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 Na₂CO₃(aq)
2. NaHCO₃(aq) and Na₂CO₃(aq)

Introduction
Consider a mixture of NaOH(aq) and Na₂CO₃(aq). Reaction between HCl(aq) and Na₂CO₃(aq) takes place in two stages:

\[
\text{HCl(aq) + Na}_2\text{CO}_3(aq) \rightarrow \text{NaHCO}_3(aq) + \text{H}_2\text{O(l)} \quad \ldots \quad (1)
\]
\[
\text{HCl(aq) + NaHCO}_3(aq) \rightarrow \text{NaCl(aq) + CO}_2(g) + \text{H}_2\text{O(l)} \quad \ldots \quad (2)
\]

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

\[
\text{HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H}_2\text{O(l)} \quad \ldots \quad (3)
\]

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 NaHCO₃(aq). Likewise, total number of moles of NaOH(aq) and Na₂CO₃(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 Na₂CO₃(aq) with HCl(aq)](image-url)
For the titration of a mixture of NaHCO₃(aq) and Na₂CO₃(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 NaHCO₃(aq) and Na₂CO₃(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 Na₂CO₃(aq), a mixture of NaHCO₃(aq) and Na₂CO₃(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 Na₂CO₃(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 cm³ 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 cm³ 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 cm³. Allow time for the evolution of CO₂ gas bubbles as their presence around 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 cm³ 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 NaHCO₃(aq) and Na₂CO₃(aq) with 0.20 M HCl(aq) using phenolphthalein indicator followed by methyl orange indicator.

Results

Table A

<table>
<thead>
<tr>
<th>Phenolphthalein indicator</th>
<th>Methyl orange indicator</th>
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</thead>
<tbody>
<tr>
<td>Final burette reading/cm³</td>
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<td></td>
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<tr>
<td>Volume of 0.15 M HCl used/cm³</td>
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</tbody>
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Table B

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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 Na₂CO₃(aq) in 25 cm³ 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 Na₂CO₃(aq) in 25 cm³ of the solution mixture.
3. Calculate the number of mole of NaOH(aq) in 25 cm³ of the solution mixture.
4. Calculate the mass of Na₂CO₃ and NaOH in 1 dm³ 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 Na₂CO₃(aq) in 25 cm³ 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 NaHCO₃(aq) in 25 cm³ of the solution mixture.
3. Calculate the mass of Na₂CO₃ and that of NaHCO₃ in 1 dm³ 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 Na₃PO₄(aq) and NaH₂PO₄(aq) in a solution mixture of the two salts? What factors should be considered?