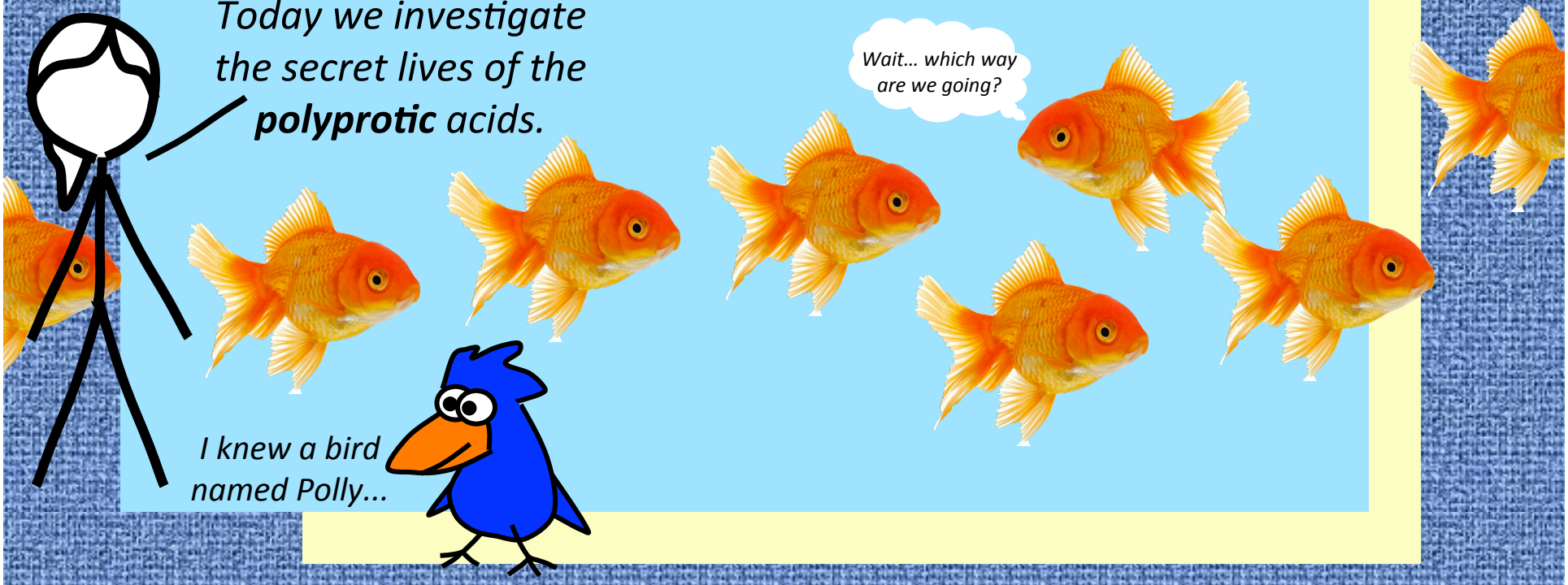
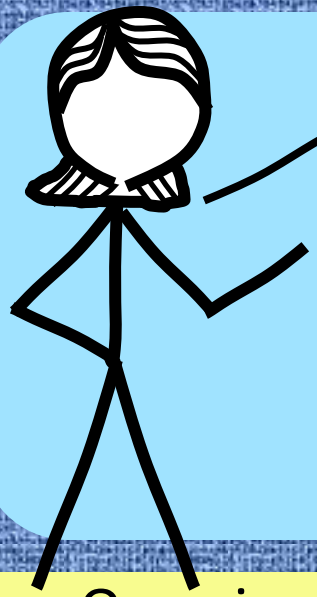
Experiment 7
pK_a and K_a of Phosphoric Acid
5 March 2020

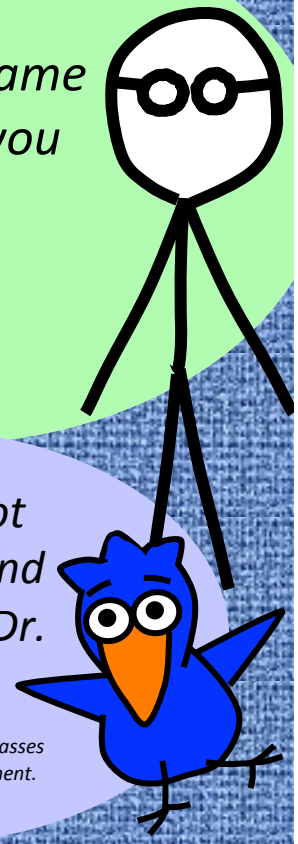


Objective: To determine the pK_a and K_a values for phosphoric acid.



This week's experiment is a laboratory practical: You will use the skills you learned last week to perform the assigned objective with minimal introduction.

You can use the same spreadsheet as you did last week.



It's "Action Shot Day" in Lab. Send your picture to Dr. Mattson.

You must be wearing your safety glasses and performing the actual experiment. Other restrictions may apply.

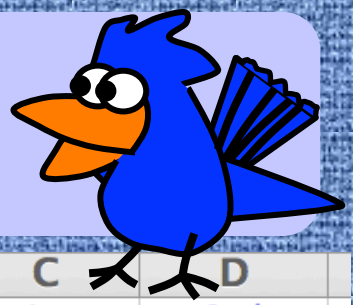
Overview:

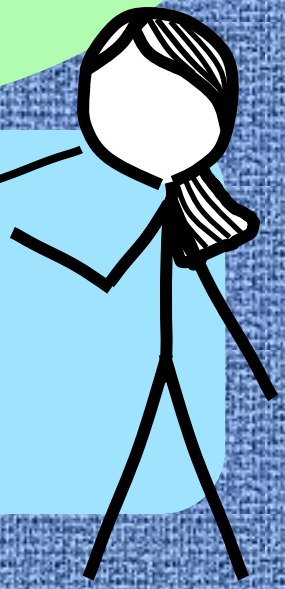
1. Collect data directly in Excel
2. Make the three graphs
3. Interpolate for equivalence points
4. Interpolate for pK_a values
5. Procedure: What we do today
6. Lab report format

1. Collect your titration data directly in Excel

Use the same formulas for derivatives as last week. Better yet, use a copy of the spreadsheet from last week, complete with the formulas!

Ooo! They added colors and formatted the numbers!

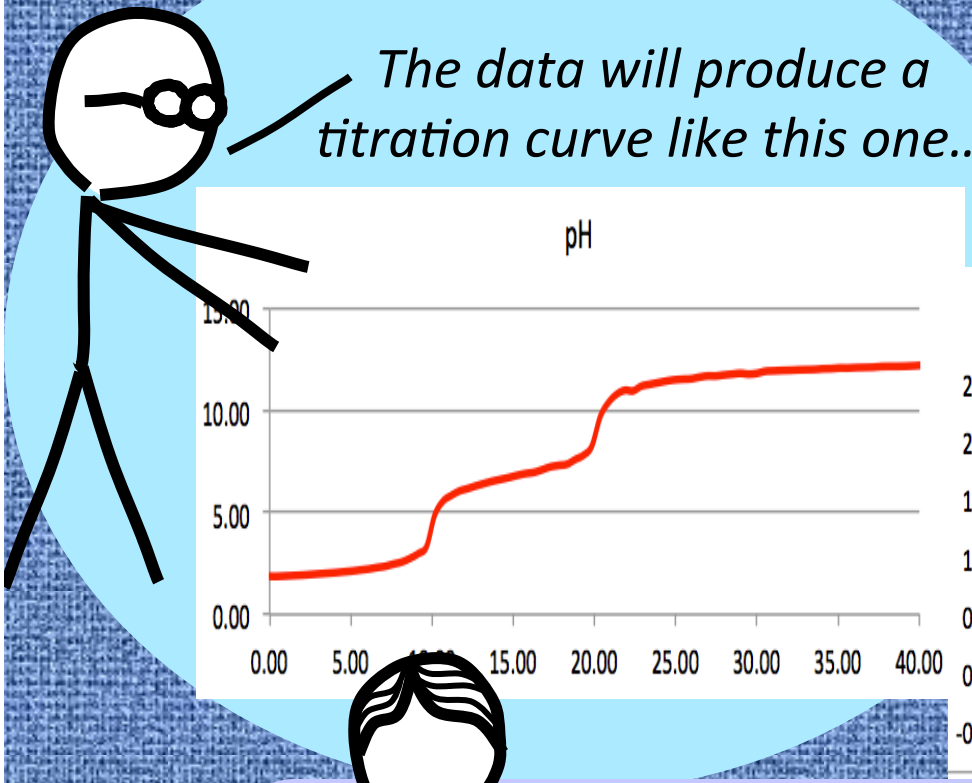




You can record the volume and pH data pairs directly in Excel - instead of Step 4 of the Procedure.

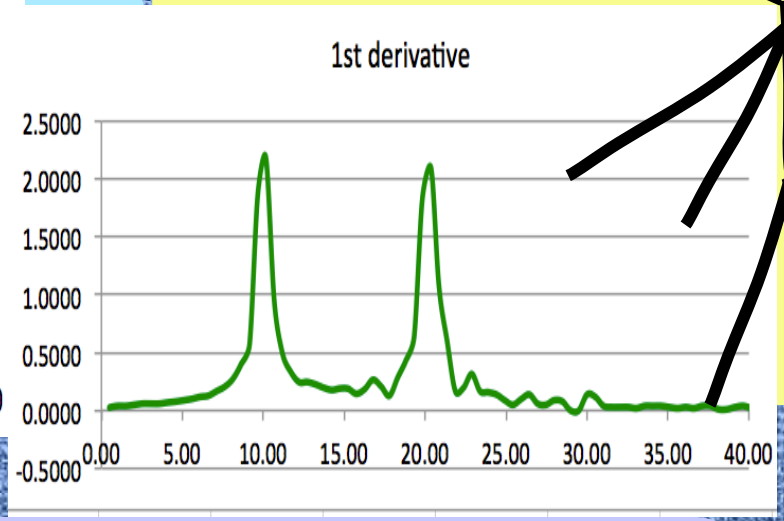
	A	B	C	D
1	Volume NaOH (mL)	pH	1st derivative	2nd derivative
2	0.00	1.86		
3	0.51	1.87	0.0295	
4	1.02	1.89	0.0393	0.0097
5	1.53	1.91	0.0393	0.0097
6	2.03	1.93	0.0492	0.0193
7	2.54	1.96	0.0590	0.0097
8	3.05	1.99	0.0590	0.0000
9	3.56	2.02	0.0590	0.0097
10	4.07	2.05	0.0688	0.0178
11	4.58	2.09	0.0771	0.0193
12	5.11	2.13	0.0885	0.0223
13	5.59	2.18	0.1003	0.0290
14	6.10	2.23	0.1180	0.0276
15	6.61	2.30	0.1278	0.0483
16	7.12	2.36	0.1672	0.0773
17	7.63	2.47	0.2065	0.1064
18	8.14	2.57	0.2753	0.193

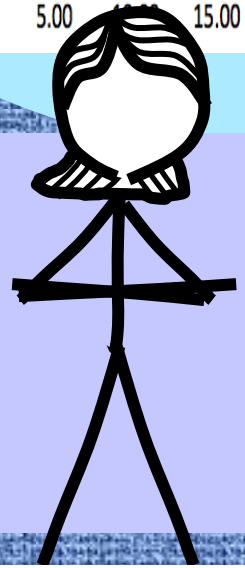
2. Making the three graphs.



The data will produce a titration curve like this one…

…and a 1st derivative plot like this one.



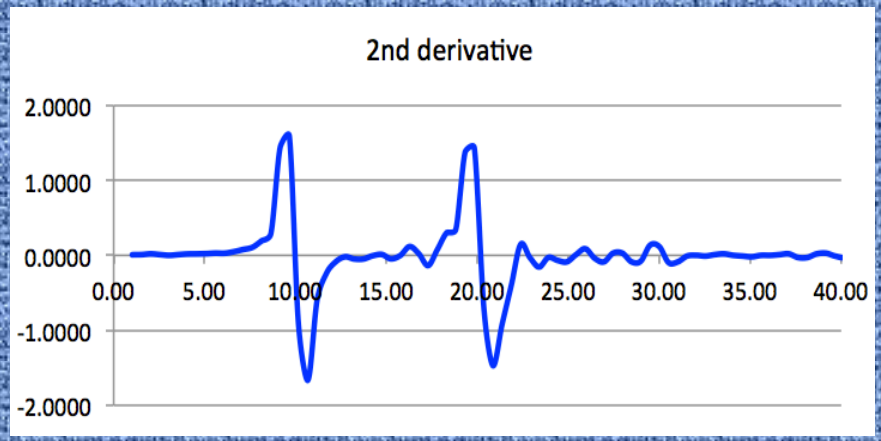


The first derivative plot shows us the approximate location of the equivalence points. In this example, the first one is ~10 mL and the second one at ~20 mL. The 3rd equivalence point (~30 mL) does not show up because the acid is too dilute.

Info for Introduction

3. Interpolate for equivalence points

By interpolation, the first equivalence point is 9.977 mL.

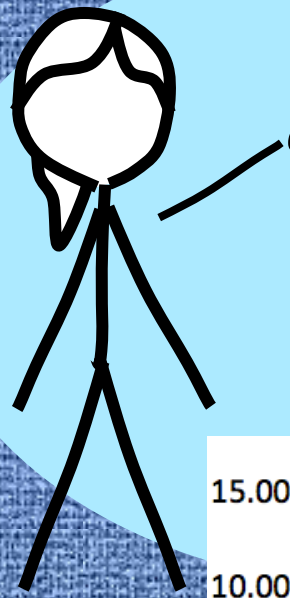


And the second one is 20.182 mL. Is that weird?

	A	B	C	D
1	Volume NaOH (mL)	pH	1st derivative	2nd derivative
19	8.64	2.75	0.4031	0.2901
20	9.15	2.98	0.5703	1.4393
21	9.66	3.33	1.8669	1.5856
22	10.16	4.86	2.1829	-0.9160
23	10.68	5.55	0.9445	-1.6630
24	11.19	5.83	0.4916	-0.5941
25	11.70	6.05	0.3343	-0.2417
26	12.20	6.17	0.2458	-0.0870

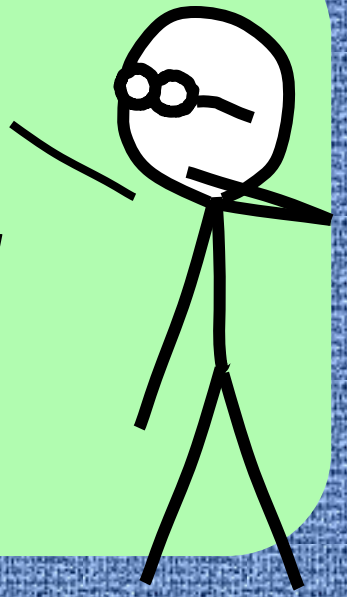
	A	B	C	D
1	Volume NaOH (mL)	pH	1st derivative	2nd derivative
38	18.31	7.36	0.2852	0.2997
39	18.81	7.59	0.4326	0.3481
40	19.32	7.80	0.6391	1.3762
41	19.83	8.24	1.8322	1.4309
42	20.36	9.70	2.0944	-0.7222
43	20.85	10.37	1.0832	-1.4696
44	21.36	10.78	0.5998	-0.9188
45	21.87	10.98	0.1672	-0.3964

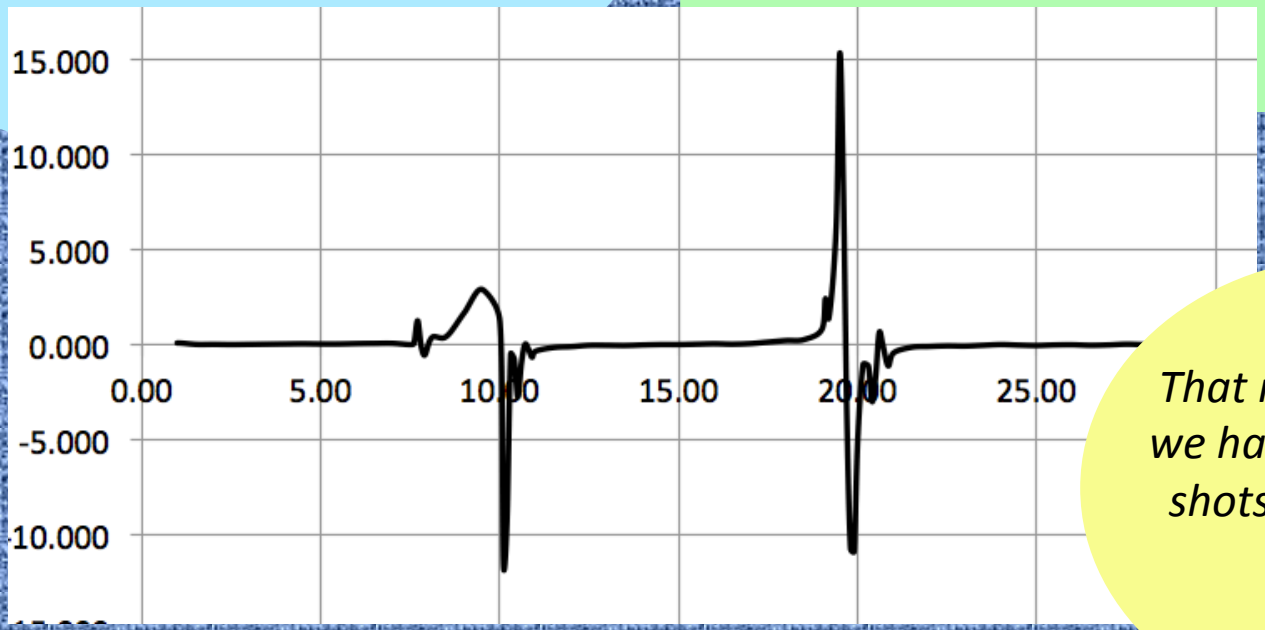
3. Interpolate for equivalence points



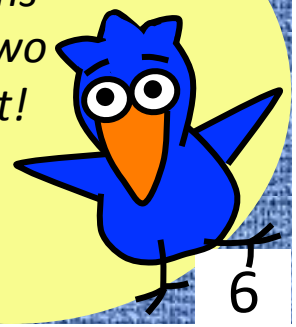
Sometimes only one of the second derivative values is useable.

In the previous example, either equivalence point could be used. In this example, the second equivalence point looks a lot better, so that one is the best one to use.





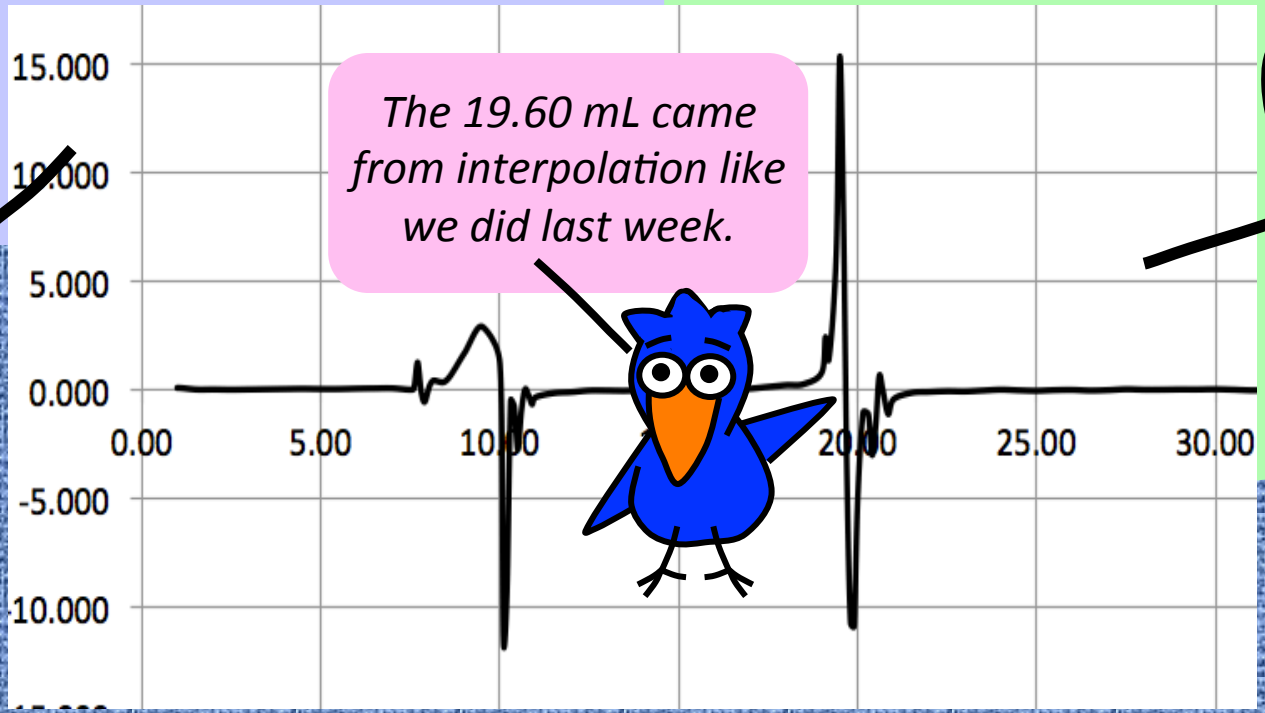
That means we have two shots at it!



3. Interpolate for equivalence points

Suppose the second equivalence point was 19.60 mL. The first one would be 9.80 mL just be dividing 19.60 by 2.

We also need to know the volumes half-way to the first equivalence point – which is 4.90 mL, and half way between the first and second equivalence point – 14.70 mL.

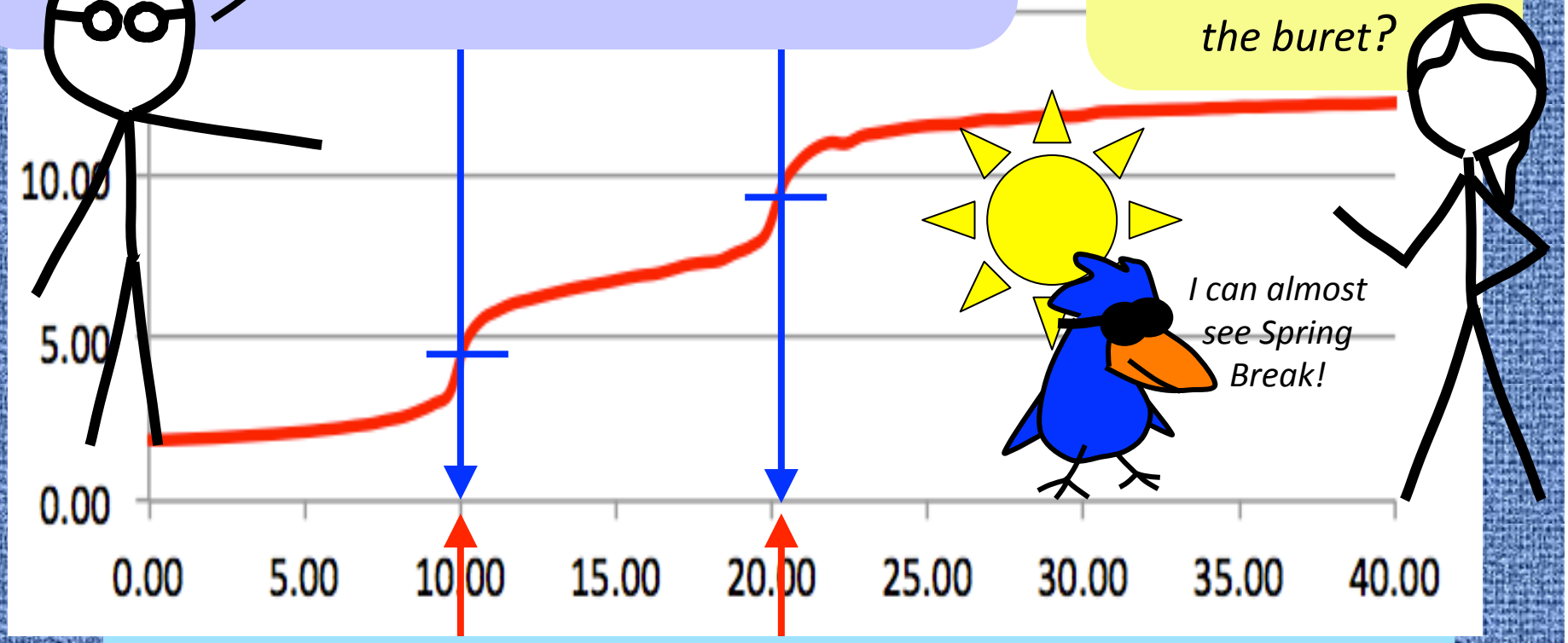


The 19.60 mL came from interpolation like we did last week.

3. Interpolate for equivalence points

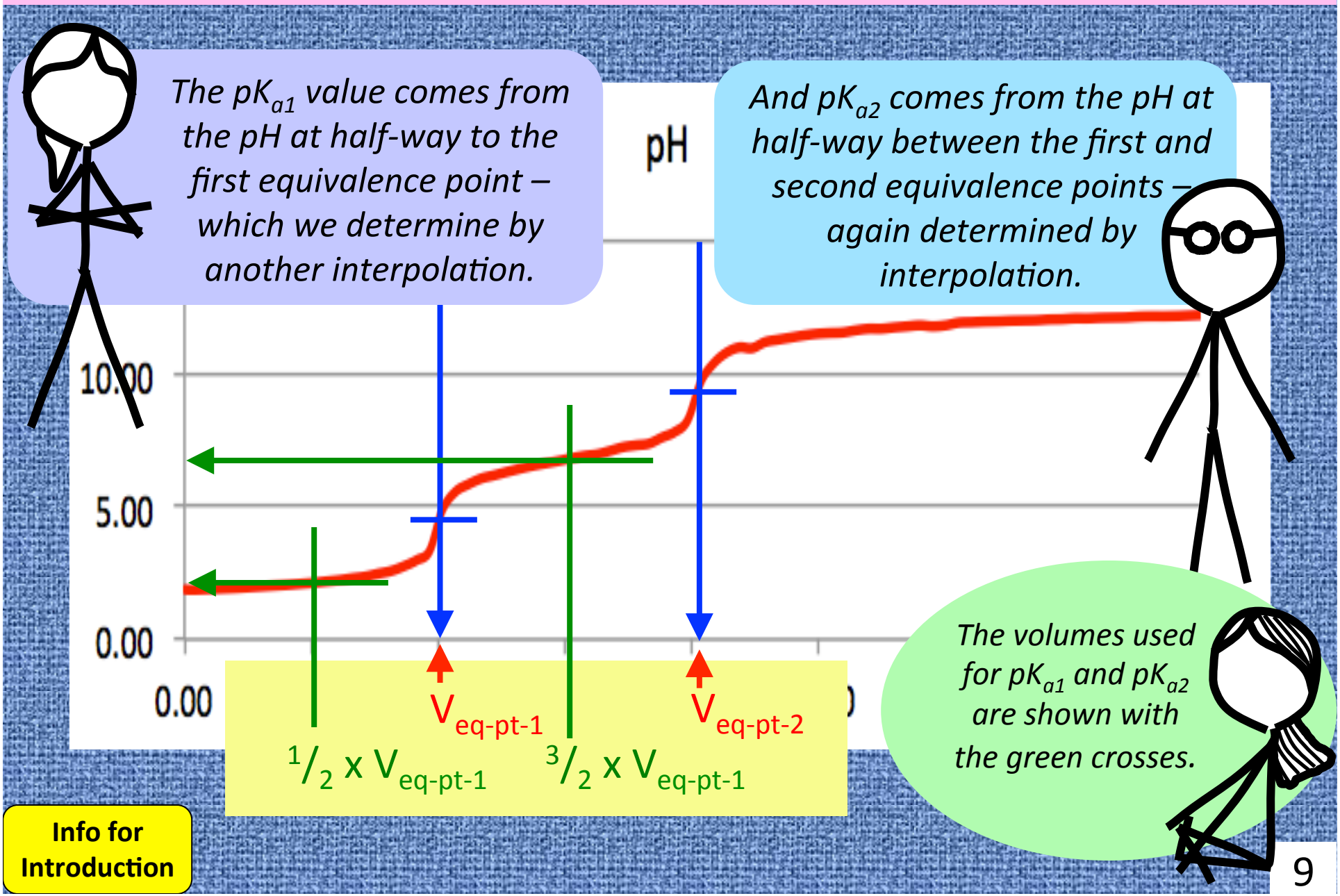
If both equivalence points can be determined by interpolation like we saw in Slide 5, the second equivalence point should be exactly twice that of the first one, but...

...it almost never turns out quite like that. What would cause these errors? Reading the buret?



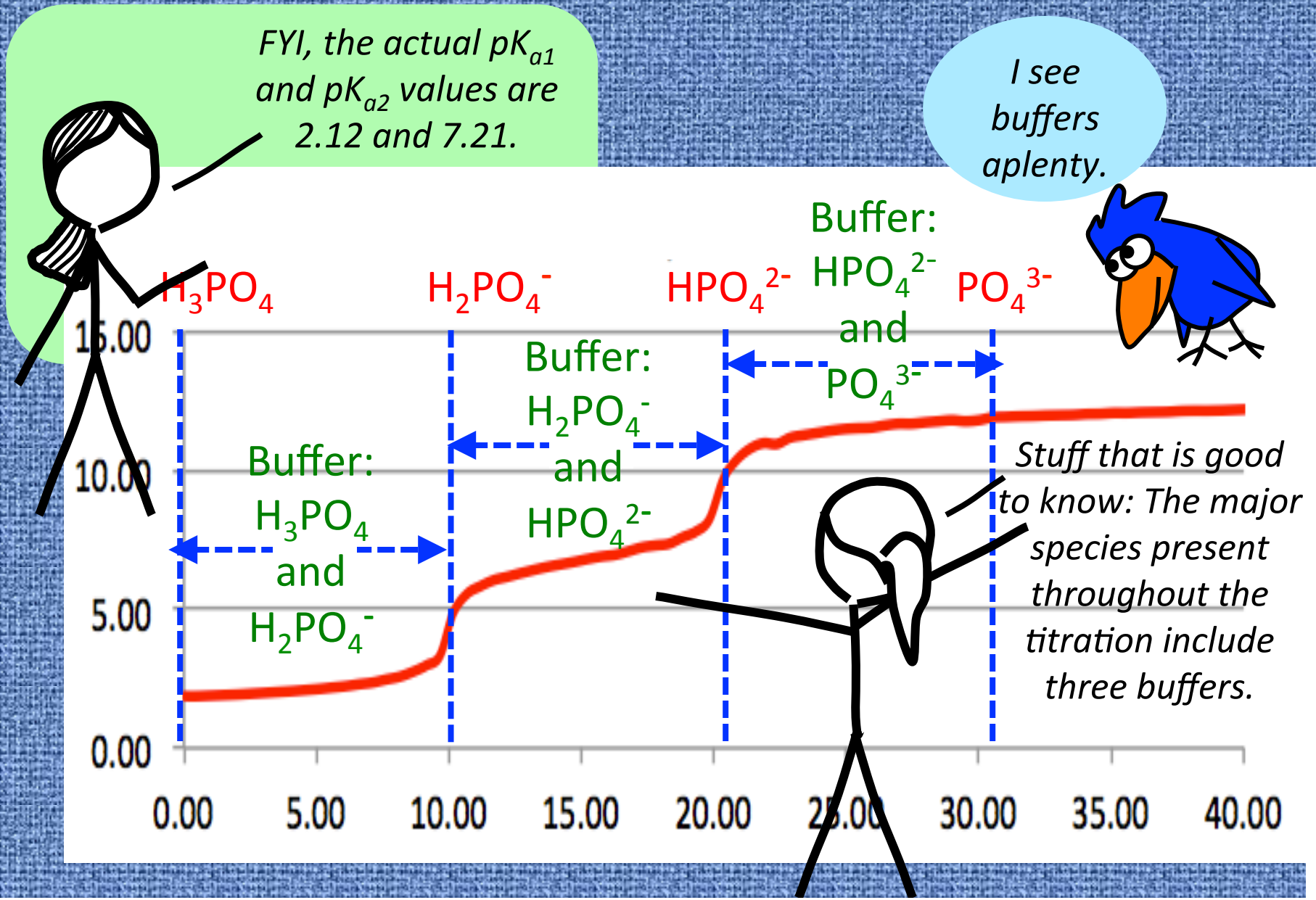
V_{EqPt-1} $V_{Eq-Pt-2}$

4. Interpolate for pK_a values

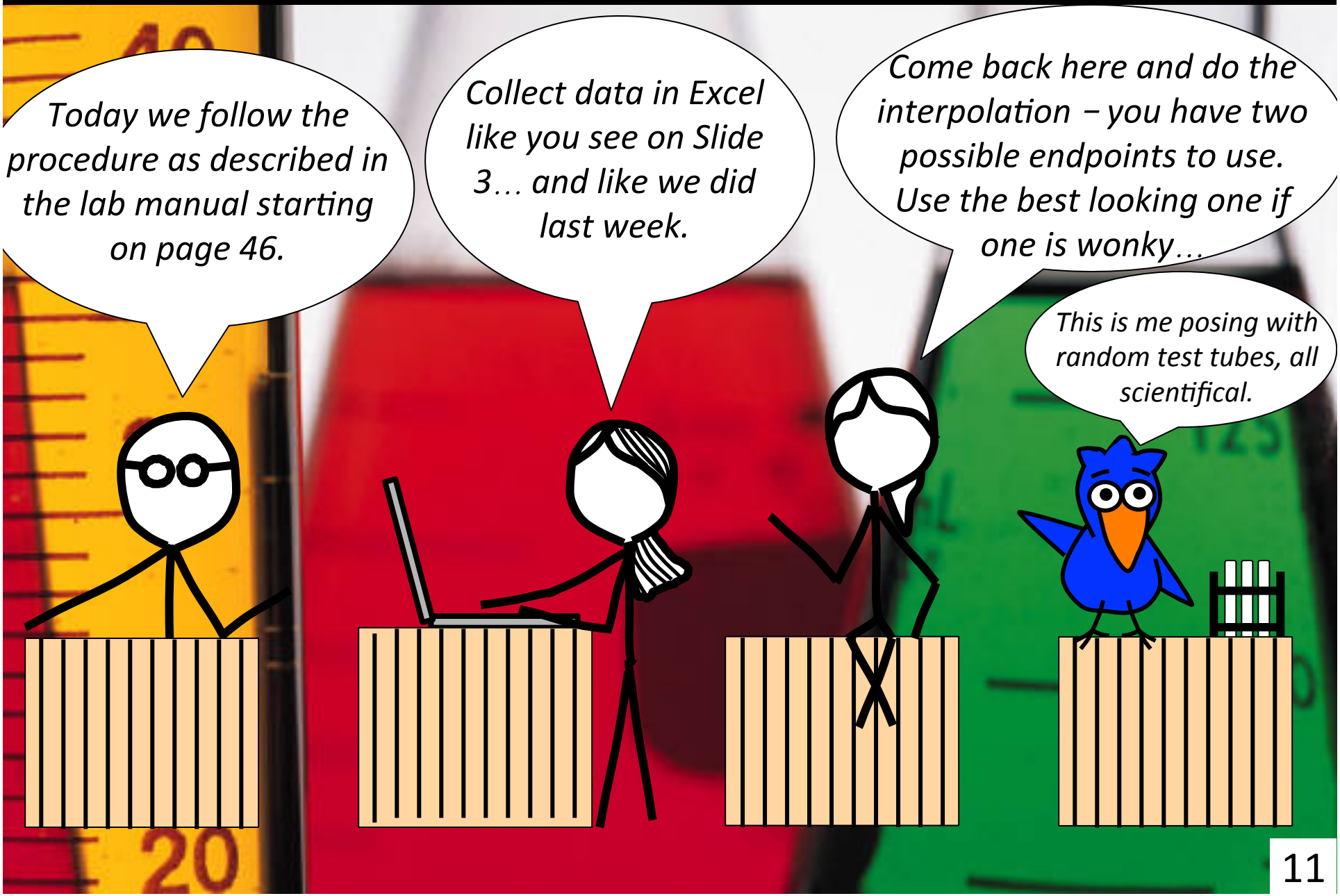


Info for Introduction

4. Interpolate for pK_a values



5. Procedure: What we do today



5. Procedure: What we do today

① *Wear your safety glasses. Dress for a mess.*

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

③ *Record observations and details as carefully as possible.*

④ *Enter your Volumes and pH values into Excel as you go.*

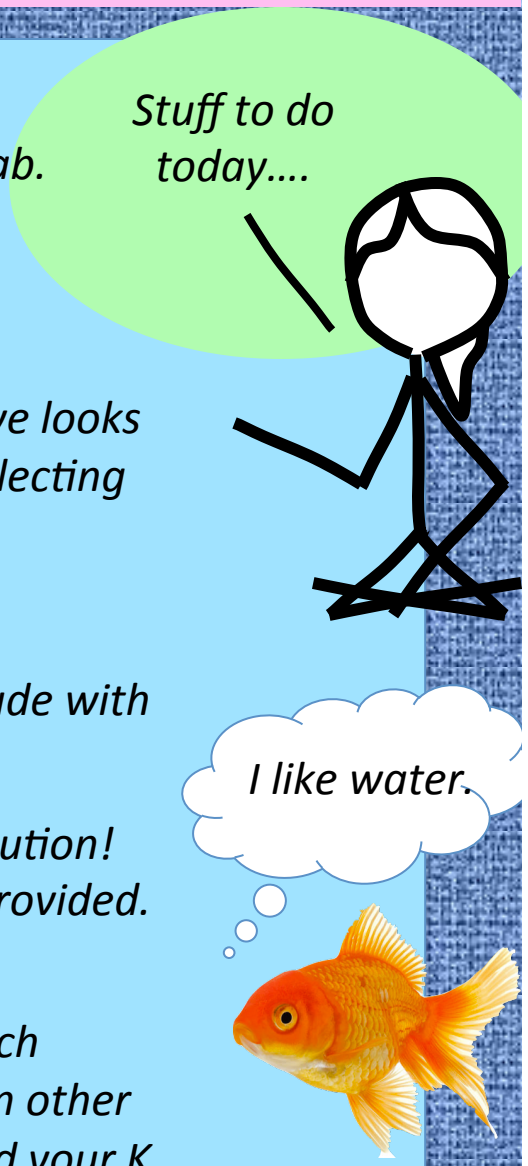
⑤ *Work in pairs. Do one titration and if at least one 2nd derivative looks good for interpolating the equivalence point, you're done collecting data.*

⑥ *Show all of your calculations involving interpolation.*

⑦ *The cover sheet summarizes everything that you need to include with your report.*

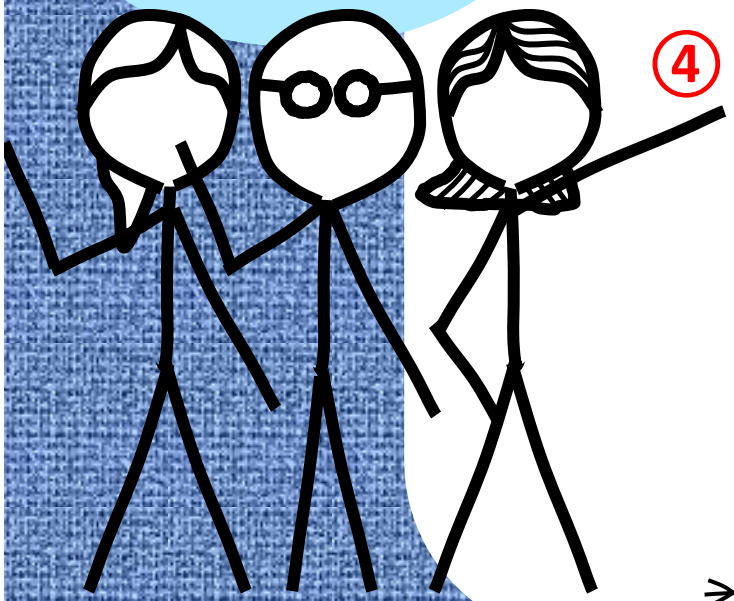
⑧ *Keep your pH probe in water or a solution – never out of a solution! The probes are safely stored in the 0.01 M HCl(aq) solution provided. The pH meters are inaccurate below pH = 2 and above 11.5.*

⑨ *Write a meaningful Conclusion. Explain why you decided which equivalence point to use. In some cases, both would work. In other cases, one equivalence point is better than the other. How did your K_a values compare with the literature values?*



5. Your Lab Report

Happy Spring Break!

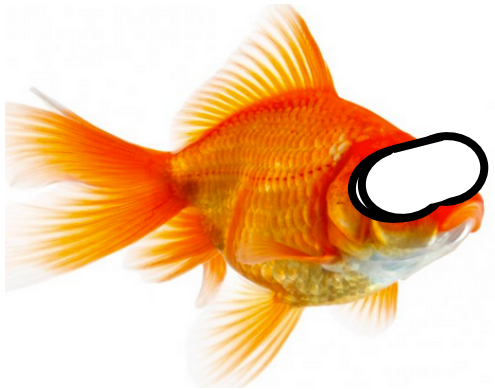


① First, the cover page with TA initials.

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

③ Attach graphs and data. Staple all together.
Reports without graphs will not be graded.

④ ***Turn in lab report before you leave today.***



Later.

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.*