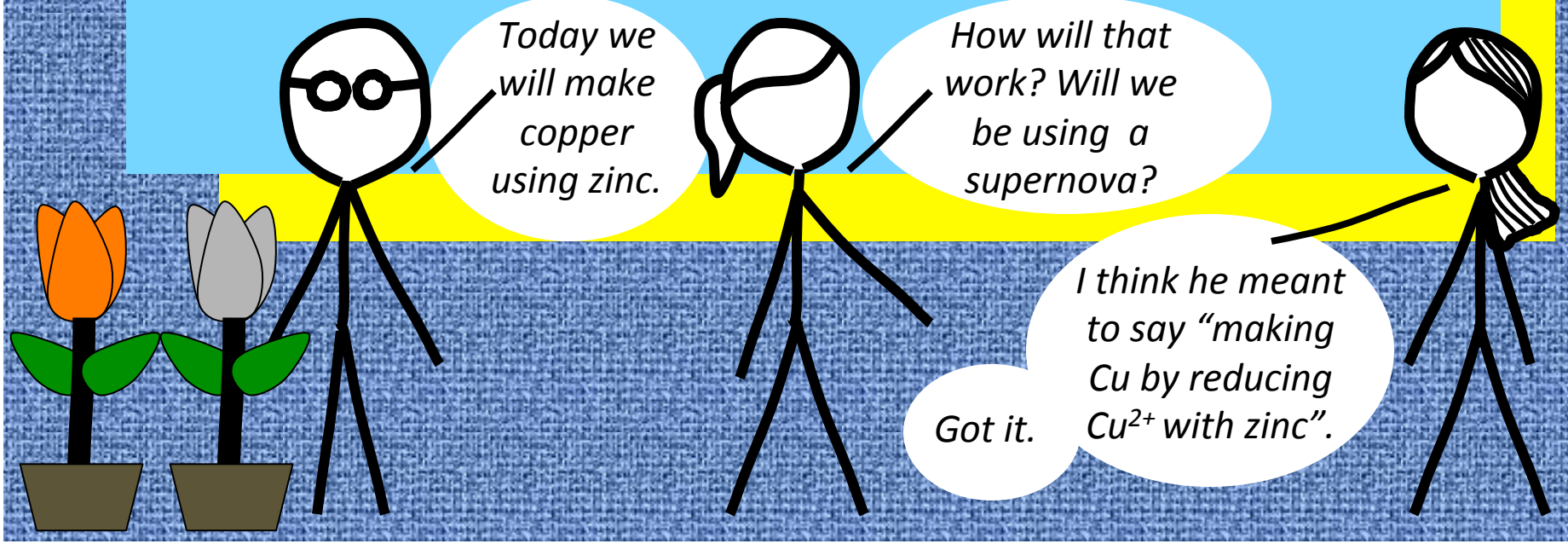
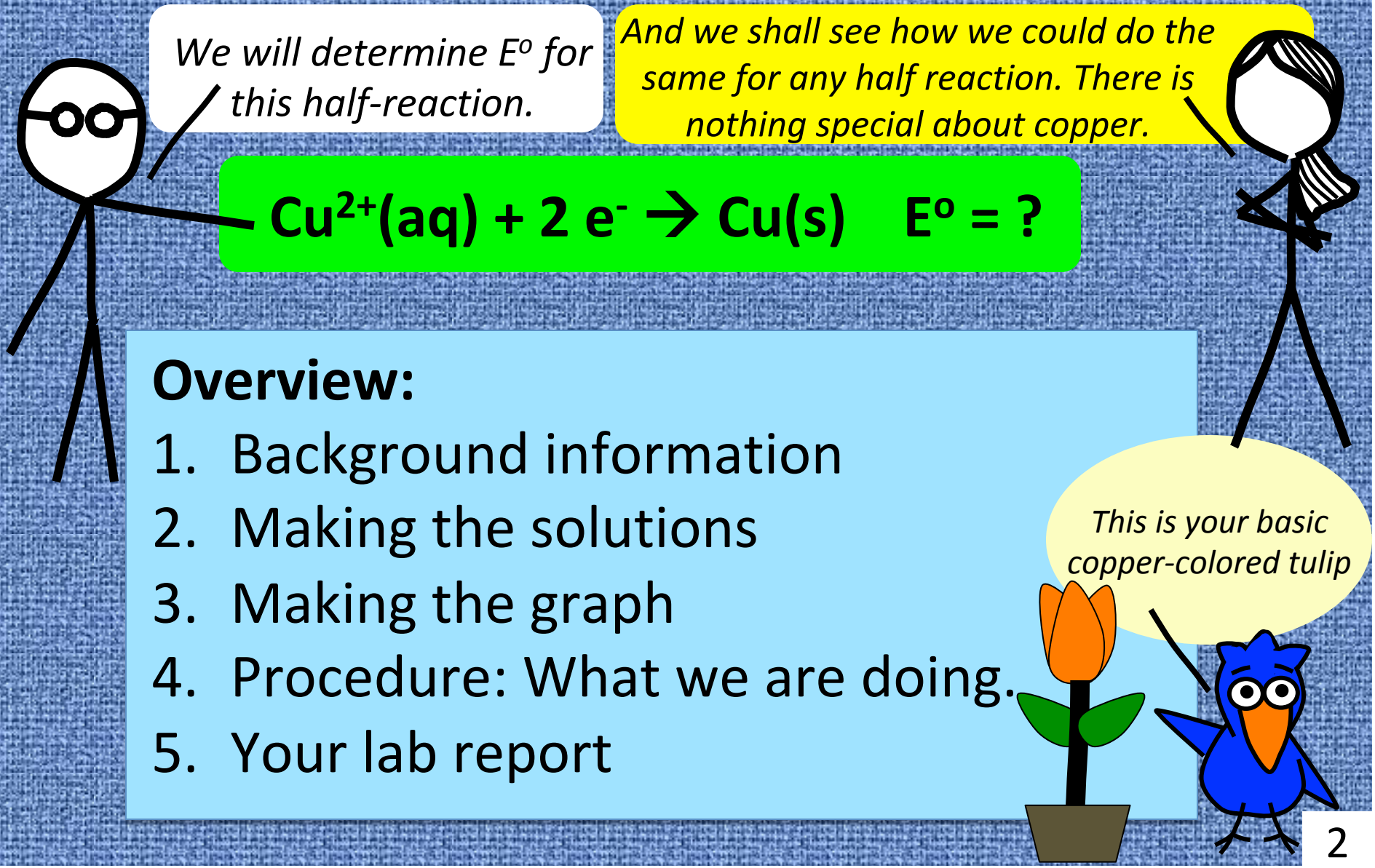
Experiment 13
30 April 2019
Determination of the Standard Reduction Potential of Cu^{2+}



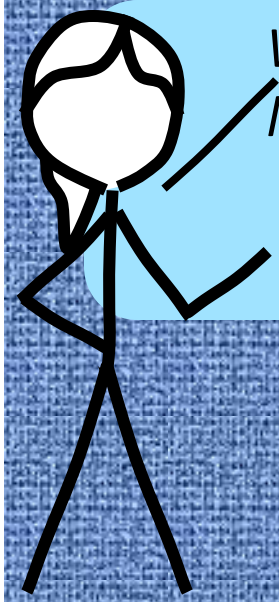
Objective: To determine the standard reduction potential, E^o, for $Cu^{2+}(aq)$



Overview:

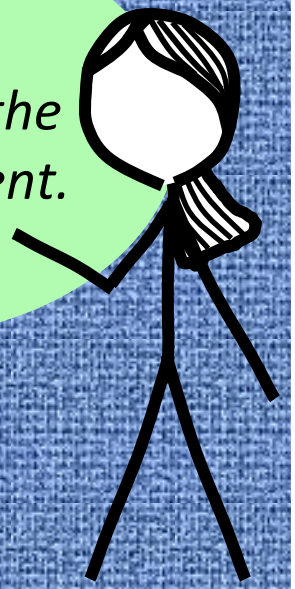
1. Background information
2. Making the solutions
3. Making the graph
4. Procedure: What we are doing.
5. Your lab report

1. Background information

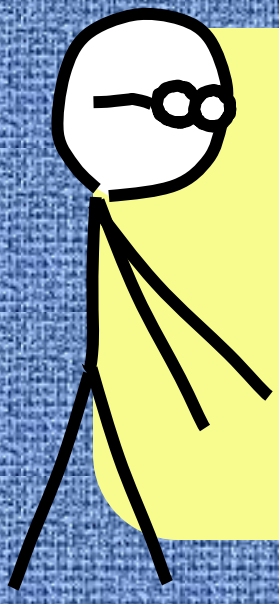


We start with the ΔG and Q_c equation we learned about in the thermo chapter. The formula is used to calculate ΔG under non-standard conditions.

We used it previously in the urea experiment.

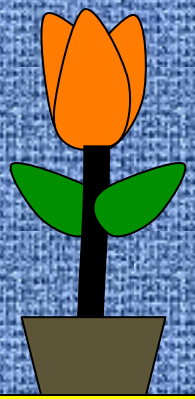


$$\Delta G_{sol'n} = \Delta G^{o}_{sol'n} + RT \ln(Q_c)$$

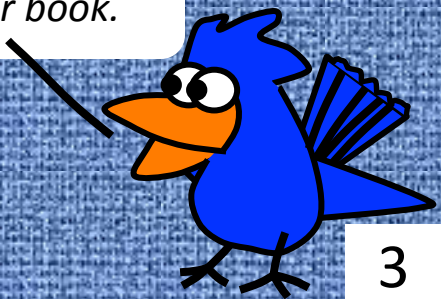


When we used it in the urea experiment, we utilized the fact that ΔG = 0 at equilibrium, so the equation becomes:

$$0 = \Delta G^{o}_{sol'n} + RT \ln(K_c)$$



See Section 17.10 in our book.



Info for Introduction

1. Background information

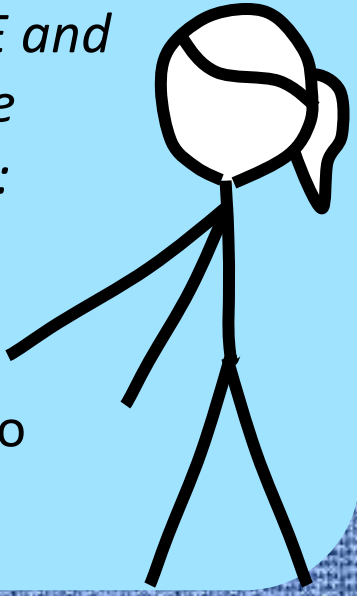
$$\Delta G = \Delta G^o + RT \ln(Q_c)$$

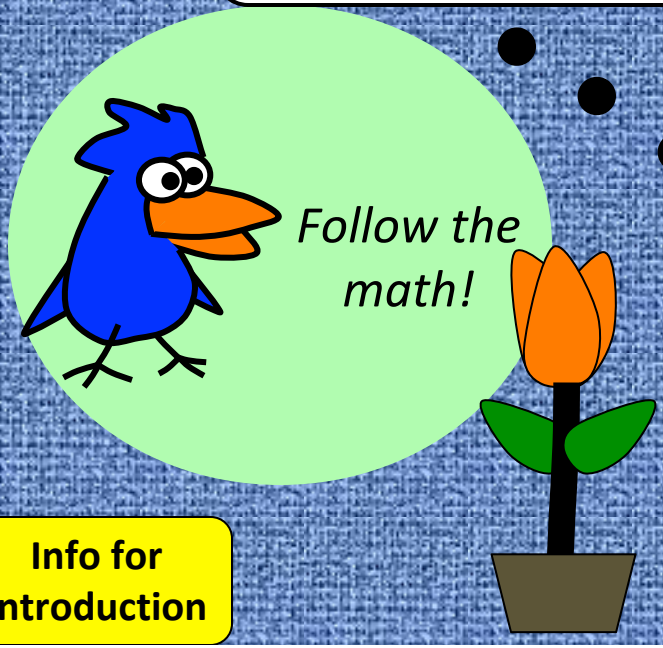
$$-nFE = -nFE^o + RT \ln(Q_c)$$

These relationships between ΔG and E and ΔG^o and E^o are substituted in:

$$\Delta G = -nFE$$

$$\Delta G^o = -nFE^o$$





$$E = E^o - \frac{RT}{nF} \ln(Q_c)$$

$$E = E^o - \frac{2.303RT}{nF} \log(Q_c)$$

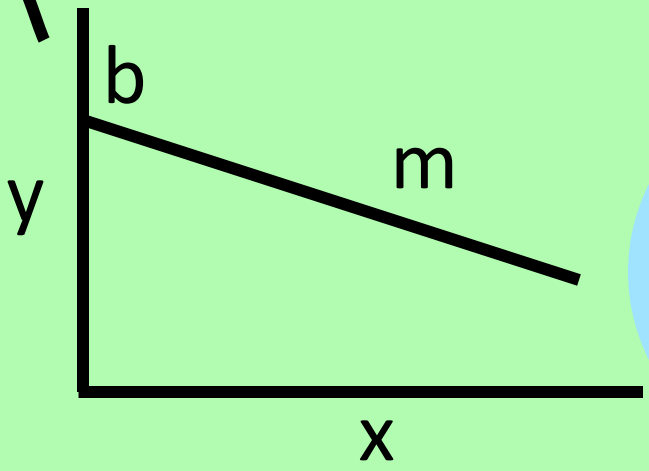
Info for Introduction

1. Background information

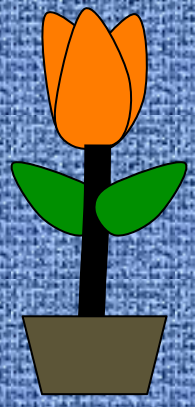
This experiment lets us determine E^o by using the equation of a straight line, $y = mx + b$.

$$E = E^o - \frac{2.303RT}{nF} \log(Q_c)$$

$$y = mx + b$$



E^o is b. That's what we are trying to determine today.



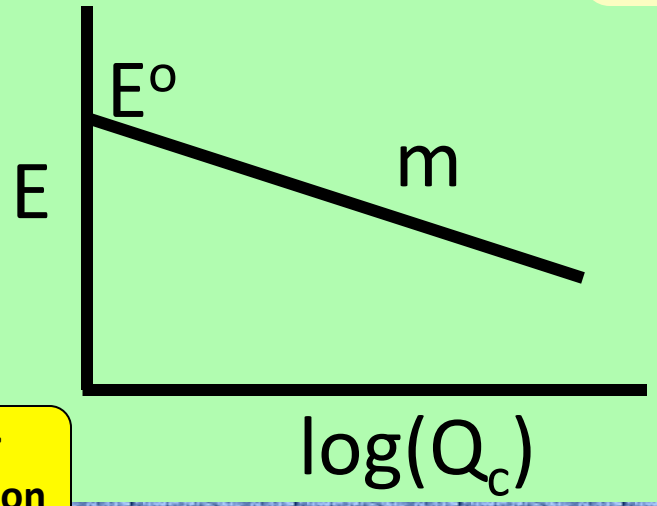
Info for Introduction

1. Background information

$$E = E^o - \frac{2.303RT}{nF} \log(Q_c)$$

$$y = mx + b$$

But first, why not add a few more simple connector lines…



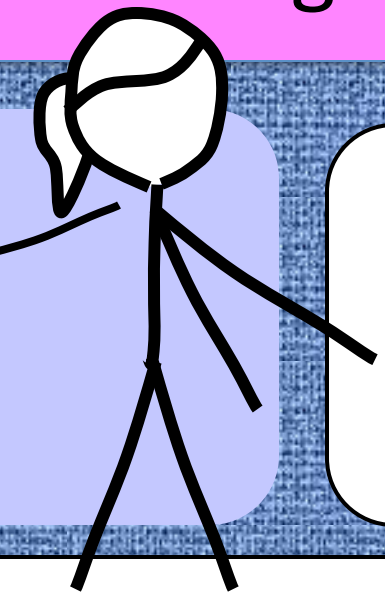
So if we graph E vs. $\log(Q_c)$, we will know E^o!

Obviously.

Info for Introduction

1. Background information

In our experiment, we study the reduction of Cu^{+2} by zinc.



Cathode: $Cu^{2+} + 2\ e^- \rightarrow Cu$

Anode: $Zn \rightarrow Zn^{2+} + 2\ e^-$

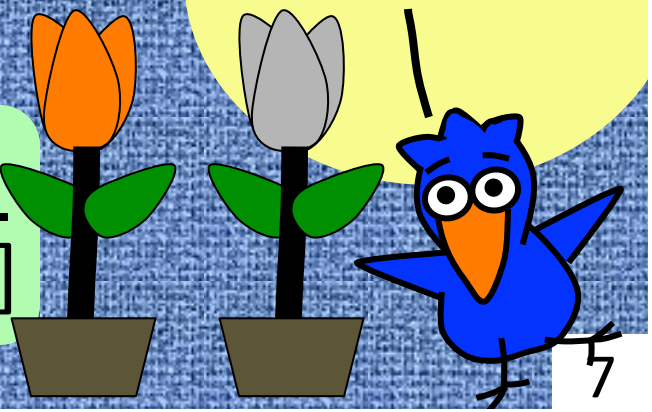
Overall: $Cu^{2+} + Zn \rightarrow Cu + Zn^{2+}$

$$Cu^{2+} + Zn \rightarrow Cu + Zn^{2+} \qquad Q_c = \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

Zinc is gray, so this is a zinc-colored tulip.

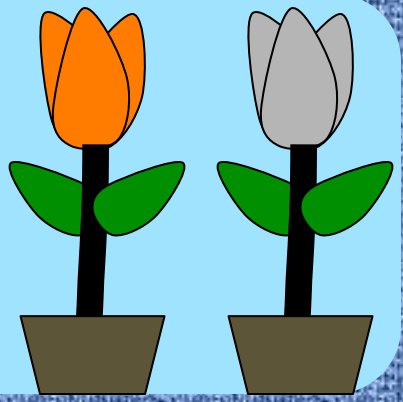
By design for this experiment, $[Zn^{2+}]$ = 0.10 M – and never changes, so…

$$Q_c = \frac{0.10}{[Cu^{2+}]}$$

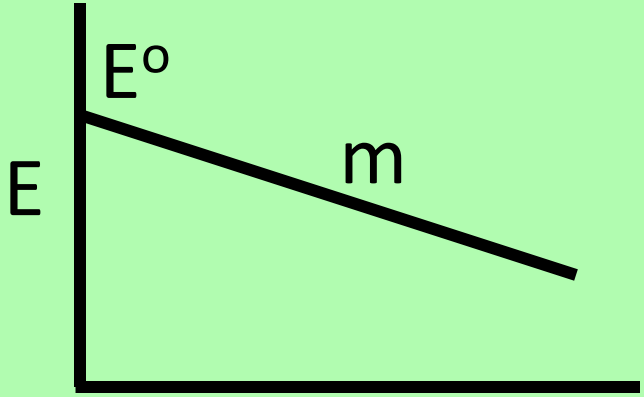


2. Making the solutions

$Cu^{2+} + Zn \rightarrow Cu + Zn^{2+}$ $\quad Q_c = \frac{0.10}{[Cu^{2+}]}$



$$E = E^o - \frac{2.303RT}{nF} \log\left(\frac{0.10}{[Cu^{2+}]}\right)$$

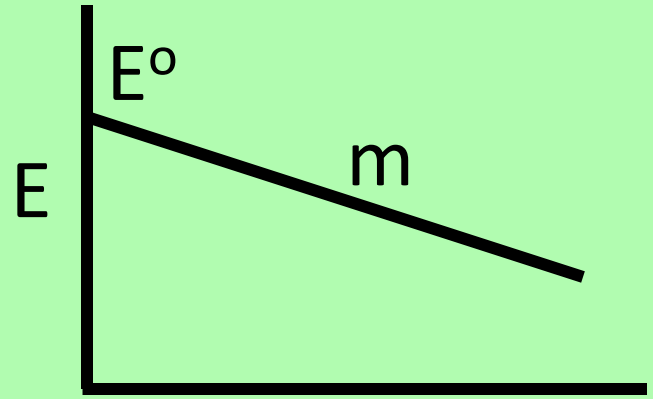


We need to make a bunch of solutions with varying concentrations of Cu^{2+} so we can have a variety of values along the x-axis. For each we will measure E and that should make a plot like this one.

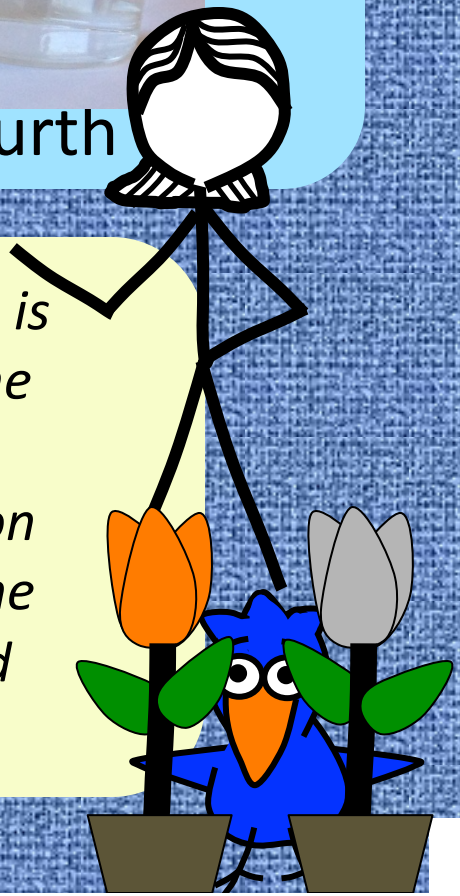
2. Making the solutions

Progressive dilutions…

Stock first second third fourth

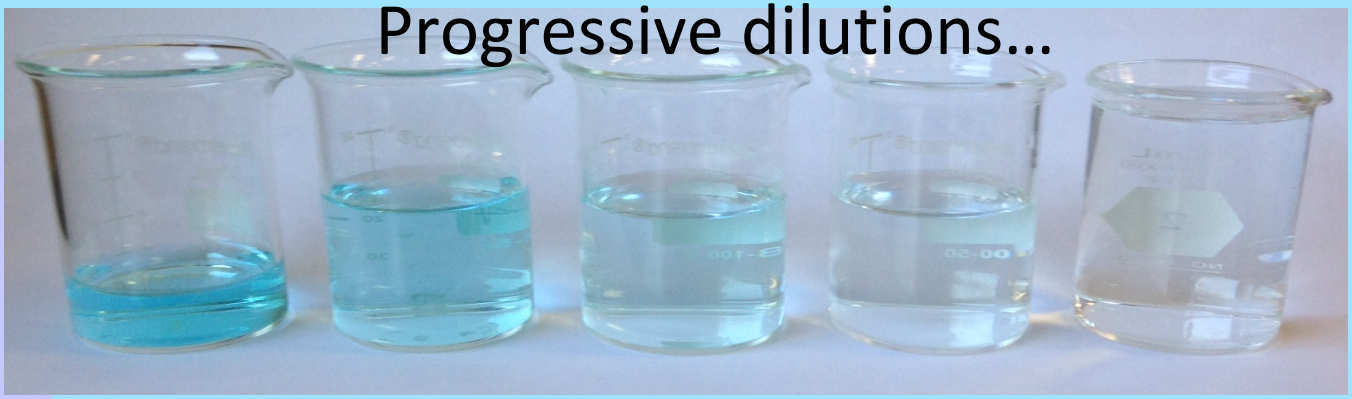


The stock Cu^{2+} solution is about 0.10 M – use the exact concentration provided. Each dilution contains 20.0 mL of the previous solution and 30.0 mL water.



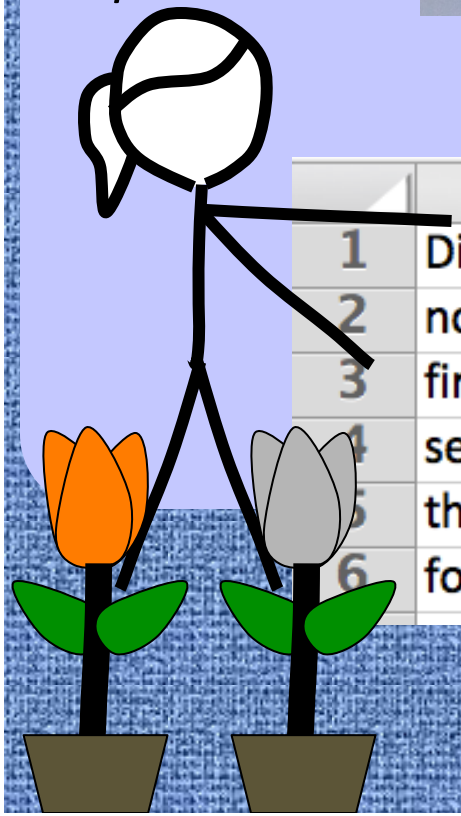
3. Making the chart

Progressive dilutions…



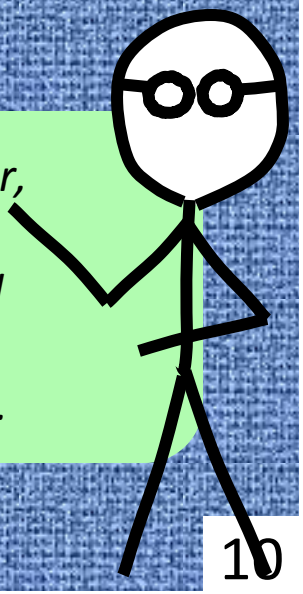
Stock first second third fourth

Set up your Excel spreadsheet



	A	B	C
1	Dilution	Cu2+(aq)	log(0.10/[M2+])
2	none	0.0997 *	=LOG(0.1/B2)
3	first	=B2*20/50	=LOG(0.1/B3)
4	second	=B3*20/50	=LOG(0.1/B4)
5	third	=B4*20/50	=LOG(0.1/B5)
6	fourth	=B5*20/50	=LOG(0.1/B6)

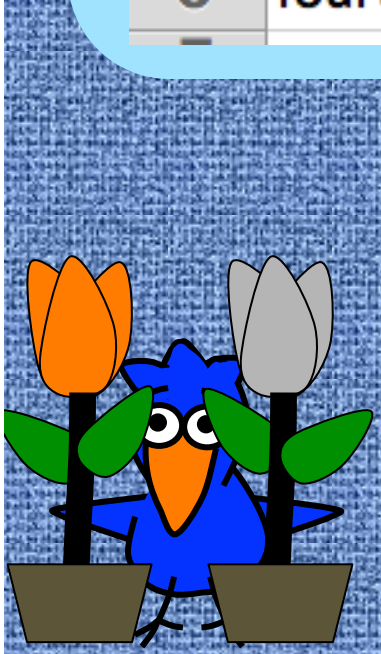
Remember, you can copy and paste formulas.



*Stock solution concentration will vary.

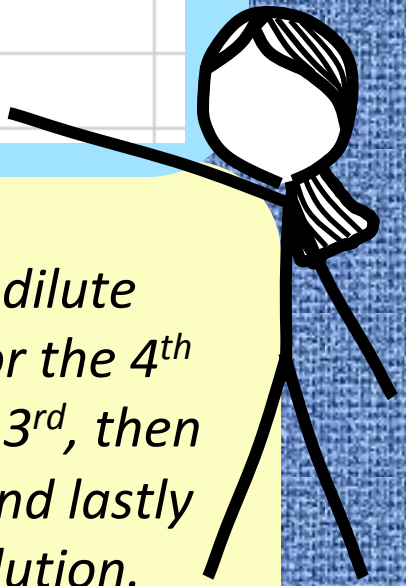
3. Making the chart

	A	B	C	D
1	Dilution	Cu2+(aq)	log(0.10/[M2+])	E (volts)
2	none	0.0997	0.001	
3	first	0.0399	0.399	
4	second	0.0160	0.797	
5	third	0.0064	1.195	
6	fourth	0.0026	1.593	***Do first***



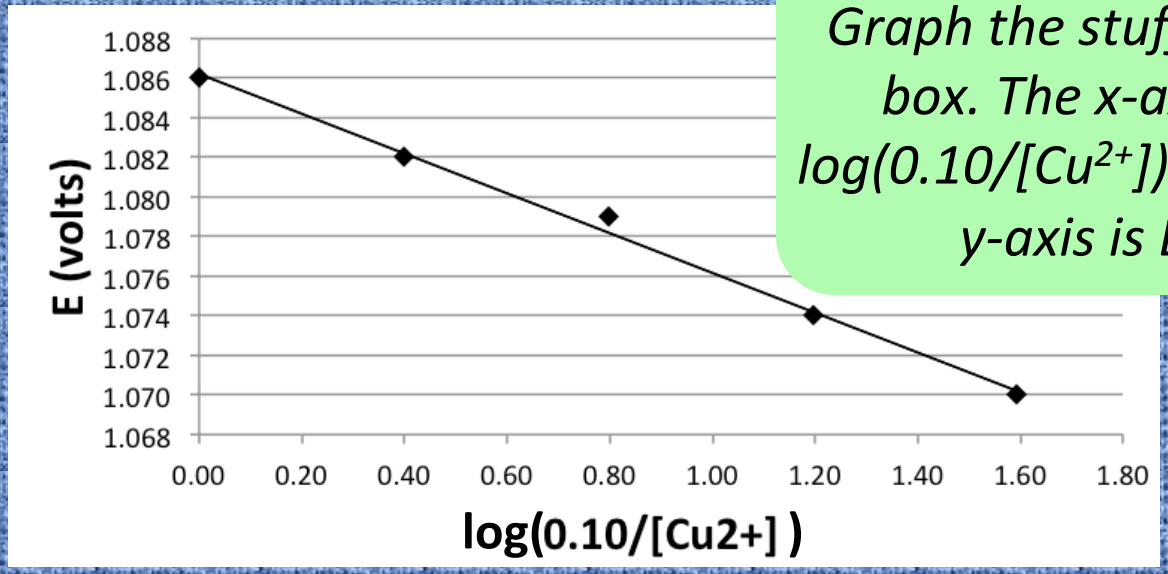
Make all five solutions before measuring any E values.

Start with the most dilute solution. Measure E for the 4th solution first, then the 3rd, then the 2nd, and the 1st, and lastly for the undiluted solution.

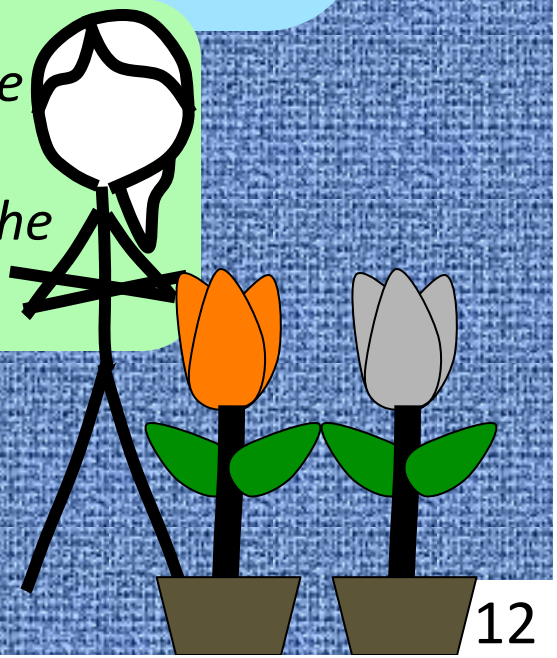


3. Making the chart

	A	B	C	D
1	Dilution	Cu2+(aq)	log(0.10/[M2+])	E (volts)
2	none	0.0997	0.001	1.086
3	first	0.0399	0.399	1.082
4	second	0.0160	0.797	1.079
5	third	0.0064	1.195	1.074
6	fourth	0.0026	1.593	1.070

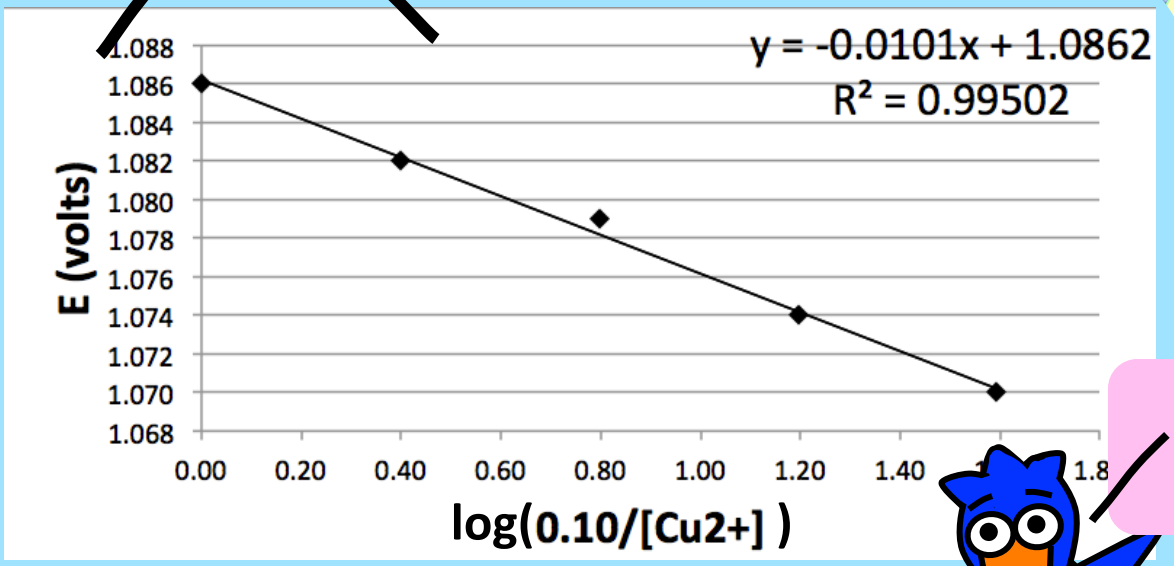


Graph the stuff in the box. The x-axis is log(0.10/[Cu^{2+}]) and the y-axis is E.



3. Making the chart

Add the trendline, display the formula and R2. This example has an excellent R2 value, 0.995 – the closer to 1.00, the better.



And the y-intercept is E^o = 1.086 V

The literature value is 1.10 V

4. What we are doing today

① *Wear your safety glasses.*

② *The cover sheet summarizes everything that you need to include with your report.*

③ *We will follow the procedure pretty closely today. In the analysis part, we do print the Excel data and chart.*

④ *Take time writing an introduction in your own words before lab.*

⑤ *Record observations and details as carefully as possible.*

⑥ *You can record data directly into Excel or you can copy the data into your lab notebook. Attach your Excel data and graph*

⑦ *Set the voltmeter to read DC Volts.*

⑧ *Red wire always goes to the copper wire*

⑨ *Values jump around a bit. Take a reading after 10 seconds or so.*

⑩ *In your conclusions, calculate percent error from the literature value, $E^o = 1.10$ V.*

5. Your lab report

① First, the cover page with TA initials.

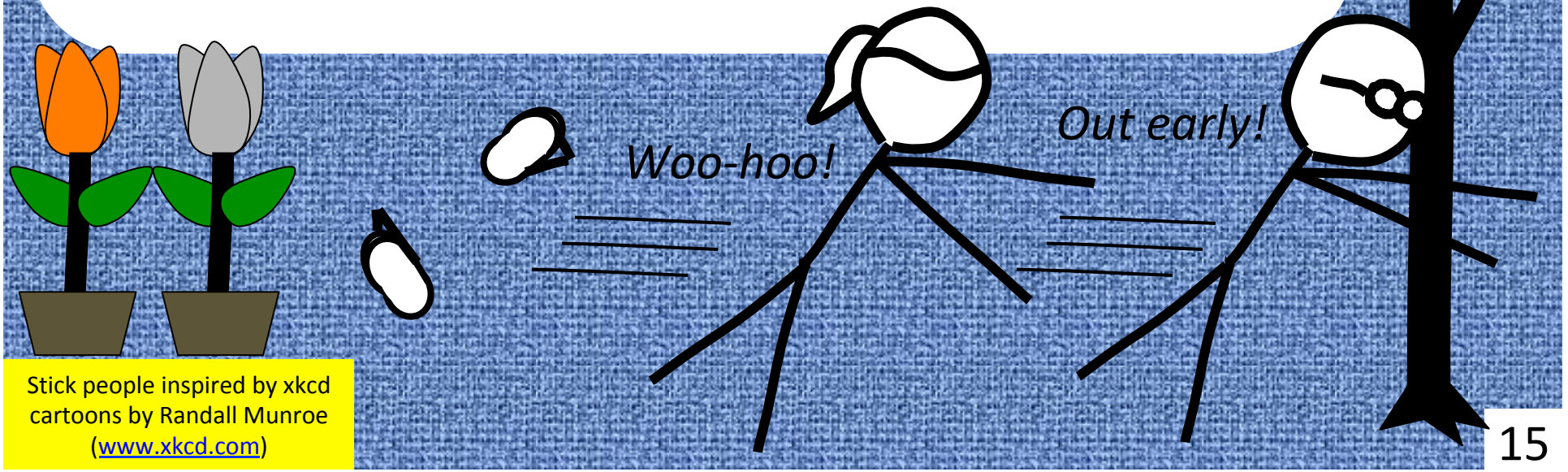
② Next, the trimmed copy pages from your lab notebook

③ Next, attach your Nernst chart, including the data.

④ Staple everything together.

⑤ **There is no on-line component this week.**

⑥ Turn in lab report today or ***before*** the start of class tomorrow. Late labs may not be graded – see the syllabus.



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