Q1. In the past 150 years, three different processes have been used to extract bromine from potassium bromide. These processes are illustrated below.

Extraction Process **1**

$2KBr + MnO_2 + 2H_2SO_4 \rightarrow MnSO_4 + K_2SO_4 + 2H_2O + Br_2$

Extraction Process **2**

The reaction of solid potassium bromide with concentrated sulfuric acid.

Extraction Process **3**

The reaction of aqueous potassium bromide with chlorine gas.

(a) Write a half-equation for the conversion of MnO_2 in acid solution into Mn^{2+} ions and water. In terms of electrons, state what is meant by the term *oxidising agent* and identify the oxidising agent in the overall reaction.

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(3)

(b) Write an equation for Extraction Process **2** and an equation for Extraction Process **3**.
Calculate the percentage atom economy for the extraction of bromine from potassium bromide by Extraction Process **3**. Suggest why Extraction Process **3** is the method in large-scale use today.

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(c) Bromine has been used for more than 70 years to treat the water in swimming pools.
The following equilibrium is established when bromine is added to water.

$$Br_2 + H_2O \rightleftharpoons HBrO + HBr$$

Give the oxidation state of bromine in HBr and in HBrO

Deduce what will happen to this equilibrium as the HBrO reacts with micro-organisms in the swimming pool water. Explain your answer.

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(4)
(Total 12 marks)

Q2. (a) State and explain the trend in electronegativities across Period 3 from sodium to sulfur.

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(4)

(b) Explain why the oxides of the Period 3 elements sodium and phosphorus have different melting points. In your answer you should discuss the structure of and bonding in these oxides, and the link between electronegativity and the type of bonding.

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(6)

(c) A chemical company has a waste tank of volume 25 000 dm^3. The tank is full of phosphoric acid (H_3PO_4) solution formed by adding some unwanted phosphorus(V) oxide to water in the tank.

A 25.0 cm^3 sample of this solution required 21.2 cm^3 of 0.500 mol dm^{-3} sodium hydroxide solution for complete reaction.

Calculate the mass, in kg, of phosphorus(V) oxide that must have been added to the water in the waste tank.

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(5)
(Total 15 marks)

Q3. Some antacid tablets contain sodium hydrogencarbonate, sucrose and citric acid.

(a) Analysis of a pure sample of citric acid showed that it contained 37.50% of carbon and 4.17% of hydrogen by mass, the remainder being oxygen. Use these data to show that the empirical formula of the acid is $C_6H_8O_7$.

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(b) When the antacid tablet is added to water, sodium hydrogencarbonate and citric acid react together to form a gas. Identify this gas.

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(1)

(c) A weighed portion of this antacid was added to water. The gas formed was collected and its volume measured.

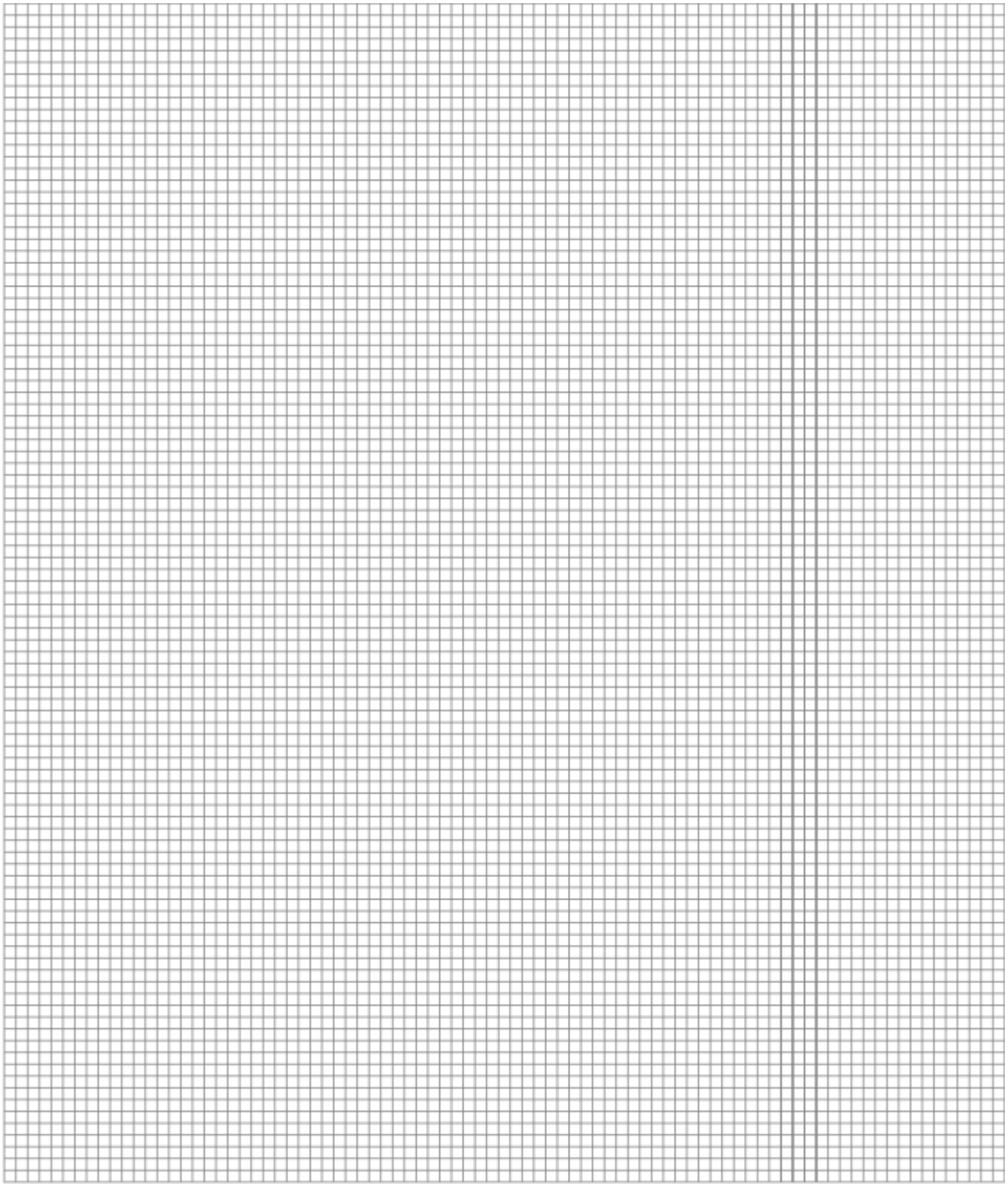
(i) Draw a diagram to show how this experiment could have been carried out to collect and measure the volume of the gas.

(ii) The experiment was repeated with further weighed portions of the same antacid.

The results are shown below.

Experiment	1	2	3	4	5
Mass of antacid / g	2.60	1.17	0.88	2.31	1.80
Volume of gas collected / cm^3	168	86	57	149	116

1 On the graph paper below, plot a graph of mass of antacid (x-axis) against volume of gas collected.



(3)

2 Draw a line of best fit on the graph, ignoring any anomalous points.

(1)

3 Use the graph to determine the volume of gas which would have been collected using 2.00 g of antacid.

Volume of gas collected .....

(1)

(d) Suggest **one** reason why the presence of sodium hydrogencarbonate in the stomach may cause a person to suffer some extra discomfort for a short time.

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(1)

(e) Explain why the value for the M_r of citric acid does not need to be an exact value to deduce the molecular formula of citric acid from its empirical formula.

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(2)

(f) Apart from misreading the gas volume, suggest **two** reasons why the volumes of gas collected may be lower than the volumes of gas produced.

Reason 1 .....

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Reason 2 .....

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(2)

(g) Explain why it is important to record the temperature and pressure when measuring the volume of a gas.

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(h) Suggest why, in an analysis of an antacid, it is important to test samples from more than one bottle of the antacid.

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(i) In the industrial production of sodium hydrogencarbonate, ammonia and carbon dioxide are bubbled through a saturated solution of sodium chloride. The equation for this reaction, and some solubility data, are shown below.

$$NaCl(aq) + NH_3(aq) + CO_2(g) + H_2O(l) \rightarrow NaHCO_3(s) + NH_4Cl(aq)$$

Compound	Solubility in water at 20 °C / g dm^{-3}
sodium chloride	360
sodium hydrogencarbonate	96
ammonium chloride	370

(i) Suggest **one** reason why sodium hydrogencarbonate precipitates from the reaction mixture at this temperature.

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(1)

(ii) Explain how this reaction could be used to remove carbon dioxide from the gases formed when fossil fuels are burned.

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(j) The thermal decomposition of sodium hydrogencarbonate produces sodium carbonate. The other products are water and carbon dioxide. Write an equation for this thermal decomposition.

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(1)

(k) Sodium carbonate is produced on an industrial scale by a multi-step process. The equation which summarises the reactions taking place is shown below.

$$CaCO_3 + 2NaCl \rightarrow CaCl_2 + Na_2CO_3$$

Calculate the percentage atom economy for the production of sodium carbonate by this reaction.

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(1)

(Total 20 marks)