Activity 5A: Acid-base titrations

Ans p. 22

1. 10.00 mL of a standard potassium carbonate solution, concentration 0.208 mol L^{-1}, is pipetted into a flask. This sample is titrated with hydrochloric acid of unknown concentration. The indicator (methyl orange) showed that the end-point had been reached after an average titre of 21.22 mL of hydrochloric acid was added.
   - **a.** What is the function of the indicator?
   - **b.** How many moles of potassium carbonate are there in the 10.00 mL sample?
   - **c.** Write a balanced equation for the reaction between hydrochloric acid and potassium carbonate.
   - **d.** How many moles of hydrochloric acid are there in the 21.22 mL titre?
   - **e.** What is the concentration of the hydrochloric acid?
2. A solution of NaOH was titrated with 15.00 mL aliquots of 0.252 mol L^{-1} ethanoic acid. An average titre of 24.96 mL of NaOH was required. Find the concentration of the NaOH.
3. During the preparation of a standard solution of anhydrous sodium carbonate, Na_2CO_3, a student obtained the following results:
   - mass of beaker and anhydrous sodium carbonate = 131.10 g
   - mass of empty beaker = 128.45 g

   The student then dissolved the sodium carbonate in enough water to form 100.00 mL of solution.
   - **a.** Calculate the mass of sodium carbonate that was weighed out.
   - **b.** Calculate the concentration of the solution prepared in:
     i. g L^{-1} **ii.** mol L^{-1} [$M(Na_2CO_3)$ = 106.0 g mol^{-1}]
   - **c.** The standard solution was then titrated against a hydrochloric acid solution of unknown concentration, using methyl orange indicator. It was found that 20.00 mL of the sodium carbonate solution was neutralised by 15.16 mL of the acid.
     - **i.** What piece of apparatus would be used to measure the 20.00 mL of standard solution into a conical flask for the titration?
     - **ii.** What piece of apparatus would be used to measure the volume(s) of acid necessary to neutralise the standard solution?
     - **iii.** Briefly describe how it was known when the two solutions were neutralised.
     - **iv.** Write an equation for the reaction which occurred between the hydrochloric acid and sodium carbonate.
     - **v.** Calculate the concentration of the hydrochloric acid solution in mol L^{-1}
4. To determine the concentration of limewater, $Ca(OH)_2$, 4 × 10.00 mL samples were titrated against 0.125 mol L^{-1} hydrochloric acid solution. The average volume of acid needed to reach the equivalence point was 24.02 mL.

   Write a balanced equation for the titration reaction and calculate the concentration of the limewater.

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1. a. To show when the equivalence point is reached.

   b. $n = cV$
   $= 0.208 \text{ mol L}^{-1} \times 0.0100 \text{ L}$
   $= 0.00208 \text{ mol}$

   c. $2HCl(aq) + K_2CO_3(aq) \longrightarrow 2KCl(aq) + CO_2(g) + H_2O(l)$

   d. $n(HCl) = 2n(K_2CO_3)$
   $= 2 \times 0.00208 \text{ mol}$
   $= 0.00416 \text{ mol}$

   e. $c = \frac{n}{V}$
   $= \frac{0.00416 \text{ mol}}{0.02122 \text{ L}} = 0.196 \text{ mol L}^{-1}$

2. $CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$

   $n(CH_3COOH) = cV = 0.252 \text{ mol L}^{-1} \times 0.01500 \text{ L}$
   $= 0.00378 \text{ mol}$

   $n(CH_3COOH) = n(NaOH) = 0.00378 \text{ mol}$

   $c(NaOH) = \frac{n}{V} = \frac{0.00378 \text{ mol}}{0.02496 \text{ L}} = 0.151 \text{ mol L}^{-1}$

3. a. $m(Na_2CO_3) = 131.10 - 128.45 \text{ g}$
   $= 2.65 \text{ g}$

   b. i. $c = \frac{m}{V} = \frac{2.65 \text{ g}}{0.100 \text{ L}} = 26.5 \text{ g L}^{-1}$

   ii. $n(Na_2CO_3) = \frac{m}{M} = \frac{2.65 \text{ g}}{106.0 \text{ g mol}^{-1}} = 0.0250 \text{ mol}$

   $c(Na_2CO_3) = \frac{n}{V} = \frac{0.025 \text{ mol}}{0.100 \text{ L}} = 0.250 \text{ mol L}^{-1}$

   c. i. 20 mL pipette.

   ii. Burette.

   iii. Indicator changes colour from yellow to red.

   iv. $2H^+ + CO_3^{2-} \longrightarrow CO_2 + H_2O$ *or*
   $2HCl(aq) + Na_2CO_3(aq) \longrightarrow CO_2(g) + H_2O(\ell) + 2NaCl(aq)$

   v. $n(Na_2CO_3) = cV = 0.250 \text{ mol L}^{-1} \times 0.0200 \text{ L}$
   $= 0.00500 \text{ mol}$

   $n(HCl) = 2n(Na_2CO_3) = 0.00500 \times 2 = 0.0100 \text{ mol}$

   $c(HCl) = \frac{n}{V} = \frac{0.0100 \text{mol}}{0.01516 \text{ L}} = 0.660 \text{ mol L}^{-1}$

4. $Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$

   $n(HCl) = c(HCl) \times V(HCl) = 0.125 \text{ mol L}^{-1} \times 0.02402 \text{ L} = 0.003003 \text{ mol}$

   From the equation:

   $n(Ca(OH)_2) = \frac{1}{2}n(HCl) = \frac{1}{2} \times 0.003003 = 0.001501$

   $c(Ca(OH)_2) = \frac{n(Ca(OH)_2)}{V(Ca(OH)_2)} = \frac{0.001501 \text{ mol}}{0.0100 \text{ L}} = 0.150 \text{ mol L}^{-1}$

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The final answer is given to 3 significant figures since the least accurate measurement (*c*(HCl)) is only given to 3 significant figures.

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