Introduction to Strong and Weak Acids

Please review the techniques for pipetting a solution, using a buret and performing a titration. There is a link on the 152LL page next to the activity.

Introduction:

Acids are considered to be strong or weak based on their degree of dissociation.

Strong Acids - An acid is called "strong" if almost all the acid molecules donate an H^+ (proton) in water. The reaction of a strong acid in water proceeds forward to products almost completely, so no equilibrium is set up because the reverse reaction does not occur to any appreciable extent. We say the ionization of a strong acid is about 100% because almost all of the original acid, HX, ionizes in water.

$$HX(aq) + H_2O(l) \rightarrow H_3O^+(aq) + X^-(aq)$$

Weak Acids - An acid is called "weak" if only a few of the acid molecules donate an H^+ (proton) in water. The reaction of a weak acid in water proceeds forward to products until it reaches equilibrium, which is when the reverse reaction is going at the same rate as the forward reaction. We say the ionization of a weak acid is considerably less than 100% (often below 5%) because few of the original acid molecules, HY, ionize in water and few products are formed.

$$HY(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Y^-(aq)$$

Percent ionization - A useful measure of the strength of an acid is its percent ionization. See equations below for the calculation of percent ionization. The hydronium ion concentration is the equilibrium concentration of H_3O^+(aq).

pH - The pH of a solution is defined as: pH = -log $[H_3O^+]_{eq}$. Because the pH is the negative log of $[H_3O^+]$, the pH decreases as the $[H_3O^+]$ or acidity increases. This equation can be rearranged to solve for $[H_3O^+]_{eq}$ using a solution's measured pH value.
Refer to Sections 14.1-14.3 of Openstax Chemistry for information on defining Bronsted-Lowry Acids and Bases, calculating $[H_3O^+]$ from pH, and relative strengths of acids and bases.

Titration of acids with a strong base

When any acid reacts with a strong base the neutralization reaction will proceed forward to completion. Even weak acids react completely with a strong base. Strong bases produce hydroxide ions in aqueous solutions and hydroxide ions have such a high affinity for protons that they will pull all the protons off weak acids or strong acids. The neutralization reaction for a acid-base titration can generally be written:

$$HA(aq) + NaOH(aq) \rightarrow NaA(aq) + H_2O(l)$$

Stoichiometry can be used to perform many titration calculations including calculating the unknown molarity for an acid or base solution as well as determining the volume of titrant needed to reach the equivalence point.

Sample titration calculation for the reaction: $3\ NaOH(aq) + H_3PO_4(aq) \rightarrow Li_3PO_4(aq) + 3\ H_2O(l)$
A student pipets 10.00 mL of 0.1369 M H_3PO_4 into an erlenmeyer flask. The end point is reached when 16.55 mL of NaOH is added. Calcualte the molarity of the NaOH solution.

$$10.00 \text{ mL } \mathrm{H_3PO_4} \left(\frac{1 \text{ L}}{1000 \text{ mL}}\right)\left(\frac{0.1369 \text{ mol } \mathrm{H_3PO_4}}{1 \text{ L}}\right)\left(\frac{3 \text{ mol NaOH}}{1 \text{ mol } \mathrm{H_3PO_4}}\right) = 0.004107 \text{ mol } NaOH$$

$$\text{Molarity NaOH} = \frac{0.004107 \text{ moles NaOH}}{0.01655 \text{ L NaOH}} = 0.2481571 \text{ M NaOH} = 0.2482 \text{ M NaOH}$$

Notice the dilution equation would not work for calculating the molarity since 3 moles of base reacts with one mole of acid. The dilution equation is only for adding water to a reagent NOT for a chemical reaction between two different chemicals. For chemical reactions, stoichiometry must always be used since it incorporates the mole-to-mole ratio between two species in a balanced equation.

Equations to use for the calculations:

$pH = -\log [H_3O^+]_{eq}$

$[H_3O^+]_{eq} = 10^{-pH}$

$\%\ ionization = \frac{[H_3O^+]_{eq}}{[HA]_{initial}} \times 100\%$

$\%\ error = \left|\frac{measured - actual}{actual}\right| \times 100\%$

Materials:

25 mL buret
5.00 mL pipet
150 mL beaker
4 – 50 mL beakers
125 mL Erlenmeyer flask
Chromebook
GoLink
pH probe
Magnetic stir bar
Hot/Stir plate
KimWipes
pH calibration solutions (pH 4 and pH 7)
NaOH
nitric acid A and B
glycolic acid A and B

NOTE: The pipet, buret and pH probe used in this activity are fragile and expensive. Please handle these carefully! If you break any of these, you will be charged a breakage fee!

Procedure:

1. Assemble the Chromebook, pH probe, and GoLink system as directed in the "Using and calibrating a pH probe" technique below. In the Vernier Graphical Analysis window, click the 3-square icon in the upper right corner to select "Meter".
2. Obtain approximately 30 mL of nitric acid A, 20 mL of nitric acid B, 30 mL of glycolic acid A and 20 mL of glycolic acid B in four different clean, dry and labeled 50 mL beakers. Record the exact concentrations for all four acids.
3. Measure and record the pH values of all four acid solutions and all of your group's beverage samples. Write your pH values for your drinks on the board. Also record beverage pH values from the rest of the class. (Save your nitric acid A and glycolic acid A solutions for the titrations described below.)
4. Obtain approximately 50 mL of sodium hydroxide in a clean, dry 150 mL beaker. Prepare the buret to be filled with this solution as described in the "Using a buret to deliver solution" technique section.
5. Pipet 5.00 mL of the nitric acid A solution into a thoroughly rinsed 125 mL Erlenmeyer flask as described in the "Pipetting a solution" technique section in the lab technique guide and add 2 drops of phenolphthalein. Add about 10 mL DI water to your flask.
6. Carefully slide the stir bar into the Erlenmeyer flask so it does not splash. Turn the stir knob until the solution is stirring at a brisk pace without splashing. Titrate the solution as described in the "Performing a titration" technique section. Make sure to record your initial and final buret volumes.
7. Repeat steps 5 and 6 for two more trials (a total of 3 trials) with nitric acid A solution. (Note: You are not titrating nitric acid B.)
8. Pour your nitric acid and titration solutions down the drain with plenty of water. Rinse your beakers and flasks thoroughly with tap water and a final rinse with DI water. The flasks may be reused wet.
9. Repeat steps 5-7 but use glycolic acid A (a monoprotic acid with the formula $HC_2H_3O_3$) instead of nitric acid. Refill the buret with sodium hydroxide to just below the zero mark.

10. Have your instructor initial the pH values you recorded for the four acid solutions and your titration data for the six trials before disassembling the equipment.
11. When your group is done with the lab, check the board to make sure you have recorded all the beverage pH values from your section.

Waste Disposal: Pour the solutions in the sink with running tap water.

Clean-Up: Rinse all glassware with lots of tap water and then a final rinse with DI water. Wipe your entire bench with a damp paper towel. Put all equipment back where you found it. Return plastic beverage vials to the designated container.

Techniques: Setting up Chromebook and Using a pH probe

Setting up Chromebook:

1. Once the Chromebook is open, select "Add Person" (in the lower corner of the screen). Sign in using your MEID and password.
2. Use Google to search the Chrome web store. Install Vernier Graphical Analysis (version 1.2 or newer).
3. Follow the steps to launch the app on the Chromebook.
4. Connect the GoLink to the Chromebook.
5. Plug probe in to GoLink.
6. Select "Sensor Data Collection".

Techniques for calibrating and using a pH probe:

1. Keep a waste beaker near the probe to collect the rinses.
2. Rinse the probe with DI water taking care to rinse the bulb at the end. Dry with a Kimwipe.
3. Click the button in the lower right corner of the screen that says "pH". Click "Calibrate".
4. Place the pH probe in the pH 4 buffer solution and gently swirl. Once the voltage stabilizes, enter "4" in the first known value and click "Keep".
5. Rinse the probe with DI water taking care to rinse the bulb at the end. Dry with a Kimwipe.
6. Place the pH probe in the pH 7 buffer solution and gently swirl. Once the voltage stabilizes, enter "7" in the first known value and click "Keep".
7. Rinse the probe with DI water taking care to rinse the bulb at the end. Dry with a Kimwipe.
8. Click "Apply".
9. Put the probe back into its special buffer solution. The probe cannot sit out of a solution for long or it will dry up and not work anymore.
10. Note: The probe has a hard time reading pH values below 1.5 or above 12.5. It takes a long time for the probe to properly respond to solutions so acidic or basic.

Sign off of the Chromebook when you are done!

Note: The storage solution is a special buffer solution to preserve the probe. If the solution is spilled, notify the instructor to have the bottle refilled. Do not pour water or any other solution into the sensor container!

Introduction to Strong and Weak Acids Pre-Lab Questions and Calculations

You will complete this quiz in Canvas 1 hour before your lab period. This page will not be turned in or graded. You may use this page to set up your calculations before you take the Canvas quiz.

1. Describe the difference(s) between strong acids and weak acids.

2. What techniques are used in this experiment?

3. What are some safety precautions required for this lab?

4. List the strong acids.

5. If an acid solution has a measured pH of 2.55, what is $[H_3O^+]_{eq}$?

6. If a 0.0865 M solution of HCl has a pH of 1.32, what is it's percent ionization?

7. 10.00 mL of a 0.15 M solution of HCl is titrated with 12.34 mL NaOH. What is the concentration of the NaOH solution?

Name: ______________________________ Partners: _________________________

Introduction to Strong and Weak Acids Lab Report
Turn in pages 5-8 as your graded lab report.

Data and Calculations

Table 1: Initial Concentrations and pH values of acids; Titration volume data

Trial	Solution	nitric acid A	nitric acid B	glycolic acid A	glycolic acid B
	Exact initial concentration, M				
	pH				
1	**V_i NaOH (mL)**				
	V_f NaOH (mL)				
	V_{total} NaOH (mL)				
2	**V_i NaOH (mL)**				
	V_f NaOH (mL)				
	V_{total} NaOH (mL)				
3	**V_i NaOH (mL)**				
	V_f NaOH (mL)				
	V_{total} NaOH (mL)				

Table 2: Beverage pH values from class

Beverage	**pH**	**Beverage**	**pH**

Instructor Initials: _________

Calculations:

1. Show sample calculations of hydronium concentration and percent ionization only for **nitric acid A.** Use the **exact** initial concentration of the acid solution for the % ionization calculation. **Show equations and values in your work below**. Report your values for all 4 acids in Results Table 3.

2. Write the balanced reaction between aqueous nitric acid and aqueous sodium hydroxide. Using the data from trial 1 of the nitric acid titration, calculate the concentration of the sodium hydroxide. Show all your work, including units, for trial 1. Do not use $M_1V_1 = M_2V_2$ as that is for dilutions not titrations. Report total volume and concentration of NaOH values for all 3 trials in Results Table 4.

   Balanced equation: ____

   [NaOH], M from trials 2 and 3: _____________ _______________

3. Write the balanced reaction between aqueous glycolic acid ($HC_2H_3O_3$) and aqueous sodium hydroxide. Using the data from trial 1 of the glycolic acid titration, calculate the concentration of the sodium hydroxide. Show all your work, including units, for trial 1. Do not use $M_1V_1 = M_2V_2$ as that is for dilutions! Report the total volume and concentration of NaOH values for all 3 trials in Results Table 4.

   Balanced equation: ____

   [NaOH], M from trials 2 and 3: ______________ ______________

Results

Table 3: Results of hydronium and percent ionization calculations

Solution	Measured pH	$[HA]_i$, M	$[H_3O^+]_{eq}$, M	% ionization
nitric acid A				
nitric acid B				
glycolic acid A				
glycolic acid B				

Table 4: Titration results

	Total volume of NaOH, mL	**Calculated [NaOH], M**
Trial 1, nitric acid A		
Trial 2, nitric acid A		
Trial 3, nitric acid A		
Trial 1, glycolic acid A		
Trial 1, glycolic acid A		
Trial 1, glycolic acid A		

4. What is the average sodium hydroxide concentration for all 6 titration trials (three from nitric A and three from glycolic A)? Show your calculation and answer below.

5. Obtain the true concentration of NaOH from your instructor. What is the percent error for your average concentration? Show your calculation and answer below.

6. Using your average sodium hydroxide concentration calculated in number 4 above, predict the volume needed to neutralize 5.00 mL of the nitric acid B solution. In your calculation make sure you use the exact nitric acid B concentration. Do not use $M_1V_1 = M_2V_2$ as that is for dilutions not titrations.

7. Using your average sodium hydroxide concentration calculated in number 4 above, predict the volume needed to neutralize 5.00 mL of the glycolic acid B solution. In your calculation make sure you use the exact glycolic acid B concentration. Do not use $M_1V_1 = M_2V_2$ as that is for dilutions not titrations.

Conclusion: Compare pH and % ionization values of strong vs weak acids. How does concentration affect the pH and % ionization for each type of acid? Report your average NaOH concentration and % error. Compare the volume of base needed to titrate a strong acid versus a weak acid of similar concentrations.

Post-Lab Questions – These questions will not be graded as part of your lab report grade. You will be responsible for the information in these questions and able to answer these or similar questions on the post-lab quiz at the start of next week's lab period.

1. Write the balanced reaction for nitric acid in water.

2. Write the balanced reaction for glycolic acid ($HC_2H_3O_3$) in water.

3. Circle which of the four acid solutions would be considered "strong."
    a. 0.1M nitric acid b. 0.001M nitric acid c. 0.1M glycolic acid d. 0.001M glycolic acid

4. Explain your choice(s) in number 4 above. Why are your choices strong and the others weak?

5. List your four acid solutions in order of increasing pH.

Lowest pH	Next	Next	Highest pH

Explain how glycolic acid can have a lower pH and be more acidic than nitric acid.

6. What was the most acidic beverage in your class? ________________________________

For the following statements, circle the acid solution in lab that best describes the property mentioned.

7. Lower pH: nitric A nitric B

8. Higher % dissociation: nitric A nitric B

9. Lower pH: glycolic A glycolic B

10. Higher % dissociation: glycolic A glycolic B

11. Lower pH: nitric A glycolic A

12. Higher % dissociation: nitric A glycolic A

For the following statements, circle the bold/italicized word or phrase that correctly completes each one.

13. A strong acid has a ***high*** / ***low*** percent dissociation.

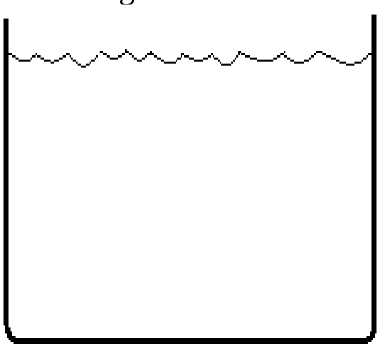
14. At the same molarity, a strong acid will have a ***higher*** / ***lower*** / ***the same*** pH as a weak acid.

15. As concentration of a weak acid decreases, the pH ***increases*** / ***decreases*** / ***is constant***.

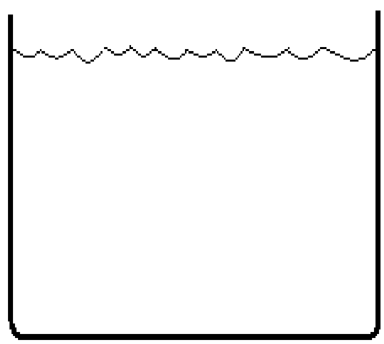
16. As concentration of a weak acid decreases, the percent dissociation ***increases*** / ***decreases***

17. Consider your answers to calculations number 6 and 7 on page 7. Explain why the sodium hydroxide volumes needed to titrate the dilute nitric acid and glycolic acid solutions are pretty close, or why they are very different. Should the stronger nitric acid require more sodium hydroxide to neutralize it than the glycolic acid? Explain.

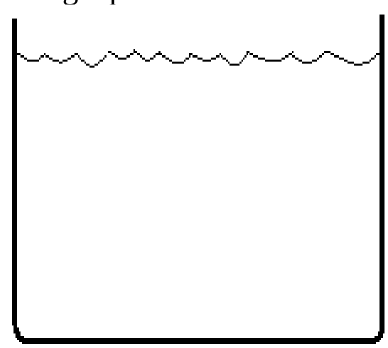
18. Starting with **10 molecules or formula units**, draw each of the following aqueous solutions.



nitric acid

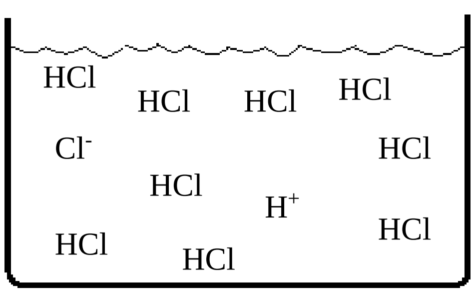


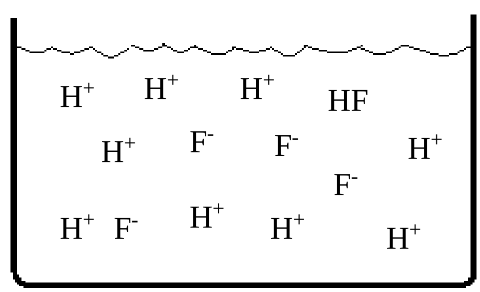
glycolic acid



sodium hydroxide

19. Identify what is wrong with each of the following pictures (there might be 1, 2, or more errors):





20. Discuss at least 2 experimental sources of error. How did they affect your results and how would you correct them if you were to repeat the experiment?