Acid-base Titration using Method of Double Indicators

Student Handout

Purposes

To determine the composition of the following mixture by double indicator method:

1. $NaOH(aq)$ and $Na_2CO_3(aq)$
2. $NaHCO_3(aq)$ and $Na_2CO_3(aq)$

Introduction

Consider a mixture of $NaOH(aq)$ and $Na_2CO_3(aq)$. Reaction between $HCl(aq)$ and $Na_2CO_3(aq)$ takes place in two stages:

$$HCl(aq) + Na_2CO_3(aq) \longrightarrow NaHCO_3(aq) + H_2O(l) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$HCl(aq) + NaHCO_3(aq) \longrightarrow NaCl(aq) + CO_2(g) + H_2O(l) \quad \ldots\ldots\ldots\ldots \quad (2)$$

While that between $HCl(aq)$ and $NaOH(aq)$ completes in only one step:

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Solution mixture of reaction (1) at the equivalence point is alkaline, that of reaction (2) is acidic and that of reaction (3) is neutral. Thus the whole titration should have three breaks in the pH curve, corresponding to the above three stages. Reactions (1) and (3) can be indicated by phenolphthalein and that of reaction (2) can be indicated by methyl orange.

Stoichiometry confines each of the above reactions to react according to a mole ratio of 1 : 1. This means, say from equation (2), the number of mole of $HCl(aq)$ determined from the methyl orange titration is equal to the number of mole of $NaHCO_3(aq)$. Likewise, total number of moles of $NaOH(aq)$ and $Na_2CO_3(aq)$ in the solution mixture can be calculated according to the volumes of $HCl(aq)$ added at the end point indicated by the colour change of the phenolphthalein indicator. Alternatively, the three break points (see Fig. 1) also indicate the volume of $HCl(aq)$ required for each reaction.

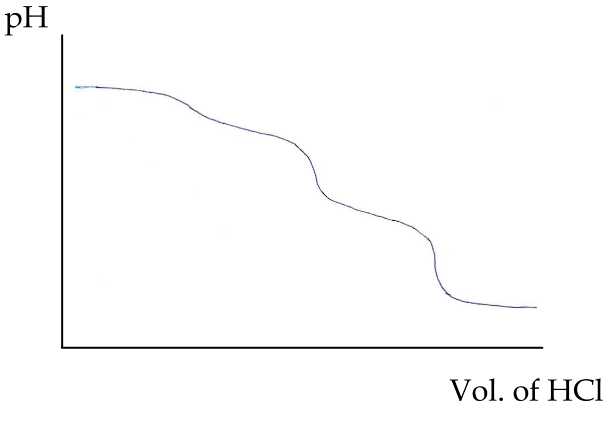

Fig. 1: Titration curve for a mixture of $NaOH(aq)$ and $Na_2CO_3(aq)$ with $HCl(aq)$

For the titration of a mixture of $NaHCO_3$(aq) and Na_2CO_3(aq) with HCl(aq), only two break points are expected (see Fig.2). Volume of HCl(aq) added for each break point can be easily obtained by observing either the colour change at the end point or the shape of the titration curve.

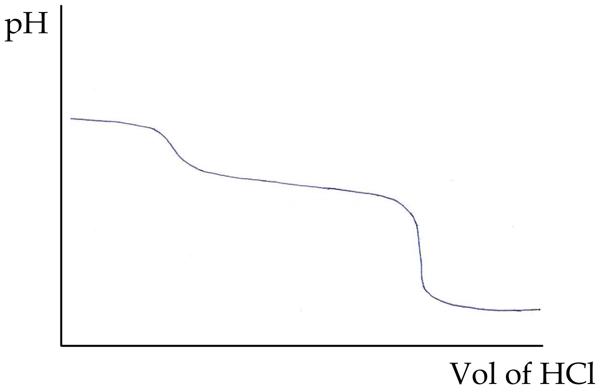

Fig. 2: Titration curve for a mixture of $NaHCO_3$(aq) and Na_2CO_3(aq) with HCl(aq)

Safety

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

Materials and Apparatus

Phenolphthalein indicator, methyl orange indicator

Standard 0.15 M and 0.2 M HCl(aq), a mixture of NaOH(aq) and Na_2CO_3(aq), a mixture of $NaHCO_3$(aq) and Na_2CO_3(aq), deionised water, a datalogger with pH sensor, computer, magnetic stirrer, small beaker, burette and pipette, stand and burette clamp.

Experimental Procedures

Part A: Titration of a mixture of NaOH(aq) and Na_2CO_3(aq) with 0.15 M HCl(aq) using phenolphthalein indicator followed by methyl orange 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 of the solution mixture into a small beaker and add 2 drops of phenolphthalein indicator. Place a stirrer bar into the alkaline 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 alkaline solution, ensuring that the glass bulb is completely immersed while the stirrer bar is spinning smoothly (see Fig. 3).

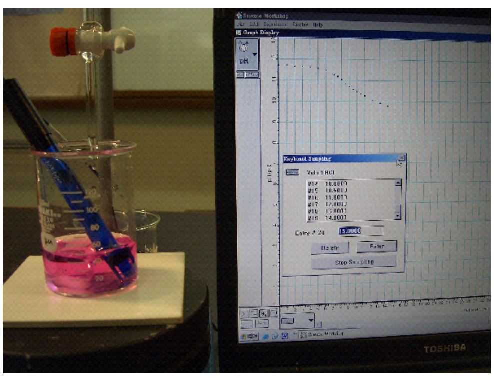

Fig. 3: Setup for pH datalogging

3. Start the datalogging software and select the pH sensor with graph display screen format. Set the pH value limits from 0 to 13. The logging mode is set to manual operation with readings taken for each cm^3 addition of the titrant.
4. Fill the burette with 0.15 M HCl(aq). Turn the stopcock of the burette open and start recording at the same time. When approaching the first end point, as judged by the rate of disappearance of the red colour of the solution in the beaker, adjust interval additions each to 0.50 cm^3. Allow time for the evolution of CO_2 gas bubbles as their presence round the glass bulb of the electrode may interfere with pH measurements.
5. Observe the colour change of the reaction mixture and the pH values displayed on the computer screen carefully when the titration passes the first end point.
6. Add 3 drops of methyl orange indicator when the reaction mixture becomes colourless. Look for the second end point and continue titration as in step (4) until a total volume of 50 cm^3 of the titrant has been added.
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 a mixture of $NaHCO_3$(aq) and Na_2CO_3(aq) with 0.20 M HCl(aq) using phenolphthalein indicator followed by methyl orange indicator.

Results

Table A

	Phenolphthalein indicator	Methyl orange indicator
Final burette reading/cm^3		
Initial burette reading/cm^3		
Volume of 0.15 M HCl used/cm^3		

Table B

	Phenolphthalein indicator	Methyl orange indicator
Final burette reading/cm^3		
Initial burette reading/cm^3		
Volume of 0.20 M HCl used/cm^3		

Treatment of Data

Part A

1. From the methyl orange end point, calculate the number of moles of 0.15 M HCl(aq) added and hence the number of moles of Na_2CO_3(aq) in 25 cm^3 of the alkaline solution mixture.
2. From the phenolphthalein end point, calculate the number of moles of 0.15 M HCl(aq) added and hence the total number of moles of NaOH(aq) and Na_2CO_3(aq) in 25 cm^3 of the solution mixture.
3. Calculate the number of mole of NaOH(aq) in 25 cm^3 of the solution mixture.
4. Calculate the mass of Na_2CO_3 and NaOH in 1 dm^3 of the solution mixture respectively.

Part B

1. From the methyl orange end point, calculate the number of moles of 0.2 M HCl(aq) added and hence the number of moles of Na_2CO_3(aq) in 25 cm^3 of the solution mixture.
2. From the phenolphthalein end point, calculate the number of moles of 0.2 M HCl(aq) added and hence the number of moles of $NaHCO_3$(aq) in 25 cm^3 of the solution mixture.
3. Calculate the mass of Na_2CO_3 and that of $NaHCO_3$ in 1 dm^3 of the solution mixture.

Discussion Questions

1. Suggest other indicators that can be used in place of methyl orange and phenolphthalein. Explain.
2. Can the same method be applied to determine the concentrations of Na_3PO_4(aq) and NaH_2PO_4(aq) in a solution mixture of the two salts? What factors should be considered?