pH Titration Curves

In this experiment you will generate titration curves for the titration of a monoprotic strong acid, a monoprotic weak acid, and a diprotic weak acid. From the titration curves you will determine the equivalence point(s) for each titration and the actual concentration of each acid. For the weak acids you will also determine the pKa(s) and K_a(s).

EQUIPMENT

You will need a LabQuest2 with the pH probe, a computer, a stir bar, a drop counter, a 500 mL Erlenmeyer flask with stopper, three clean and dry 10.00 mL volumetric pipettes, three 250 mL beakers, a ring stand with a burette clamp, a rubber bulb, a magnetic stirrer, and your goggles.

CHEMICALS

You will need about 10 mL of ~6M NaOH solution and about 20 mL of each acid solution and about 1.5 grams of KHP.

WASTE DISPOSAL

All solutions used in this experiment can go down the drain.

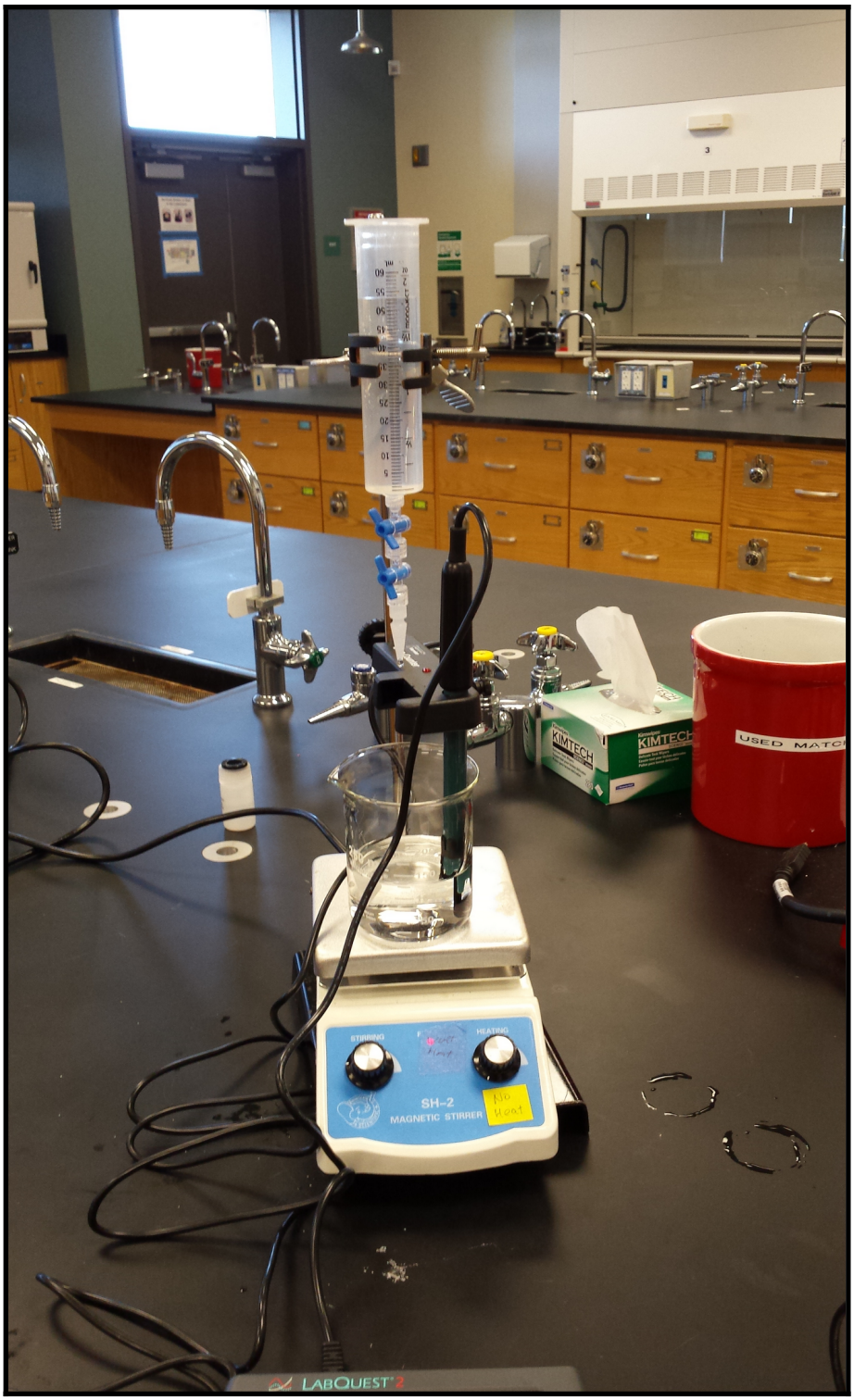
SAFETY

Wear your goggles the entire time. Be careful not to get the acids or base on you. If you do, wash your skin with soap and water.

PROCEDURE

Setup the LabQuest2 and probes to look like the following picture. The drop counter is digital and connects to the top of the LabQuest2. The pH probe is not digital and connects to a side port on the LabQuest2. The LabQuest2 should be connected with a USB cable to a computer.

Obtain your unknown solutions one at a time when you are ready to do each titration. One is a solution of a monoprotic strong acid, one is a solution of a monoprotic weak acid, and one is a solution of a diprotic weak acid. You will determine the concentration of acid in each of your unknowns, the pKa for the monoprotic weak acid, and both pKa's for the diprotic weak acid.



PREPARATION AND STANDARDIZATION OF STOCK NaOH SOLUTION

Dilute about 10 mL of ~6M NaOH solution to ~500 mL with D.I. water in your 500 mL Erlenmeyer flask. Mix well. This is your stock solution. Label the flask "Sodium Hydroxide" and place the stopper in it.

MAKE SURE TO SAVE YOUR STOCK SOLUTION FOR THE SECOND WEEK!

Label three 250 mL beakers as “A”, “B”, and “C”.

Weigh between 0.4 and 0.5 grams of KHP (M.W. 204.22 g/mol) into each of the three 250 mL beakers. Record each mass to three places past the decimal in your data table.

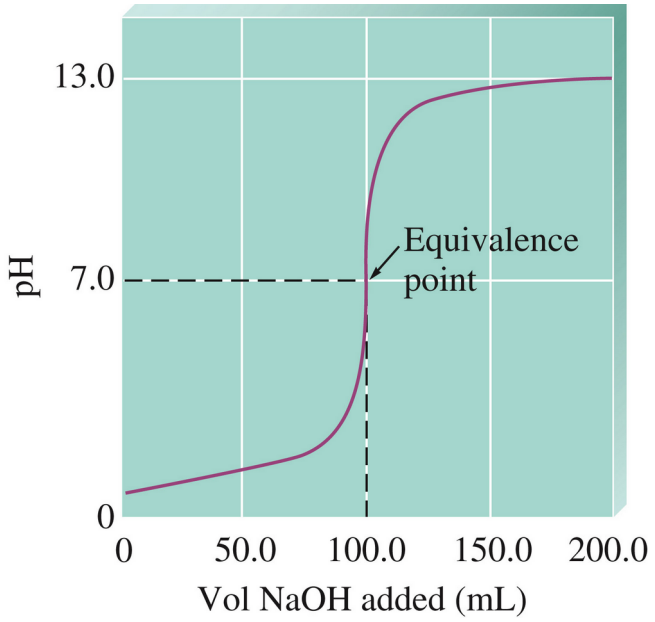
Add about 100 mL of D.I. water to each beaker and swirl to dissolve the KHP.

Fill the syringe of the drop counter with your stock NaOH solution. Place a temporary beaker on the magnetic stirrer. Adjust the drop rate to about 2 drops every 1 second. Use the top valve to turn the flow on or off. Use the bottom valve to adjust the drop rate.

You will not have to adjust the drop rate any more as long as you do not touch the bottom valve on the syringe.

Remove the temporary beaker and place beaker “A” on the magnetic stirrer. Add the stir bar to the beaker and turn on the magnetic stirrer.

Titrate the solution past the endpoint. Record the volume of NaOH added at the equivalence point in your data table. The equivalence point is the point halfway along the linear vertical region of the graph, the inflection point of the curve where the second derivative is zero.



Repeat for beakers “B” and “C”.

Empty the three beakers down the drain and rinse each beaker at least three times with D.I. water.

TITRATION OF THE MONOPROTIC STRONG ACID UNKNOWN

Using a 10.00 mL volumetric pipette transfer 10.00 mL of the monoprotic strong acid unknown solution into each of the three beakers ("A", "B", and "C") . Add ~100 mL of D.I. water to each beaker.

Making sure the syringe of the drop counter is full, titrate each beaker past the endpoint.

Record the volume of NaOH added at the equivalence point for each of the three beakers in your data table.

Empty the three beakers down the drain and rinse each beaker at least three times with D.I. water.

TITRATION OF MONOPROTIC WEAK ACID UNKNOWN

Using a 10.00 mL volumetric pipette transfer 10.00 mL of the monoprotic weak acid unknown solution into each of the three beakers ("A", "B", and "C") . Add ~100 mL of D.I. water to each beaker.

Making sure the syringe of the drop counter is full, titrate each beaker past the endpoint.

Record the volume of NaOH added at the equivalence point for each of the three beakers in your data table. Also record the pH halfway to the equivalence point in your data table for each of the three beakers.

To find the pH at halfway to the equivalence point divide the volume at the equivalence point by 2. Find the closest volume to this is the data (to the left of the graph) and read the pH at this volume.

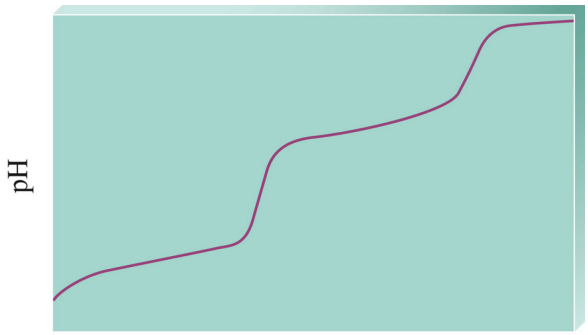
Empty the three beakers down the drain and rinse each beaker at least three times with D.I. water.

TITRATION OF DIPROTIC WEAK ACID UNKNOWN

Using a 10.00 mL volumetric pipette transfer 10.00 mL of the diprotic weak acid unknown solution into each of the three beakers ("A", "B", and "C") . Add ~100 mL of D.I. water to each beaker.

Making sure the syringe of the drop counter is full, titrate each beaker past **both endpoints**.

Record the volume of NaOH added at **both equivalence points** for each of the three beakers in your data table (the middle of each vertical region is an equivalence point). Also record the pH values halfway to the first equivalence point and the pH halfway between the first and second equivalence points in your data table for each of the three beakers.



To find the pH at halfway to the first equivalence point divide the volume at the first equivalence point by 2. Find the closest volume to this is the data (to the left of the graph) and read the pH at this volume.

To find the pH at halfway between the first equivalence point and the second equivalence point add the volume at the first equivalence point to the volume at the second equivalence point and divide by 2. Find the closest volume to this is the data (to the left of the graph) and read the pH at this volume.

Empty the three beakers down the drain and rinse each beaker at least three times with D.I. water.

CALCULATIONS

You will need to calculate:

1.) The concentration of NaOH for each of the three titrations of your stock solution.
2.) The average [NaOH] in your stock solution. This is what you will use for all further calculations.
3.) The actual concentration of each of the three acids. To do this you will multiply the volume at the equivalence point (only the first equivalence point for the diprotic acid) by the average [NaOH} from step 2 above, then divide by the volume of unknown acid (10.00 mL).
4.) Do this for all three trials of each unknown. Find the average concentration of each unknown.
5.) The pK_a and K_a for each trial of the monoprotic weak acid unknown. Calculate the average pK_a and K_a for the monoprotic weak acid.
6.) The pK_{a1}, pK_{a2}, K_{a1}, and K_{a2} for each trial of the diprotic weak acid unknown. You will get the pK_a's from the point on the graphs where pH = pK_a. This is where [base] = [acid] in the Henderson-Hasselbalch equation. Calculate the average pK_{a1}, pK_{a2}, K_{a1}, and K_{a2} for the diprotic weak acid.

CONCLUSION

Report the average [NaOH] in your stock solution.

Report the average concentration of each unknown.

For the monoprotic weak acid unknown report the average for the pK_a and the K_a.

For the diprotic weak acid unknown report average for the pK_{a1}, pK_{a2}, K_{a1}, and K_{a2}.

Determine and analyze one potential source of experimental error. Please read "How to Determine and Analyze a Source of Experimental Error".