1 Copper(II) sulfate solution, $CuSO_4(aq)$, can be made by adding an excess of solid copper(II) oxide, CuO, to boiling dilute sulfuric acid. This is an exothermic reaction.

The balanced equation for this reaction is

$$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$$

(a) (i) Complete the ionic equation for this reaction, including state symbols.

(2)

CuO(s) +

(ii) Calculate the mass of copper(II) oxide needed, if a 10% excess is required, when 0.020 mol of sulfuric acid is completely reacted.

[Relative atomic masses: Cu = 63.5 and O = 16.0]

(2)

(b) (i) Suggest, with a reason, how the copper(II) oxide should be added to the boiling sulfuric acid.

(2)

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(ii) When the reaction is complete, the excess copper(II) oxide is removed by filtration.

To prepare crystals of copper(II) sulfate-5-water, $CuSO_4.5H_2O$, the resulting solution is boiled to remove excess water.

How would you know when sufficient water had been removed?

(1)

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(iii) After cooling the solution, crystals form. State the colour of the crystals.

(1)

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(iv) The crystals all have the same shape. What does this indicate about the arrangement of the ions?

(1)

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(c) (i) Calculate the molar mass of copper(II) sulfate-5-water, $CuSO_4.5H_2O$. Remember to include the appropriate units in your answer. You will need to use the Periodic Table as a source of data.

(2)

(ii) Calculate the percentage yield if 2.7 g of copper(II) sulfate-5-water is obtained from 0.020 mol of sulfuric acid.

(2)

(iii) What is the most likely reason for the yield being well below 100%?

(1)

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(d) When the crystals are heated, they turn white. On adding water, they return to their original colour. Suggest a use for this reaction.

(1)

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(Total for Question = marks)

2 The percentage by mass of tin in a piece of rock containing tin(IV) oxide, SnO_2, was determined as described in the procedure below.

Step 1 A sample of rock, with mass 10.25 g, was crushed and dissolved in sulfuric acid.

Step 2 The solution was treated with a reducing agent to convert the Sn^{4+} to Sn^{2+} ions.

Step 3 50 cm^3 of aqueous iodine solution with concentration 0.250 mol dm^{-3} was added to the solution of Sn^{2+} ions. The following reaction occurred:

$$Sn^{2+}(aq) + I_2(aq) \rightarrow Sn^{4+}(aq) + 2I^-(aq)$$

Step 4 The **excess** iodine was titrated with sodium thiosulfate solution with concentration 0.100 mol dm^{-3}. The volume of sodium thiosulfate solution required was 11.60 cm^3.

(a) Thiosulfate ions react with iodine as shown below.

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

(i) Calculate the number of moles of sodium thiosulfate which were used in **Step 4**.

(1)

(ii) Calculate the number of moles of iodine which reacted with this amount of sodium thiosulfate.

(1)

(iii) Calculate the number of moles of iodine added to the solution of Sn^{2+} ions in **Step 3**.

(1)

(iv) Use your results from (ii) and (iii) to calculate the number of moles of iodine which reacted with the Sn^{2+} ions from the rock.

(1)

(v) Hence calculate the percentage by mass of tin in the rock.

(2)

(b) (i) What change could be made in **Step 4** to improve the reliability of the result?

(1)

(ii) The error each time the burette was read was ± 0.05 cm^3. Calculate the percentage error in the titre value of 11.60 cm^3.

(1)

(iii) How could the percentage error in the titre value be reduced without using a different burette?

(1)

(c) The titration can be carried out with or without an indicator. What colour **change** would be seen at the end-point if an indicator was **not** used? The tin ions are colourless.

(1)

(Total for Question = marks)

3 This is a question about Group 2 compounds.

Limewater is a solution of calcium hydroxide, commonly used in the identification of carbon dioxide gas. Since calcium hydroxide is only sparingly soluble in water, technicians often make the solution by adding an excess of the solid calcium hydroxide to the required volume of deionised water, shaking the container and then leaving the mixture to settle. In this way, a saturated solution is produced but it can be of variable concentration.

Two students were each given a sample of limewater, from the same batch, in order to determine its concentration. Using 50.0 cm^3 portions of the limewater, they carried out titrations using 0.100 mol dm^{-3} hydrochloric acid. One of the students obtained the following results:

Titration	Trial	1	2
Final Volume /cm^3	14.50	28.60	42.70
Initial Volume /cm^3	0.00	14.50	28.60
Volume Added /cm^3	14.50	14.10	14.10

The student decided that the mean titre was 14.10 cm^3

The equation for the reaction is:

$$Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$$

(a) (i) Calculate the number of moles of hydrochloric acid that reacted.

(1)

(ii) Calculate the number of moles of calcium hydroxide, $Ca(OH)_2$, that reacted with the acid.

(1)

(iii) Calculate the concentration of $Ca(OH)_2$, in mol dm^{-3}, in this sample of limewater.

(1)

(iv) Calculate the concentration of $Ca(OH)_2$, in g dm^{-3}, in this sample of limewater. Use the Periodic Table as a source of data.

(2)

(v) This student did not include the trial value when calculating the mean titre. Explain why.

(1)

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(vi) The second student obtained a different mean titre value for the experiment and thought that this difference may be due to the use of a faulty pipette.

Suggest a simple method, involving distilled water and a balance, by which the accuracy of the pipette in measuring out exactly 50.0 cm^3 could be checked.

(2)

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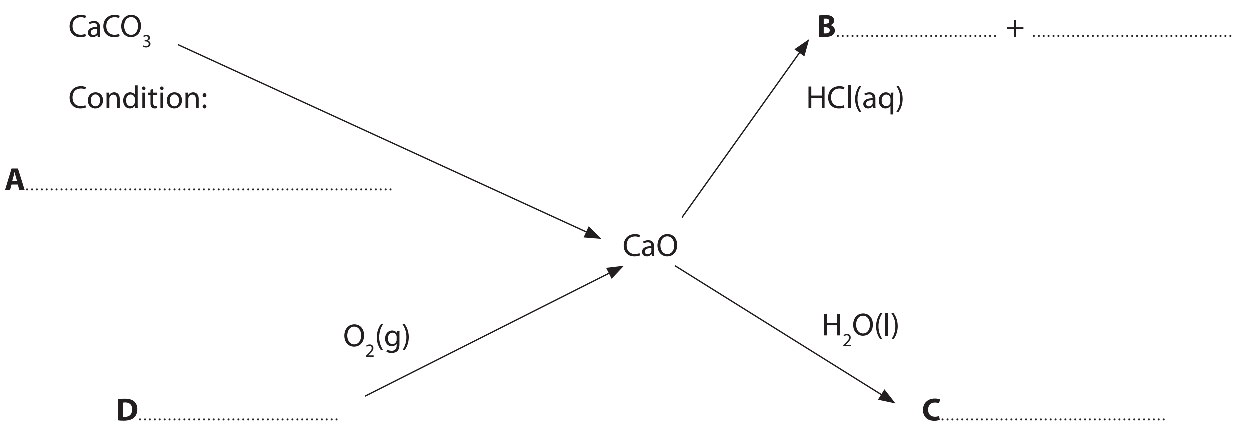
(b) Complete the missing details from the reaction flowchart shown below, giving the condition for **A** and using chemical formulae for answers **B**, **C** and **D**. State symbols are not required.

(4)



(c) In certain areas of the UK, calcium and magnesium carbonates tend to be deposited as an off-white solid on the inside surface of pipes and the surface of heating elements in kettles. These deposits can be removed by treatment with a weak acid. An equation for this is shown below.

$$CaCO_3(s) + 2HA(aq) \rightarrow CaA_2(aq) + H_2O(l) + CO_2(g)$$

State **one** observation, other than the solid disappearing, that would be made when the above reaction is carried out.

(1)

(d) The thermal stability of these carbonates depends on a combination of factors, including the size of their lattice energies.

Explain why the lattice energy of calcium carbonate is less exothermic than that of magnesium carbonate.

(2)

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(e) Calcium and magnesium ions can be distinguished by the use of a flame test. State the difference in the flame colour and explain how colours in a flame are produced in terms of electronic transitions.

(3)

Calcium ....

Magnesium ....

Colour produced by ....

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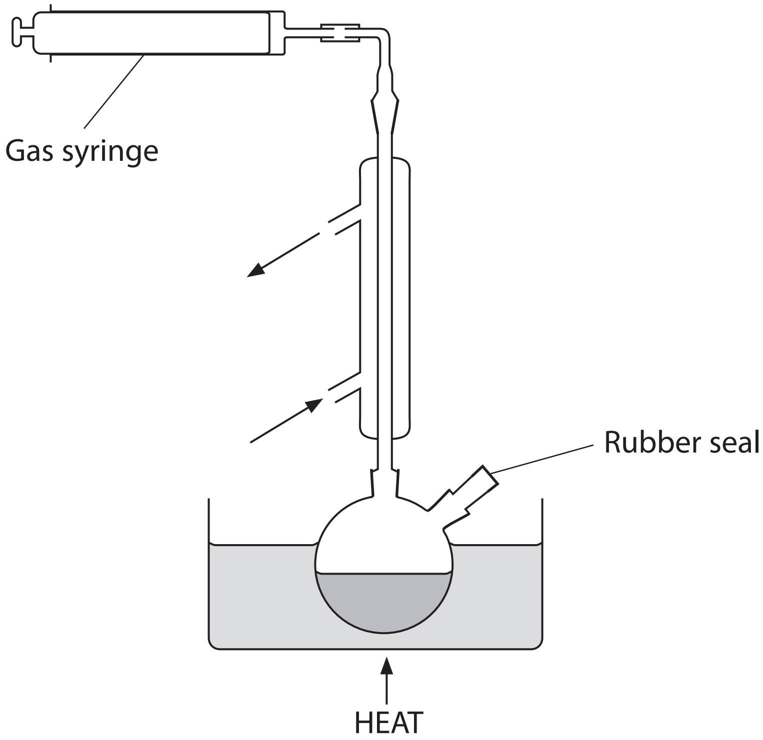
(Total for Question = marks)

4 This question is about the elimination of hydrogen bromide from bromoalkanes by reaction with alcoholic potassium hydroxide.

$$C_4H_9Br + KOH \rightarrow C_4H_8 + KBr + H_2O$$

To investigate the kinetics of this reaction the following apparatus was used:



A solution of concentrated potassium hydroxide in ethanol was refluxed and the gas syringe connected as shown.

0.6 cm^3 of 1-bromobutane was added to the solution with a hypodermic syringe through a rubber seal.

A stop clock was started and the volume of gas, V_t, measured at 2 minute intervals, for 12 minutes. When there was no further evolution of gas the volume of gas, V_{final}, was 76.5 cm^3.

(a) (i) Calculate the number of moles of 1-bromobutane used. You will need the values of the density and molar mass of 1-bromobutane from your Data booklet.

(2)

(ii) Calculate the maximum volume of gaseous but-1-ene, in cm^3, that could form.

[Molar volume of a gas 24 000 cm^3 under reaction conditions]

Suggest **two** reasons why this volume is unlikely to form.

(3)

(b) The results obtained are shown in the table below.

Time t/min	Volume of but-1-ene V_t/cm^3	$(V_{final} - V_t)/cm^3$
0	0	76.5
2	31.5	45.0
4	51.0	25.5
6	62.5	14.0
8	68.5	8.0
10	72.0	4.5
12	74.0	2.5

(i) Explain why a large excess of potassium hydroxide is used in this experiment.

(1)

(ii) Plot a graph of $(V_{final} - V_t)/cm^3$ against t/min.

(3)

(iii) Suggest why the value of $(V_{final} - V_t)$ was plotted on your graph.

(1)

(iv) Measure two successive half lives from your graph.

(2)

First half life .... min

Second half life .... min

(v) Deduce the order of reaction with respect to 1-bromobutane.

Justify your answer.

(2)

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(c) In another experiment, an excess of 1-bromobutane is reacted with varying concentrations of hydroxide ions. The results for the initial rate of the reaction are shown in the table below.

Experiment Number	$[C_4H_9Br]$ $/10^{-2}$ mol dm^{-3}	$[OH^-]$ $/10^{-3}$ mol dm^{-3}	Initial rate $/10^{-5}$ mol dm^{-3} min^{-1}
1	2.50	2.50	5.00
2	2.50	1.25	2.50
3	2.50	0.50	1.00

(i) Deduce the order of reaction with respect to hydroxide ions. Justify your answer using the data in the table.

(2)

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(ii) Write the rate equation for the reaction using your answers to parts (b)(v) and (c)(i).

(1)

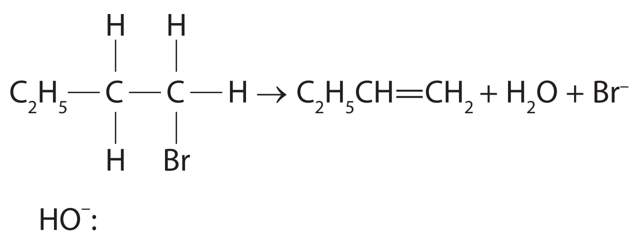
(iii) Give the units of the rate constant.

(1)

*(iv) It is suggested that the reaction begins with the slow attack by a hydroxide ion on a hydrogen atom in the 1-bromobutane, as shown below.

Complete the electron pair movement for this reaction using curly arrows and explain why this step is consistent with the rate equation for the reaction you have given in (c)(ii).

(3)



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(Total for Question = marks)