Choice of Indicators in Acid–base Titrations

Student Handout

Purposes

To decide suitable indicators for the following acid-base titrations.

1. HCl(aq) vs NH_3(aq)
2. CH_3COOH(aq) vs NaOH(aq)

Introduction

Acid-base titration indicators are usually weak acids (HIn) which ionise as follows:

$$\underset{\text{(colour 1)}}{HIn(aq)} \overset{K_a}{\rightleftharpoons} \underset{\text{(colourless)}}{H^+(aq)} + \underset{\text{(colour 2)}}{In^-(aq)}$$

$$pH = pK_a + \log \frac{[In^-(aq)]}{[HIn(aq)]}$$

For the reaction mixture to impart colour 1 with confidence, $\frac{[In^-(aq)]}{[HIn(aq)]}$ has to be $\leq \frac{1}{10}$.

For the reaction mixture to impart colour 2 with confidence, $\frac{[In^-(aq)]}{[HIn(aq)]}$ has to be ≥ 10.

In other words, for the reaction mixture to impart colour 1 with confidence, pH value of the solution should be pK_a - 1 or lower, and for the reaction mixture to impart colour 2 with confidence, pH value of the solution should be pK_a +1 or higher. Hence pH range of an indicator = $pK_a \pm 1$.

As shown in the pH titration curve for a weak acid with a strong alkali (Fig. 1), pH range of the indicator cuts the steepest part of the pH variation curve. Thus the rapid change in pH value at the equivalent point matches with a sharp change in colour of the indicator at the end point. This is the criterion of choosing a suitable indicator for acid-base titration.

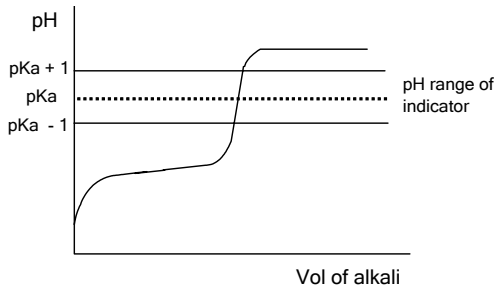

Fig. 1: Titration curve for a weak acid with a strong alkali

Safety

Avoid skin contact with chemicals. Any acid or alkali spilt should be thoroughly washed with tap water.

Materials and Apparatus

0.5 M NaOH(aq) 

Phenolphthalein indicator, methyl orange indicator 

0.5 M HCl(aq), 0.5 M CH_3COOH(aq), 0.5 M NH_3(aq), deionised water, a datalogger with pH sensor, computer, magnetic stirrer, small beaker, burette and pipette, retort stand and burette clamp.

Experimental Procedures

Part A: Titration of 0.5 M HCl(aq) with 0.5 M NH_3(aq) using methyl orange as indicator

1. Set up the interface box and connect it to the computer. Arrange the setup for pH determination. The pH sensor should be calibrated before use.
2. Pipette 25 cm^3 0.5 M HCl(aq) into a small beaker and add 3 drops of methyl orange indicator. Place a stirrer bar into the acid solution and rest the beaker on a magnetic stirrer which is covered by a white tile. Switch on the magnetic stirrer. Lower the pH electrode into the HCl(aq), ensuring that the glass bulb is completely immersed while the stirrer bar is spinning smoothly (see Fig. 2).

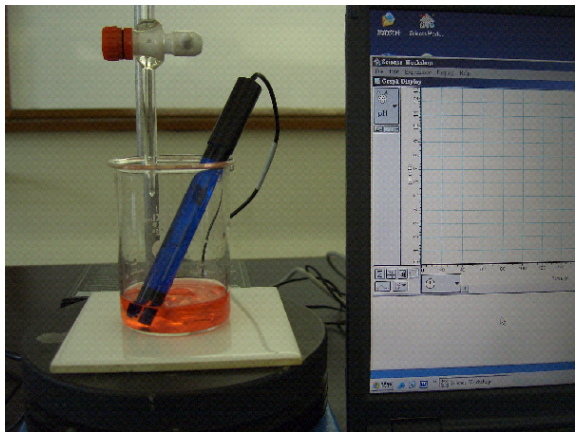

Fig. 2: Setup for pH data logging

3. Start the datalogging software and select the pH sensor with graph display screen format. Set the pH value limits from 0 to 13 and a total logging time of 240 seconds at a rate of one sample per second.
4. Fill the burette with 0.5 M NH_3(aq). Turn the stopcock of the burette open and start recording at the same time. The free fall dropping rate of the titrant, controlled by manipulating the stopcock, should be about 50 cm^3 in 4 minutes.
5. Observe the colour of the reaction mixture and change in pH values displayed on the computer screen carefully when the titration is close to the end point.
6. Stop the titration when the volume of titrant added is well beyond the end point.
7. Save the data file.
8. Carefully empty the contents of the beaker, pay special attention to retain the small stirrer bar. Clean the pH electrode with deionised water.

Part B

9. As described above, titrate 0.5 M HCl(aq) with 0.5 M NH_3(aq) using phenolphthalein as indicator.

Part C

10. As described above, titrate 0.5 M CH_3COOH(aq) with 0.5 M NaOH(aq) using phenolphthalein as indicator.

Part D

11. As described above, titrate 0.5 M CH_3COOH(aq) with 0.5 M NaOH(aq) using methyl orange as indicator.

Discussion Questions

1. From the results of Parts A and B, decide and explain which indicator, methyl orange or phenolphthalein, is suitable for the titration between HCl(aq) and NH_3(aq).
2. From the results of Parts C and D, decide and explain which indicator, methyl orange or phenolphthalein, is suitable for the titration between CH_3COOH(aq) and NaOH(aq).
3. What method can be used to detect the end point of the titration between a weak acid and a weak alkali?