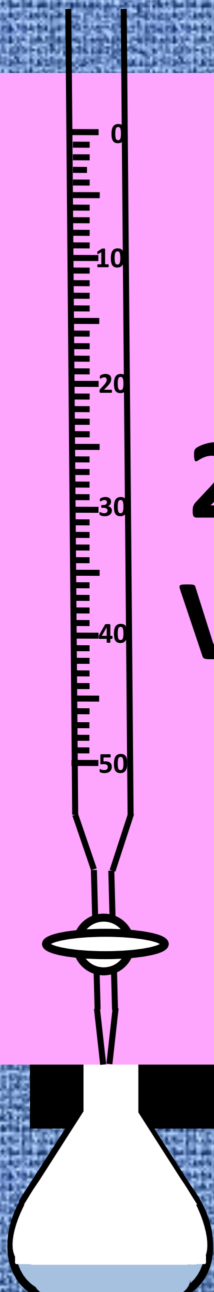
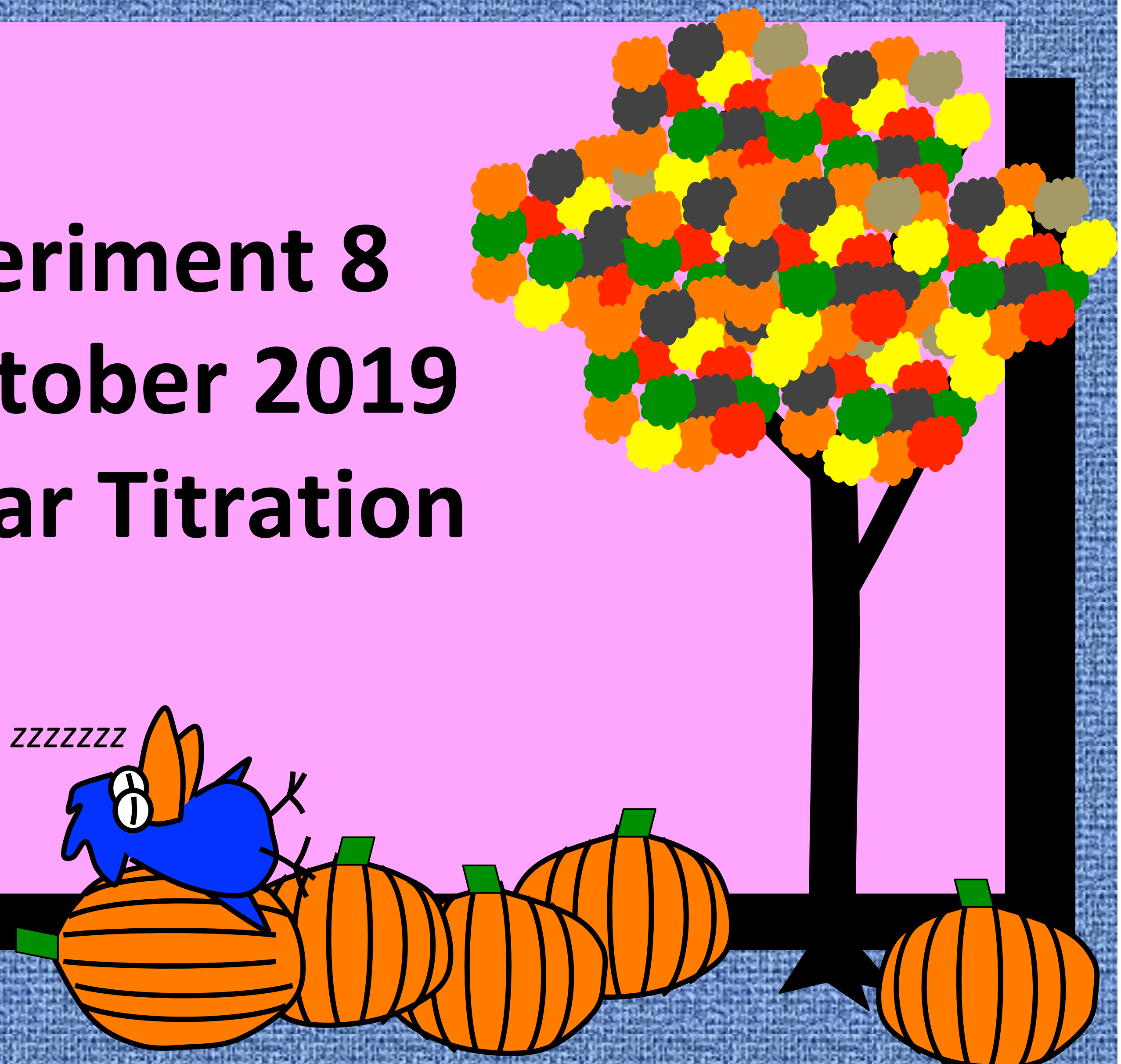
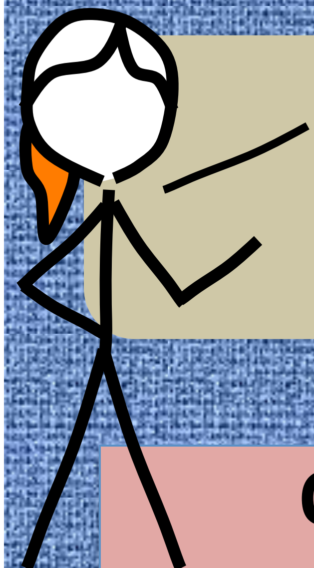


Experiment 8
22 October 2019
Vinegar Titration

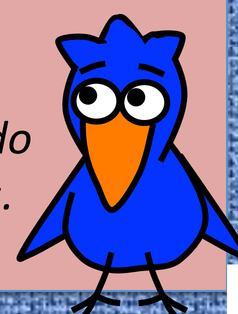


Objective: To use an acid-base titration to determine the concentration of vinegar.



Overview:

1. Titrations, neutralization reactions, and n = MV
2. Calculating molarity and mass percent
3. Procedure: What we are doing today
4. Tricks of the trade
5. Your lab report



1. Titrations, neutralization reactions, and n = MV

$$HC_2H_3O_2(aq) + NaOH(aq) \rightarrow H_2O(l) + NaC_2H_3O_2(aq)$$

acetic acid + sodium hydroxide → water + sodium acetate

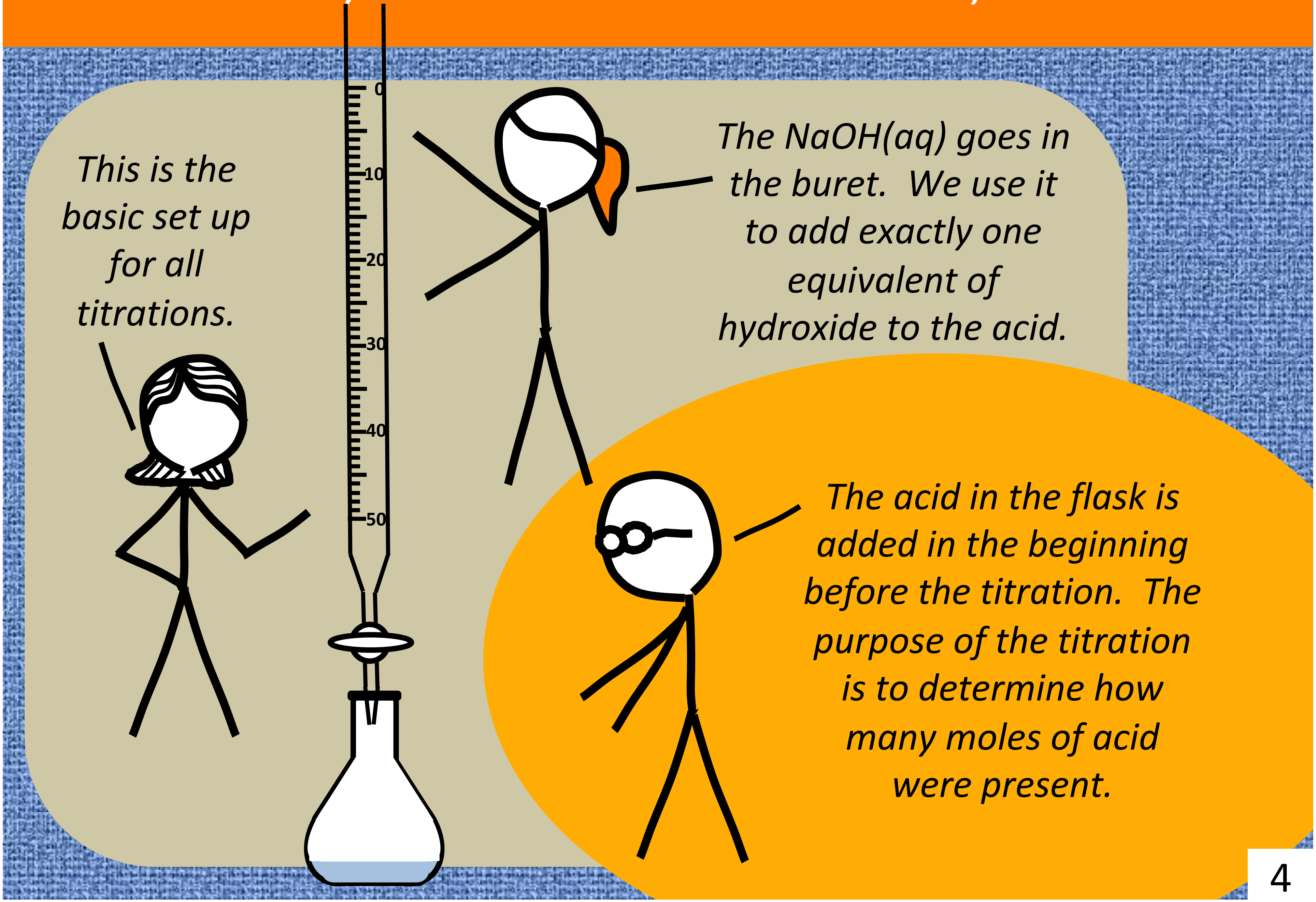
This is the balanced equation. One "equivalent" of acid reacts with one "equivalent" of base. For example, 0.10 mol acid reacts stoichiometrically with 0.10 mol base.

In a titration, when the acid and base have reacted "stoichiometrically", that is one-to-one, we call that the equivalence point.

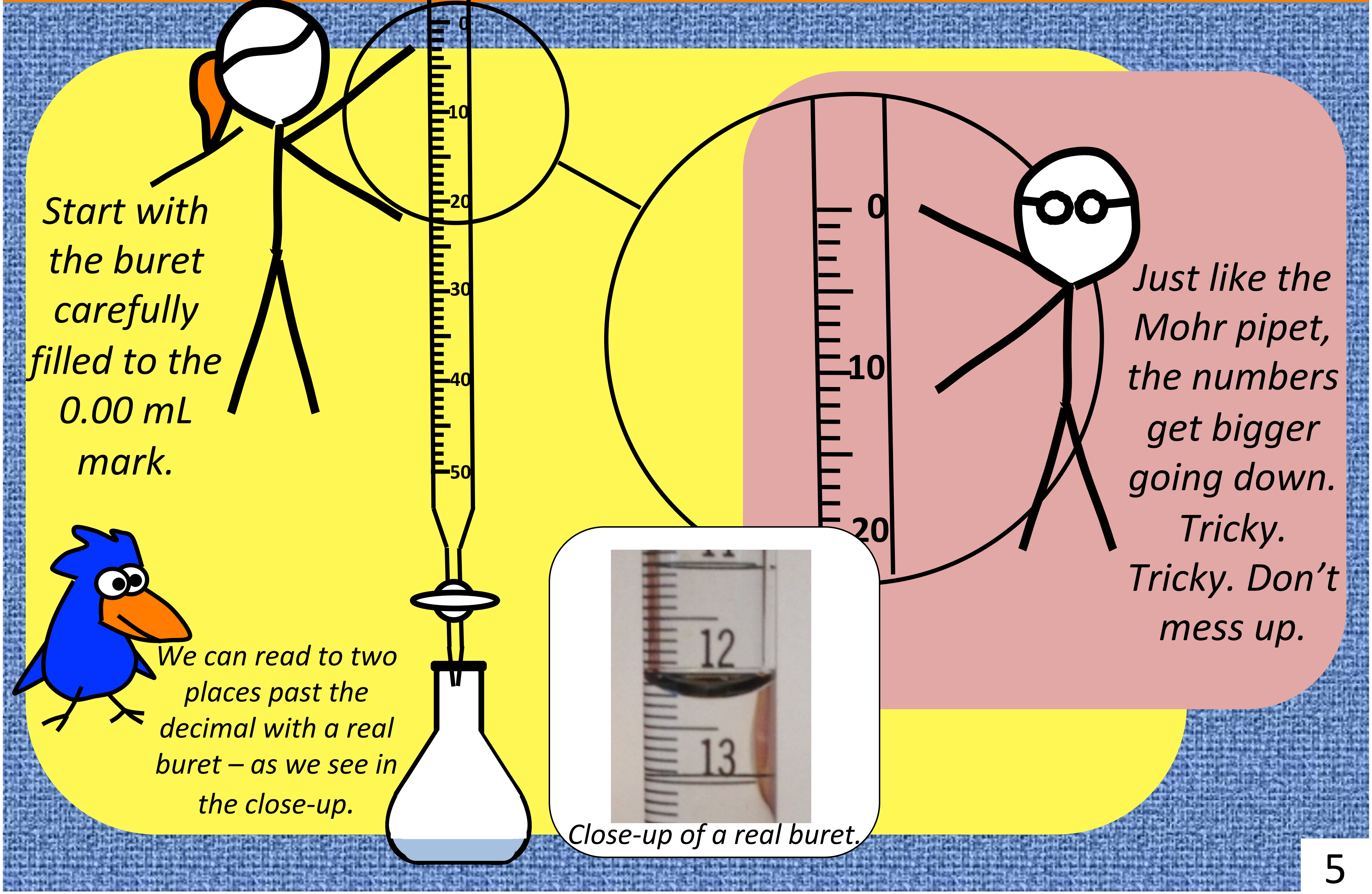
"Stoichiometric" is a fun word. I like to drop it into polite conversation.

Info for Introduction

1. Titrations, neutralization reactions, and n = MV



1. Titrations, neutralization reactions, and n = MV



Close-up of a real buret.

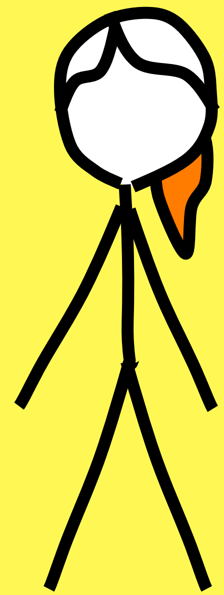
1. Titrations, neutralization reactions, and n = MV

$$HC_2H_3O_2(aq) + NaOH(aq) \rightarrow H_2O(l) + NaC_2H_3O_2(aq)$$

acetic acid + sodium hydroxide → water + sodium acetate

The acetic acid is in the flask. In our experiment, we use 2.00 mL acetic acid and about 40 mL deionized water – the volume of water doesn't matter too much.

The sodium hydroxide is in the buret and we can add as much as we need until we've added an amount equivalent to the acid present.

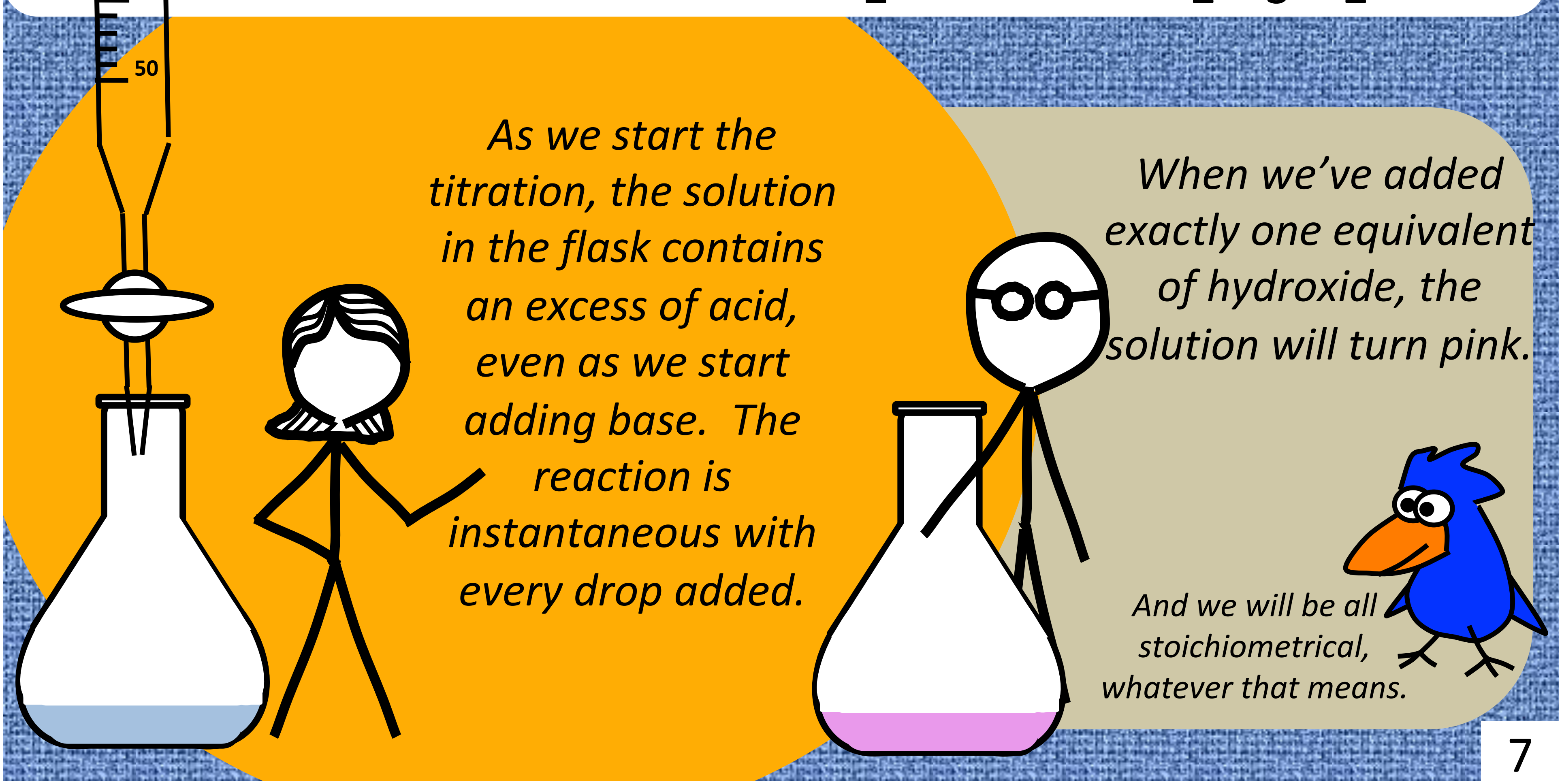


A few drops of phenolphthalein tells us when we've added enough hydroxide.

Info for Introduction

1. Titrations, neutralization reactions, and n = MV

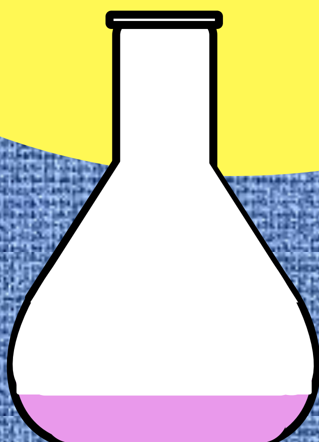
$$HC_2H_3O_2(aq) + NaOH(aq) \rightarrow H_2O(l) + NaC_2H_3O_2(aq)$$



1. Titrations, neutralization reactions, and n = MV

$$HC_2H_3O_2(aq) + NaOH(aq) \rightarrow H_2O(l) + NaC_2H_3O_2(aq)$$

The first sign of pink that persists for a few seconds with stirring means we've reached the equivalence point and we are ready for calculations.



We use the formula ***n = M x V*** *for NaOH. We will be given the molarity of NaOH, M_{NaOH}, and we determine the volume used from the buret.*

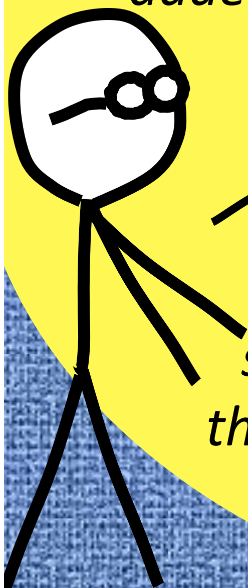
Suppose M_{NaOH} was 0.09858 mol/L and we used 14.22 mL…

$n_{NaOH} = M_{NaOH}V_{NaOH}$
$= 0.09858$ mol/L x 0.01422 L
$= 0.001402$ mol NaOH

Info for calculations

2. Calculating molarity and mass percent

To repeat, we determined the number of moles of NaOH from the ***n = M x V*** *formula using the volume added at the equivalence point. We got 0.001402 mol NaOH*



$n_{NaOH} = M_{NaOH}V_{NaOH}$

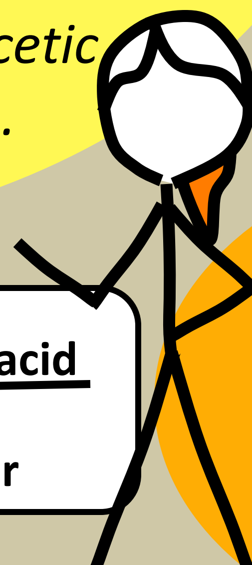
$= 0.09858 \text{ mol/L} \times 0.01422 \text{ L}$

$= 0.001402 \text{ mol NaOH}$

From the equation and the 1:1 stoichiometry, we know we have the same number of moles of acetic acid, 0.001402 mol $HC_2H_3O_2$.

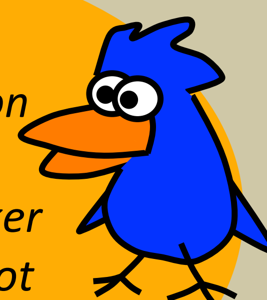
$n_{\text{acetic acid}} = n_{NaOH}$

$= 0.001402 \text{ mol } HC_2H_3O_2$



Here is the formula for molarity. We know both the moles and the volume!

$$M_{\text{acetic acid}} = \frac{n_{\text{acetic acid}}}{V_{\text{vinegar}}}$$

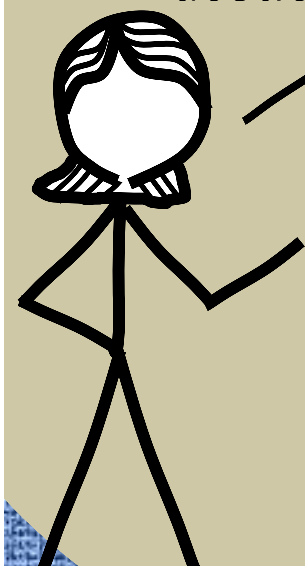


So listen up. The actual concentration of NaOH will be written on the marker board in lab. It is not 0.09858 mol/L

Info for Introduction

2. Calculating molarity and mass percent

With this formula, we need to use 0.00200 L (2.00 mL) for the volume of acid used in the first place. So the acetic acid tested was 0.7009 mol/L.



$$\mathbf{M_{acetic\ acid}} = \frac{\mathbf{n_{acetic\ acid}}}{\mathbf{V_{vinegar}}}$$

$$\mathbf{M_{acetic\ acid}} = \frac{\mathbf{0.001402\ mol}}{\mathbf{0.00200\ L}}$$

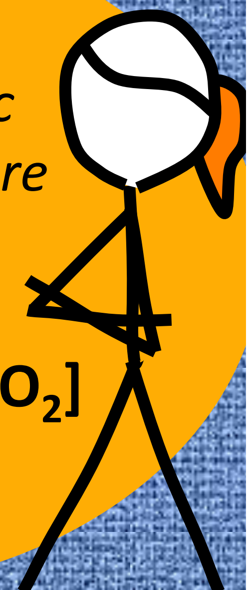
$$\mathbf{M_{acetic\ acid}} = 0.7009\ \text{mol/L}$$

$$\mathbf{M_{acetic\ acid}} = 0.701\ \text{mol/L}$$

(with 3 sig figs)

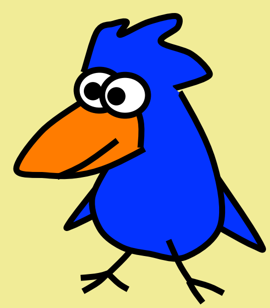
We can write molarity of acetic acid by using square parentheses.

$\mathbf{M_{acetic\ acid}}$ is $\mathbf{[HC_2H_3O_2]}$



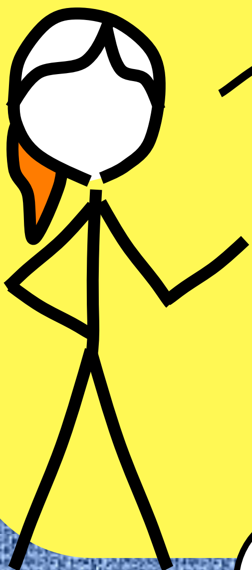
$\mathbf{M_{acetic\ acid}}$ *is* $\mathbf{[HC_2H_3O_2]}$

What she said. It's the same thing...



Info for calculations

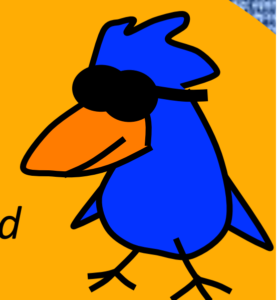
2. Calculating molarity and mass percent



Mass percent is a tad trickier. The formula is…

$$\text{Mass \%} = 100\% \times \frac{m_{\text{acetic acid}}}{m_{\text{vinegar sol'n}}}$$

We can easily figure out the mass of the acetic acid using ***m = n x MM****, that is mass = moles x molar mass.*



The molar mass of $HC_2H_3O_2$ is 60.05 g/mol. Ooops! I wasn't supposed to tell you that.

$$\text{mass}_{\text{acetic acid}} = n_{\text{acetic acid}} \times MM_{\text{acetic acid}}$$

$$\text{mass}_{\text{acetic acid}} = 0.001402 \text{ mol} \times 60.05 \text{ g/mol}$$

$$\text{mass}_{\text{acetic acid}} = 0.08419 \text{ g } HC_2H_3O_2$$

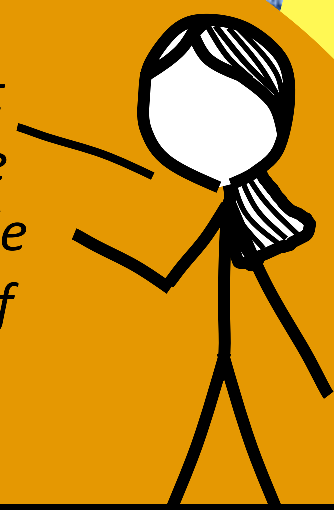
Info for Introduction

2. Calculating molarity and mass percent

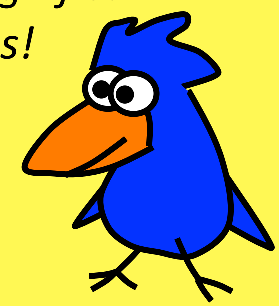
Sooo, if we measure the mass of the little vinegar solution as we go, we'll be all set…

$$\text{Mass \%} = 100\% \times \frac{m_{\text{acetic acid}}}{m_{\text{vinegar sol'n}}}$$

Suppose during our first trial, we determined the mass of a 2.00 mL sample of vinegar had a mass of 2.02 g



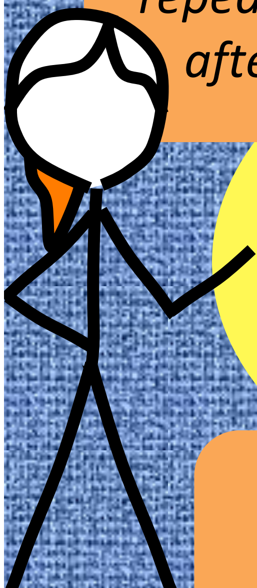
Ooooo. Now we have only three significant figures!



$$\text{Mass \%} = 100\% \times \frac{0.08419 \text{ g } HC_2H_3O_2}{2.02 \text{ g vinegar}} = 4.17\%$$

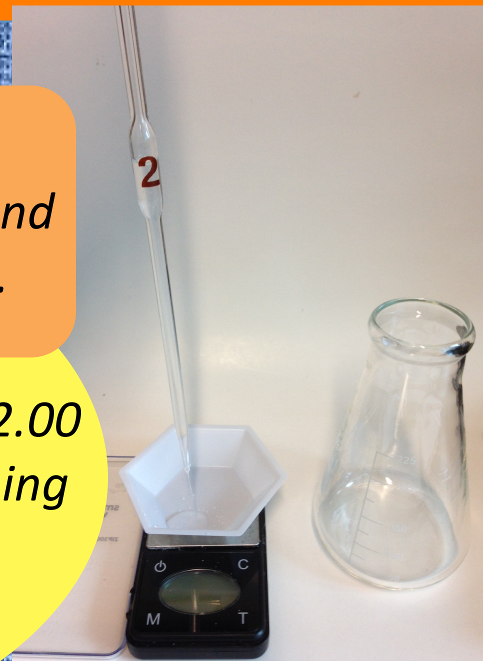
Info for calculations

3. Procedure: What we are doing today.



Today we are doing three trials – repeating the experiment three times and after that we will average the results.

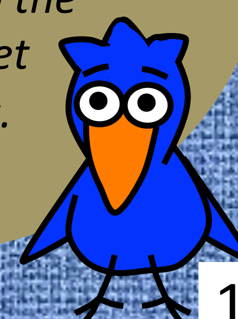
Each trial starts with measuring 2.00 mL of vinegar into a tared weighing boat on a mini-balance.



Record the mass of the vinegar solution – it should be very close to 2.00 g.

Next pour the vinegar into the flask. Rinse the last drops into the flask with deionized water

If the mass is less than 1.99 or more than 2.02, you messed up. Redo the volumetric pipet measurement.



Info for Introduction

3. Procedure: What we are doing today.

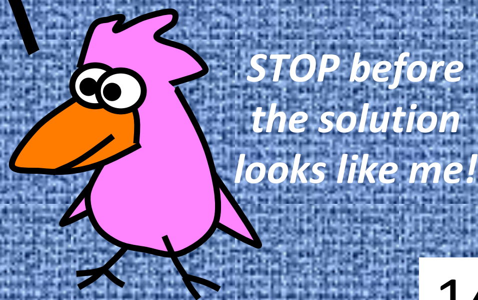
From each trial, we determine the moles of acetic acid and use that to calculate the molarity and the mass percent of the of acetic acid in the vinegar.

We need three good trials. If you add too much NaOH, it will be too pink. Write “Over-titrate” in your lab notebook and start over on that trial.

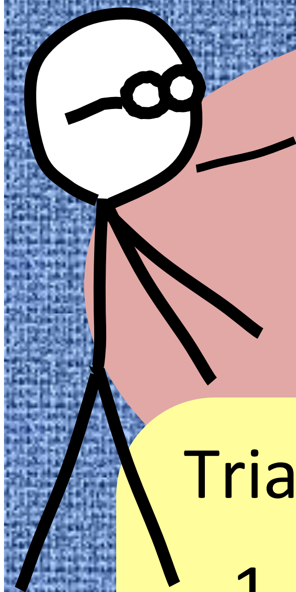
And here are the aforementioned equations you will use to do these calculations.

$$n_{acetic\ acid} = n_{NaOH} = M_{NaOH}V_{NaOH}$$

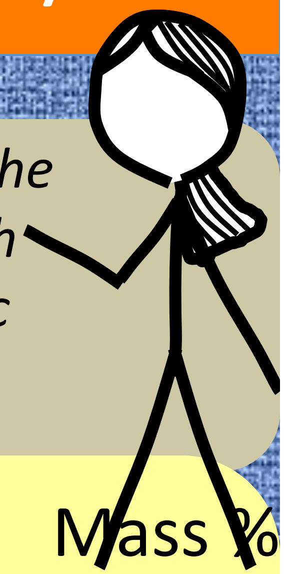
$$\text{Mass \%} = 100\% \times \frac{m_{acetic\ acid}}{m_{vinegar\ sol'n}}$$



3. Procedure: What we are doing today.

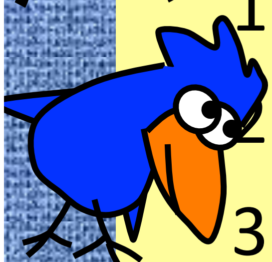


For each trial we determine molarity and mass percent. Then we average the results from three good trials.



Remember $[HC_2H_3O_2]$ is the same as $M_{acetic\ acid}$. Both mean molarity of acetic acid in units of mol/L.

Trial	V_{NaOH}	$m_{solution}$	$n_{acetic\ acid}$	$[HC_2H_3O_2]$	Mass %
1	14.22 mL	2.02 g	0.001402 mol	0.7009 M	4.17%
2	14.90 mL	2.00 g	0.001469 mol	0.7344 M	4.41%
3	14.28 mL	2.01 g	0.001408 mol	0.7039 M	4.21%
Avera					



See how the volumes of NaOH for Trial 2 is not very similar to the other two. They really should be if you are doing it right… This is how you know if one of the trials is probably bad.

Info for calculations

3. Procedure: What we are doing today.

Because Trial 2 was wonky, we do another trial and if it looks similar to the other two, we average those three!

We average the three good molarities and mass percents.

Trial	V_{NaOH}	$m_{solution}$	$n_{acetic\ acid}$	$[HC_2H_3O_2]$	Mass %
1	14.22 mL	2.02 g	0.001402 mol	0.7009 M	4.17%
~~2~~	~~14.90 mL~~	~~2.00 g~~	~~0.001469 mol~~	~~0.7344 M~~	~~4.41%~~
3	14.28 mL	2.01 g	0.001408 mol	0.7039 M	4.21%
4	14.26 mL	[illegible]00 g	0.001406 mol	0.7029 M	4.22%
Average				**0.7025 M**	**4.20%**

Trial 2 was too pink, wasn't it?

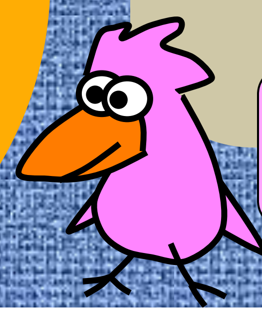
Info for calculations

3. Procedure: What we are doing today.

Show all of your calculations for each trial in your lab notebook. If you decide to throw out a trial, just draw a single line through it.

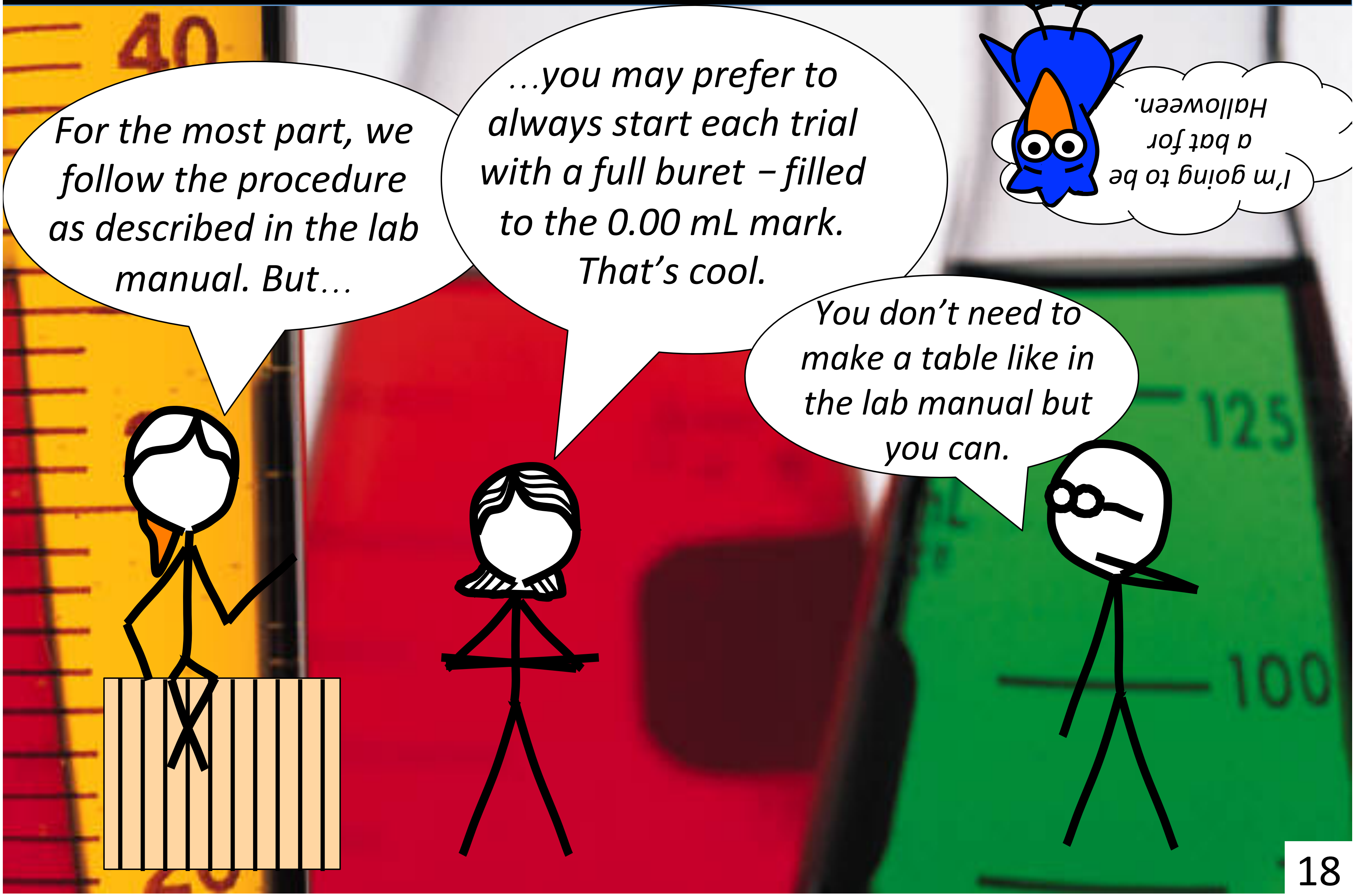
We are shooting for a very faint pink that persists for 15 seconds with stirring. This will lead to the fewest moles of NaOH. How do you think that will affect molarity of the acid?

It's important to recognize trials that are probably bad and should be repeated. If you use too much NaOH, the solution will be too pink. In the three trials in the previous slide, Trial 1 was the least pink and Trial 2 was the most pink. Your three trials should come within 0.5 mL of each other.

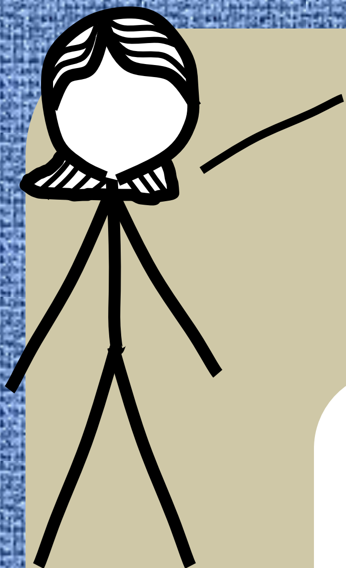


Ask about bonus points for very faint persistent pinks.

3. Procedure


For the most part, we follow the procedure as described in the lab manual. But…
…you may prefer to always start each trial with a full buret – filled to the 0.00 mL mark. That's cool.
You don't need to make a table like in the lab manual but you can.
I'm going to be a bat for Halloween.

3. Procedure: What we are doing today.



You will be turning in results on-line today. Many of the numbers are small, such as 0.001402 M. You can enter this number just as shown: 0.001402 M…

BUT if you use exponential notation, there is only one correct way to enter this sort of data so Excel can recognize it. Use this E format and NO spaces at all:

1.402E-3

Picky Picky
1.402 x 10-3 doesn't work.
1.402 E-3 doesn't work.
1.402 x 10^-3 doesn't work.
Incorrect entries result in point loss.

There are no spaces except to add units.

1.402E-3 M

is ok

3. Procedure: What we are doing today.

Wear your safety glasses today and dress for a mess.

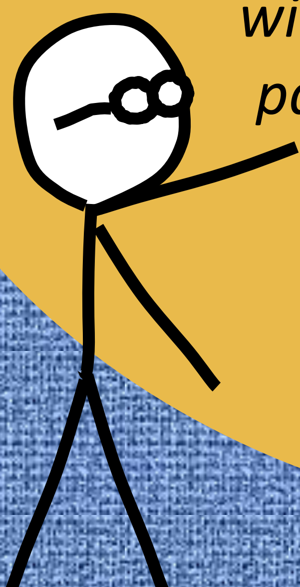
The cover sheet summarizes everything that you need to include with your report.

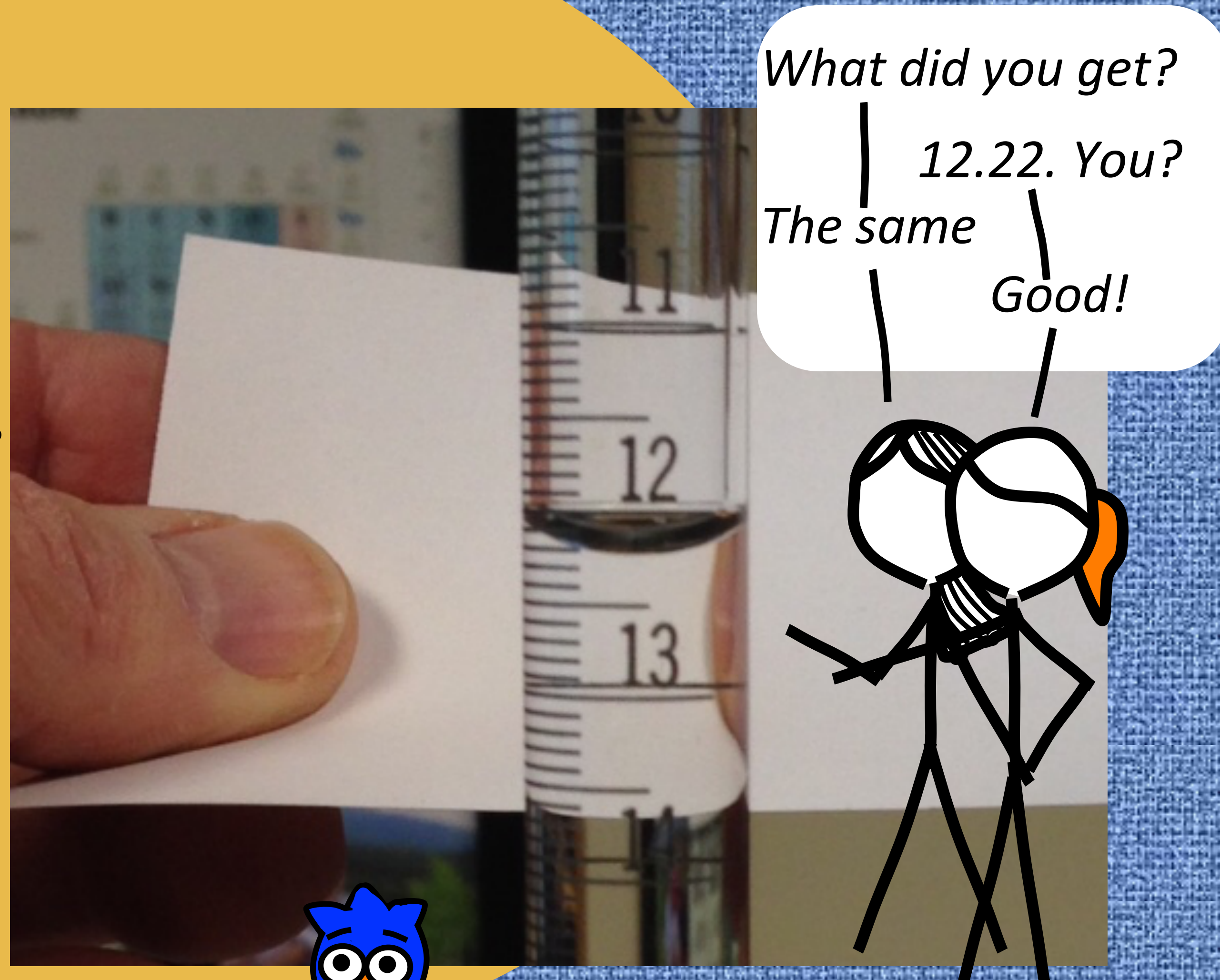
We do three separate calculations for moles, molarity and mass percent for each of the three trials.

4. Tricks of the trade

Use a 3 x 5 notecard as a light scoop…

… and compare what you get with your partner.

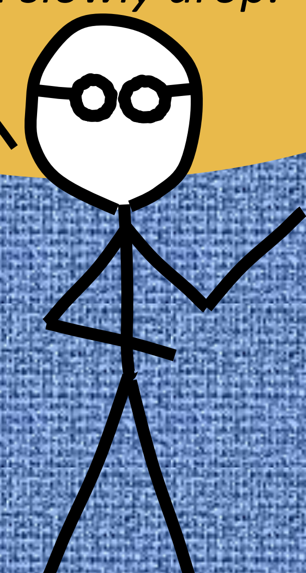


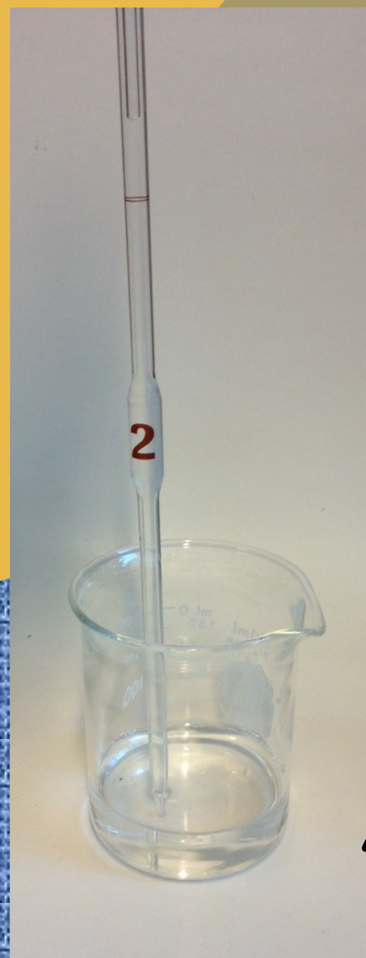


This is how to prevent buret reading errors.

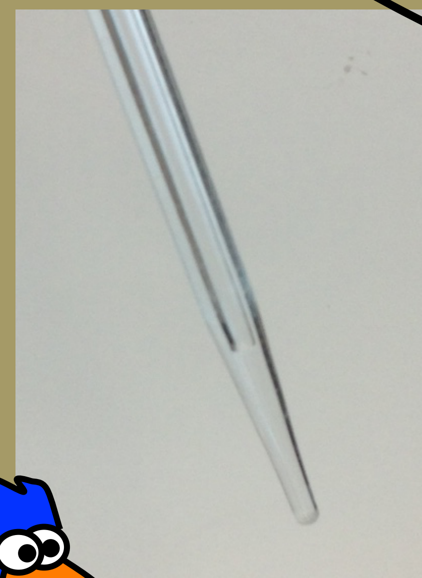
4. Tricks of the trade

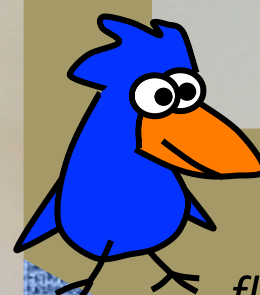
One easy way to start exactly at the mark is to draw the solution up past the mark, hold your finger firmly on the top and hold the tip of the pipet on the bottom of the beaker. Roll your finger slightly off the pipet and solution will slowly drop.





The last drop in a volumetric pipet is supposed to stay in the pipet. It's been calibrated to work that way.

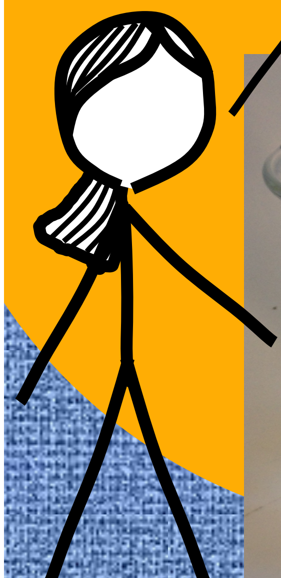


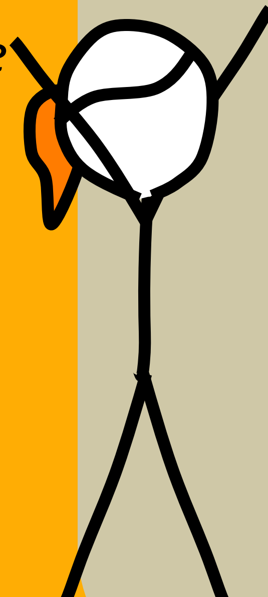


So don't shake, flick or blow it out

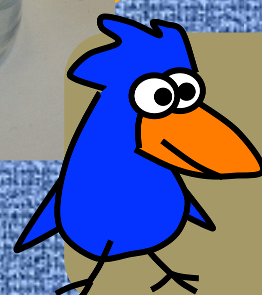
4. Tricks of the trade

We can touch the pipet to the side of the receiving vessel in order to dislodge a hanging drop, however.



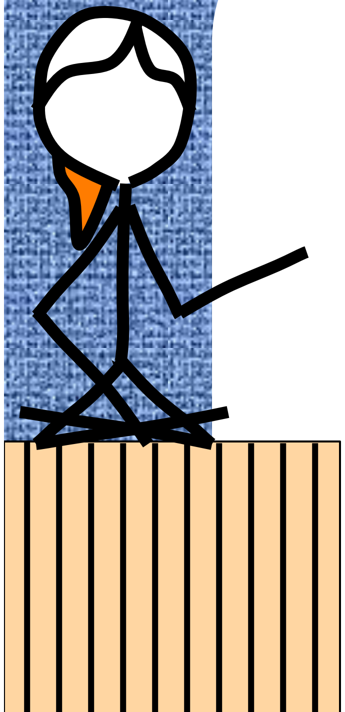


The best “Trick of the trade” is that we can speed titrate! Remember how the volumes of NaOH added were so similar in Slide 15? That lets us “speed titrate” and get out a bit earlier. Remember how the first titration took 14.22 mL? That means the other titrations will take about the same – so we can jet in the first 12 or 13 mL and then slow down for the perfect pink.

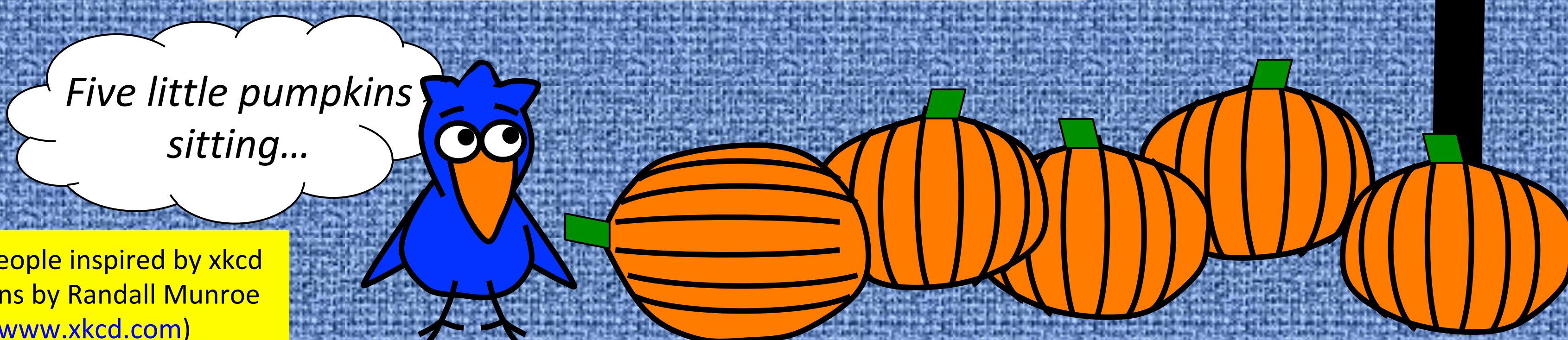


If you “think” maybe you should add one more drop, write down the buret volume before you do – just in case it was a bad idea.

5. Your lab report



1. *First, the cover page with TA initials.*
2. *Next, the trimmed copy pages from your lab notebook stapled together.*
3. *On-line results due at the end of class today. Late submissions are not graded – see the syllabus.*
4. *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)

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.*