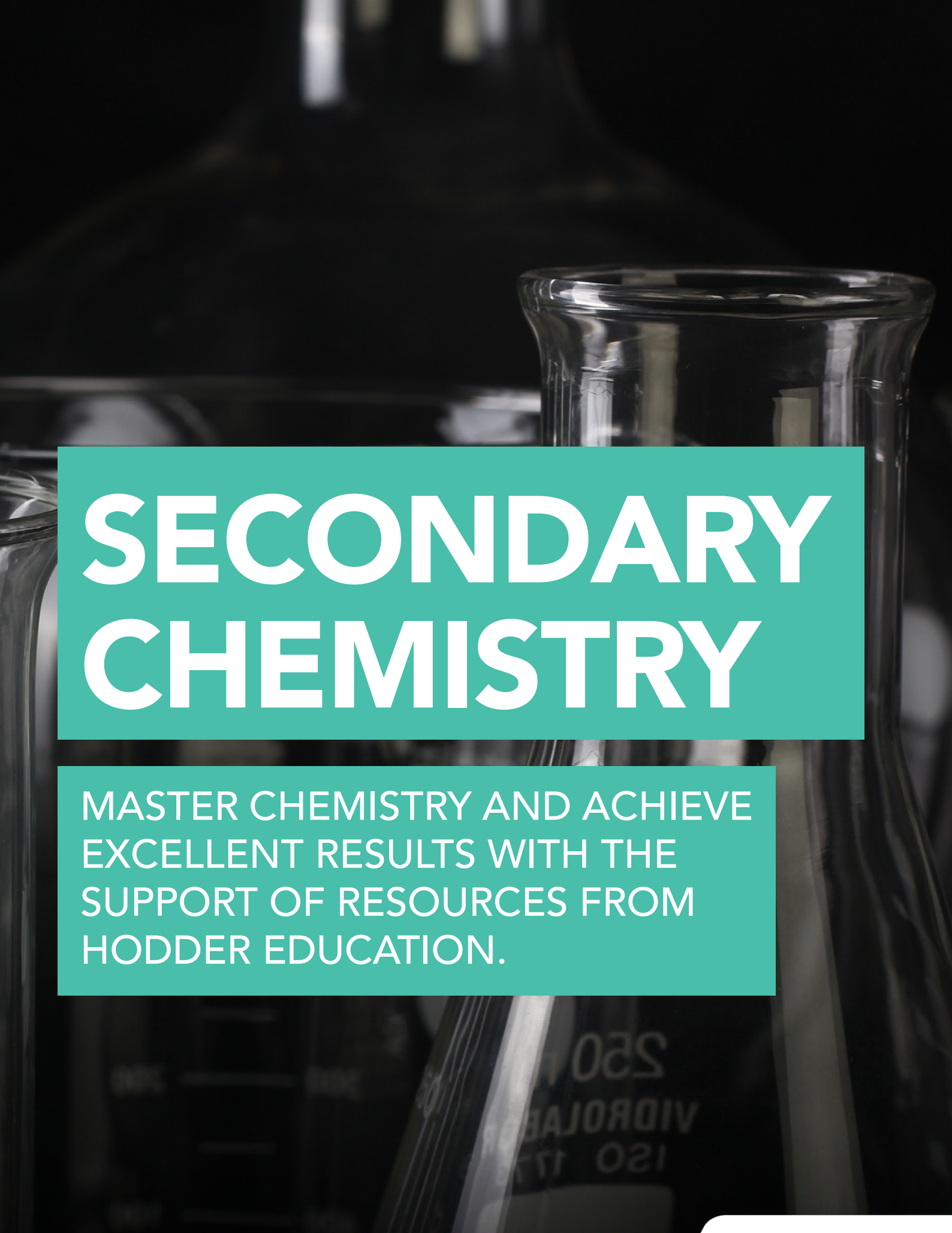

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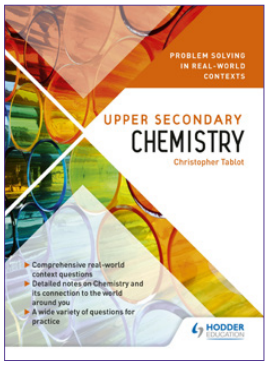

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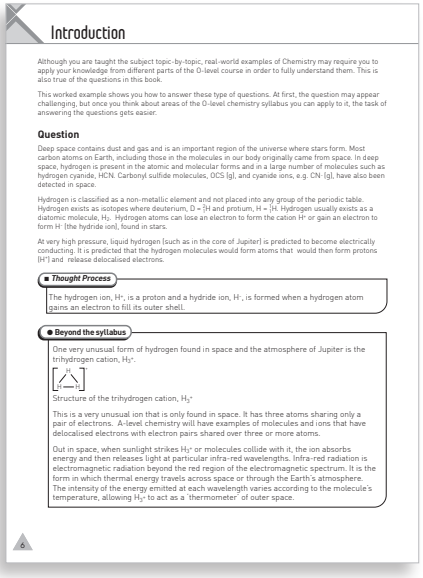
Problem Solving in Real-World Contexts Upper Secondary Chemistry

Prepare for the challenging questions in the GCE 'O' Level Chemistry examinations with real-world contexts that ensure an understanding of the topics and how they are connected.

- Prepare for the real-world context questions with notes and guidance, worked examples and exam-style questions.
- Deepen understanding and explore the connections of how various topics come together with practice questions.
- Check understanding with detailed answers and explanations at the back of the book.



Introduction

Although you are taught the subject topic-by-topic, real-world examples of Chemistry may require you to apply your knowledge from different parts of the O-level course in order to fully understand them. This is also true of the questions in this book.

This worked example shows you how to answer these type of questions. At first, the question may appear challenging, but once you think about areas of the O-level chemistry syllabus you can apply to it, the task of answering the questions gets easier.

Question

Deep space contains dust and gas and is an important region of the universe where stars form. Most carbon atoms on Earth, including those in the molecules in our body originally came from space. In deep space, hydrogen is present in the atomic and molecular forms and in a large number of molecules such as hydrogen cyanide, HCN. Carbonyl sulfide molecules, OCS (g), and cyanide ions, e.g. CN^-(g), have also been detected in space.

Hydrogen is classified as a non-metallic element and not placed into any group of the periodic table. Hydrogen exists as isotopes where deuterium, D = ^2H and protium, H = ^1H. Hydrogen usually exists as a diatomic molecule, H_2. Hydrogen atoms can lose an electron to form the cation H^+ or gain an electron to form H^-(the hydride ion), found in stars.

At very high pressure, liquid hydrogen (such as in the core of Jupiter) is predicted to become electrically conducting. It is predicted that the hydrogen molecules would form atoms that would then form protons (H^+) and release delocalised electrons.

Thought Process

The hydrogen ion, H^+, is a proton and a hydride ion, H^-, is formed when a hydrogen atom gains an electron to fill its outer shell.

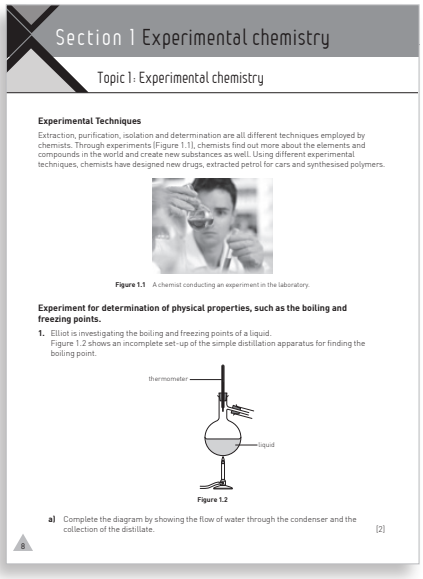
Beyond the syllabus

One very unusual form of hydrogen found in space and the atmosphere of Jupiter is the trihydrogen cation, H_3^+.

Structure of the trihydrogen cation, H_3^+

This is a very unusual ion that is only found in space. It has three atoms sharing only a pair of electrons. A-level chemistry will have examples of molecules and ions that have delocalised electrons with electron pairs shared over three or more atoms.

Out in space, when sunlight strikes H_3^+ or molecules collide with it, the ion absorbs energy and then releases light at particular infra-red wavelengths. Infra-red radiation is electromagnetic radiation beyond the red region of the electromagnetic spectrum. It is the form in which thermal energy travels across space or through the Earth's atmosphere. The intensity of the energy emitted at each wavelength varies according to the molecule's temperature, allowing H_3^+ to act as a 'thermometer' of outer space.



Section 1 Experimental chemistry

Topic 1: Experimental chemistry

Experimental Techniques

Extraction, purification, isolation and determination are all different techniques employed by chemists. Through experiments (Figure 1.1), chemists find out more about the elements and compounds in the world and create new substances as well. Using different experimental techniques, chemists have designed new drugs, extracted petrol for cars and synthesised polymers.

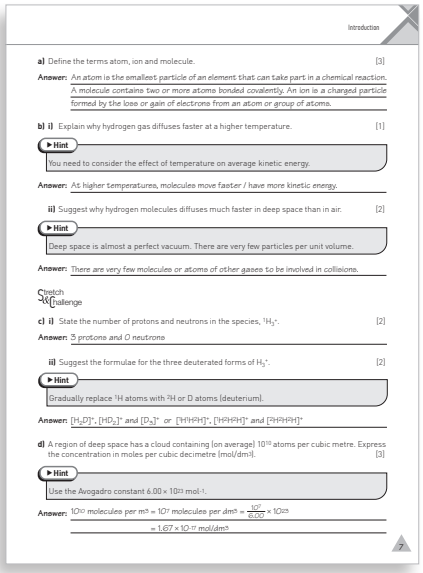
Figure 1.1 A chemist conducting an experiment in the laboratory.

Experiment for determination of physical properties, such as the boiling and freezing points.

1. Elliot is investigating the boiling and freezing points of a liquid.
Figure 1.2 shows an incomplete set-up of the simple distillation apparatus for finding the boiling point.

Figure 1.2

a) Complete the diagram by showing the flow of water through the condenser and the collection of the distillate. [2]



a) Define the terms atom, ion and molecule. [3]

Answer: *An atom is the smallest particle of an element that can take part in a chemical reaction. A molecule contains two or more atoms bonded covalently. An ion is a charged particle formed by the loss or gain of electrons from an atom or group of atoms.*

b) i) Explain why hydrogen gas diffuses faster at a higher temperature. [1]

Hint

You need to consider the effect of temperature on average kinetic energy.

Answer: *At higher temperatures, molecules move faster / have more kinetic energy.*

ii) Suggest why hydrogen molecules diffuses much faster in deep space than in air. [2]

Hint

Deep space is almost a perfect vacuum. There are very few particles per unit volume.

Answer: *There are very few molecules or atoms of other gases to be involved in collisions.*

Stretch & Challenge

c) i) State the number of protons and neutrons in the species, $^1H_3^+$. [2]

Answer: *3 protons and 0 neutrons*

ii) Suggest the formulae for the three deuterated forms of H_3^+. [2]

Hint

Gradually replace ^1H atoms with ^2H or D atoms (deuterium).

Answer: $[H_2D]^+$, $[HD_2]^+$ and $[D_3]^+$ or $[^1H^1H^2H]^+$, $[^1H^2H^2H]^+$ and $[^2H^2H^2H]^+$

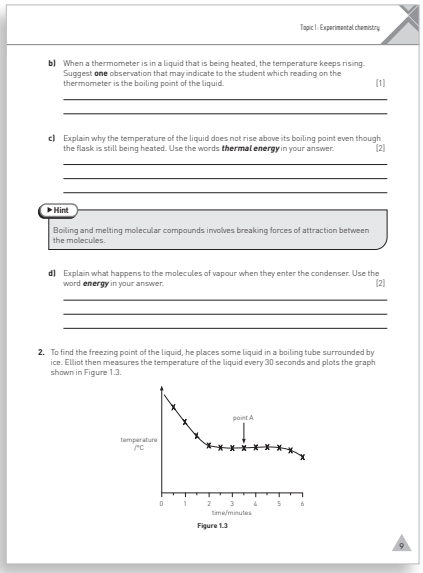
d) A region of deep space has a cloud containing (on average) 10^{10} atoms per cubic metre. Express the concentration in moles per cubic decimetre (mol/dm^3). [3]

Hint

Use the Avogadro constant 6.00×10^{23} mol^{-1}.

Answer: 10^{10} *molecules per m*^{3} $= 10^7$ *molecules per dm*^{3} $= \frac{10^7}{6.00} \times 10^{23}$

$= 1.67 \times 10^{-17}$ *mol/dm*^{3}



b) When a thermometer is in a liquid that is being heated, the temperature keeps rising. Suggest **one** observation that may indicate to the student which reading on the thermometer is the boiling point of the liquid. [1]

c) Explain why the temperature of the liquid does not rise above its boiling point even though the flask is still being heated. Use the words ***thermal energy*** in your answer. [2]

Hint

Boiling and melting molecular compounds involves breaking forces of attraction between the molecules.

d) Explain what happens to the molecules of vapour when they enter the condenser. Use the word ***energy*** in your answer. [2]

2. To find the freezing point of the liquid, he places some liquid in a boiling tube surrounded by ice. Elliot then measures the temperature of the liquid every 30 seconds and plots the graph shown in Figure 1.3.

Figure 1.3

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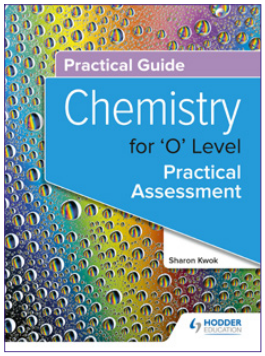

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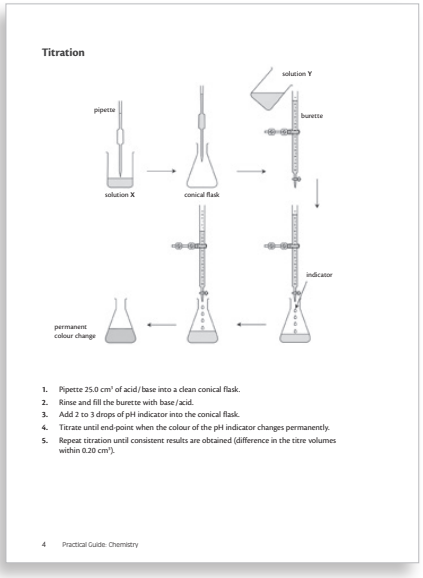
Practical Guide: Chemistry for 'O' Level

The Practical Guide for 'O' Level is based on the latest syllabus and designed to provide structured and scaffolded instructions on how to approach the practical examination as well as to develop the essential skills in answering the questions effectively.

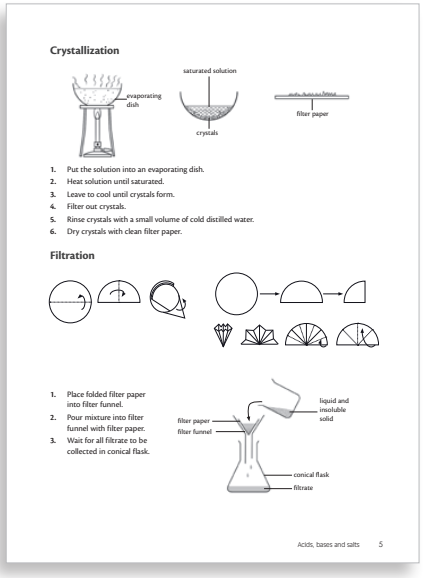
- Build on and reinforce the key laboratory skills required with tips on experimental techniques and planning experiments, including full colour picture inserts and experiment videos.
- Practise on all the topics in the syllabus that may come up for the GCE 'O' Level practical examinations with simulated exam style practical questions.
- Develop in-depth understanding of each topic with the detailed explanations of how to approach each experiment.



Titration

1. Pipette 25.0 cm³ of acid / base into a clean conical flask.
2. Rinse and fill the burette with base / acid.
3. Add 2 to 3 drops of pH indicator into the conical flask.
4. Titrate until end-point when the colour of the pH indicator changes permanently.
5. Repeat titration until consistent results are obtained (difference in the titre volumes within 0.20 cm³).

4 Practical Guide: Chemistry



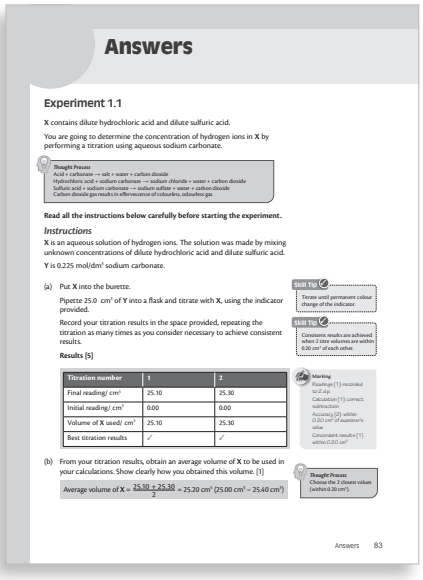
Crystallization

1. Put the solution into an evaporating dish.
2. Heat solution until saturated.
3. Leave to cool until crystals form.
4. Filter out crystals.
5. Rinse crystals with a small volume of cold distilled water.
6. Dry crystals with clean filter paper.

Filtration

1. Place folded filter paper into filter funnel.
2. Pour mixture into filter funnel with filter paper.
3. Wait for all filtrate to be collected in conical flask.

Acids, bases and salts 5



Answers

Experiment 1.1

X contains dilute hydrochloric acid and dilute sulfuric acid.

You are going to determine the concentration of hydrogen ions in **X** by performing a titration using aqueous sodium carbonate.

Thought Process
Acid + carbonate → salt + water + carbon dioxide
Hydrochloric acid + sodium carbonate → sodium chloride + water + carbon dioxide
Sulfuric acid + sodium carbonate → sodium sulfate + water + carbon dioxide
Carbon dioxide gas results in effervescence of colourless, odourless gas.

Read all the instructions below carefully before starting the experiment.

Instructions

X is an aqueous solution of hydrogen ions. The solution was made by mixing unknown concentrations of dilute hydrochloric acid and dilute sulfuric acid.

Y is 0.225 mol/dm³ sodium carbonate.

(a) Put **X** into the burette.

Pipette 25.0 cm³ of **Y** into a flask and titrate with **X**, using the indicator provided.

Record your titration results in the space provided, repeating the titration as many times as you consider necessary to achieve consistent results.

Skill Tip
Titrate until permanent colour change of the indicator.

Skill Tip
Consistent results are achieved when 2 titre volumes are within 0.20 cm³ of each other.

Results [5]

Titration number	1	2
Final reading/ cm³	25.10	25.30
Initial reading/ cm³	0.00	0.00
Volume of **X** used/ cm³	25.10	25.30
Best titration results	✓	✓

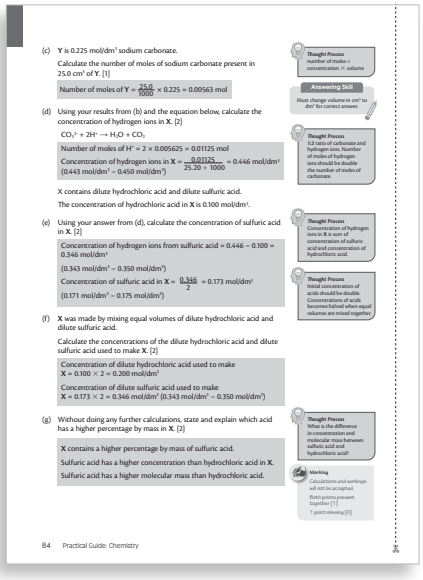
Marking
Rounding [1] reconciled to 2 dp
Calculation [1] correct subtraction
Accuracy [2] within 0.20 cm³ of examiner's value
Concordant results [1] within 0.20 cm³

(b) From your titration results, obtain an average volume of **X** to be used in your calculations. Show clearly how you obtained this volume. [1]

Thought Process
Choose the 2 closest values (within 0.20 cm³).

Average volume of **X** = $\frac{25.10 + 25.30}{2}$ = 25.20 cm³ (25.00 cm³ – 25.40 cm³)

Answers 83



(c) **Y** is 0.225 mol/dm³ sodium carbonate.

Calculate the number of moles of sodium carbonate present in 25.0 cm³ of **Y**. [1]

Thought Process
number of moles = concentration × volume

Answering Skill
Must change volume in cm³ to dm³ for correct answer.

Number of moles of **Y** = $\frac{25.0}{1000}$ × 0.225 = 0.00563 mol

(d) Using your results from (b) and the equation below, calculate the concentration of hydrogen ions in **X**. [2]

$CO_3^{2-} + 2H^+ \rightarrow H_2O + CO_2$

Thought Process
1:2 ratio of carbonate and hydrogen ions. Number of moles of hydrogen ions should be double the number of moles of carbonate.

Number of moles of H^+ = 2 × 0.005625 = 0.01125 mol

Concentration of hydrogen ions in **X** = $\frac{0.01125}{25.20 \div 1000}$ = 0.446 mol/dm³ (0.443 mol/dm³ – 0.450 mol/dm³)

X contains dilute hydrochloric acid and dilute sulfuric acid.

The concentration of hydrochloric acid in **X** is 0.100 mol/dm³.

(e) Using your answer from (d), calculate the concentration of sulfuric acid in **X**. [2]

Thought Process
Concentration of hydrogen ions in **X** is sum of concentration of sulfuric acid and concentration of hydrochloric acid.

Concentration of hydrogen ions from sulfuric acid = 0.446 − 0.100 = 0.346 mol/dm³

(0.343 mol/dm³ – 0.350 mol/dm³)

Concentration of sulfuric acid in **X** = $\frac{0.346}{2}$ = 0.173 mol/dm³

(0.171 mol/dm³ – 0.175 mol/dm³)

Thought Process
Initial concentration of acids should be double. Concentrations of acids becomes halved when equal volumes are mixed together.

(f) **X** was made by mixing equal volumes of dilute hydrochloric acid and dilute sulfuric acid.

Calculate the concentrations of the dilute hydrochloric acid and dilute sulfuric acid used to make **X**. [2]

Concentration of dilute hydrochloric acid used to make **X** = 0.100 × 2 = 0.200 mol/dm³

Concentration of dilute sulfuric acid used to make **X** = 0.173 × 2 = 0.346 mol/dm³ (0.343 mol/dm³ – 0.350 mol/dm³)

(g) Without doing any further calculations, state and explain which acid has a higher percentage by mass in **X**. [2]

Thought Process
What is the difference in concentration and molecular mass between sulfuric acid and hydrochloric acid?

Marking
Calculations and workings will not be accepted.
Both points present, together [1]
1 point missing [0]

X contains a higher percentage by mass of sulfuric acid.

Sulfuric acid has a higher concentration than hydrochloric acid in **X**.

Sulfuric acid has a higher molecular mass than hydrochloric acid.

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