Characterization of Weak Acids

INSTRUCTOR RESOURCES

The CCLI Initiative

Learning Objectives

The objectives of the experiment are to . . .

- understand the titration curve for a weak acid.
- calculate the molar mass of the weak acid.
- calculate the dissociation constant for the weak acid.
- use the molar mass and values to identify the acid.

Procedure Overview

- after calibration of drop size and the pH electrode, a solution of NaOH is standardized with KHP.
- an unknown weak acid is titrated with the standardized base. The molar mass and dissociation constant for the acid are calculated.
- the identity of the unknown acid is determined from the molar mass and Ka values.

Name ________________________________ Section __________ Date ___________________

CHARACTERIZATION OF A WEAK ACID

Report Sheet

Calibration of drop size

Give the equation for conversion from drops NaOH to ml NaOH:

Standardization of NaOH

	Trial 1	Trial 2
data file name	__________	__________
mass KHP	__________ g	__________ g
molarity NaOH	__________ M	__________ M
Average molarity		__________ M

Titration of unknown acid

Unknown # _____

	Trial 1	Trial 1	Trial 1	Trial 1
data file name	__________	__________	__________	__________
mass of acid	________ g	________ g	________ g	________ g
volume H2O	________ml	________ml	________ml	________ml
molar mass of acid	__________	__________	__________	__________
			Average molar mass	__________
Kal values	__________	__________	__________	__________
Ka2 values	__________	__________	__________	__________
	Average	Ka1_______	Ka2_______	

Identity of unknown acid ____

Name ______________________________ Section __________ Date __________________

CHARACTERIZATION OF A WEAK ACID

Report Sheet (page 2)

Calculations

Standardization of NaOH

1. Determine the moles of KHP.

2. Calculate the molarity of NaOH for each trial.

3. Calculate the average molarity of NaOH.

Titration of unknown acid

1. Calculate the molar mass for the acid.

2. Determine the dissociation constant(s) for the acid at a minimum of *three* points along the curve.

Name ______________________________ Section __________ Date __________________

CHARACTERIZATION OF A WEAK ACID

Questions/Problems

1. A 33.50 ml volume of 0.1050 *M NaOH* was required to just neutralize a 0.2500 g sample of a monoprotic organic acid dissolved in 50.00 ml of water. What is the molar mass of the acid? If the dissociation constant of the acid were 3.0 x 10-6, what would be the pH

2. Indicate how each of the following would affect the values of and molar mass for a weak acid calculated in this experiment. (In other words, would the Ka and molar mass obtained be higher, lower, or unchanged from what it should be?)

   a. the molarity of the NaOH is actually greater than believed.

   b. the pH meter reads 0.60 high all the time.

   c. the sample of weak acid was actually impure, containing about 5% of an inert material.

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CHARACTERIZATION OF A WEAK ACID

Questions/Problems (page 2)

3. A 0.0050 mole sample of a weak acid with a dissociation constant of 1.0 x 10-7 was titrated with 0.200 *M NaOH,* after being dissolved in 50.0 ml of water. Calculate the pH of the solution.

   a. before any NaOH was added.

   b. after 10.0 ml of NaOH was added.

   c. after 24.9 ml ofNaOH was added.

   d. after 25.1 ml ofNaOH was added

CHARACTERIZATION OF A WEAK ACID

Tips and Traps

1. Students must use boiled, deionized water for their solutions.

2. It is helpful to show students the proper titration set-up. The tip of the buret should be level with the top of the drop counter and centered on the cross lines on the case for optimum results.

3. Students should take time to align the drop counter properly. Most problems in the titrations result from a poorly aligned counter. No program is necessary for alignment. All students need to do is start the buret dripping and watch the counter light on the interface. If it blinks at each drop, alignment is correct.

4. The KHP should be dried at 110°C for two hours.

5. Unknown acids should NOT be dried. Some of them will decompose.

6. It is easiest to take all data for all trials at one sitting instead of making one solution at a time.

Using the *MicroLAB* tools

Instructions on the use of the *MicroLAB* tools such as probe calibration, use of the drop counter, obtaining derivatives and interpolating between titration points are given in **Useful Titration Operations** within the **Useful Tools folder**. Their first derivative graphs may look similar to the following graph. There is a lot of noise around the equivalence point which results from a small irregularities in the pH caused by mixing of the solution and the lag time in the probe to measure pH. When the data is read every 0.1 pH units, it produces a classic first and second derivative as seen in Figure 2.That peak point is closest to the equivalence point. The second derivative at that point, going from positive to negative, will then give the exact equivalence point. This then gives the volume of titrant required to reach the equivalence point, from which can be calculated the number of moles of the analyte.

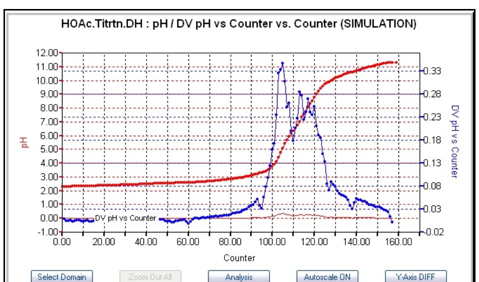


Figure 1. HOAc titration curve by drop counter, with first derivative overlay.

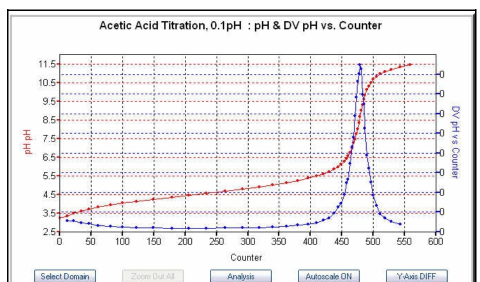


Figure 2. HOAc titration curve by drop counter, with data taken every 0.1 pH units and with first derivative overlay resulting in classic derivative plots.

CHARACTERIZATION OF A WEAK ACID

Tips and Traps

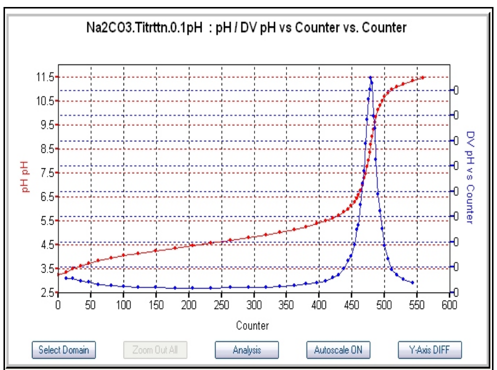
Titration Program: The following program will result in the type of titration curve and derivative as seen in the figure.

Acid/Base Titration, data taken every 0.1 pH units. Use for any titration of an acid with a base, or a base with an acid, recording the data each time the pH has changed by 0.1 pH units. Use of this program results in very smooth titration curves and generally very well shaped derivatives.
Experiment name: . ***pH.temp.vs.drop.titr.0.1pH.exp***.

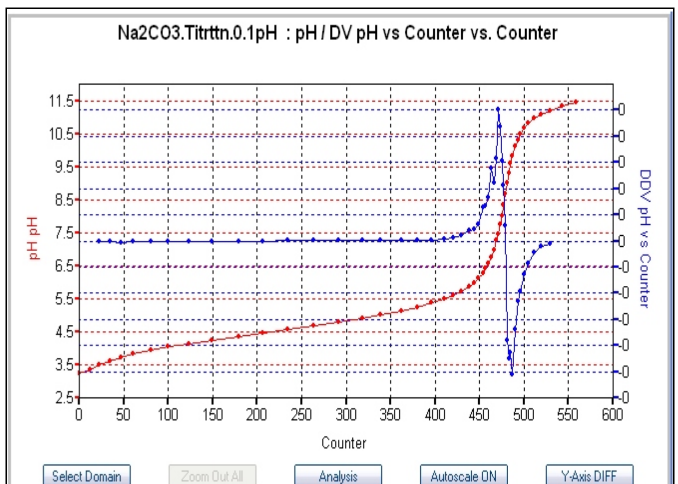
Sensors: **drop counter**: X axis, Col. A, DD on top, units = drops; **pH**: Y1 axis, Col B, DD in middle, units = pH; **Temp**: Y2 axis, Col C, DD on bottom, units °C. (Use of temperature at instructors discretion.)

Special Program:
Read Sensors
*Repeat when counter change (*Sets to read only when a drop has passed through the counter.*)*
  If Delta pH > +/- 0.100 (Sets to read only when pH has changed by 0.1 pH units.)
    Read Sensors (Reads all variables selected in Data Sensors/Variables and stores in a data grid.)
  Else
  End If
Until Stop Button is pressed

Comment: Calibrate the drop counter using one of the ***dropcal.exp*** before and after the series of titrations . If temperature is measured with a Temp(IC) probe, it must be wrapped in Saran Wrap to prevent grounding the pH probe. This program can be saved as a **Template**. See **Measurement Manual** for details.



Titration curve of HOAc with pH versus drop counter values. In this titration the pH was taken only after the pH had changed by 0.1 pH units. Note that the curve is much smoother, and the first derivative is classic in shape.



Titration curve of HOAc with pH verses drop counter values, taken at o.1 pH values, with second derivative classic shape.

CHARACTERIZATION OF A WEAK ACID

Suggested Answers to Questions/Problems

1. A 33.50 ml volume of *0.1 050* M NaOH was required to just neutralize a *0.2500* g sample of a monoprotic organic acid dissolved in 50.00 ml of water. What is the molar mass of the acid? If the dissociation constant of the acid were 3.0 x 10-6, what would be the pH at the equivalence point?
   Molar Mass = 71.07 **g**
   pH=3.45

2. Indicate how each of the following would affect the values of and molar mass *for* a weak acid calculated in this experiment. (In other words, would the Ka and molar mass obtained be higher, lower, or unchanged *from* what it should be?)

   a. the molarity of the NaOH is actually greater than believed.

      Ka: lower
      MM: higher

   b. the pH meter reads *0.60* high all the time.

      Ka: higher
      MM: unchanged

   c. the sample of weak acid was actually impure, containing about 5% of an inert material.

      Ka: lower
      MM: higher

3. A *0.0050* mole sample of a weak acid with a dissociation constant of 1.0 x 10-7 was titrated with *0.200* M NaOH, after being dissolved in 50.0 ml of water. Calculate the pH of the solution.

   a. Before any NaOH was added.
      pH = 4.00

   b. After 10.00 ml of NaOH was added
      pH = 6.82

   c. After 24.9 ml of NaOH was added
      pH = 9.40

   d. After 25.1 ml of NaOH was added
      pH= 10.42

CHARACTERIZATION OF A WEAK ACID

Sample Data

Calibration of drop size

Students should provide the equation for conversion from drops NaOH to ml NaOH:

Standardization of NaOH

	Trial 1		Trial 2
mass KHP	0.5910 g		0.6020 g
data file name	___________		___________
molarity NaOH	0.09516 M		0.09482 M
		Average molarity	0.049499 M

Titration of unknown acid

Unknown # _____

	Trial 1	Trial 1	Trial 1	Trial 1
mass of acid	0.3937 g	0.3152 g	0.3843 g	0.3521 g
volume H2O	________ml	________ml	________ml	________ml
data file name	___________	___________	___________	___________
molar mass of acid	150.9	152.1	152.7	151.9

Average molar mass 151.9 (Actual 152.15)

Kal values	3.9×10^{-4}	3.5×10^{-4}	3.5×10^{-4}	
Ka2 values	___________	___________	___________	___________
	Average	Ka1$3.6 \times 10^{-4}$	Ka2_______	(actual 1.4×10^{-4})

Identity of unknown acid ___Mandelic acid_______________________________________

CHARACTERIZATION OF A WEAK ACID

Calculations

Calculations

Standardization of NaOH

1. Determine the moles of KHP.

$$\frac{\mathbf{0.5910\ g\ KHP}}{\mathbf{204.3\ g/mol}} = \mathbf{2.893\ x10^{-3}\ mol\ KHP}$$

2. Calculate the molarity of NaOH for each trial.

$$\frac{\mathbf{2.893\ X\ 10^{-3}\ mol\ OH^{-}}}{\mathbf{30.41\ x\ 10^{-2}\ L}} = \mathbf{0.09516}\ \boldsymbol{M}$$

3. Calculate the average molarity of NaOH.

$$\frac{\mathbf{0.09516}\ \boldsymbol{M} + \mathbf{0.09491}\ \boldsymbol{M} + \mathbf{0.09474}\ \boldsymbol{M}}{\mathbf{3}} = \mathbf{0.9499}\ \boldsymbol{M}$$

Titration of unknown acid

1. Calculate the molar mass for the acid.

$$\mathbf{475\ x\ \frac{0.05784\ ml}{drop}\ x\ \frac{0.09499\ mmol}{ml} = 2.6098\ mmol}$$

$$\frac{\mathbf{0.3937\ g}}{\mathbf{2.6098\ x\ 10^{-3}\ mol}} = \mathbf{150.9\ g/mol}$$

2. Determine the dissociation constant(s) for the acid at a minimum of *three* points along the curve.

Varies with unknown . . .

CHARACTERIZATION OF A WEAK ACID

Laboratory Preparation (per student station)

Equipment
- pH electrode
- ring stand
- ***MicroLAB*** drop counter
- buret with buret clamp
- Nalgene bottle
- wash bottle (for NaOH)
- 250 ml beakers

Supplies
- paper towels

Chemicals
- KHP
- unknown acids (2.5 - 2.6 g samples), see attached list
- sodium hydroxide stock solution (6 M)
- buffer solution (pH 7.0)

Safety and Disposal
- no special precautions needed

Unknown Acids (Use 2.5 - 2.6 gram samples)
- adipic acid
- benzoic acid
- o-bromobenzoic acid
- o-chlorobenzoic acid
- p-chloropropanoic acid
- dimethylmalic acid
- p-hydroxybenzoic acid
- mandelic acid
- malonic acid
- o-nitrobenzoic acid
- oxalic acid
- phenylacetic acid
- potassium hydrogen phosphate
- salicylic acid
- sulfanilic acid
- tartaric acid

a-bromoacetic acid
a-chloroacetic acid
3-chloropropanoic acid

fumaric acid
lactic acid
maleic acid

phthalic acid
potassium hydrogen phthalate
succinic acid

trimethvlacetic acid