Introduction to Acids, Bases and Titration

INSTRUCTOR RESOURCES

By

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Learning Objectives

The objectives of this experiment are . . .

- an introduction to pH as a means of determining the amount of an acid or base present.
- exploration of the change in acidity versus the volume of titrant added during a titration.
- determine the difference between a strong acid and a weak acid titration curve.
- determine the effect of a weak acid/strong base titration on the acidity of the equivalence point.

Procedure Overview

- Students will explore the nature of acids and bases by observing the effect of buffers in the range of pH 2 to 11, on various indicator papers and solutions.
- A simple titration is performed using NaOH as the titrant and hydrochloric and acetic acids as the analytes and utilizing the ***MicroLAB*** Interface to get a feel for a titration curve.
- A comparison is made of the differences and similarities of the strong and weak titration curves.

Name ______________________________ Section ___________ Date _________________

INTRODUCTION TO ACIDS, BASES AND TITRATION

Report Sheet

Acidity and indicators

1. Indicate how well the Alkacid paper color matched the color chart on the vial for each of the following buffer solutions. Indicate chart color and whether the observed color is lighter, darker or the same as the chart.

	2	3	4	5	6	7	8	9	10	11	12
Alkacid:											
Chart:											
Observed:											

2. How accurate and precise is this method of determining the acidity of a solution?

3. Specific pH indicators

Indicator	Acid pH Range	Acid Color	Base pH Range	Base Color	Transition	
					Range	Color
Phenolphthalein						
Methyl Orange						
Bromothymol Blue						

4. How did the transition pH and the transition ranges vary for the three indicators?

5. How would these indicators be helpful in doing a titration without a pH meter?

Name ______________________________ Section ___________ Date __________________

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Report Sheet (page 2)

Titrations

File name:	1st _______________	2nd ______________	3rd ______________
Calibration: (sec/5 ml)	1st _______________	2nd ______________	3rd ______________
Indicator used:	1st _______________	2nd ______________	3rd ______________
pH of color change:	1st _______________	2nd ______________	3rd ______________

1. If you did not have a pH meter with which to do the HOAc titration, which would be the easiest indicator to use? Why?

2. Examine the time vs. derivative data in the table to find the maximum of the first derivative, which represents the closest data point to the equivalence point for that titration. From this maximum, determine the time of the equivalence point for each titration.

   Time of equivalence point: 1st __________ 2nd ____________ 3rd __________

3. Which of the three indicators would be the best to use for the HCl titration? Why?

4. Which of the three indicators would be the best to use for the HOAc titration? Why?

5. What happens to the pH of the analyte as the titration nears the equivalence point? Explain why this occurs?

6. Why does the titration curve flatten out at the top?

7. Discuss the differences and similarities between the strong and weak acid titration curves.

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Tips and Traps

1. This is a fairly long experiment. If the students have organized their work schedules, they will have no trouble finishing in the allotted time.

2. During the calibration of the pH probes, students may compare millivolt readings and become concerned that they may differ widely from system to system. Assure them that this is natural and is a function of differences in the nature of the pH electrodes. The values should be around 0 ±100 millivolts if the pH probe is good.

3. You may find a wide variation in the quality of electrodes depending upon the manufacturer and/or age of the electrode. Some electrodes will reach equilibrium quite rapidly, while others may take a while. All electrodes should be checked out in advance to determine if they obtain equilibration within about 5 to 10 seconds. If not, the electrodes should be treated with an enzymatic cleaner, then soaked in an electrode conditioning solution, both of which can be obtained from Markson.

4. It is not necessary in this experiment to know absolute pH, only relative pH, since we are only looking at changes in pH to determine the general shape of the titration curve.

5. There is a tendency for students to leave the pH probe hanging out in the air between titrations. If the time between titrations is small, this probably won't matter much, but it is better to teach them good practice, and that is to store the probe in their buffer in a beaker placed at the back of the bench between titrations. There is less chance of breakage this way, and the probe is equilibrating at or near the equivalence point pH.

6. In between uses, all electrodes should be kept in a sealed container with the bulbs covered with the conditioning solution mentioned above.

INTRODUCTION TO ACIDS, BASES AND TITRATION

Sample Data

Acidity and indicators

1. Indicate how well the Alkacid paper color matched the color chart on the vial for each of the following buffer solutions. Indicate chart color and whether the observed color is lighter, darker or the same as the chart.

	2	3	4	5	6	7	8	9	10	11	12
Alkacid:	purple	red	dark orange	light orange	yellow	light green	green	dark green	green/ blue	light blue	blue
Chart:	purple		orange		gold		green		green/blue		blue
Observed:	same	lighter	same	darker	same	lighter	same	darker	same	lighter	same

2. How accurate and precise is this method of determining the acidity of a solution?

   This method can to approximate pH to about one or two pH units, depending upon how good the individual is at extrapolating color.

3. Specific pH indicators

Indicator	Acid pH Range	Acid Color	Base pH Range	Base Color	Transition Range	Transition Color
Phenolphthalein	2 - 8	colorless	10 - 11	pink	8 - 10	lt pink
Methyl Orange	2 - 3	red	5 - 12	yellow	3 - 5	orange
Bromothymol Blue	2 - 6	yellow	8 - 12	blue	6 - 8	green

4. How did the transition pH and the transition ranges vary for the three indicators?

   Each indicator has a different transition pH, but the range over which each indicator made the color transition was 1.5 to 2 pH units.

5. How would these indicators be helpful in doing a titration without a pH meter?

   Choosing the proper indicator would allow the chemist to stop the titration at or near the equivalence point, i.e., where equivalent amounts of base and acid have reacted.

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Sample Data (page 2)

Titrations

File name:	1st	***Phenol.Titr***	2nd	***MethOr.Titr***	3rd	***BromTitr***
Calibration: (sec/5 ml)	1st	***53285***	2nd	***42848***	3rd	***43356***
Indicator used:	1st	***Phenophth.***	2nd	***Methyl Or.***	3rd	***Bromo.Blue***
pH of color change:	1st	***9.2***	2nd	***3.5***	3rd	***7.2***

1. If you did not have a pH meter with which to do the HOAc titration, which would be the easiest indicator to use? Why?

   The easiest indicator to use would be the phenolphthalein, because it changes very sharply from colorless to pink, giving a very clear end point. Also, this indicator gives good end points for both the HCl and HOAc titrations.

2. Examine the time vs. derivative data in the table to find the maximum of the first derivative, which represents the equivalence point for that titration. From this maximum, determine the time of the equivalence point for each titration.

   Time of HCl equivalence point: 1st______ 2nd __________ 3rd _________

   Time of HOAc equivalence point: 1st______ 2nd __________ 3rd _________

3. Which of the three indicators would be the best to use for the HCl titration? Why?

   Bromothymol blue would be the best indicator to use in this titration because the transition pH of 7.2 is very near to the pH at the equivalence point of the titration.

4. Which of the three indicators would be the best to use for the HOAc titration? Why?

   The phenolphthalein would also be the best indicator to use in this titration because the transition pH is very near to the pH at the equivalence point of the titration.

5. What happens to the pH of the analyte as the titration nears the equivalence point? Explain why this occurs?

   The pH of the analyte increases very rapidly as the titration nears the equivalence point because there is very little hydrogen ion remaining in solution, and therefore very small amounts of added base removes a relatively large percentage of the remaining hydrogen ion.

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Sample Data (page 3)

6. Why does the titration curve flatten out at the top?

   The titration curve flattens out at the top because base is being added to the solution without any acid to neutralize it. Thus, as larger amounts of base accumulate, the smaller the percentage change occurs as more base is added.

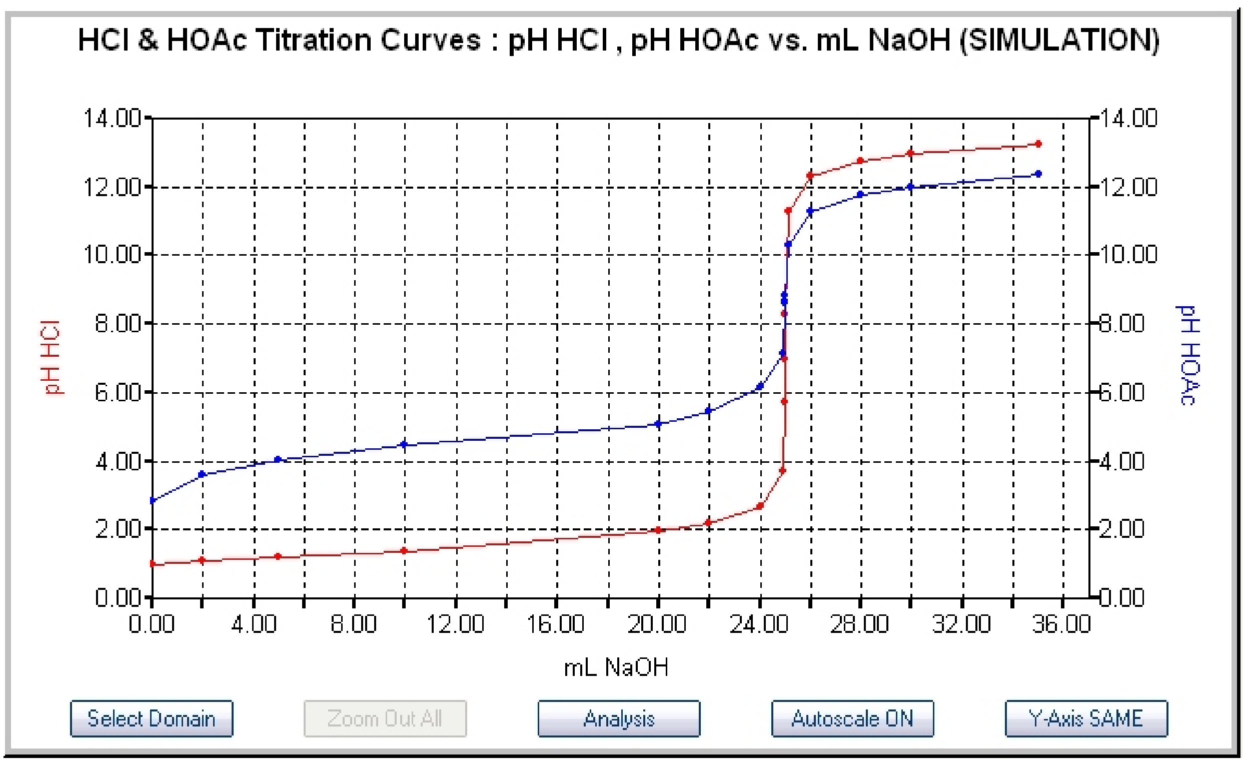
7. Discuss the differences and similarities between the strong and weak acid titration curves.

   The strong acid begins at a lower pH, e.g., about pH 1 as compared to a pH of 3.8 for the weak acid.

   The weak acid has a more gentle slope before the equivalence region due to the buffer action of the weak acid and its conjugate base.

   The equivalence point region for the strong acid is steeper, e.g., rises more rapidly than does the equivalence point region for the weak acid, again due to the conjugate system.

   ***The region of the titration curve beyond the equivalence point is identical in shape for both types of titrations except the weak acid curve does not rise as high due to the conjugate system. They both are simply diluting the excess base in the same total volume but the conjugate base equilibrium suppresses the dilution factor*.**



Calculated titration curves for HCl and HOAc acids with NaOH.

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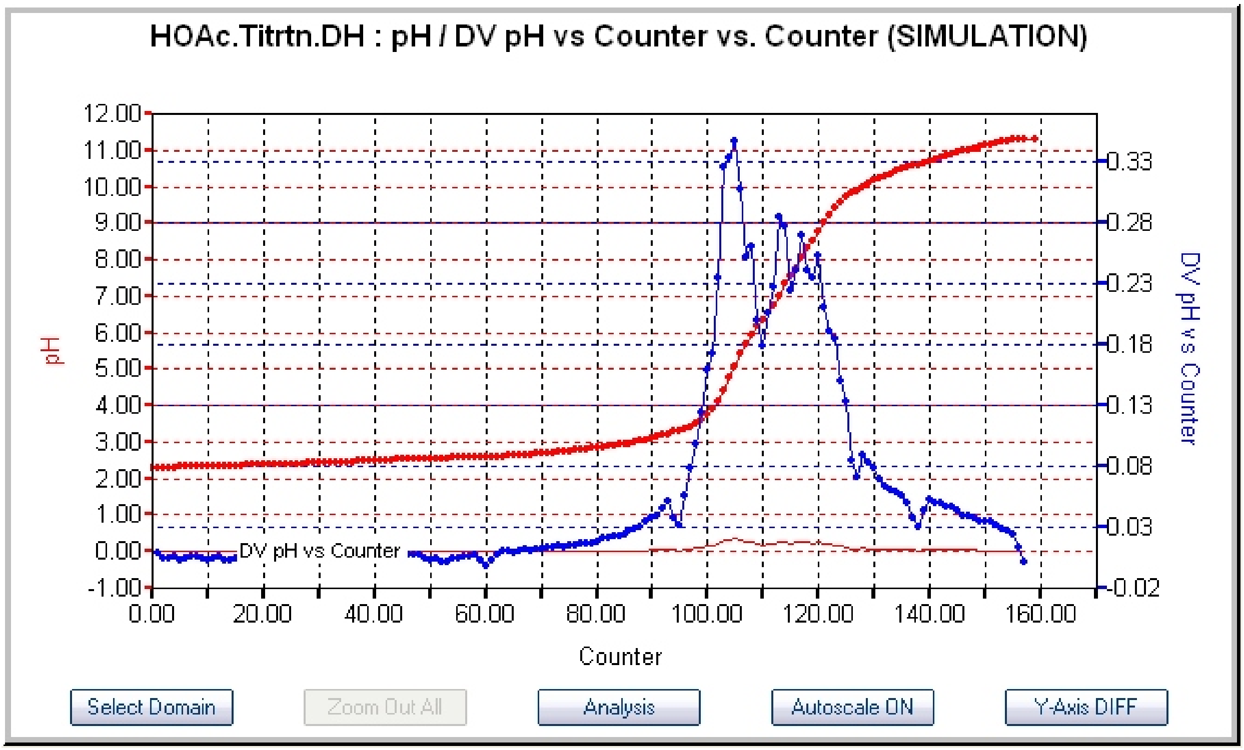
Sample Data (page 4)

Actual titration curves for HCl and HOAc acids with NaOH

This titration curve for HOAc was collected using the ***MicroLAB*** drop counter, but it would look very similar to this using Time as the X axis.



INTRODUCTION TO ACIDS, BASES AND TITRATION

Laboratory Preparation (per student station)

Equipment

1 - 50 ml buret with cork stopper
3 - 250 ml beakers
1 - magnetic stirrer with stirring bar
50 - toothpicks
1 - pH probe with BNC connector
1 - *MicroLAB* interface
1 - buret clamp
1 - 25 ml beaker
1 - 50 ml beaker
1 - ring stand
1- twelve well, plastic well plate
1 tube of Alkacid for every pair of students

Chemicals

- 100 ml of 0.100 *M* NaOH solution in a 250 ml wash bottle, need not be standardized, but should be close.
- 30 ml of ~0.100 *M* HCl solution
- 30 ml of ~0.100 *M* HOAc solution (HOAc is an abbreviation for acetic acid)
- 15 ml of each of pH 4, 7, and 10 buffer solutions per pair of students phenolphthalein, methyl orange and bromothymol blue indicators in dropper bottles per pair of students.

Chemical Cautions

- **Hydrochloric Acid solution:** Toxic by ingestion and inhalation, strong irritant to eyes and skin.
- **Acetic Acid solution:** Corrosive liquid, skin burns are possible, very dangerous to eyes.
- **Sodium Hydroxide solution:** Corrosive liquid, skin burns are possible, very dangerous to eyes.
- **pH 2 - 12 Buffers solutions:** Below pH 6 and above pH 8 should be considered corrosive to eyes.

Keep all chemicals away from eyes and mouth, wash hands after use and before leaving the laboratory, and use prudent laboratory practices at all times.

Waste Disposal

- The acids and bases should be neutralized and then flushed down the drain with lots of water.