Titrating an Unknown

Question
How can you determine the concentration of acid in a sample?

Prediction
By using sodium hydroxide as the titrant, predict the concentration of acetic acid present in a sample of vinegar.

Materials
computer system and interface
pH sensor
50 mL burette
50 mL of 0.15 M NaOH (sodium hydroxide) solution
5 mL of household vinegar sample CH_3COOH (acetic acid).
graduated cylinder
pipette
250 mL beaker
dropper
1% phenolphthalein indicator
stir bar and stirrer (if available — otherwise use a stir rod)

Safety Precautions

- If any acid or base is accidentally spilled, inform your teacher immediately and wash with copious amounts of water.
- Never pipette by mouth. Always use a pipette bulb or pipette pump.
- Be sure to dispose of materials properly.

Procedure
1. Set up the computer system with the pH sensor.

2. Display the pH sensor with a graph display (pH vs. time) and a digits display.

3. Calibrate the pH sensor and set it to sample once per second.

4. Add 50 mL of distilled water to the beaker.

5. Carefully pipette 5 mL of vinegar into the beaker. Add 3 drops of phenolphthalein indicator and the stir bar.

6. Rinse and properly fill a burette with the NaOH solution. Adjust the volume of NaOH solution in the burette until the meniscus is at 0.0 mL.

7. Place the pH sensor into the acid solution in the beaker. Place the beaker on the stir plate just under the burette containing the NaOH solution. Begin gently stirring and position the pH sensor so that it does not interfere with the stir bar.

8. Start the pH data recording.

9. Begin adding the NaOH from the burette to the beaker at a rate of about 1 mL every 10 seconds.

10. As soon as the graph shows a noticeable increase, slow the rate of delivery of NaOH to the beaker to about 1 drop every 5 seconds.

11. Observe and record the pH and volume of NaOH used when the solution maintains the slightest pink colour throughout the solution.

12. Continue delivering the NaOH solution to the beaker for an additional 3 minutes.

13. Stop the data recording.

14. Discard the solutions as directed by your teacher. Wash your hands thoroughly.

Analysis

1. At what pH did the slightest pink colour appear to maintain? This is the end point.

2. Draw a straight line along the titration curve in the region of most rapid change. Extrapolate lines from the plateaus before and after the maximum slope line into a line segment. Determine the midpoint of this line. This is the equivalence point.

4. What was the volume of NaOH used at the equivalence point?

5. Calculate the number of moles of NaOH used (#moles = $M \times V$).

6. The acid, acetic acid, reacts with the base, sodium hydroxide, in a one-to-one ratio. What were the number of moles of acetic acid used?

Conclusions

7. Calculate the concentration of the acetic acid in the sample using:

$$M = \frac{\#\text{moles}}{V}$$

Applications

8. If the molar mass of acetic acid is 60.1 g/mol, how many grams/litre of acetic acid were used?

9. What was the percentage of acetic acid in your vinegar sample?

10. Why are titration curves useful?

11. Does the volume of water used have to be precisely 50 mL? Why or why not?

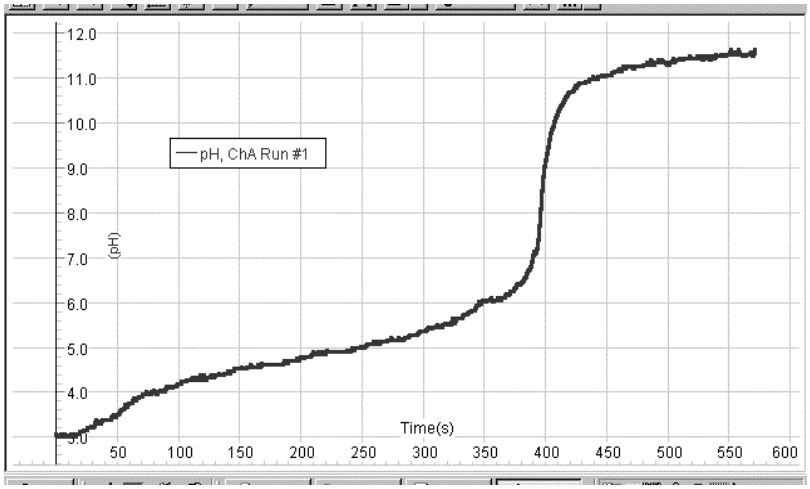
12. In comparing the pH of the end point determined by the change in colour of the indicator and the equivalence point determined by the midpoint of the most vertical section of the graph, which method is more accurate?

13. After checking with your teacher and getting your experiment approved, try this lab using H_2SO_4, H_3PO_4, H_2S, or H_2CO_3. You will note a difference in the graphed line from that obtained in this investigation. Do library or Internet research to find out why this is so.

Teacher Information

Sample Data – Answer Sheet

Observations



Graph 1

Answers

1. End point pH = 9

2. Equivalence point pH = 8.8

4. 24.2 mL

5. #moles of NaOH = 0.15 M × 0.0242 L
#moles of NaOH = 0.00363 mol

6. #moles of NaOH
= #moles of acetic acid
= 0.00363 mol

7. $M = \dfrac{0.00363 \text{ mol}}{0.005 \text{ L}}$
M = 0.726 mol/L

8. 43.6 g/L

9. 4.36%

10. They are good graphic representations of exactly what occurs during a titration process.

11. No. The number of hydronium ions in the vinegar sample remains constant.

12. The method using the midpoint of the graphed line is more accurate. The midpoint of the graphed line can also be determined through mathematical methods. The use of a colour indicator is, however, more convenient at times.

13. With polyprotic acids such as H_2SO_4, H_3PO_4, H_2S, or H_2CO_3, students would note that the graphed line showed two steady horizontal regions, with a rise in between.