Titration Calculation Practice Questions

1. Eggshells contain calcium carbonate. The following procedure was used to determine the percentage, by mass, of calcium carbonate in 1.13 g of eggshell.

   Step 1 The 1.13 g of eggshell were crushed and added to 100.0 mL of 0.300 mol L^{-1} HCl solution. Excess HCl remained after the reaction was complete.

   $$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

   Step 2 20.0 mL samples of the excess HCl were titrated with 0.10 mol L^{-1} Na_2CO_3 solution.

   (a) Calculate the initial number of moles of HCl present before the reaction in Step 1.

   (b) The equation for the titration reaction in Step 2 is shown below:

   $$2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2$$

   In one titration 8.35 mL of Na_2CO_3 was needed to neutralise the HCl in one 20.0 mL sample.

   (i) Calculate the number of moles of Na_2CO_3 needed to neutralise the HCl in Step 2.

   (ii) Hence state the number of moles of HCl in the 20.0 mL sample titrated in Step 2.

   (iii) Hence calculate the total number of moles of excess HCl that remained after the reaction with the eggshell in Step 1.

   (c) Calculate the number of moles of HCl that reacted with the eggshell in Step 1.

   (d) Calculate the mass of calcium carbonate in the 1.13 g of eggshell.

   (e) Calculate the percentage mass of calcium carbonate in eggshell.

2. The following procedure was used to determine the concentration of hydrogen gas in a sample of air:

   Step 1 1.0×10^2 L of air was bubbled through 0.0500 L of 0.300 mol L^{-1} acidified $K_2Cr_2O_7$ solution. An equation for the reaction that occurred is shown below:

   $$3H_2 + Cr_2O_7^{2-} + 8H^+ \rightarrow 2Cr^{3+} + 7H_2O$$

   Excess $Cr_2O_7^{2-}$ remained in the solution after the reaction.

   Step 2 The excess $Cr_2O_7^{2-}$ was titrated with 2.00 mol L^{-1} Fe^{2+} solution. An equation for the reaction that occurred is shown below:

   $$6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$$

   A titre value of 17.75 mL was obtained.

   (a) Calculate the number of moles of $Cr_2O_7^{2-}$ present before the reaction with H_2 in Step 1.

   (b) Calculate the number of moles of Fe^{2+} required to react with the $Cr_2O_7^{2-}$ in Step 2.

   (c) Hence calculate the number of moles of $Cr_2O_7^{2-}$ left unreacted after Step 1.

   (d) Hence calculate the number of moles of $Cr_2O_7^{2-}$ that reacted with H_2 in Step 1.

   (e) Calculate the number of moles of H_2 in the 1.0×10^2 L of air.

   (f) Calculate the concentration, in %w/v, of hydrogen gas in the air.

3. Solid pellets containing calcium hypochlorite, $Ca(OCl)_2$ can be added to swimming pool water to control the levels of harmful bacteria.

The concentration of $Ca(OCl)_2$ in one brand of solid pellets was determined by titration with a standard solution of Pb^{2+}, using the following procedure:

Step 1 Two pellets, each of mass 1.00 g, were crushed and made up to a solution of approximately 100 mL.

Step 2 The 100 mL of solution was titrated with a 0.500 mol L^{-1} solution of Pb^{2+} in the burette. The equation for the reaction is shown below:

$$Pb^{2+} + OCl^{-} + 2H^{+} \rightarrow Pb^{4+} + Cl^{-} + H_2O$$

A titre of 40.80 mL was needed to reach end-point.

(a) Calculate the number of moles of Pb^{2+} needed to reach end-point.

(b) State the number of moles of OCl^{-} in the solution.

(c) Calculate the mass of $Ca(OCl)_2$ in the solution.

(d) Hence calculate the percentage, by mass, of $Ca(OCl)_2$ in each pellet.

4. The concentration of nitric acid in a commercial nitric acid solution can be determined by titration with sodium carbonate solution, following the procedure below:

Step 1 Dilute 10.00 mL of the commercial nitric acid solution to 250.0 mL with water.

Step 2 Pipette 20.00 mL of the dilute nitric acid solution into a conical flask.

Step 3 Titrate with sodium carbonate solution that has a concentration of 0.1170 mol L^{-1}. The equation for the reaction is shown below:

$$2HNO_3 + Na_2CO_3 \rightarrow 2NaNO_3 + H_2O + CO_2$$

In one titration, a titre of 31.46 mL was required to completely react with the dilute nitric acid solution.

(a) Calculate the number of moles of Na_2CO_3 that reacted in the titration.

(b) Hence calculate the number of moles of nitric acid in the dilute solution.

(c) Calculate the concentration, in mol L^{-1}, of nitric acid in the commercial nitric acid solution.

(d) Calculate the concentration, in %w/v, of the commercial nitric acid solution.

5. The concentration of oxalic acid, $H_2C_2O_4$, in a solution was determined by following the procedure below:

Step 1 An excess quantity of standard $KMnO_4$ solution was added to a sample of the solution. The equation for the reaction is shown below:

$$5H_2C_2O_4 + 2MnO_4^- + 6H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$$

Step 2 The excess MnO_4^- was titrated with standard Cu^{2+} solution:

$$5Cu^{2+} + MnO_4^- + 8H^+ \rightarrow 5Cu^{3+} + Mn^{2+} + 4H_2O$$

In this analysis, 20.00 mL of 0.00490 mol L^{-1} $KMnO_4$ solution was added to a 50.00 mL sample of the solution containing oxalic acid. Then 14.55 mL of 0.0233 mol L^{-1} Cu^{2+} solution was added to completely react with the excess MnO_4^-.

(a) Calculate the number of moles of MnO_4^- in 20.00 mL of 0.00490 mol L^{-1} $KMnO_4$ solution.

(b) Calculate the number of moles of Cu^{2+} solution that reacted in the titration in Step 2.

(c) Calculate the number of moles of MnO_4^- ions that reacted in Step 2.

(d) Calculate the number of moles of MnO_4^- that reacted in Step 1, and hence the number of moles of oxalic acid in the original sample of the solution.

(e) Calculate the concentration of oxalic acid, in μg mL^{-1}, in the solution.

6. Tablets of ascorbic acid are commonly taken as a source of vitamin C. The following procedure was used to determine the percentage, by mass, of ascorbic acid in vitamin C tablets.

Step 1 Five vitamin C tablets, each of mass 500 mg, were crushed and added to 50.0 mL of 1.0 mol L^{-1} NaOH solution. Excess NaOH remained after the reaction was complete.

$$C_6H_8O_6 + NaOH \rightarrow NaC_6H_7O_6 + H_2O$$

Step 2 The excess NaOH was titrated with 0.50 mol L^{-1} H_2SO_4 solution from a burette.

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

(a) Calculate the number of moles of NaOH solution added to the vitamin C tablets in Step 1.

(b) In one titration 38.79 mL of H_2SO_4 was required to react completely with the excess NaOH.

(i) Calculate the number of moles of H_2SO_4 needed to neutralise the excess NaOH.

(ii) Hence calculate the number of moles of excess NaOH.

(iii) Hence calculate the number of moles of NaOH that reacted with the vitamin C tablets in Step 1.

(c) Calculate the total mass of ascorbic acid in the tablets and hence the percentage, by mass, of ascorbic acid in the tablets.