Acid-Base Titration Lab AP Chemistry

Introduction:

In this lab, you will be titrating both a strong acid (HCl) and then a weak acid ($HC_2H_3O_2$) with a strong base (NaOH) while recording the pH. From the collected data, a titration curve will be plotted for each acid and differences in the curves noted.

Strong acids, such as HCl, ionize almost completely in water. However, most substances that are acidic in water are actually weak acids. Because weak acids dissociate only partially in aqueous solution, equilibrium is formed between the acid and its ions. The ionization equilibrium is given by:

$$HX_{(aq)} \leftrightarrow H^+{}_{(aq)} + X^-{}_{(aq)}$$

Where X^- is the conjugate base.

The equilibrium constant is then:

$$K_a = [H^+][X^-] / [HX]$$

The smaller the value for Ka, the weaker the acid. Weaker acids ionize less ($[H^+]$ is smaller compared to [HX]) and therefore have a less drastic effect on pH.

Purpose: To construct two titration curves - One of a strong acid with a strong base and the other, a weak acid with a strong base AND to determine the Ka of the weak acid using the constructed titration curve.

Procedure

Strong Acid Strong Base Titration

1. Obtain a clean, dry 125 mL Erlenmeyer flask.
2. Using a volumetric pipet, pipet 25.00 mL of 0.1M HCl solution to your Erlenmeyer flask. Add 2-3 drops of the bromothymol blue indicator.
3. In a 100-mL beaker (label Beaker B), add 75-mL of the 0.1M NaOH solution using a graduated cylinder.
4. Rinse the buret with the titrant two times. (With the stopcock closed add approximately 2-mL of the 0.1M NaOH, using the buret funnel. Swirl the NaOH around the buret, discard into the sink and repeat.)
5. Make sure the stopcock is closed. Using the buret funnel, carefully add the 0.1M NaOH to the buret. Go about a half inch past the top line on the buret, being careful not to let it overflow.
6. With Beaker B under the buret, slowly bring the meniscus to the zero mL line or below. Record this volume in a data table - this data table should include a column for volume of NaOH added, pH, and color of analyte solution.
7. Turn on the pH meter and place it into the Erlenmeyer flask. Record the pH and note the color of the solution.
8. Add 2.0-mL of NaOH to the Erlenmeyer flask. Swirl the solution and record the new pH and note the color of the solution.
9. Repeat step 8 until you reach a volume of 20. mL of NaOH.
10. From 20. mL to 30. mL of NaOH, measure the pH in 1.0 mL increments.
11. From 30. mL to 50. mL, add the NaOH in 2.0 mL increments.
12. Stop the experiment at 50. mL. Refill the burette with NaOH for the next titration (you should only need 50 mL). You do not need to empty it - you are using the same titrant for both.
13. Completely rinse out your Erlenmeyer flask and attempt to dry the best you can.

Weak Acid Strong base Titration

1. Using a 25.00 mL volumetric pipet, pipet 25.00 mL of 0.1M $HC_2H_3O_2$ solution to your clean, dry Erlenmeyer flask. Add 2-3 drops of phenolphthalein indicator. Repeat the previous experiment with the weak acid.

Data Analysis:

For each of the titrations plot the graph of pH versus volume of base added. In each titration curve, locate the equivalence point. The equivalence point corresponds to the midpoint of the vertical portion of the curve (the inflection point), where pH is increasing rapidly. On the weak acid graph, also identify the half-way point which corresponds to the midpoint of the horizontal portion of the curve, where pH is changing very little. For each graph, read the volume of base needed to reach the end point (and half-way point for the weak acid titration).

How to graph in Google Sheets:

1. Record *Volume of NaOH Added (mL)* into column A and *pH* in column B - Highlight all data including headings
2. Choose Insert > Chart - When the chart comes up, it should be a “line chart”
3. Choose Customize
    a. Chart and Axis Titles
        i. Choose Chart Subtitle and identify the titrant and analyte (Ex.Titrant (NaOH) / Analyte (HCl)
    b. Series
        i. Point size > 2x
    c. Horizontal Axis
        i. Max > 52
    d. Vertical Axis
        i. Max > 14.00
    e. Gridlines and Ticks
        i. Horizontal Axis
            1. Minor Count > 19
            2. Checkmark > Major Gridlines, Minor Gridlines, Major Ticks, and Minor Ticks
        ii. Vertical Axis
            1. Minor Count > 19
            2. Checkmark > Major Gridlines, Minor Gridlines, Major Ticks, and Minor Ticks
4. Go back to graph and choose the three vertical dots in the top, right corner > move to own sheet

Post-lab questions:

1. If both the HCl and the $HC_2H_3O_2$ have a concentration of 0.1 M - why does the $HC_2H_3O_2$ have a higher initial pH? Explain the difference between each acid. Which acid is a better electrolyte?
2. How exactly does an indicator let you know when the titration has reached an equivalence point?
3. Why did we choose to use Bromothymol Blue (pH range of 6.0 - 7.6) rather than phenolphthalein (pH range of 8.2 - 10.0) for the strong acid-strong base titration?
4. What is the original pH of the NaOH?
5. If the $HC_2H_3O_2$ has an original concentration of 0.1 M, based on its original pH value, what is the K_a of the acetic acid?
6. Based on your titration curve for the strong acid-strong base, what volume of NaOH had to be added to the HCl to reach the equivalence point? At what pH did this occur?
7. Based on your titration curve for the weak acid-strong base, what volume of NaOH had to be added to the $HC_2H_3O_2$ to reach the equivalence point? At what pH did this occur?
8. Explain the similarities and differences between the equivalence points and pH values for each titration.
9. Based on your titration curve for the weak acid-strong base, what is the pK_a of the $HC_2H_3O_2$? Based on this information, what is the K_a for the acid? How does this value compare to the K_a you determined in question #5? How does it compare to the actual K_a of $HC_2H_3O_2$ (1.8×10^{-5} at 25 °C)?
10. What is the percent ionization of the $HC_2H_3O_2$?
11. Based on your titration curve for HCl and NaOH, how do the concentrations of the H^+ and OH^- compare at the equivalence point? Explain.
12. Describe the differences in the titration curve between a weak acid-strong base and a strong acid-strong base?
13. What would the pH be if 0.8 M $NaC_2H_3O_2$ was added to your original sample of acetic acid (use the pK_a from your graph)?
14. Based on the buffer created in #13, what would happen to the pH if 0.03 moles of NaOH are added to 1 L of the solution?
15. What would happen to the buffering capacity of the solution if 1.8 M $NaC_2H_3O_2$ was added to the original sample instead? Explain what would happen if an acid/base was added to the buffer solution.