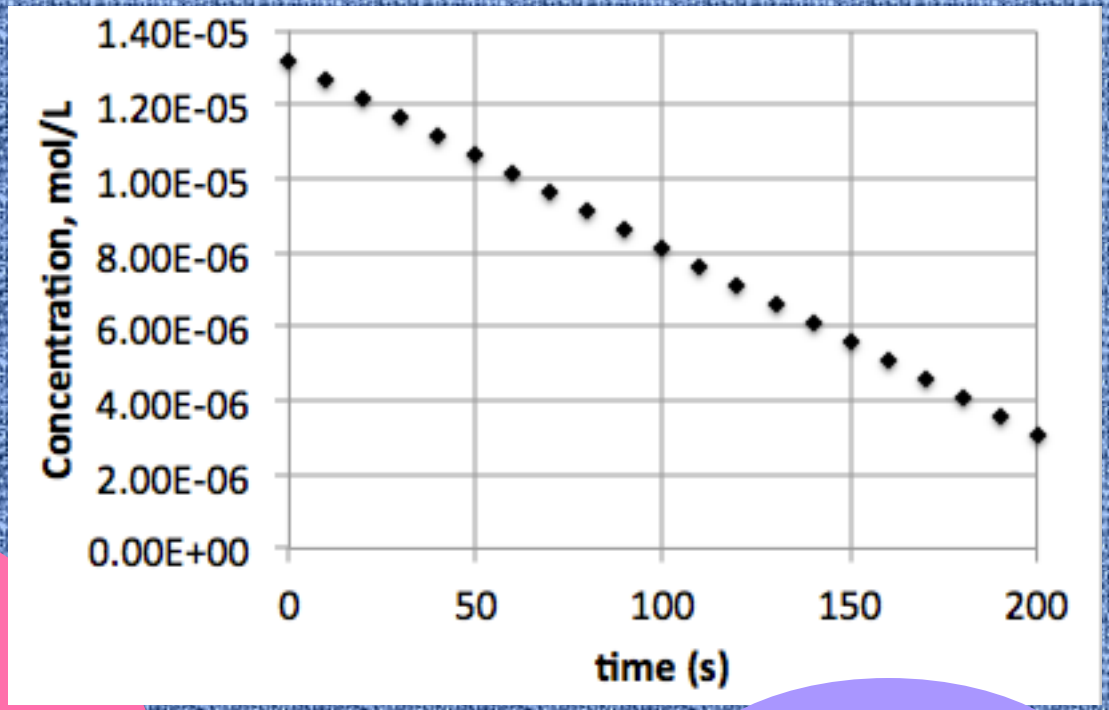
If the data plot up as a curve, that tells us what the order is not. If they plot up linear, we know the order.

Info for Introduction

1. Kinetics and reaction order



Here is how things might look if the reaction were zero order – concentration vs. time is linear!



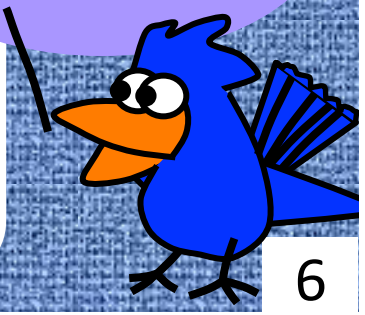
And here is the rate law and the time concentration expression for a zero order reaction…

$$\text{rate} = k[\text{Blue}]^0$$

$$[\text{Blue}]_t = -kt + [\text{Blue}]_o$$

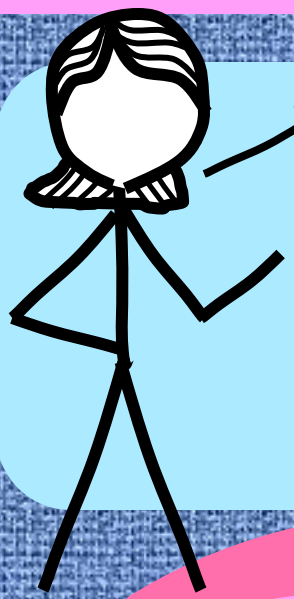
$$y = mx + b$$

See how the slope equals –k?

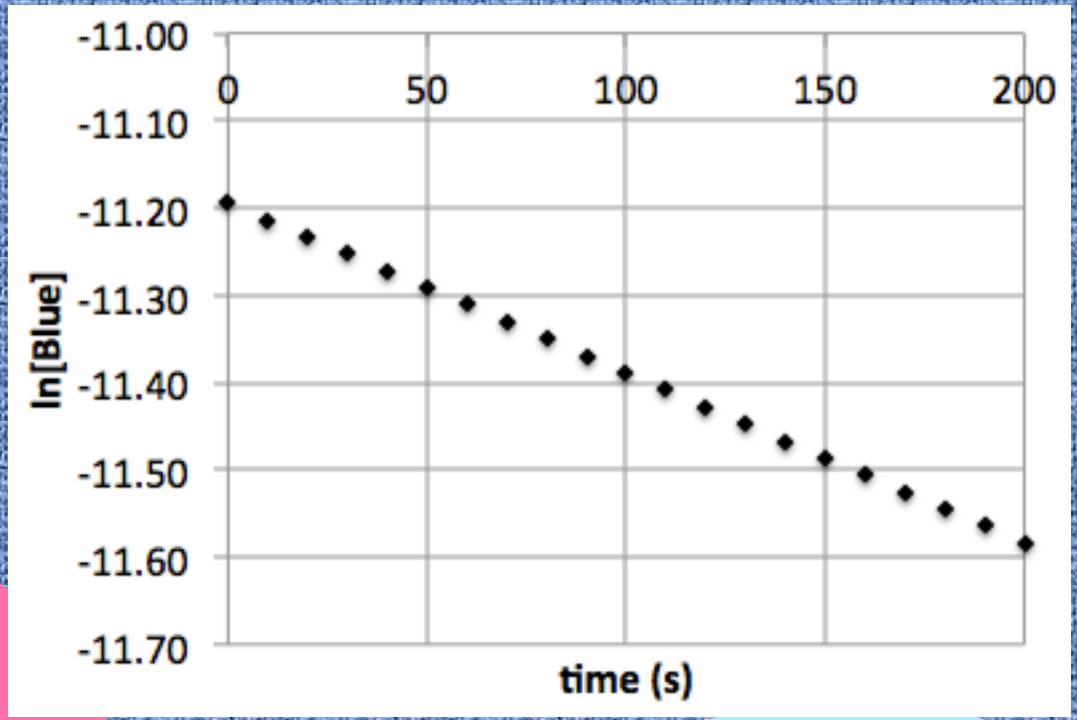


Info for Introduction

1. Kinetics and reaction order



And here is how the graph might look if the reaction were first order. Excel puts the x-axis labels on top if y values are negative.



The rate law and the time concentration expression for a first order reaction…

$$\text{rate} = k[\text{Blue}]^1$$

$$\ln[\text{Blue}]_t = -kt + \ln[\text{Blue}]_o$$

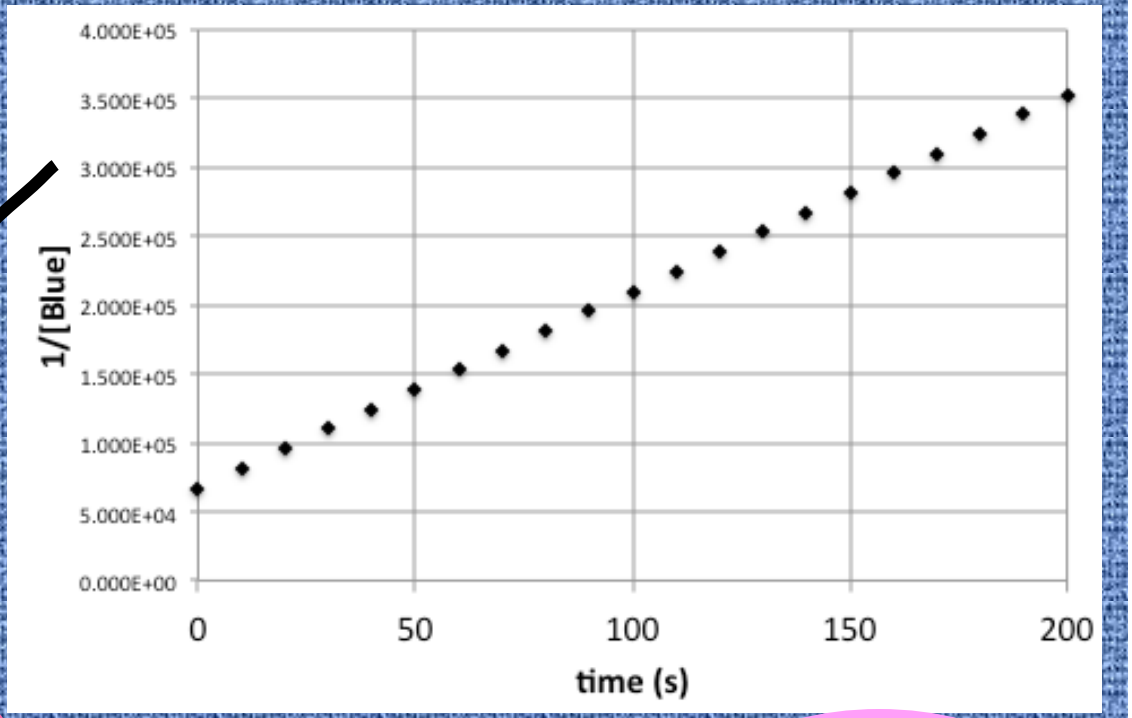
$$y = mx + b$$

Again, the slope equals –k

Info for Introduction

1. Kinetics and reaction order

Second order reactions give charts like this one.



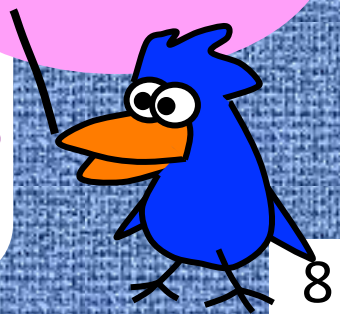
Second order reactions have this rate law and time-concentration expression.

$$\text{rate} = k[\text{Blue}]^2$$

$$1/[\text{Blue}]_t = kt + 1/[\text{Blue}]_o$$

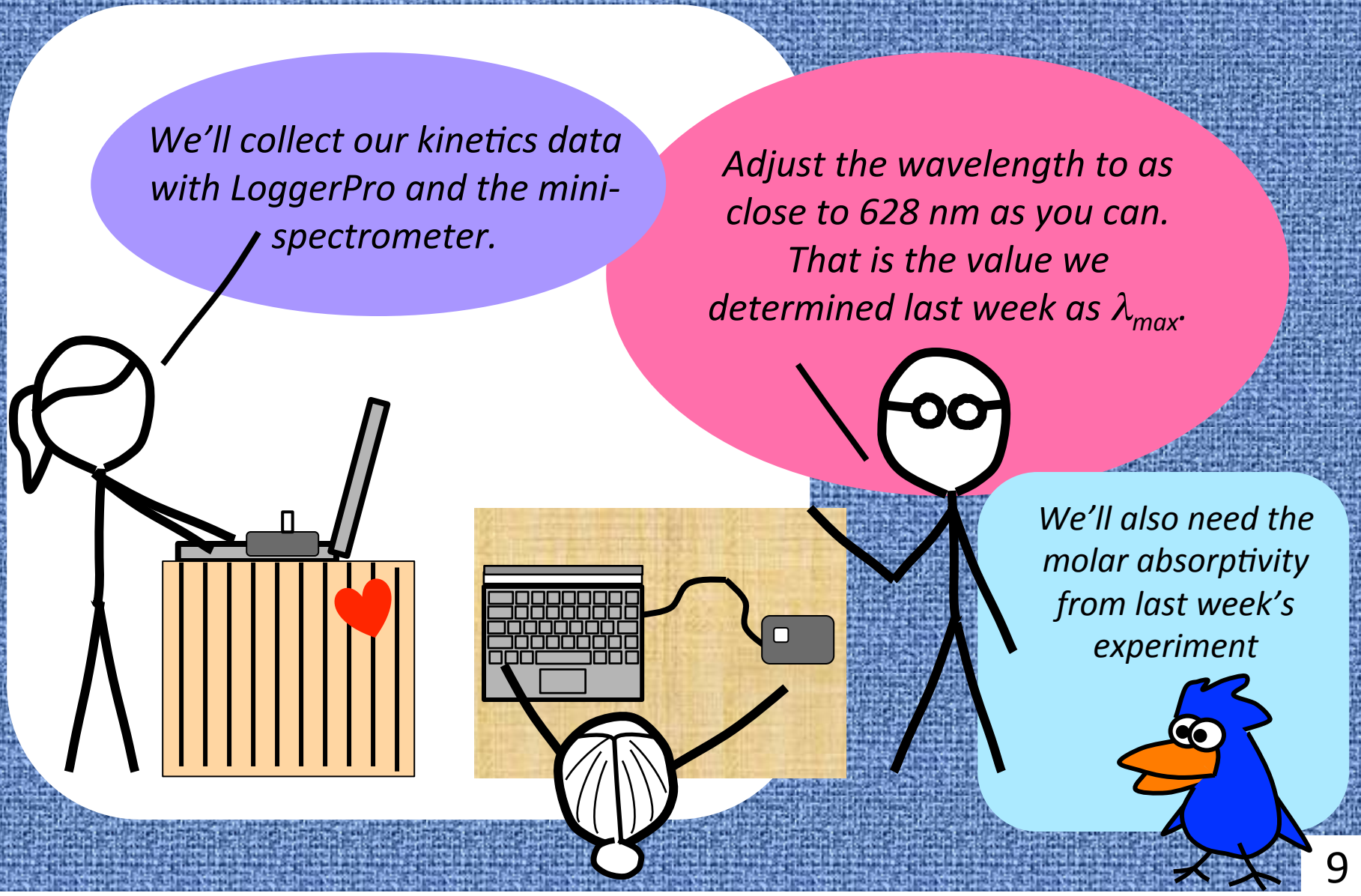
$$y = mx + b$$

This time the slope equals +k



Info for Introduction

2. Collecting the data

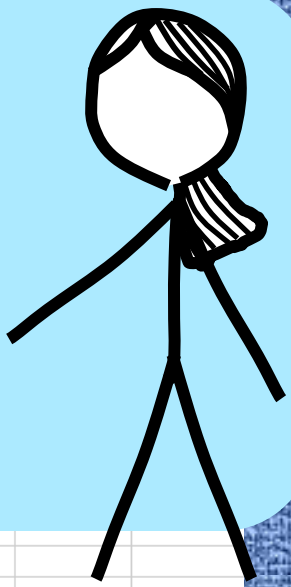


3. Using Excel: Transferring data from LoggerPro

Kinetics data for dry lab.xls

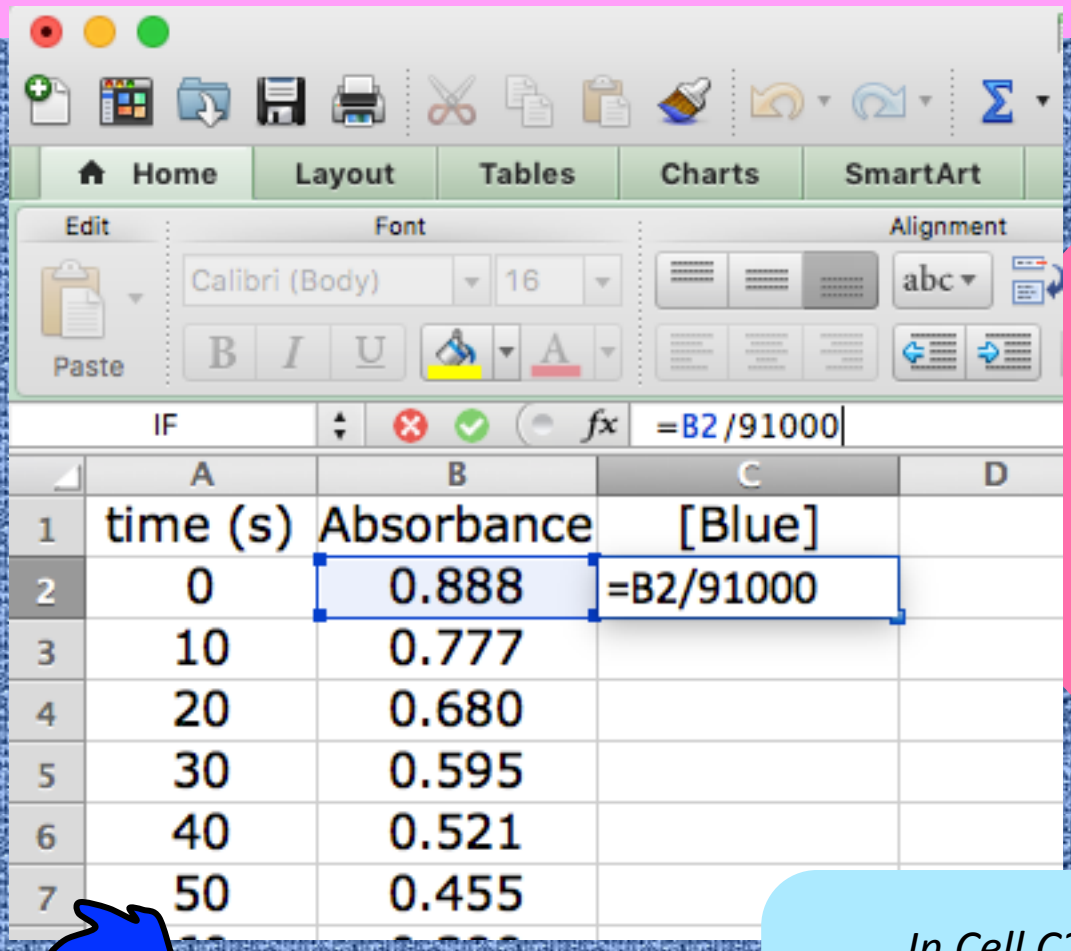
	A	B
1	time (s)	Absorbance
2	0	0.888
3	10	0.777
4	20	0.680
5	30	0.595
6	40	0.521
7	50	0.455
8	60	0.399
9	70	0.349
10	80	0.305
11	90	0.267
12	100	0.234
13	110	0.204
14	120	0.179
15	130	0.157
16	140	0.137
17	150	0.120
18	160	0.105
19	170	0.092
20	180	0.080
21	190	0.070
22	200	0.061

We will work up the data in Excel, so launch Excel. Then highlight and copy the time and Absorbance data from LoggerPro and paste it into Excel using Paste Special, then use Values or Text, depending on the dialog box that comes up.



It should look like this

3. Using Excel: Writing a formula



	A	B	C	D
1	time (s)	Absorbance	[Blue]	
2	0	0.888	=B2/91000	
3	10	0.777		
4	20	0.680		
5	30	0.595		
6	40	0.521		
7	50	0.455		

Here is Beer's law how we normally write it and then again solved for [Blue]

$A = \varepsilon b[Blue]$

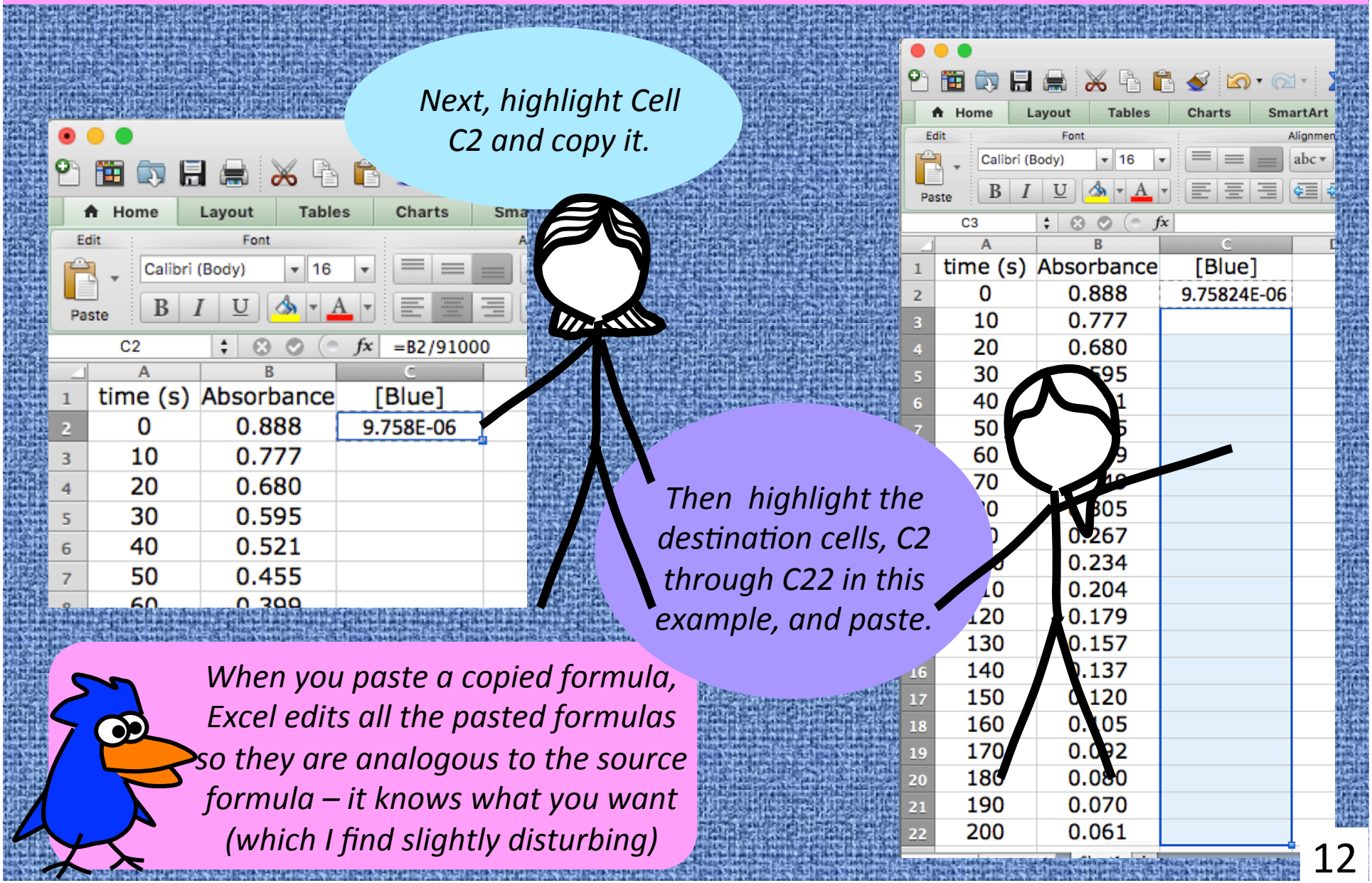
$b = 1\ cm$

$[Blue] = A/\varepsilon$

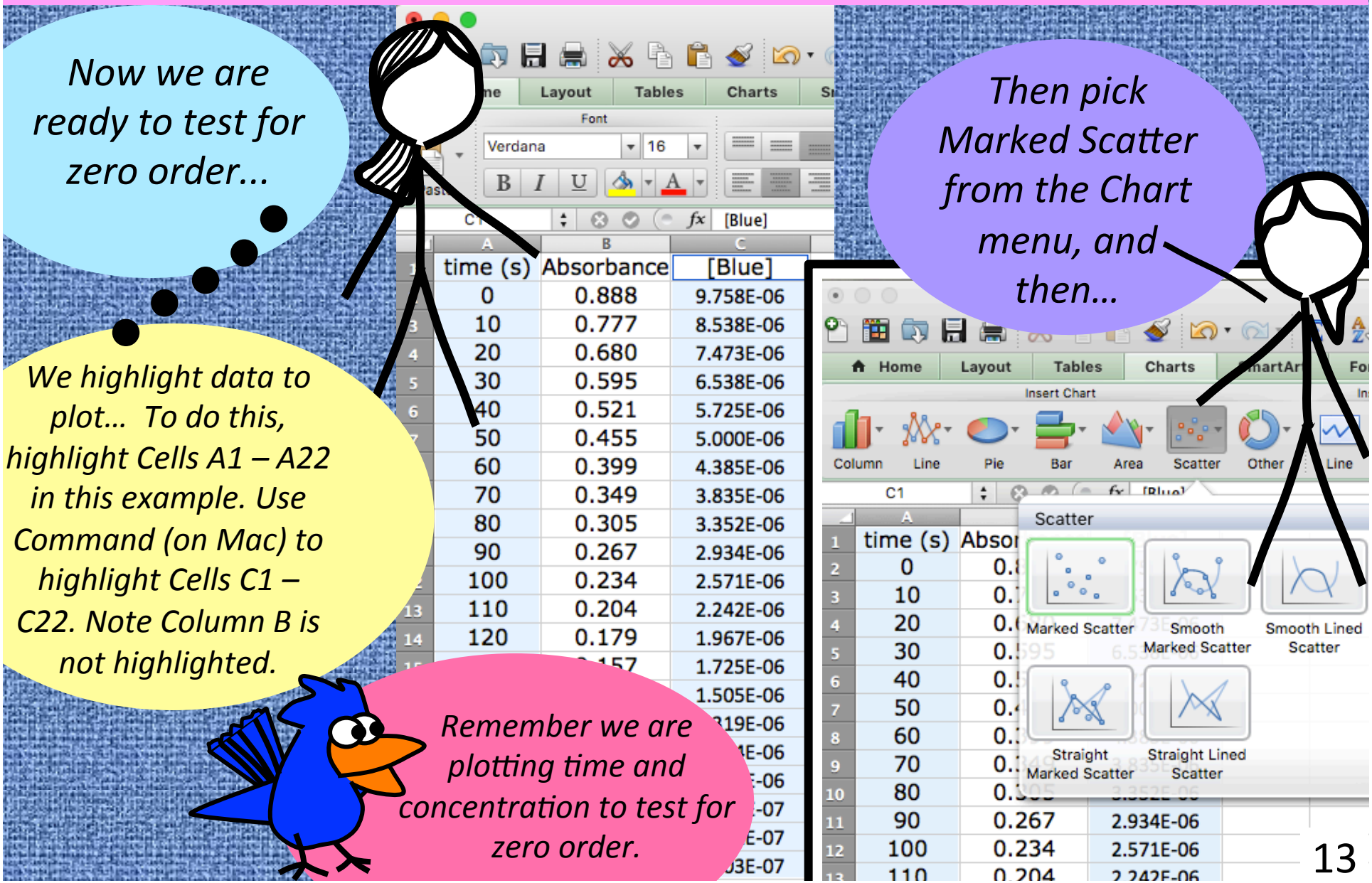
In this example, ε is 91000. Our value will be different – we'll use what we got last week.

In Cell C2, we enter the formula for [Blue] preceded by an equals sign – that's how Excel knows it's a formula.

3. Using Excel: Copy and paste formulas



3. Using Excel: Making a scatter chart

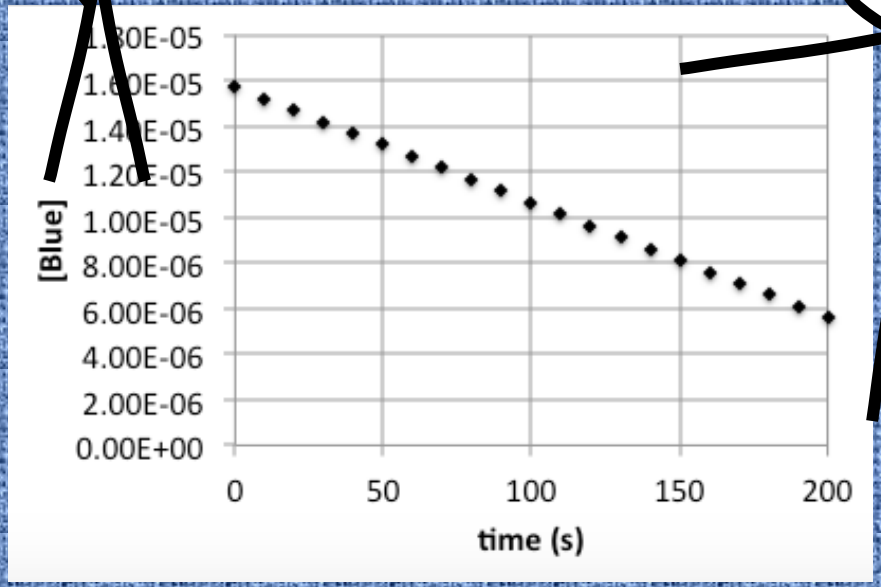


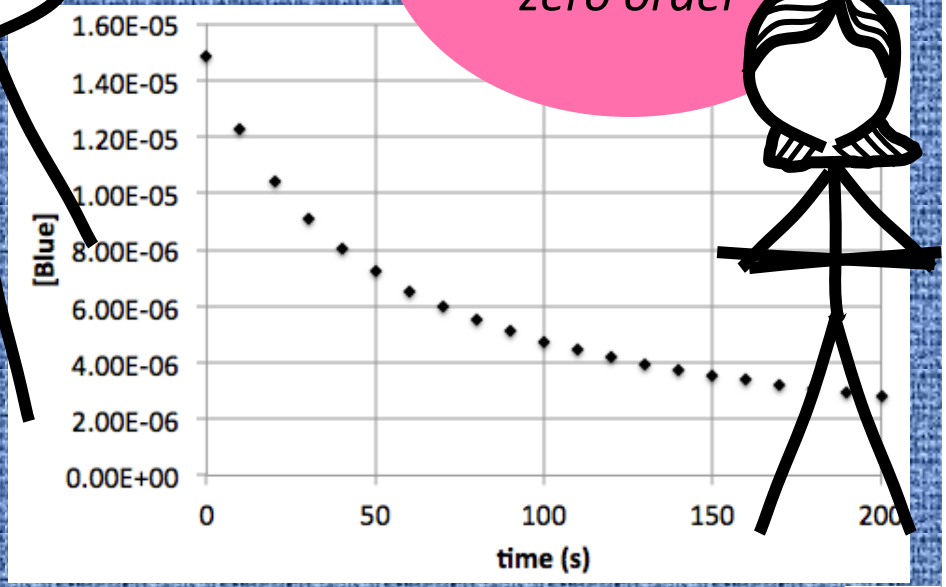
3. Using Excel: Test for zero order

…our chart appears! Almost like magic.

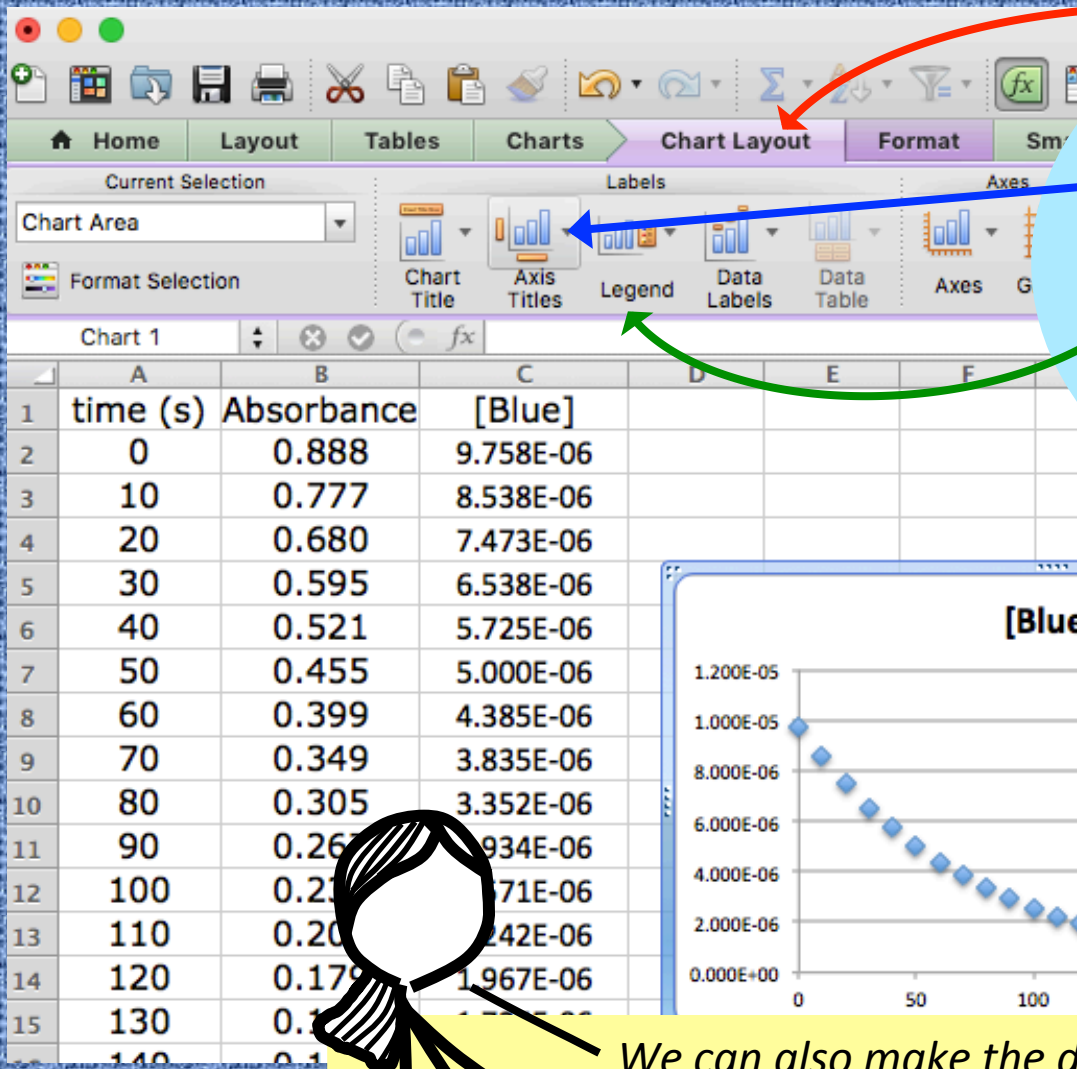
And if it looks like this one on your left, my right, it passes the test for zero order…

But if our data plot up all curvy, the reaction is not zero order



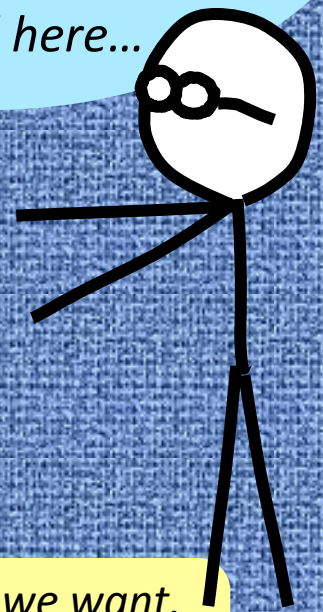


3. Using Excel: Adding chart titles, legend



	A	B	C
1	time (s)	Absorbance	[Blue]
2	0	0.888	9.758E-06
3	10	0.777	8.538E-06
4	20	0.680	7.473E-06
5	30	0.595	6.538E-06
6	40	0.521	5.725E-06
7	50	0.455	5.000E-06
8	60	0.399	4.385E-06
9	70	0.349	3.835E-06
10	80	0.305	3.352E-06
11	90	0.26	934E-06
12	100	0.2	71E-06
13	110	0.20	242E-06
14	120	0.17	1.967E-06
15	130	0.	

*You can click on **Chart Layout** and **pick Axis Title** to add labels for the x- and y-axes. **Then add a legend** (a title to your chart.) Maybe something about zero order? Just thinking out loud here…*



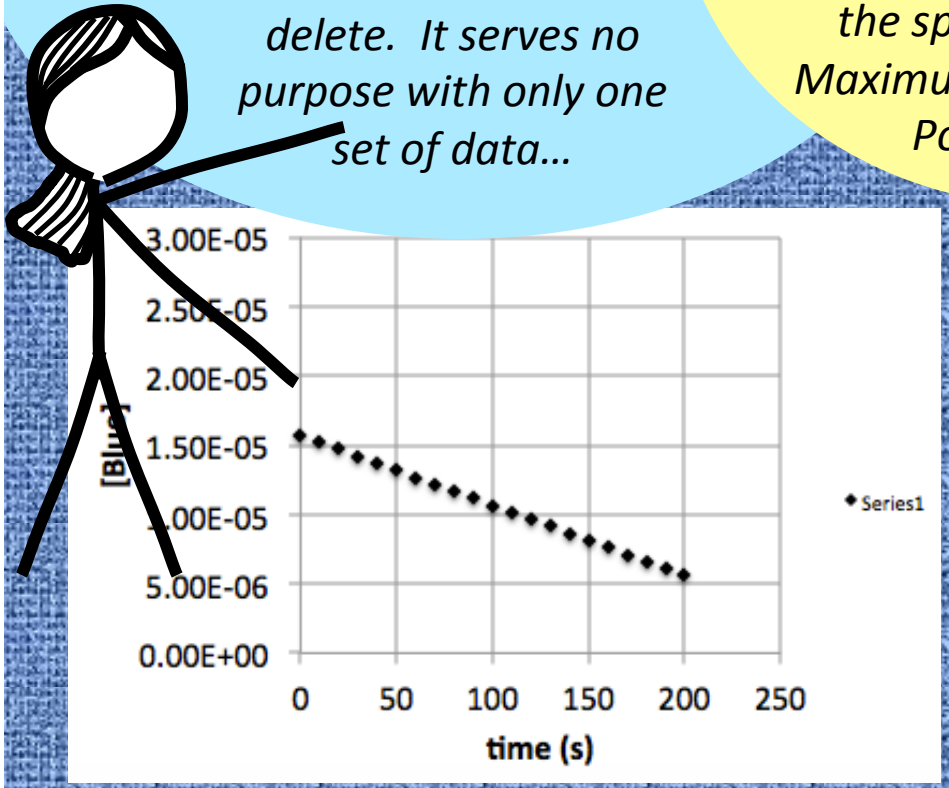
We can also make the data points look like we want. Select the points by clicking on one of them and then do Format Selection. See previous and next slides.

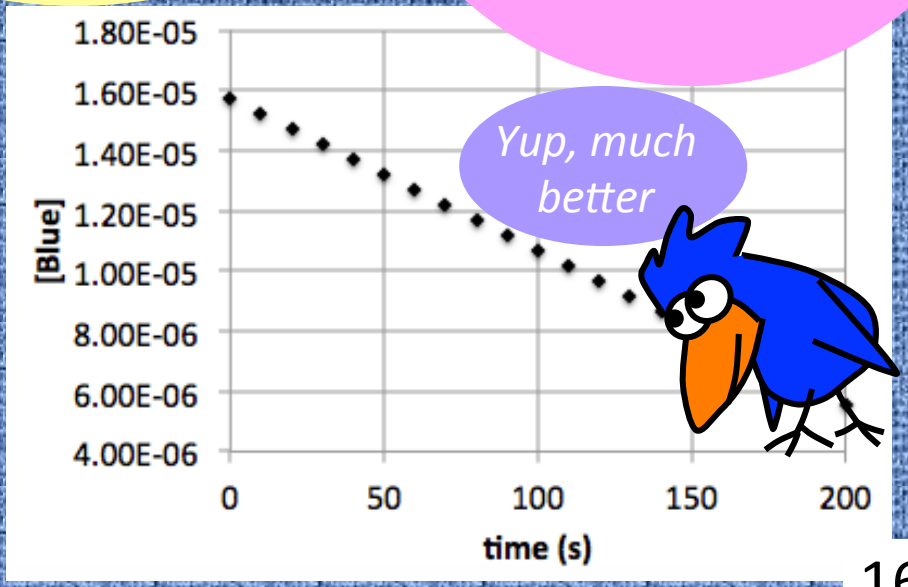
3. Using Excel: Custom fitting the layout

Now we can make our graph a bit prettier. Check out the charts below. They are the same except for cosmetic differences. Click on Series1 and hit delete. It serves no purpose with only one set of data…

The data along both axes are not optimally displayed. Select the labels on the x-axis (double click) and select Scale. Adjust the scale for the best use of the space – change the Maximum from 250 to 200. Poof it's better.

The scale along the y-axis is also less than ideal. Change it to Minimum = 5.00E-06 and Maximum = 1.80E-5.



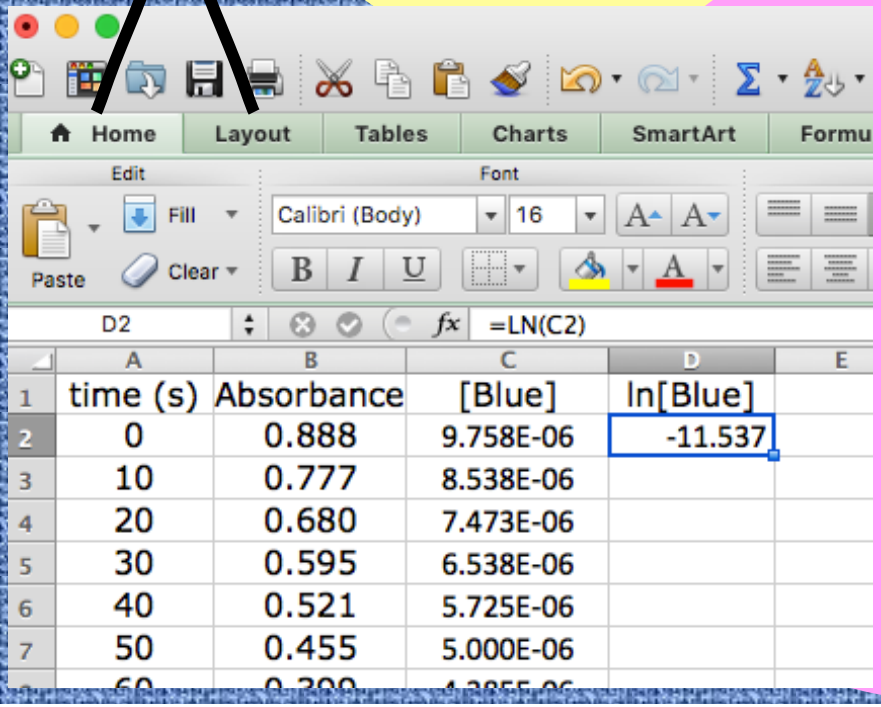


3. Using Excel: Test for first order

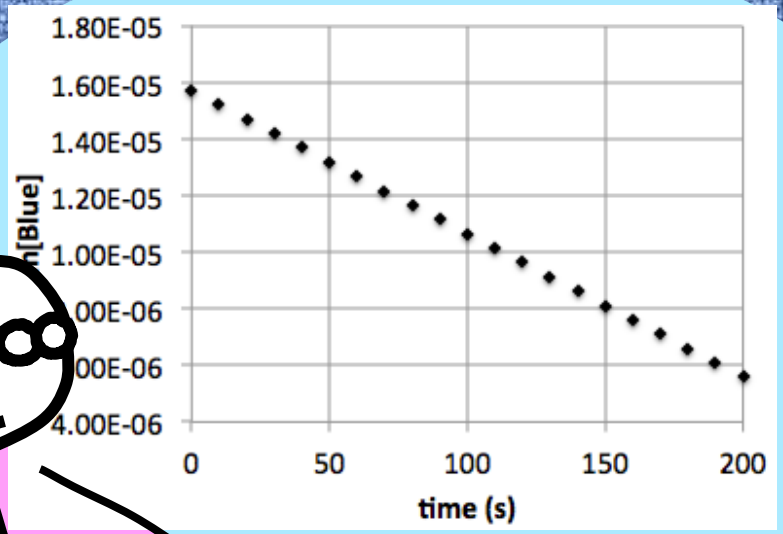
Next, we test for first order. In Cell D2, enter

=ln(C2)

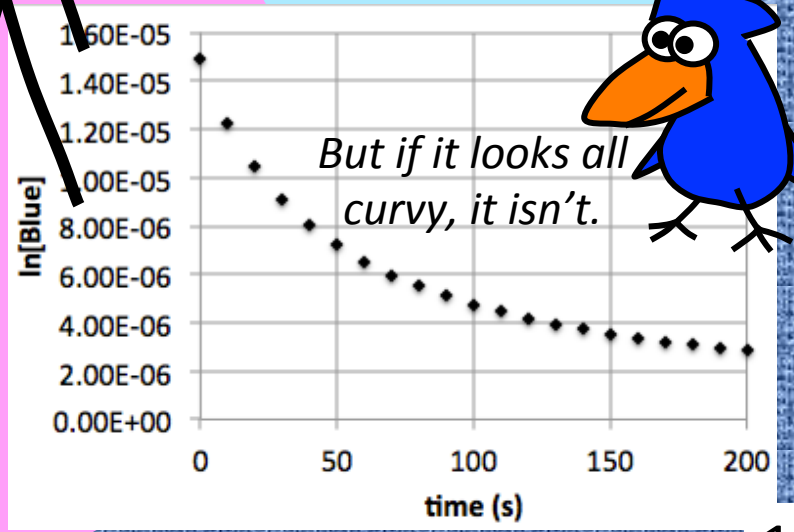
Copy Cell D2 and paste it into D3-D22. Then make a chart like we did for zero order.



	A	B	C	D	E
1	time (s)	Absorbance	[Blue]	ln[Blue]	
2	0	0.888	9.758E-06	-11.537	
3	10	0.777	8.538E-06		
4	20	0.680	7.473E-06		
5	30	0.595	6.538E-06		
6	40	0.521	5.725E-06		
7	50	0.455	5.000E-06		



Hmmm... This looks like first order...



But if it looks all curvy, it isn't.

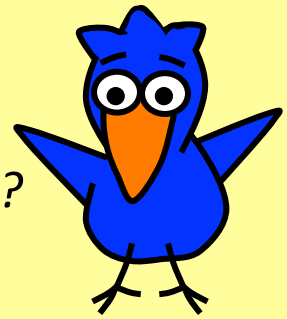
3. Using Excel: Test for second order

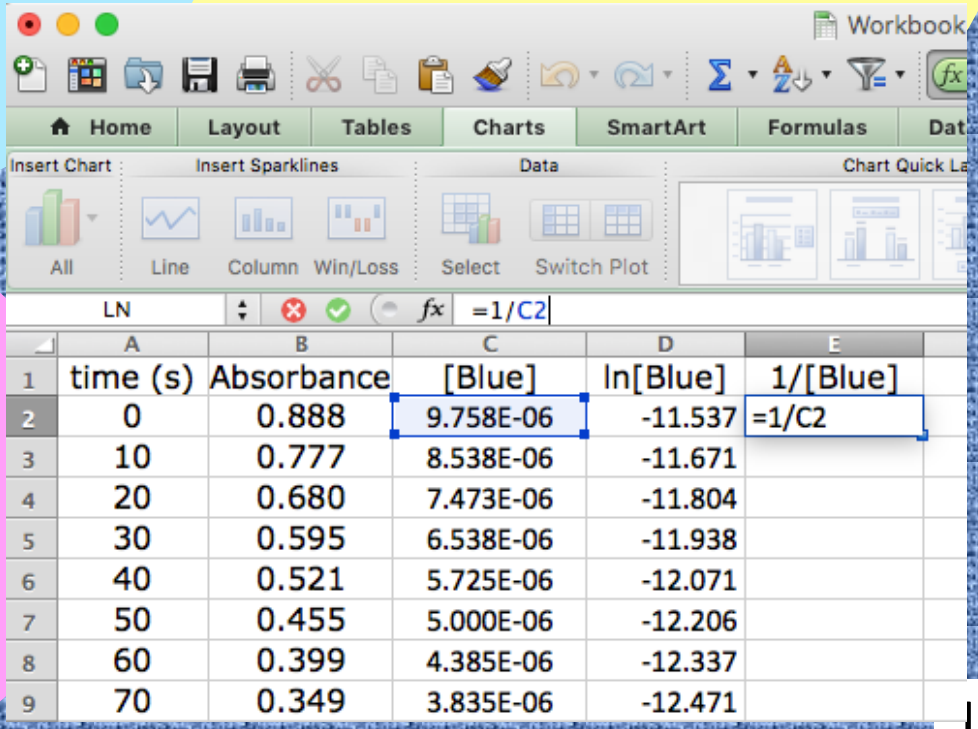
Next, we test for second order. In Cell E2, enter

=1/(C2)

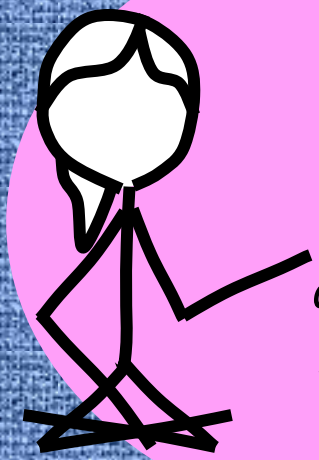
Copy Cell E2 and paste it into E3-E22. Then make a chart...

...and what happens next?



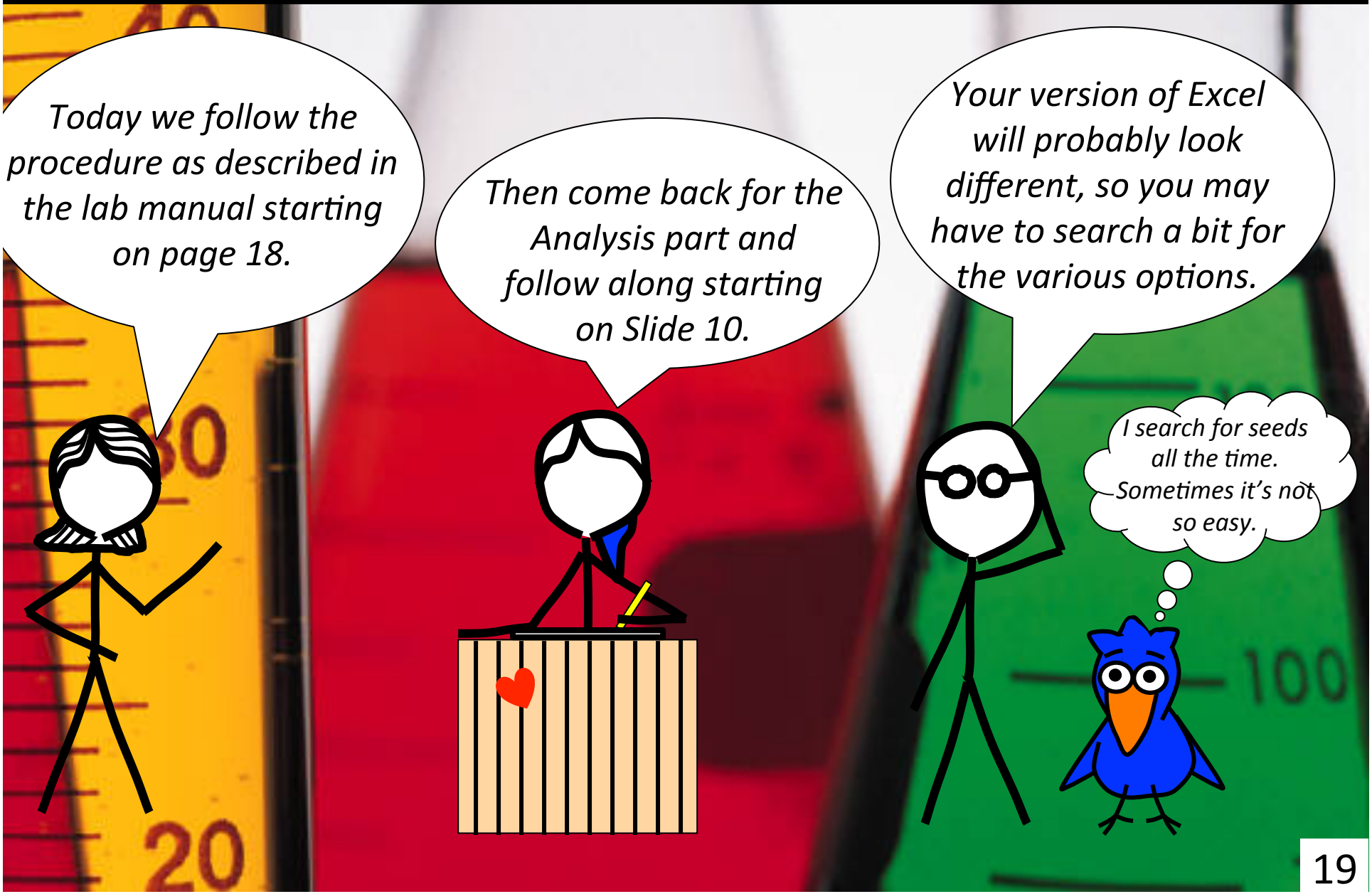


	A	B	C	D	E
1	time (s)	Absorbance	[Blue]	ln[Blue]	1/[Blue]
2	0	0.888	9.758E-06	-11.537	=1/C2
3	10	0.777	8.538E-06	-11.671	
4	20	0.680	7.473E-06	-11.804	
5	30	0.595	6.538E-06	-11.938	
6	40	0.521	5.725E-06	-12.071	
7	50	0.455	5.000E-06	-12.206	
8	60	0.399	4.385E-06	-12.337	
9	70	0.349	3.835E-06	-12.471	



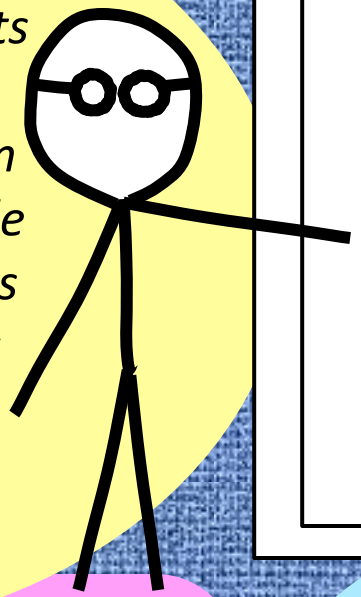
Once we know the order, we know the rate constant and the rate law. Right?

4. Procedure: What we will do today



4. Procedure: What we will do today

Arrange your data and charts so they have this general shape and can be printed on one page. It may take a little fiddling… You can make this arrangement in Excel or by taking screen shots and pasting into a Word document.



Your Excel data should be presented here – all of the data – 5 columns and ~25 rows.

Zero order chart

First order chart

Second order chart

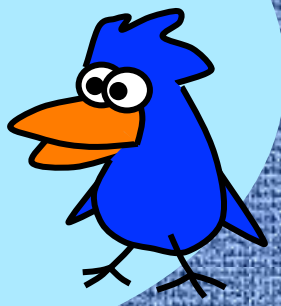
The rate constant, k, comes from the slope of the straight-line plot and is always positive. Absorbance data had 3 significant figures, but trendline uses data from them as a set, so it is possible to report four sig figs.

Eye on the prize! What is the rate law?

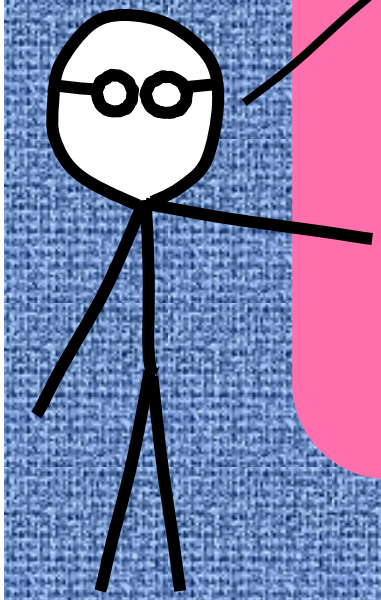
rate = k[Blue]^0

rate = k[Blue]^1

rate = k[Blue]^2



4. Procedure: What we will do today

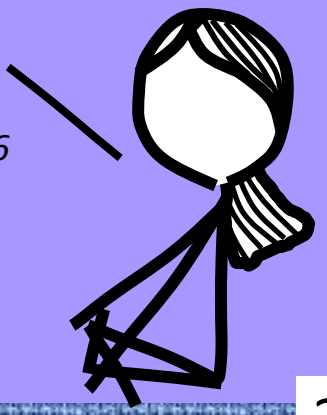


Save your Excel spreadsheet for the quiz next week. You will use your laptop during the quiz. Data that will be used in the quiz are provided at the Chm 206 website so you can prepare the worksheet prior to the quiz.

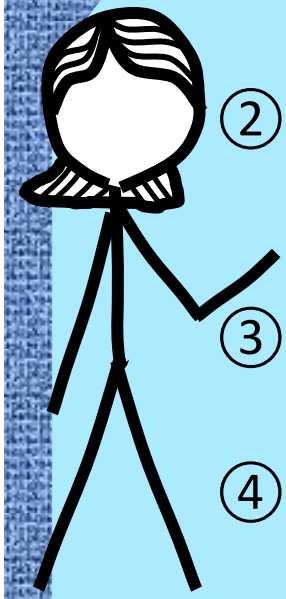
Use the same cell layout as in the examples. A question might be: "What formula is entered in Cell D15?"

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 will do today



① *Wearing your safety glasses is necessary due to the bleach. Also, dress for a mess.*

② *Take time writing an introduction in your own words before lab. Include Objective from Slide 2 and equations from Slides 3 – 8. Also mention how the slope gives us k for each order.*

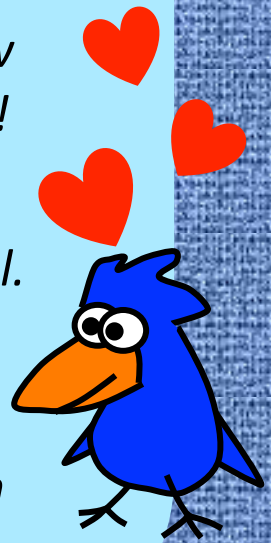
③ *Each pair of students performs Parts A - D of the procedure as per lab manual.*

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

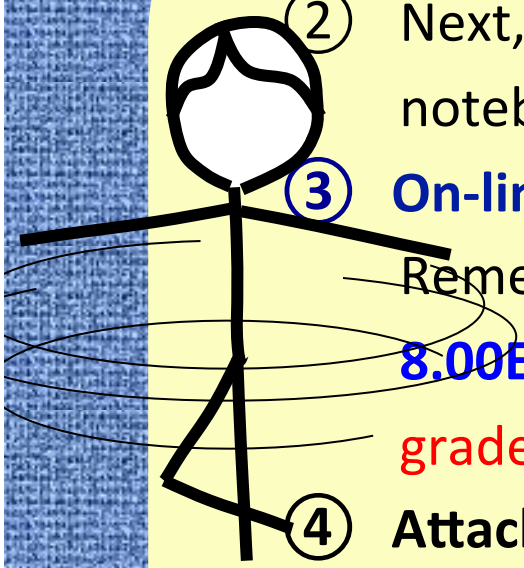
⑤ *Analysis is done using Excel. For the purposes of next week's quiz, use the format given here rather than in the Lab Manual.*

⑥ *Determine order, rate constant (from slope of trendline) and half-life as part of your lab report. Determine the rate constant from the slope of the line. Calculate half life – watch the sig figs.*

⑦ *Submit on-line data before you leave today.*



5. Your lab report



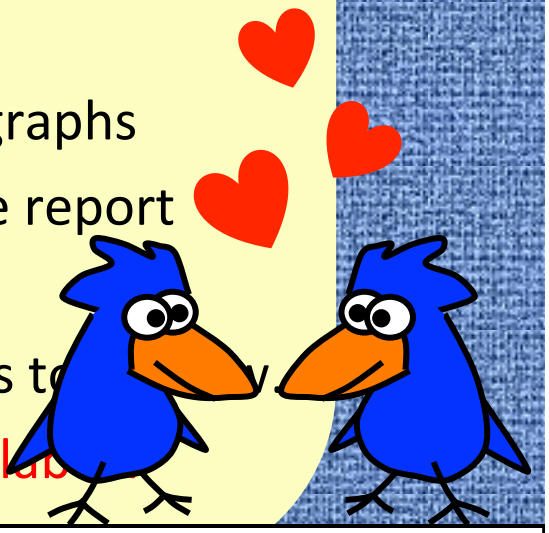
① First, the cover page with TA initials.

② Next, the trimmed copy pages from your lab notebook.

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 **Attachments:** Your Excel data and three graphs (preferably all on one page). Staple entire report together.

⑤ Turn in lab report ***before*** the start of class t[illegible]. Late labs may not be graded – see the syll[illegible]



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.*