#13 pH-Titration of Weak Acids with Strong Bases

Purpose: A weak acid solution is titrated with a strong base solution. A titration curve is then used to identify the unknown acid and to find its concentration.

Introduction

A pH-meter will be used to follow the titration of an unknown weak acid, HA(aq) with sodium hydroxide, NaOH(aq).

$$HA\,(aq) \;+\; NaOH(aq) \;\rightarrow\; NaCl(aq) \;+\; H_2O$$

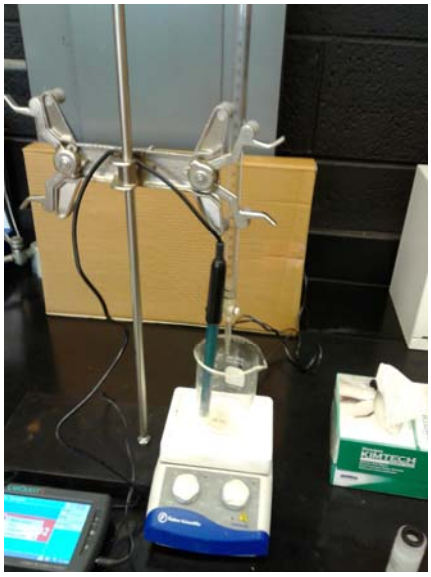
The weak acid will have a concentration around 0.1 M. The result of the pH vs vol. NaOH plot is an "S" shaped curve which is not as steep as the one arising from titration of a strong acid. The equivalence point this time will be at an alkaline pH (not 7 as in strong acid vs strong base). From the equivalence point, the concentration of the unknown acid, HA is found. In addition the acid constant K_a can be determined.

$$HA + H_2O = H_3O^+ + A^-$$

$$K_a = \frac{[H_3O^+]\,[A^-]}{[HA]}$$

From the value of K_a the unknown acid is identified from the table of weak acids below.

Apparatus:



Procedure:

Titration of Unknown HA with Standard NaOH

1. Place about 200 mL of standard NaOH solution in a clean, 250 mL Erlenmeyer flask. Record the molarity of the NaOH(aq).

2. Clean a 50 mL burette thoroughly with tap water, then rinse it with several small portions of the standard NaOH solution, being sure to run some solution through the tip.

3. Fill the burette above the '0' mL mark, then lower the meniscus back to '0'.

4. Using a volumetric pipette and a pipette pump measure 25.00 mL of unknown weak acid into a 150 mL beaker. Place the beaker on a stir plate and clamp the electrode so that it is supported in the solution. Your instructor will assemble a sample set-up.

5. Place a magnetic stir bar in the beaker so that it does not touch the electrode while stirring. *(When electrode is not in use for more than a few minutes, return to storage bottle.)*

6. Add 5 drops of phenol red or phenolphthalein indicator to the acid solution.

7. Trial run: Add NaOH in roughly 2 mL volumes until the endpoint is reached, that is, when the phenol red changes from yellow (acidic) to red (basic) or the phenolphthalein turns from colorless (acidic) to pink (basic). Record the approximate volume of NaOH used to reach this point.
Note: The equivalence point for a weak acid vs. strong base titration is at pH >7.

8. Perform 2 careful runs: Add NaOH gradually (1 mL at a time) until you approach within 1 mL of the estimated equivalence point. Then proceed much more slowly drop by drop. After the endpoint is reached, measure 5-10 more points adding 1 mL of NaOH at a time, to see the titration curve leveling off again.
Note: With practice you should be able to deliver half drops near the end point.

9. Plot the pH vs. the volume of NaOH added. Find the concentration of the unknown acid. To find K_a, p K_a is determined by examining the titration curve. The negative log of the K_a is p K_a and is the same as the pH at half the equivalence point volume. Be sure to gather some pH data around this volume. You can compare the value of pK_a to those in the table to find the identity of the unknown acid. The value of K_a is also given.

Table Ka and pKa Values of some Weak Acids

Acid	Formula	Ka	pKa
Oxalic	$C_2H_2O_4$	5.6×10^{-2}	1.2
o-Phthalic	$C_8H_6O_4$	1.3×10^{-3}	2.9
Citric	$C_6H_8O_7$	7.1×10^{-4}	3.1
Glycolic	$C_6H_{12}O_7$	1.5×10^{-4}	3.8
Lactic	$C_3H_6O_3$	1.4×10^{-4}	3
Ascorbic	$C_6H_8O_6$	7.9×10^{-5}	4.1
Acetic	$C_2H_4O_2$	1.75×10^{-5}	4.7
Propionic	$C_3H_6O_2$	1.3×10^{-5}	4.9
Carbonic	H_2CO_3	4.5×10^{-7}	6.3

Data and Results 1 (Weak acid titration)

Name(s) _____

Molarity of standard NaOH: _____ M Code number/letter of unknown acid: _____

Trial run: equivalence point: _____ mL NaOH

Careful Runs

Titration 1				Titration 2			
NaOH(mL)	pH	NaOH(mL)	pH	NaOH(mL)	pH	NaOH(mL)	pH

Equivalence point 1: _____ mL NaOH. Equivalence point 2: _____ mL NaOH

Average of 1 & 2: _____ mL NaOH. Concentration of acid: . _____ M

pK_a (pH at half-equivalence volume): _____ K_a: _____

Questions:

1. Include plot with your data. What is the pH at the equivalence point? Explain why it isn't 7. Hint: Write the neutralization reaction.

2. Use the table and list any weak acids that have a pKa close to the one you found.

Instructor's Guide
#13 Titration of Weak Acid

Molarity of standard NaOH: ___*0.100*___ M. Code number/letter of unknown acid:

Titration 1				Titration 2			
pH	NaOH(mL)	pH	NaOH(mL)	pH	NaOH(mL)	pH	NaOH(mL)
2.48	*0*	*5.37*	*38*				
3.03	*2*	*5.66*	*40*				
3.38	*4*	*6.18*	*42*				
3.58	*6*	*6.52*	*42.5*				
3.74	*8*	*7.4*	*43*				
3.89	*10*	*10.17*	*43.5*				
4.16	*15*	*10.82*	*44*				
4.38	*20*	*11.32*	*45*				
4.61	*25*	*11.59*	*50*				
4.83	*30*						
4.91	*32*						
5.03	*34*						
5.18	*36*						

Equivalence point: *43.2* mL NaOH. Concentration of acid: ____0.1_____ M

pK_a (pH at half-equivalence volume): *4.5* K_a: *3 x 10^{-5}*

Questions:

1. Include plot with your data. What is the pH at the equivalence point?
Explain why it isn't 7. Hint: Write the neutralization reaction.

2. Use the table and list any weak acids that have a pKa close to the one you found.

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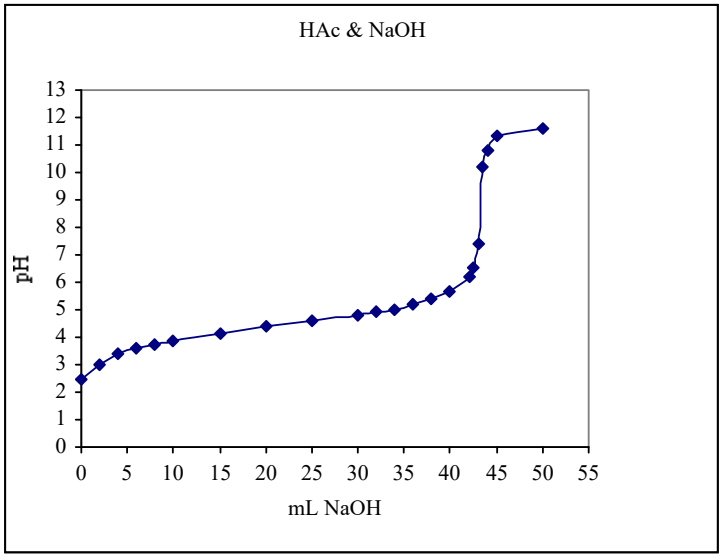
1. *The pH is about 8.5 at the equivalence point.*
NaOH + HAc → NaAc + H_2O
Acetate ion (Ac^-) is basic.

2. *The closest is acetic acid with a pK of 4.7.*



Instructor's Guide
Titration of Weak Acid (cont'd)

Time: 1 h

Equipment and Materials: Per group

Items	Number	Comment
0.1 M NaOH(aq)	2 L	includes trial run.
Labquest 2	1	pH probe
buffers 4, 7,10	1 ea	for each buffer 20-mL vials
250-mL Erlenmeyer flasks	1	for dispensing NaOH(aq) standard
25.00 mL pipettes	1	
pipette pumps	1	
Phenol red	3 per class	dropper bottles
150-mL beakers	6	
Kimwipes, box	1	
stir plates	1	
stir bars	1	
stir bar retriever	2 per class	
funnels (plastic)	1	to fill burettes
ring stands	1	
burettes	1	
burette holders	1	
wash bottles	1	distilled water
Waste bottle	1 per class	
Unknown weak acid	1 L	Unknown weak acid is 0.1 M acetic acid
Safety glasses	1 per student	
Rubber gloves	1 box per class	

Ideas/ Information

Unknown weak acid solution could be prepared by adding concentrated acetic acid (17 M) to a volumetric flask and then diluting with distilled water to the mark on the flask.

Molarity mol/L	mL con. acetic acid for 1 L solution	mL con. acetic acid for 500 mL solution
0.1	5.88	2.94

Standard NaOH solution could be prepared by adding solid NaOH to a volumetric flask and then diluting with distilled water to the mark on the flask.

Molarity mol/L	g NaOH for 1 L solution	g NaOH 500 mL solution
0.1	4	2