Titrating Calcium Ions

A Level

The concentration of calcium ions in hard water can be determined by titration with a reagent X which forms a complex with $\mathrm{Ca}^{2+}(\mathrm{aq})$, giving a change of colour. Three moles of X combine with one mole of $\mathrm{Ca}^{2+}(\mathrm{aq})$.

A $25.0\,\mathrm{cm}^3$ sample of hard water reacted with $24.0\,\mathrm{cm}^3$ of $1.00 \times 10^{-4}\,\mathrm{mol\ dm}^{-3}\ \mathrm{X}(\mathrm{aq})$.

Determine the concentration, in $\mathrm{mol\ dm}^{-3}$, of calcium ions in the hard water.

Adapted with permission from UCLES, A Level Chemistry, June 1995, Paper 3, Question 3

Essential Pre-Uni Chemistry B7.4

A Level

Three students each prepare a standard solution by dissolving $10.6\,\mathrm{g}$ of solid from different bottles labelled 'sodium carbonate' in exactly $1\,\mathrm{dm}^3$ of water. They use this standard solution in a titration to determine the exact concentration of a solution of sulfuric acid at approximately $0.1\,\mathrm{mol\,dm}^{-3}$. They each use a pipette to measure out exactly $25.00\,\mathrm{cm}^3$ of the standard solution into a conical flask, they each use the same indicator and they each carry out their titrations with great care and accuracy.

The volumes of sulfuric acid solution that they each use are listed below. Only student A finds the correct concentration of the sulfuric acid. Student B is within $20\,\%$ but student C is so far out that they know something is wrong. Student C asks for help and is reminded that some solids can contain water of crystallization. Student A uses anhydrous sodium carbonate, but what is x in the formula $\mathrm{Na_2CO_3 \cdot xH_2O\,(s)}$ for students B and C?

Student A: $23.75\,\mathrm{cm}^3$
Student B: $20.20\,\mathrm{cm}^3$
Student C: $8.80\,\mathrm{cm}^3$

Part A Acid concentration

Calculate the exact concentration of the sulfuric acid. Give your answer to 3 significant figures.

Part B $\mathrm{Na_2CO_3 \cdot xH_2O\,(s)}$

Find x in $\mathrm{Na_2CO_3 \cdot xH_2O\,(s)}$ for student B.

Find x in $\mathrm{Na_2CO_3 \cdot xH_2O\,(s)}$ for student C.

Titrating Sulfur Dioxide

A Level

Sulfur dioxide is a by-product of the combustion of coal in power stations. It can react with oxygen and water vapour in the air to form sulfuric acid, $\mathrm{H_2SO_4}$. This is one of the causes of acid rain.

The amount of sulfur dioxide in the air may be determined by bubbling a sample of the air through sodium hydroxide solution, where it reacts according to the equation below:

$$\mathrm{SO_2\,(g) + 2\,NaOH\,(aq) \longrightarrow Na_2SO_3\,(aq) + H_2O\,(l)}$$

The concentration of the unreacted sodium hydroxide can be determined by titration against a standard solution of hydrochloric acid.

$1000\,\mathrm{dm^3}$ of air were bubbled through $200\,\mathrm{cm^3}$ of a $1.00\,\mathrm{mol\,dm^{-3}}$ solution of sodium hydroxide. The remaining solution was diluted to $1000\,\mathrm{cm^3}$ with water, and $25.0\,\mathrm{cm^3}$ of this solution was neutralised by $20.4\,\mathrm{cm^3}$ of a $0.100\,\mathrm{mol\,dm^{-3}}$ solution of hydrochloric acid.

Part A $\mathrm{H_2SO_4}$ formation

Construct an overall equation for the formation of sulfuric acid from sulfur dioxide (do not include state symbols).

Part B Neutralisation reaction

Give the (net) ionic equation for the reaction of sodium hydroxide with hydrochloric acid.

Part C Unreacted moles

Find the amount, in moles, of unreacted sodium hydroxide.

Part D Sulfur dioxide moles

Find the amount, in moles, of sulfur dioxide in $1000\,\mathrm{dm}^3$ of air.

Part E Percentage by volume

Hence calculate the percentage by volume of sulfur dioxide in air. (You may assume $1\,\mathrm{mol}$ of any gas occupies $24\,\mathrm{dm}^3$ at this temperature and pressure.)

Adapted with permission from OCR, A Level Chemistry, June 1999, General and Physical Paper, Question 3

Essential Pre-Uni Chemistry B7.3

A Level

All of the ozone in $5.00\,\mathrm{m}^3$ of air was reacted with $250\,\mathrm{cm}^3$ of potassium iodide solution. The liberated iodine was titrated against a standard solution of sodium thiosulfate with a concentration of $0.0400\,\mathrm{mol\,dm}^{-3}$. $25.0\,\mathrm{cm}^3$ of the iodine solution was used in each titration. The results of the titration are shown in the table below. Fill in the remaining titres (Parts A-C), and then answer the questions in Parts D-G.

Titration	Initial burette reading / cm^3	Final burette reading / cm^3	Titre / cm^3
Rough	0.10	25.40	25.30
1	0.80	26.10	**Part A**
2	1.20	26.20	**Part B**
3	1.00	25.90	**Part C**

Part A **1, Titre/cm^3**

Give your answer to 4 significant figures.

Part B **2, Titre/cm^3**

Give your answer to 4 significant figures.

Part C **3, Titre/cm^3**

Give your answer to 4 significant figures.

Part D Concentration

Calculate the concentration of the iodine solution in $\mathrm{mol\,dm^{-3}}$

Part E Amount of ozone

Calculate the amount of ozone in the $5.00\,\mathrm{m^3}$ of air. Give your answer to 3 significant figures.

Part F Piece of apparatus

Name the piece of apparatus that should be used to transfer the iodine solution into a conical flask, ready for titration.

- 50 ml beaker
- Erlenmeyer flask
- Glass rod
- Burette
- 25 ml measuring cylinder & funnel
- Glass dropper pipette
- Volumetric pipette

Part G Indicator and colour change

Name a suitable indicator for this titration, and give its colour change at the end point.

Suitable indicator:

- Glycerol
- Starch
- Silver iodide
- Phenolphthalein
- Methyl orange
- Litmus
- Universal indicator

Initial colour:

- Red
- Colourless
- Blue
- Purple/violet
- Orange
- Black
- Yellow/brown

Final colour:

- Purple/violet
- Yellow/brown
- Orange
- Blue
- Black
- Colourless
- Red

Essential Pre-Uni Chemistry B7.2

GCSE C C C A Level P P P

$2.50\,\mathrm{g}$ of an unknown carbonate were dissolved in $100\,\mathrm{cm^3}$ of $1.00\,\mathrm{mol\,dm^{-3}}$ hydrochloric acid (an excess). The resulting solution was made up to $250\,\mathrm{cm^3}$ in a volumetric flask. $25.00\,\mathrm{cm^3}$ aliquots of this solution were titrated against $0.250\,\mathrm{mol\,dm^{-3}}$ sodium hydroxide. Some of the results are shown below. Fill in the gaps in the table (Parts A-D), and then calculate the quantities in Parts E-L to identify the cation (Part M).

Titration	Initial burette reading / $\mathrm{cm^3}$	Final burette reading / $\mathrm{cm^3}$	Titre / $\mathrm{cm^3}$
Rough	0.60	25.10	**Part A**
1	0.15	**Part B**	24.10
2	**Part C**	25.25	24.45
3	1.35	25.45	**Part D**

Part A **Rough, Titre/$\mathrm{cm^3}$**

Give your answer to 4 significant figures.

Part B **1, Final burette reading/$\mathrm{cm^3}$**

Give your answer to 4 significant figures.

Part C **2, Initial burette reading/$\mathrm{cm^3}$**

Give your answer to 2 significant figures.

Part D **3, Titre/cm^3**

Give your answer to 4 significant figures.

Part E **Average concordant titre**

Calculate the average concordant titre. Give your answer to 4 significant figures.

Part F **Amount of sodium hydroxide**

Calculate the amount of sodium hydroxide in that volume. Give your answer to 3 significant figures.

Part G **Amount of hydrochloric acid**

The amount of hydrochloric acid in each aliquot. Give your answer to 3 significant figures.

Part H **Initial amount of HCl**

Calculate the initial amount of hydrochloric acid added to the carbonate. Give your answer to 3 significant figures.

Part I **Final amount of HCl**

Calculate the amount of hydrochloric acid remaining after reaction. Give your answer to 3 significant figures.

Part J **Amount of HCl used**

Calculate the amount of hydrochloric acid used in reaction with the carbonate. Give your answer to 3 significant figures.

Part K Amount of carbonate

Calculate the amount of carbonate in $2.50\,\mathrm{g}$. Give your answer to 3 significant figures.

Part L Molar mass of carbonate

Calculate the molar mass of the carbonate. Give your answer to 3 significant figures.

Part M Identity of cation

Identify the cation in the carbonate.