LAD G1 (pg 1 of 5) Standardizing NaOH with KHP

Name_________________________Per___

What % of vinegar is really $HC_2H_3O_2$ aka CH_3COOH ?

What is the K_a of acetic acid?

Introduction:

The acid in vinegar is acetic acid. An inorganic chemist would write acetic acid as (hydrogen acetate) $HC_2H_3O_2$ and an organic chemist would write it as CH_3COOH. Both are acceptable.

The quantity of acetic acid in a sample of vinegar may be found by titrating the sample against a standardized basic solution. Most commercial vinegar is labeled as 5% acetic acid, but can have a mass percentage that ranges between 4.0% and 5.5% acetic acid. By determining the volume of standardized sodium hydroxide solution needed to neutralize a measured quantity of acetic acid, the molarity and mass percentage of the vinegar can be calculated.

PreLAD:

Data Table − Set up your Data Table.

Set up a data/results table after doing preLab problems 1-4, by reading the Procedure Overview, Procedure and Processing the Data. Put your data entries in rows and your various trials will be the columns. Be sure and make three rows for the NaOH: intial volume, final volume, and volume actually used.

Reactions

1. KHP is an alkali salt, and the anion portion of this salt, hydrogen phthalate, is a weak acid (one of the few instances in which a negative ion is an acid not a base.).
   a. Write a balanced equation that represents just the dissolving of solid $KHC_8H_4O_4$.

   b. Write a balanced net ionic equation that represents the neutralization reaction between the hydrogen phthalate ion solution and sodium hydroxide solution.

2. Vinegar is an aqueous solution of acetic acid, a weak acid.
   Write a balanced net ionic equation for the neutralization reaction of acetic acid solution with sodium hydroxide solution.

Problems − Support your answers with clear calculations. Pay attention to units and significant figures.

3. For Procedure A, it would be helpful to know approximately how much base will be required to reach the equivalence point.
   a. Since the procedure suggests using between 0.25 − 0.35 g of KHP, calculate the number of moles of KHP in 0.30 g of potassium hydrogen phthalate (aka KHP), $KHC_8H_4O_4$. (MM = 204.22 g/mol)

   b. KHP is a monoprotic acid, what are the number of moles of ionizable H^+ in the approximately 0.30 g of KHP?

   c. Calculate the volume of ~0.12 M NaOH that would be necessary to neutralize the moles of KHP.

10/

 Vinegar Titration

4. For Procedure B, it is suggested that you use ~2 g of vinegar (an acetic acid solution). It will be helpful to know approximately how much base you'll need to add in order to neutralize the acetic acid that is in vinegar.
   - Calculate the mass of acetic acid in 2.0 g of a 5.0 % solution of acetic acid (vinegar).
   - Determine the number of moles of acetic acid ($HC_2H_3O_2$ MM = 60.1 g/mol) in the mass you just calculated.
   - Determine the volume of _______ M NaOH that would be required to neutralize this number of moles of acetic acid.

Materials per group

- ring stands with buret for NaOH solution
- phenolphthalein
- stirring plate & stirring bar
- 125 ml flask with parfilm to cover
- 100 ml beakers (for refilling NaOH buret)
- vinegar with pipet
- vial of KHP
- plastic dishes for weighing KHP
- scoops for KHP

Procedure Overview: *There are three parts to the procedure.*

Part A: Standardization of the NaOH solution

Part A as stated in the first title of this lab, is to *standardize* the sodium hydroxide solution. This is a preparation for Part B. In Part A you may recall from the Lab B2 - Redox Titration, that the first step in that Lab was to determine the concentration of the purple permanganate solution. This process is called *standardization*. In this Lab we will use KHP (potassium hydrogen phthalate), a very stable monoprotic solid acid, $KHC_8H_4O_4$ as our primary standard. Because of KHP's stability, when you mass a particular amount of it, you can be confident that you are delivering to your flask, the moles of acid that you calculate from the mass that you measure. When you titrate to the *equivalence point*, you can conclude that the moles of acid is equal to the moles of base. Knowing the moles of base and its volume, allows for the calculation of the concentration of the NaOH solution.

Part B: Analysis of vinegar

Part B is stated in the second title, Determining the amount of acetic acid in a vinegar solution. By titrating the standardized sodium hydroxide solution (from part A) with a sample of vinegar, you can calculate the mass percentage of acetic acid in the vinegar solution. Further as a second method of reporting the concentration of the vinegar, from the same titration data, you can calculate the molarity of a sample of vinegar.

Part C: Determination of the K_a of acetic acid

Part C. We will brainstorm the best way to use our solutions from this lab and a pH probe to determine the K_a of acetic acid.

Vinegar Titration

Procedure − *Protective eyewear is not optional.*

Part A − Standardization of NaOH ***All waste solutions can go down the sink. Please do not lose the stirring bar.***

A. Follow good lab procedures by preparing the base buret by rinsing out the burets with some of the solution that will be going in them, by twirling and pouring into the sink and being sure to allow some of it to run through the tip . Fill the buret with the NaOH solution, making sure to clear any air bubbles from the tip by allowing it to run through before taking your initial reading.

B. Measure out between 0.25−0.35 g of KHP into a flask. Dissolve the KHP in a small amount of water (enough to just barely cover the stirring bar) using the water in the squirt bottle. Add seveal drops of phenolphthalein and insert a stirring bar. Set the solution on the stirrer.

C. Read the starting volume of NaOH in the buret, then titrate the KHP solution with the NaOH solution to the endpoint. The endpoint is signaled by the solution turning from colorless to pale pink. If the solution is dark pink, it means you have gone too far and added too much base.

D. Record the final volume of base.

E. Rinse out the flask. PLEASE BE CAREFUL TO CATCH THE STIR BAR. Wipe off the outside of the flask, no need to dry the inside. Perform the Part A calculations (go to the process the data section) and report the molarity to the class data table. Repeat the titration and again calculate the molarity of the NaOH solution. Report the molarity to the class data table. Repeat a third trial if necessary.

Part B − Analysis of Acetic Acid in Vinegar. ***Do NOT discard your titration solution at the equivalence point.***

F. Rinse out your flask, and wipe off the outside, no need to dry the inside. Tare the balance and use your plastic pipet to add ~1.5−2 grams of vinegar to the flask. You must record the *exact* mass that you use.

G. Drop in the stirring bar, and then add just enough distilled water to the flask to just cover the bar. This will give the stirrer something to stir to make the mixing more consistent, and make color change at the equivalence point easier to see.

H. Add a few drops of phenolphthalein solution to the flask to serve as an endpoint indicator and place the flask on the magnetic stirrer. Be sure and read the initial volume of the base in the buret.

I. Run the titration quickly until closing in on the endpoint, and then add the base more carefully. When one drop is added, and the faint pink color does not disappear within 20-30 seconds, you have reached the endpoint. Read the final volume in the buret, and record it in your data table.

J. After reaching the equivalence point. Do not dump the flask. Cap the flask, and leave it on your lab bench and return to your desk to work on your calculations. We will use the flask of acetic acid at the equivalence point after discussing the results.

K. Leave your lab set-up and return to the classroom to process your data for Part B.

Part C − Determination of K_a of Acetic Acid. ***All waste solutions can go down the sink. Hang on to the stirring bar.***

L. Looking at a tritration curve, **state the point** at which it is easiest to determine the K_a of a weak acid?

M. In the space below, **describe** how you can convert the solution that you saved in part J to the point that you describe in Procedure L.

N. Let's go back to the lab and adjust our equivalence point solutions from Procedure K and determine the pH.

5/

 Vinegar Titration

Processing the data: *(Your Google Data Table with embedded calculations should be completed for this LAD.)*

Part A − Standardization of NaOH solution.

5. Calculate the moles of KHP. (*Let's be clear, KHP is NOT the chemical formula, its an acronym. The formula is given in the PreLAD.*)
6. Calculate the molarity of the NaOH solution.
   - KHP is monoprotic and sodium hydroxide is "mono-basic".
   - Thus the moles of solid KHP acid equals the moles of NaOH in solution.
7. Repeat the calculation for all three trials. Report your molarity values for NaOH to the class spreadsheet, and you will use the class average as the molarity of NaOH as you proceed to part B.

Part B − Use the Class Average of the molarity of the NaOH solution.

1. Calculate the % (by mass) of acetic acid in the vinegar solution. *Need help? Steps (a) − (c) below should help.*
   a. First, calculate the moles of acetic acid in the vinegar sample
      - Using the average standardized molarity of the NaOH that the class calculated in part A of the LAD, calculate the moles of base that was necessary to neutralize the vinegar − the solution of acetic acid.
      - Since acetic acid is monoprotic, and sodium hydroxide is "mono-basic", you can assume that the moles of base equals the moles of acid.

   b. Next, determine the mass of acetic acid in the vinegar solution.
      - Using the molar molar mass of acetic acid with the moles of acetic acid just calculated in the previous calculation.

   c. Finish by calculating the % of acetic acid in the vinegar solution.
      - Since % is part out of total, you'll need to divide the mass of acetic acid in the vinegar by the mass of the vinegar solution.

   d. Repeat the calculations for all trials.
2. Calculate the the molarity of the vinegar solution. You can calculate one of two slightly different methods:
   - Acetic acid is a monoprotic acid and sodium hydroxide is "mono-basic" so you can use the $M_a \times V_a = M_b \times V_b$ equation.
   - Vinegar is mostly water, and thus the density of the vinegar is ~1.05 g/ml which will allow you to calculate the volume, in milliliters, of the solution.

   OR

   - Using the moles of acid you calculated in part (a) in the % calculation, you can simply divide those moles by the volume of vinegar you measured out.
   - Since vinegar is mostly water, you can assume the density of the vinegar is ~1 g/ml and thus the mass of vinegar that you originally measured out is approximately equal to the volume, in milliliters, of the solution.

Part C − In your data table, be sure you have formatted any K_a values to scientific notation.

1. As discussed, the pH is the pK_a of the acetic acid.
2. The theoretical K_a of acetic acid is 1.8×10^{-5}. Convert the theoretical K_a into a theoretical pK_a
3. Calculate percent error using the measured pH (which is the experimental pK_a) and the theoretical K_a value.

Post LAD Questions

1. In procedure part B, item H, you were asked to add "some" water to the 1−2 g of vinegar that you very carefully measured out so that the stirring bar could actually stir. **Why is it *not* important** that you measure this water, **the molarity of the acetic acid change** in the flask when you add extra water, but **why does that change NOT affect** the *calculated* mass percent and molarity results for the vinegar as we calculated in this lab?

5

LAD G1 (pg 5 of 5) Vinegar Titration

2. The graph shown below is a titration curve for 100.0 ml of an aqueous solution of potassium hydrogen phthalate with 0.12 M NaOH. Use the graph, marking it up to support the information/data you need to answer the following questions.
Be sure and show your work for all calculations as well as marking the graph.

   a. **Calculate** the molarity of the potassium hydrogen phthalate solution?

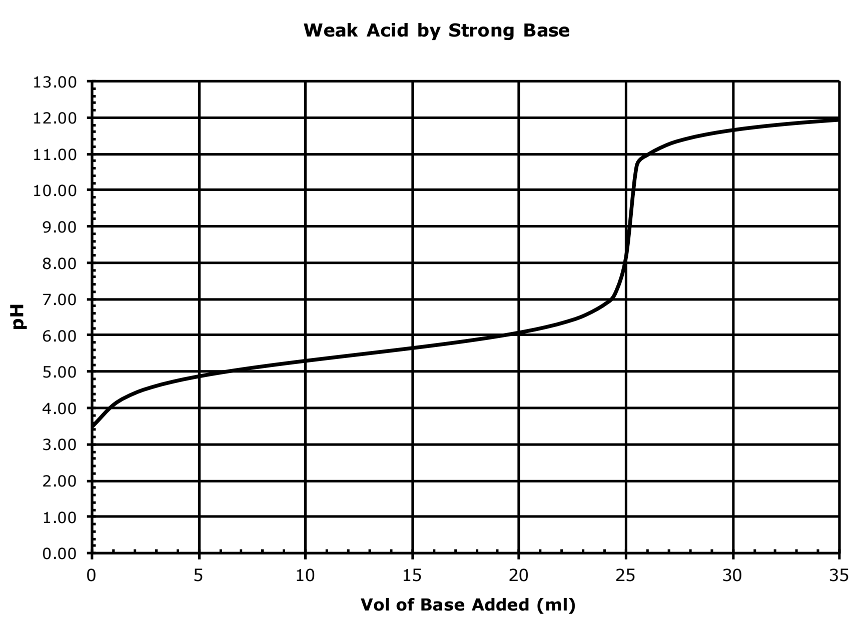
   b. The instructor made 500.0 ml of this aqueous acidic solution, **calculate** the mass of potassium hydrogen phthalate that was weighed out into the 500.0 ml volumetric flask?

   c. **Use the graph** to determine the K_a of the hydrogen phthalate ion. Explain why this determination is justified.

   d. Use the K_a to **perform a calculation** that will confirm the initial pH listed on the graph

   e. **Explain** why the pH at the equivalence point is not 7. **Show a net ionic equation** that supports your reasoning.

   f. At pH 7, which ion; $HC_8H_4O_4^-$ or $C_8H_4O_4^{2-}$, is greater, or are they the same? **Explain**.



10/

Scoring Rubric	
5	**PRE**
35	Questions
35	Data Table
________	*Out of 75*
25	Lab Quiz