LAB:
Titration of Vinegar
[25 pts]

Name Key
Lab Partner(s) ____________
Period ______

Purpose: To determine the molarity and percent acetic acid in ordinary vinegar by titration.

Introduction: If acetic acid is added to NaOH with an exact mole ratio of 1:1, then the acetic acid will be perfectly neutralized as shown below. (Notice that only a salt and water are formed.)

$$HC_2H_3O_2\,(aq) + NaOH\,(aq) \rightarrow NaC_2H_3O_2\,(aq) + HOH\,(l)$$

acetic acid — sodium hydroxide — sodium acetate — water

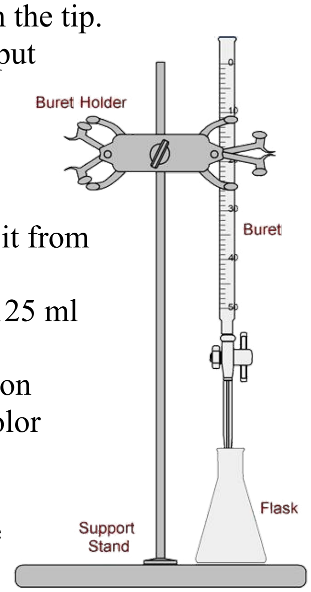
We will use the pH indicator, phenolphthalein, to tell us when the acid has been completely neutralized. Phenolphthalein is **clear when acidic** and it is **pink when basic**, so the solution will stay pink when there is no more acid and a slight excess NaOH is added at the equivalence point. If this is done carefully, the solution will turn *very light* pink with the addition of just one drop of NaOH past the *endpoint*.

Materials

50-mL buret	buret funnel	ring stand
buret clamp	125 mL Erlenmeyer flask	10 mL volumetric pipet
pipet filler	100 mL beaker	50 mL Erlenmeyer flask
50-55 mL standardized NaOH	30 mL vinegar	dropper bottle of phenolphthalein

Procedure:

1) Put about **50-55 ml of the standardized NaOH** solution into a clean, dry 100 ml beaker. (Please conserve the NaOH; we have a limited supply.) Record the molarity of NaOH below.
2) Rinse the buret with ~3-5 mL of the NaOH solution. Discard this solution through the tip.
3) Fill the buret all the way up with the NaOH. ***Slowly*** open the valve to fill the tip (put your beaker of NaOH under it), get any air bubbles out of the tip and refill the buret to about 0 mL. (Make sure you read the buret correctly—it reads downwards—**do NOT subtract from 50!** Read to the tenths place—1 decimal point!) Record initial volume in data table on the top of the next page.
4) Obtain ~30 mL of vinegar in a clean, dry 50-mL Erlenmeyer flask (to distinguish it from the NaOH).
5) Use volumetric pipet to measure **10.0 ml of the acetic acid** solution into a clean 125 ml flask.
6) **Add 2 drops of phenolphthalein** indicator to the vinegar in the flask. (The solution should be clear.) Place a sheet of white paper beneath the flask to better see the color change during the titration.
7) Start adding NaOH to the flask, about 1 mL at a time at first. Swirl the flask after every addition until the pink color disappears. Use shorter length squirts when the pink color persists longer. Try to get it so that one quick squirt suddenly causes the color to stay pink. (Swirl for about 30 seconds to make sure it is permanently pink.) The fainter the pink color, the better.



8) Record final volume level of NaOH in buret at the endpoint. Determine the volume of NaOH added, in mL: $V_{NaOH} = V_{Final} - V_{Initial}$.
9) Pour the products down the sink and rinse your flask with deionized water and do at least two trials. Repeat steps 5-8, starting with a fresh sample of vinegar. Add new indicator too. If you have less NaOH than you needed for the first trial remaining in the buret, refill it so that you do not run out during the titration. Record the current volume level as $V_{Initial}$ for the new trial.
10) You MUST do a third trial if your values for the volume of NaOH are not within 0.4 mL. (I will deduct points if this is not done)
11) When done, drain any leftover NaOH solution into the beaker and pour it back into the original container. Rinse the buret well with distilled water, leave the valve open, and put it back where you got it. Rinse all other glassware and put it away.

Data: [8 pts] **Molarity of standardized NaOH (from board): 0.50 M**

	Trial 1	**Trial 2**	**Trial 3 (if necessary)**
Initial volume of NaOH (mL)			
Final volume of NaOH (mL)			
Volume of NaOH added (mL)			

Average Volume of NaOH added (average your ***closest two*** trials): 17.5 mL (Note: sample data only)

Calculations: Show all work! Keep THREE Sig Figs throughout your calculations!!! UNITS on ***every*** number!

1) Follow these steps to determine the **molarity of the acetic acid in vinegar**.

   a. [1 pt] Calculate the **moles of NaOH** added to the acetic acid solution from the average volume and the molarity.

   Moles NaOH = 0.50 M × 0.0175 L = 0.00875 moles (8.75×10^{3} moles)

   b. [1 pt] How many **moles of $HC_2H_3O_2$** must have been in the vinegar you used? How do you know this? *[Hint: stoichiometry! Given? Wanted? Ratio from balanced chemical equation?]*

   Moles $HC_2H_3O_2$ = Moles NaOH because there is a 1:1 mole ratio in the balanced equation, so moles $HC_2H_3O_2 = 8.75 \times 10^{-3}$ moles

   -OR-

   $$\text{mol } HC_2H_3O_2 = 8.75 \times 10^{-3} \text{ mol NaOH} \times \frac{1 \text{ mol } HC_2H_3O_2}{1 \text{ mol NaOH}} = \boxed{8.75 \times 10^{-3} \text{ mol } HC_2H_3O_2}$$

   c. [1 pt] Calculate the **molarity of $HC_2H_3O_2$** in vinegar. *[What volume of vinegar did you use? Remember to convert to L!]*

   $$M_{HC_2H_3O_2} = \frac{8.75 \times 10^{-3} \text{ mol}}{0.010 \text{ L}} = \boxed{0.875 \text{ M } HC_2H_3O_2}$$

2) Follow these steps to determine the **percent by mass of acetic acid in vinegar.**

   a. [1 pt] Find **mass of acetic acid** in your vinegar sample. *(moles of acetic acid was calculated above)*

   MM $HC_2H_3O_2$ = 4×1.01 g + 2×12.01 g + 2×16.00 g = 60.06 g/mol

   $$? \text{ g } HC_2H_3O_2 = 8.75 \times 10^{-3} \text{ mol } HC_2H_3O_2 \times \frac{60.06 \text{ g } HC_2H_3O_2}{1 \text{ mol } HC_2H_3O_2} = \boxed{0.526 \text{ g } HC_2H_3O_2}$$

   b. [1 pt] Find the **mass of your total vinegar** sample. *Hint: You used 10.0 mL of vinegar. Since vinegar is mostly water, we can assume that the density of vinegar is very close to that of pure water (1 g/mL)*

   $$? \text{ g vinegar} = 10.0 \text{ mL} \times \frac{1 \text{ g}}{1 \text{ mL}} = \boxed{10.0 \text{ g vinegar}}$$

c. [1 pt] Calculate the **percent** by mass of acetic acid in vinegar. *[mass of acetic acid/ mass of vinegar × 100]*

$$\% \ HC_2H_3O_2 = \frac{0.526 \text{ g } HC_2H_3O_2}{10.0 \text{ g vinegar}} \times 100 = \boxed{5.26\% \ HC_2H_3O_2}$$

d. [1 pt] The % acetic acid reported on vinegar bottle is 5%. What was your %error?

$$\% \text{ error} = \frac{|5.26\% - 5\%|}{5\%} \times 100\% = \boxed{5.2\%}$$

Post Lab Questions:

3) [2 pts] Why is it necessary to use an indicator when doing a titration? To do the most accurate titration, at what pH should the indicator change color (i.e. where should the *end point* be)?
An indicator is used to show when the *end point* of the titration has been reached. To be most accurate, the pH at which the indicator changes should be equal to the pH as close to the *equivalence point* as possible, which for weak acids and strong bases occurs at pH > 7.

4) A bottle of H_2SO_4 is found in a lab cabinet, but the bottle is not labeled with any molarity. Thus, you decide to do a titration with a standardized solution of NaOH. It is found that it takes 45.8 mL of the 2.65 M NaOH solution to titrate 30.0 mL of the H_2SO_4 solution to a sharp endpoint. The ***unbalanced*** equation is:

$$\underset{30.0 \text{ mL of ?? M}}{H_2SO_4 \text{ (aq)}} + \underset{45.8 \text{ mL of 2.65 M}}{2 \ NaOH \text{ (aq)}} \rightarrow Na_2SO_4 \text{ (aq)} + 2 \ HOH \ (l)$$

a) [1 pt] How many moles of NaOH were used to neutralize the H_2SO_4? (Remember: Convert to L.)
Moles NaOH = 2.65 M × 0.0458 L = 0.121 moles

b) [1 pt] How many moles of H_2SO_4 were titrated? Show your calculation. *[Hint: stoichiometry! Balance your equation FIRST! It is **not** a 1:1 mole ratio!]*

$$\text{mol } H_2SO_4 = 0.121 \text{ mol NaOH} \times \frac{1 \text{ mol } H_2SO_4}{2 \text{ mol NaOH}} = 0.0607 \text{ mol } H_2SO_4$$

c) [1 pt] What is the molarity of the H_2SO_4 solution? (Remember to convert to liters.)
M = 0.0607 mol / 0.0300 L = 2.02 M

Read the attached article on Acid Rain and answer the following questions.

Air pollutants which cause acid rain:

1) [1 pt] What gas in the air makes rain **naturally** slightly acidic? ______CO_2___ Write the equation below:

   $CO_2\ (g) + H_2O\ (\ell) \rightarrow H_2CO_3\ (aq) \rightleftharpoons H^+\ (aq) + HCO_3^-\ (aq)$

2) [3 pts] What three gases released into the air cause acid rain? ____________SO_2, SO_3, NO_2____________ Write the 3 equations:

   $SO_2\ (g) + H_2O\ (\ell) \rightarrow H_2SO_3\ (aq) \rightarrow H^+\ (aq) + HSO_3^-\ (aq)$

   $SO_3\ (g) + H_2O\ (\ell) \rightarrow H_2SO_4\ (aq) \rightarrow H^+\ (aq) + HSO_4^-\ (aq)$

   $2\ NO_2\ (g) + H_2O\ (\ell) \rightarrow HNO_3\ (aq) + HNO_2\ (aq) \rightarrow 2\ H^+\ (aq) + NO_3^-\ (aq) + NO_2^-(aq)$

Harmful effects of Acid Rain

3) [2 pts] Why does acid rain disintegrate buildings and statues made of limestone, marble and concrete? Write equation and explain.

   $CaCO_3\ (s) + H_2SO_4\ (aq) \rightarrow CaSO_4\ (aq) + H_2O\ (\ell) + CO_2\ (g)$
   The acid reacts with the insoluble $CaCO_3$ in limestone, marble and concrete to form $CaSO_4$—a more soluble solid.

4) [1 pt] Why is it harmful when acid rain falls on lakes?
   Because it can kill and damage fish and other aquatic life.

5) [1 pt] What can be done to help an overly acidic lake?
   Lime (CaO) is added to lakes since CaO (like $CaCO_3$) can neutralize acids.

Why SO_2 (g) and SO_3 (g) are released into the air

6) [2 pts] What is the major cause of SO_2 (g) and SO_3 (g) pollution? Write the chemical equations.
   Coal and oil that contains sulfur:

   $S\ (\text{in coal or oil}) + O_2\ (g) \rightarrow SO_2\ (g)$

   $S\ (\text{in coal or oil}) + \frac{3}{2}\ O_2\ (g) \rightarrow SO_3\ (g)$

7) [1 pt] What can be done to reduce the amount of SO_2 (g) released into the air?
   "Clean" coal can be used or the sulfur can be removed prior to burning the fuels.

Why NO_2 (g) is released into the air.

8) [2 pts] What is the major source of NO_2 (g) pollution? Write equations that show its formation.
   Emissions from cars and trucks.

   $N_2\ (g) + O_2\ (g) + \text{heat and pressure} \rightarrow 2\ NO\ (g)$

   $2\ NO\ (g) + O_2\ (g) \rightarrow 2\ NO_2\ (g)$

9) [2 pts] What part of your car significantly reduces the amount of NO_2 (g) released into the air? _catalytic converter_________________________ Write equations involved. What catalysts are most commonly used?

   $2\ NO\ (g) + 2\ CO\ (g) \rightarrow N_2\ (g) + 2\ CO_2\ (g)$ Platinum, Palladium, and Rhodium

   $2\ NO\ (g) + 2\ H_2\ (g) \rightarrow N_2\ (g) + 2\ H_2O\ (g)$