EXPERIMENT 20H

Titration Curves

You have already performed a number of acid-base titrations in earlier experiments (20C and 20G). You should therefore be well aware of the fact that the pH of a solution changes very rapidly at the equivalence point, the point where the number of moles of H_3O^+ equals the number of moles of OH^-. The rate of change of pH is very clearly seen if a graph is plotted for pH versus the volume of acid or base added as the reaction proceeds. Such a graph is called a *titration curve*. These graphs can also be obtained by interfacing a pH meter with a microcomputer.

In this experiment you will obtain three titration curves by manually plotting your results. The first curve's pH data will be obtained by calculation; it will be for a strong base titrated against a strong acid (Part I). It will be assigned as a pre-lab activity, and will give you useful practice in titration calculations as well as enable you to see the relationship between pH and volume of base added. The second curve will be of the same type, but will be obtained experimentally using a buret to deliver the base solution and a pH meter to measure the pH. The third curve, also obtained experimentally, will be for a strong base titrated against a weak acid, and the shape of the curve will be compared to that for the strong acid.

A pH meter is an instrument with a wide variety of applications, ranging from the testing and monitoring of water quality to manufacturing processes and research. Meters vary in their construction and method of operation, but some general principles apply to all. A glass electrode is connected to the pH meter and inserted into the test solution. A voltage is then produced which is dependent on the pH of the solution. A needle on a scale or a digital readout gives the actual voltage obtained, but a scale showing the pH value directly is generally more useful. The meter must be set for the temperature, then calibrated by placing the electrode in one or more buffers of accurately known pH. Your teacher will give you specific instructions for the pH meter available to you.

OBJECTIVES

1. to calculate the pH at various stages of the titration of a strong base against a strong acid and plot the results on a graph
2. to measure experimentally the pH at various stages of the titration of a strong base against a strong acid and plot the results on a graph
3. to measure experimentally the pH at various stages of the titration of a strong base against a weak acid, plot the results on a graph, and compare the shape to that obtained in Objective 2

MATERIALS

Apparatus

pipet (25 mL)
buret (50 mL)
buret stand and clamp
pH meter and electrode
beaker (250 mL)
suction bulb
glass stirring rod
lab apron
safety goggles

Reagents

0.100*M* NaOH
0.100*M* HCl
0.100*M* acetic acid, CH_3COOH
phenolphthalein solution *or* universal indicator solution

PROCEDURE

Part I Calculated Titration Curve

In order to become acquainted with titration curves, perform the following calculations as a pre-lab activity:

1. Calculate the pH that results when 25.00 mL of 0.100*M* HCl is titrated with 0.100*M* NaOH solution run in from a buret, at each of the following stages of volume of 0.100*M* NaOH added (in mL): 0.00, 5.00, 10.00, 15.00, 20.00, 22.00, 24.00, 24.50, 24.80, 24.90, 24.95, 24.99, 25.00, 25.01, 25.05, 25.10, 25.20, 25.50, 26.00, 28.00, 30.00, 40.00, 50.00.

   The calculations can be done in either of two ways: (a) Calculate moles of acid or base left over, then divide by the total volume to get $[H^+]$ (or $[OH^-]$ if the titration has passed the equivalence point). (b) Since the concentrations used are identical, subtraction can give the volume of HCl or NaOH left over. The concentration of 0.100*M* then has to be reduced by multiplying by the dilution factor (volume unreacted divided by the total volume) to obtain $[H^+]$ (or $[OH^-]$ if beyond the equivalence point).

   Having now obtained the $[H^+]$ or $[OH^-]$, you can calculate the pH. Record your calculated results in your copy of Table 1, Part I, in your notebook.

2. Plot a graph of the results, with pH plotted against the volume of NaOH added.

Part II Experimentally Obtained Titration Curve for NaOH against HCl

1. Put on your lab apron and safety goggles.
2. Set up and calibrate your pH meter according to your teacher's instructions.
3. Using a suction bulb on your pipet, withdraw 25 mL of 0.100*M* HCl and transfer it to a 250 mL beaker. Remember to rinse your pipet with the HCl first.
4. Add 3 drops of phenolphthalein (or universal indicator solution) to the acid in order to observe the pH changes by means of a color change as well as with the pH meter.
5. Set up the buret in the stand and clamp, and rinse it out with 10 mL of NaOH solution. Discard the rinsings through the tip.
6. Refill the buret with NaOH solution, allow some to drain through the tip to fill it, then adjust the volume to 0.00 mL. (This will make it easier to obtain a large number of volume readings.)
7. Place the electrode of the pH meter in the acid solution in the beaker, and read the pH.
8. Run in as close as possible to 5.00 mL of NaOH solution, stirring the solution in the beaker constantly (with a stirring rod, not the electrode!). Again read the pH.
9. Continue adding NaOH and recording the volume of NaOH added, with its related pH, under Part II of Table 1. Get as close as possible to the volume values for which you calculated the pH in Part I.

HAZARD

CAUTION: The hydrochloric acid and sodium hydroxide solutions are corrosive to skin, eyes, and clothing. Wash any spills and splashes with plenty of water. Call your teacher.

CAUTION: Phenolphthalein solution is harmful when ingested and is flammable. Do not get any in your mouth; do not swallow any. Make sure there are no burners in the vicinity.

The volume increments must become successively smaller as you approach the equivalence point. Be careful in this region, since the equivalence point will only be at 25.00 mL if both solutions were of precisely the same concentration, which may not be the case.

Part III Experimentally Obtained Titration Curve for NaOH against CH_3COOH

HAZARD

CAUTION: The acetic acid solution is corrosive. Keep it off your skin and out of your eyes. Wash any spills and splashes with plenty of water.

1. Rinse off the electrode for the pH meter before beginning the titration.
2. Repeat the Procedure in Part II, but titrate the NaOH against 0.100*M* CH_3COOH instead of HCl. Record all results under Part III of Table 1.
3. Clean up, following the instructions for reagent disposal.
4. Before leaving the laboratory, wash your hands thoroughly with soap and water; use a fingernail brush to clean under your fingernails.

REAGENT DISPOSAL

Wash all solutions formed as a result of the titration down the sink with plenty of water. Return unused portions of original solutions to the container designated by your teacher.

POST LAB DISCUSSION

When an acid and a base react together and neutralize one another, water is formed and a salt is left over in the solution. If the titration is between a strong acid and a strong base, then the salt which is present at the equivalence point will not undergo hydrolysis, and the solution will be neutral. If the titration is between a strong base and a weak acid, then the salt which is present at the equivalence point will undergo anionic hydrolysis, producing OH^- ions. Therefore, the pH at the equivalence point will be on the basic side of neutral; that is, it will be greater than 7. If the titration is between a weak base and a strong acid, then the salt present at the equivalence point will undergo cationic hydrolysis, producing H_3O^+. The pH at the equivalence point will therefore be on the acidic side of neutral, that is, less than 7. By studying the titration curves you can determine which indicator can be used for each type of titration in order to get a color change in the vertical portion of the graph on either side of the equivalence point. The transition point of the indicator should match the equivalence point of the titration as closely as possible.

DATA AND OBSERVATIONS

It would be a good idea to have these tables ready in your notebook before coming to the laboratory. Remember to do the calculations for Part I before coming to the laboratory. Show your calculations in your report, as well as recording the values in the table.