1 The following pairs of compounds can be distinguished by simple test−tube reactions.

For each pair of compounds, give a reagent (or combination of reagents) that, when added separately to each compound, could be used to distinguish between them.
State what is observed in each case.

(a) Butan−2−ol and 2−methylpropan−2−ol

Reagent ....

Observation with butan−2−ol

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....

Observation with 2−methylpropan−2−ol

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(3)

(b) Propane and propene

Reagent ....

Observation with propane

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Observation with propene

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(3)

(c) Aqueous silver nitrate and aqueous sodium nitrate

Reagent ....

Observation with aqueous silver nitrate

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Observation with aqueous sodium nitrate

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(3)

(d) Aqueous magnesium chloride and aqueous barium chloride

Reagent ....

Observation with aqueous magnesium chloride

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Observation with aqueous barium chloride

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(3)
(Total 12 marks)

2 Calamine lotion can contain a mixture of zinc carbonate and zinc oxide in suspension in water. A manufacturer of calamine lotion claims that a sample contains 15.00 g of zinc carbonate and 5.00 g of zinc oxide made up to 100 cm^3 with distilled water.

(a) A chemist wanted to check the manufacturer's claim. The chemist took a 20.0 cm^3 sample of the calamine lotion and added it to an excess of sulfuric acid.
The volume of carbon dioxide evolved was measured over time. The chemist's results are shown in the table.

Time / s	0	15	30	45	60	75	90	105	120	135
Volume / cm^3	0	135	270	380	470	530	560	570	570	570

(i) Plot a graph of the results in the table on the grid. The volume should be on the *y*-axis. Draw a best-fit curve through **all** the points.

(3)

(ii) Estimate the time taken for the reaction to be completed.

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(1)

(b) (i) The volume of carbon dioxide in part (a) was measured at 293 K and at a pressure of 100 kPa.

Use information from your graph to calculate the maximum amount, in moles, of carbon dioxide evolved from the zinc carbonate in this 20.0 cm^3 sample.

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Show your working.

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(3)

(ii) Use your answer to part (i) to calculate the mass of zinc carbonate in the 20.0 cm^3 sample of calamine lotion.

(If you were unable to complete part (i), you may assume that the amount of carbon dioxide evolved was 0.0225 mol. This is **not** the correct answer.)

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(2)

(iii) Calculate the difference between your answer to part (ii) and the manufacturer's claim that there are 15.00 g of zinc carbonate in 100 cm^3 of the calamine lotion.

Express this difference as a percentage of the manufacturer's claim.

(If you were unable to complete part (ii), you may assume that the mass of zinc carbonate in the 20 cm^3 sample of calamine lotion was 2.87 g. This is **not** the correct answer.)

Difference ....

Percentage ....

....

(2)

(c) Draw a diagram of a suitable apparatus needed to perform the experiment outlined in part (a). Include in your diagram a method for collecting and measuring the carbon dioxide. The apparatus should be airtight.

(2)
(Total 13 marks)

3 (a) Suggest **one** reason why sugars are often added to antacid tablets.

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(1)

(b) In one titration, a student added significantly more phenolphthalein than instructed. The volume of sodium hydroxide solution in this titration was greater than the average value of the concordant titres.

State a property of the indicator that would explain this result.

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(1)

(c) Some other types of antacid tablets contain carbonate ions.

Suggest why this may be a disadvantage when used as a medicine to relieve indigestion.

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(1)
(Total 3 marks)

4 A teacher noticed that a student had not cleared a large air bubble from below the burette tap in preparing the burette for use before starting the titration. This air bubble was ejected during the first titration of the volumetric flask mixture.

(a) State the effect that this mistake would have on the value of the first titre.

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(1)

(b) State and explain the effect, if any, that this mistake would have on the average titre for this experiment.

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(2)
(Total 3 marks)

5 A laboratory technician discovered four badly−labelled bottles, each containing one pure white solid. Each bottle contained a compound of a different Group 2 metal (magnesium, calcium, strontium and barium).

Some tests were carried out on the solids or, if the compound was soluble, on the aqueous solution. The results are given in the table.

Test	**Compound 1**	**Compound 2**	**Compound 3**	**Compound 4**
Added to water	Dissolves	Insoluble	Dissolves	Dissolves
Solution or solid added to HCl(aq)	Solution remains colourless	Gives off carbon dioxide gas and a colourless solution forms	Solution remains colourless	Solution remains colourless and heat released
Solution or solid added to NaOH(aq)	Solution gives a white precipitate	Solid remains insoluble	Solution gives a slight white precipitate	Solution has no visible change
Solution or solid added to H_2SO_4(aq)	Solution has no visible change	Gives off carbon dioxide gas and a white solid remains	Solution slowly forms a slight white precipitate	Solution forms a white precipitate

(a) One of the bottles has a very faint label that could be read as 'Magnesium Sulfate'.

Use the information in the table to deduce which **one** of the four compounds is magnesium sulfate and explain your answer.

Compound ....

Explanation ....

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(3)

(b) The bottle containing **Compound 2** has a 'TOXIC' hazard symbol.

Use the information in the table to identify **Compound 2**.

Explain both observations in the reaction with H_2SO_4(aq).

Identity of **Compound 2** ....

Explanation ....

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(3)

(c) Identify the compound that is strontium hydroxide.

Give an equation for the reaction of strontium hydroxide with sulfuric acid.

Compound ....

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Equation ....

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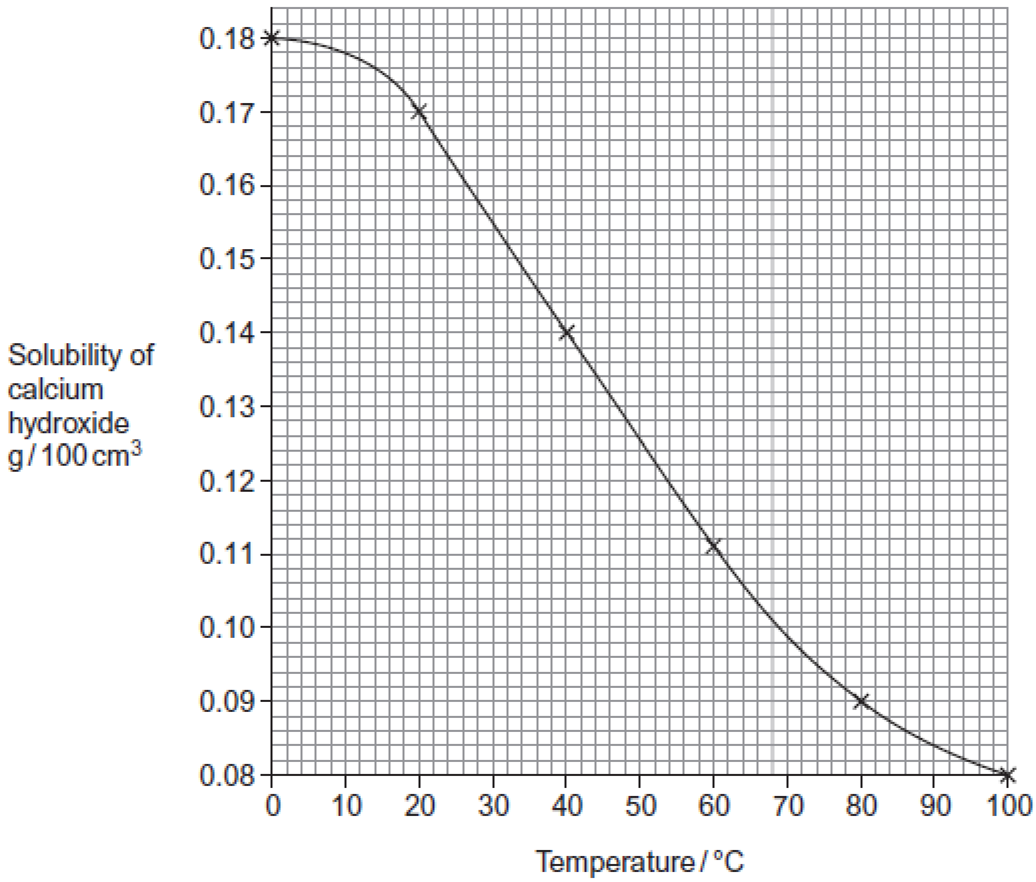
(2)
(Total 8 marks)

6 Calcium hydroxide is slightly soluble in water at room temperature. As the temperature rises, the solubility decreases. When the maximum amount of solid has dissolved at a particular temperature the solution is said to be **saturated**.

In an experiment, the solubility of calcium hydroxide was measured over a range of temperatures. The results are shown in the graph.



(a) Use data from the graph to calculate the concentration, in mol dm^{-3}, of a saturated solution of calcium hydroxide at 30 °C. Give your answer to 3 significant figures.

Show your working.

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(3)

(b) You are given a sample of saturated calcium hydroxide solution. Outline the practical steps that you would take to determine the solubility of calcium hydroxide in this solution.

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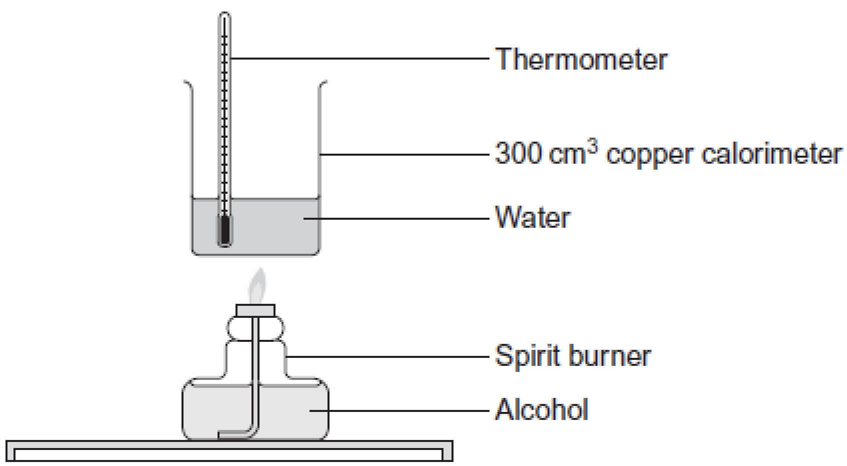
(3)
(Total 6 marks)

7 A value for the enthalpy of combustion of an alcohol can be determined using the apparatus shown in the diagram. The calorimeter is held in position by a clamp.



This experiment can be repeated by using a different volume of water that would result in a more accurate value for the enthalpy of combustion because there would be a reduction in the heat lost.

State a change in the volume of water that would cause a reduction in heat loss and explain your answer.

Change in volume: ....

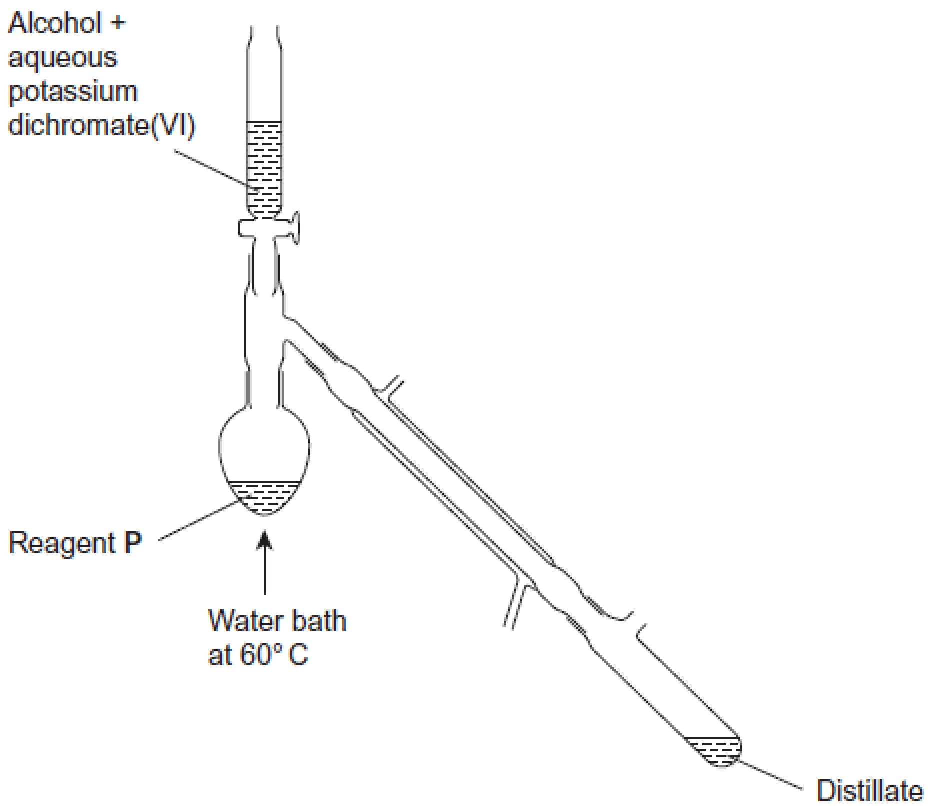
Explanation: ....

....

(Total 2 marks)

8 This question concerns the oxidation of a primary alcohol.

The experiment was carried out using the distillation apparatus shown in the diagram.
The oxidation product was distilled off as soon as it was formed.



(a) Suggest the identity of reagent **P**.

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(1)

(b) State the chemical change that causes the solution in the flask to appear green at the end of the reaction.

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(1)

(c) Give **one** reason why using a water bath is better than direct heating with a Bunsen burner.

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(1)

(d) Suggest a reagent that could be used to confirm the presence of an aldehyde in the distillate.
State the observation you would expect to make if an aldehyde were present.

Reagent ....

Observation ....

(2)
(Total 5 marks)

9 (a) A sample of solid chromium(III) hydroxide displays amphoteric character when treated separately with dilute hydrochloric acid and with dilute aqueous sodium hydroxide.

Write an ionic equation for each of these reactions. Include the formula of each complex ion formed.
Describe the changes that you would observe in each reaction.

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(5)

(b) Aqueous solutions of copper(II) sulfate and cobalt(II) sulfate undergo ligand substitution reactions when treated separately with an excess of dilute aqueous ammonia.

Write equations for these reactions. Include the formulae for any complex ions. Describe the changes that you would observe in each reaction.

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(6)
(Total 11 marks)

10 A green solution, **X**, is thought to contain $[Fe(H_2O)_6]^{2+}$ ions.

(a) The presence of these ions can be confirmed by reacting separate samples of solution **X** with aqueous ammonia and with aqueous sodium carbonate.

Write equations for each of these reactions and describe what you would observe.

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(4)

(b) A 50.0 cm^3 sample of solution **X** was added to 50 cm^3 of dilute sulfuric acid and made up to 250 cm^3 of solution in a volumetric flask.

A 25.0 cm^3 sample of this solution from the volumetric flask was titrated with a 0.0205 mol dm^{-3} solution of $KMnO_4$
At the end point of the reaction, the volume of $KMnO_4$ solution added was 18.70 cm^3.

(i) State the colour change that occurs at the end point of this titration and give a reason for the colour change.

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(2)

(ii) Write an equation for the reaction between iron(II) ions and manganate(VII) ions.

Use this equation and the information given to calculate the concentration of iron(II) ions in the original solution **X**.

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(5)
(Total 11 marks)

11 N-phenylethanamide is used as an inhibitor in hydrogen peroxide decomposition and also in the production of dyes.

N-phenylethanamide can be produced in a laboratory by the reaction between phenylammonium sulfate and an excess of ethanoic anhydride:

(a) A student carried out this preparation using 1.15 g of phenylammonium sulfate (M_r = 284.1) and excess ethanoic anhydride.

$$(C_6H_5NH_3)_2SO_4 + 2(CH_3CO)_2O \rightarrow 2C_6H_5NHCOCH_3 + 2CH_3COOH + H_2SO_4$$

(i) Calculate the maximum theoretical yield of N−phenylethanamide that could be produced in the reaction. Record your answer to an appropriate precision.

Show your working.

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(3)

(ii) In the preparation, the student produced 0.89 g of N−phenylethanamide.

Calculate the percentage yield for the reaction.

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(1)

(b) The student purified the crude solid product, N−phenylethanamide, by recrystallisation.

(i) Outline the method that the student should use for this recrystallisation.

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(4)

(ii) Outline how you would carry out a simple laboratory process to show that the recrystallised product is a pure sample of N−phenylethanamide.

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(3)

(iii) Assume that the reaction goes to completion.

Suggest **two** practical reasons why the percentage yield for this reaction may **not** be 100%.

1 ....

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2 ....

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(2)

(c) The reaction to form N−phenylethanamide would happen much more quickly if the student used ethanoyl chloride instead of ethanoic anhydride.

Explain why the student might prefer to use ethanoic anhydride, even though it has a slower rate of reaction.

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(2)
(Total 15 marks)

12 In a titration experiment, a good technique is essential for an accurate result to be obtained.

(a) Suggest a reason for removing the funnel after it has been used for filling the burette.

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(1)

(b) Suggest **one** other source of error in using the burette to carry out a titration.

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(1)

(c) During the titration, the inside of the conical flask is rinsed with distilled water.

Suggest why rinsing improves the accuracy of the titre.

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(1)

(d) Explain why adding this extra water does **not** change the volume of EDTA solution that is required in the titration.

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(1)
(Total 4 marks)

13 The maximum errors for the pipette and the burette are shown below. These errors take into account multiple measurements.

Pipette ± 0.05 cm^3
Burette ± 0.15 cm^3

Estimate the maximum percentage error in using each of these pieces of apparatus.

Use an average titre 24.25 cm^3 to calculate the percentage error in using the burette.

Show your working.

Pipette ....

....

Burette ....

....

(Total 2 marks)

14 A biocide is a chemical that kills bacteria. A biocide is added to prevent the growth of bacteria in the water used in vases of flowers. Household bleach contains aqueous chlorine and can be used as the biocide. The concentration of chlorine in vase water decreases with time. It was decided to investigate the rate of this decrease.

The following experimental method was used to determine the concentration of chlorine in vase water at different times.

- A sample of vase water was taken.
- An excess of potassium iodide solution was added to the sample.
- The chlorine in the sample oxidised the I^- ions to I_2
- The iodine was titrated with sodium thiosulfate ($Na_2S_2O_3$) solution.
- These steps were repeated using further samples taken from the vase water at hourly intervals.

(a) Suggest **two** reasons why the concentration of chlorine in the vase water decreases with time.

Reason 1 ....

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Reason 2 ....

....

(2)

(b) Suggest why this sampling technique has no effect on the rate at which the concentration of chlorine in the vase water decreases.

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(1)

(c) Why was it important to use an **excess** of potassium iodide solution?

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(1)

(d) Use the following standard electrode potential data to explain why I_2 oxidises $S_2O_3^{2-}$ under standard conditions.

$$\tfrac{1}{2}I_2 + e^- \longrightarrow I^- \qquad E^\ominus = +0.54\ \text{V}$$

$$\tfrac{1}{2}S_4O_6^{2-} + e^- \longrightarrow S_2O_3^{2-} \qquad E^\ominus = +0.09\ \text{V}$$

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(1)

(e) Deduce an ionic equation for the reaction between I_2 and $S_2O_3^{2-}$

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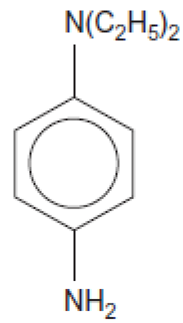
(1)
(Total 6 marks)

15 Chlorine can be found in water. One method for the determination of chlorine in water is to use colorimetry.

A colourless sample of water from a vase of flowers was analysed after the addition of compound Z as the addition of Z resulted in a purple solution.

Compound W



(a) Calculate the M_r of Compound **W**.

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(1)

(b) Determine the percentage, by mass, of nitrogen in this compound.

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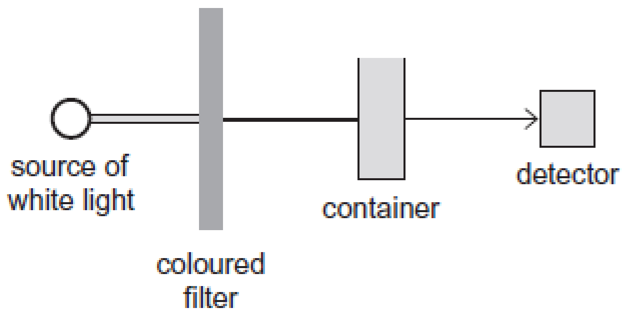
(1)

(c) A simplified diagram of a colorimeter is shown below.



(i) Suggest why it is important that the container for each sample has the same dimensions.

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(1)

(ii) Suggest why the coloured filter is used.

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(1)

(iii) Suggest **one** reason why a colorimetric method might be chosen in preference to titration.

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(1)
(Total 5 marks)

16 An experiment was carried out to determine the equilibrium constant, K_c, for the following reaction.

$$CH_3CH_2COOH + CH_3CH_2CH_2OH \rightleftharpoons CH_3CH_2COOCH_2CH_2CH_3 + H_2O$$

A student added measured volumes of propan-1-ol and propanoic acid to a conical flask. A measured volume of concentrated hydrochloric acid was added to the flask, which was then sealed.

After 1 week, the contents of the flask were poured into water and the solution was made up to a known volume.
This solution was titrated with standard sodium hydroxide solution.

(a) Explain how the student could determine the amount, in moles, of propan-1-ol added to the flask.

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(2)

(b) The titration described above gives the total amount of acid in the equilibrium mixture. Explain how, by carrying out a further experiment, the student could determine the amount of propanoic acid in the equilibrium mixture.

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(2)

(c) In a repeat experiment, the student failed to seal the flask that contained the equilibrium mixture.

Explain why this error would lead to the student obtaining an incorrect value for the equilibrium constant K_c

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(2)
(Total 6 marks)

17 This question is about the chemical properties of chlorine, sodium chloride and sodium bromide.

(a) Sodium bromide reacts with concentrated sulfuric acid in a different way from sodium chloride.

Write an equation for this reaction of sodium bromide and explain why bromide ions react differently from chloride ions.

Equation ....

Explanation ....

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....

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(3)

(b) A colourless solution contains a mixture of sodium chloride and sodium bromide.

Using aqueous silver nitrate and any other reagents of your choice, develop a procedure to prepare a pure sample of silver bromide from this mixture.
Explain each step in the procedure and illustrate your explanations with equations, where appropriate.

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(6)

(c) Write an ionic equation for the reaction between chlorine and cold dilute sodium hydroxide solution.
Give the oxidation state of chlorine in each of the chlorine-containing ions formed.

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(2)
(Total 11 marks)

18 This question is about reactions of calcium compounds.

(a) A pure solid is thought to be calcium hydroxide. The solid can be identified from its relative formula mass.

The relative formula mass can be determined experimentally by reacting a measured mass of the pure solid with an excess of hydrochloric acid. The equation for this reaction is

$$Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O$$

The unreacted acid can then be determined by titration with a standard sodium hydroxide solution.

You are provided with 50.0 cm^3 of 0.200 mol dm^{-3} hydrochloric acid.
Outline, giving brief practical details, how you would conduct an experiment to calculate accurately the relative formula mass of the solid using this method.

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(8)

(b) A 3.56 g sample of calcium chloride was dissolved in water and reacted with an excess of sulfuric acid to form a precipitate of calcium sulfate.

The percentage yield of calcium sulfate was 83.4%.

Calculate the mass of calcium sulfate formed.
Give your answer to an appropriate number of significant figures.

Mass of calcium sulfate formed = ... g

(3)
(Total 11 marks)

19 A student carried out an experiment to determine the number of C=C double bonds in a molecule of a cooking oil by measuring the volume of bromine water decolourised.

The student followed these instructions:

- Use a dropping pipette to add 5 drops of oil to 5.0 cm^3 of inert organic solvent in a conical flask.
- Use a funnel to fill a burette with bromine water.
- Add bromine water from a burette to the solution in the conical flask and swirl the flask after each addition to measure the volume of bromine water that is decolourised.

The student's results are shown in the table below.

Experiment	**Volume of bromine water / cm^3**
1	39.40
2	43.50
3	41.20

(a) In a trial experiment, the student failed to fill the burette correctly so that the gap between the tap and the tip of the burette still contained air.

Suggest what effect this would have on the measured volume of bromine water in this trial. Explain your answer.

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(2)

(b) Other than incorrect use of the burette, suggest a reason for the inconsistency in the student's results.

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(1)

(c) Outline how the student could improve this practical procedure to determine the number of C=C double bonds in a molecule of the oil so that more consistent results are obtained.

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(4)

(d) The oil has a density of 0.92 g cm^{-3} and each of the 5 drops of oil has a volume of 5.0×10^{-2} cm^3.
The approximate M_r of the oil is 885.
The concentration of bromine water used was 2.0×10^{-2} mol dm^{-3}.

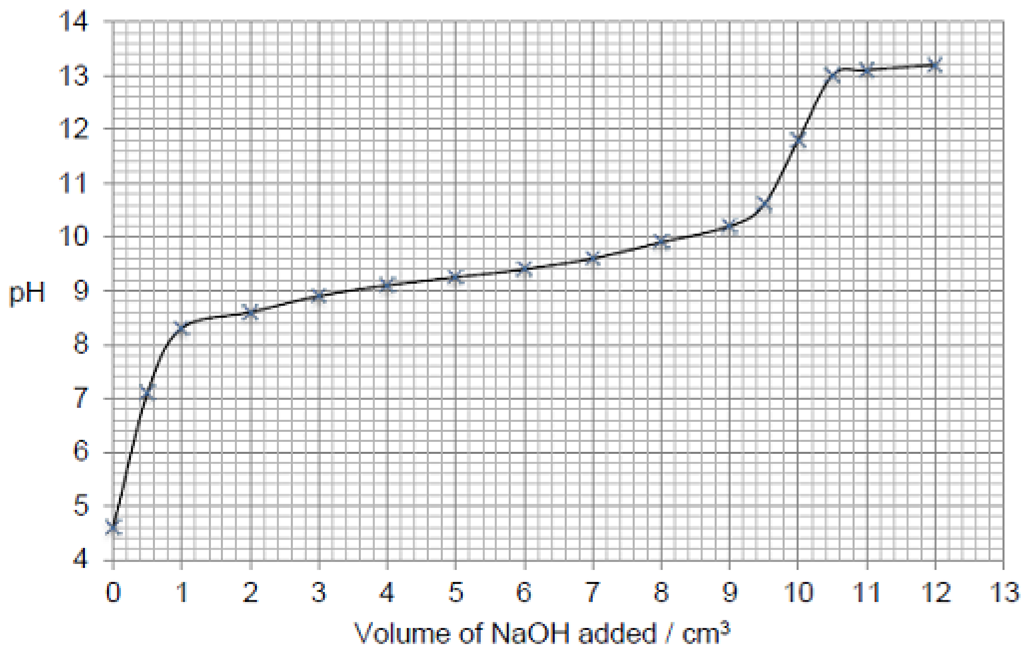
Use these data and the results from experiment **1** to deduce the number of C=C double bonds in a molecule of the oil.
Show your working.

(5)
(Total 12 marks)

20 Ammonium chloride, when dissolved in water, can act as a weak acid as shown by the following equation.

$$NH_4^+(aq) \rightleftharpoons NH_3(aq) + H^+(aq)$$

The following figure shows a graph of data obtained by a student when a solution of sodium hydroxide was added to a solution of ammonium chloride. The pH of the reaction mixture was measured initially and after each addition of the sodium hydroxide solution.



(a) Suggest a suitable piece of apparatus that could be used to measure out the sodium hydroxide solution.
Explain why this apparatus is more suitable than a pipette for this purpose.

Apparatus ....

Explanation ....

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(2)

(b) Use information from the curve in the figure above to explain why the end point of this reaction would be difficult to judge accurately using an indicator.

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(2)

(c) The pH at the end point of this reaction is 11.8.

Use this pH value and the ionic product of water, $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6}, to calculate the concentration of hydroxide ions at the end point of the reaction.

Concentration = ... mol dm^{-3}

(3)

(d) The expression for the acid dissociation constant for aqueous ammonium ions is

$$K_a = \frac{[NH_3][H^+]}{[NH_4^+]}$$

The initial concentration of the ammonium chloride solution was 2.00 mol dm^{-3}.

Use the pH of this solution, before any sodium hydroxide had been added, to calculate a value for K_a

K_a = ... mol dm^{-3}

(3)

(e) A solution contains equal concentrations of ammonia and ammonium ions.

Use your value of K_a from part **(d)** to calculate the pH of this solution. Explain your working.

(If you were unable to calculate a value for K_a you may assume that it has the value 4.75×10^{-9} mol dm^{-3}. This is **not** the correct value.)

pH= ....

(2)
(Total 12 marks)

21 A 5.00 g sample of potassium chloride was added to 50.0 g of water initially at 20.0 °C. The mixture was stirred and as the potassium chloride dissolved, the temperature of the solution decreased.

(a) Describe the steps you would take to determine an accurate minimum temperature that is **not** influenced by heat from the surroundings.

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(4)

(b) The temperature of the water decreased to 14.6 °C.

Calculate a value, in kJ mol^{-1}, for the enthalpy of solution of potassium chloride.

You should assume that only the 50.0 g of water changes in temperature and that the specific heat capacity of water is 4.18 J K^{-1} g^{-1}.
Give your answer to the appropriate number of significant figures.

Enthalpy of solution = ... kJ mol^{-1}

(4)

(c) The enthalpy of solution of calcium chloride is −82.9 kJ mol^{-1}.
The enthalpies of hydration for calcium ions and chloride ions are −1650 and −364 kJ mol^{-1}, respectively.

Use these values to calculate a value for the lattice enthalpy of dissociation of calcium chloride.

Lattice enthalpy of dissociation = ... kJ mol^{-1}

(2)

(d) Explain why your answer to part **(c)** is different from the lattice enthalpy of dissociation for magnesium chloride.

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(2)
(Total 12 marks)

22 The table below shows observations of changes from some test-tube reactions of aqueous solutions of compounds **Q**, **R** and **S** with five different aqueous reagents. The initial colours of the solutions are not given.

	$BaCl_2$ + HCl	$AgNO_3$ + HNO_3	NaOH	Na_2CO_3	HCl (conc)
Q	no change observed	pale cream precipitate	white precipitate	white precipitate	no change observed
R	no change observd	white precipitate	white precipitate, dissolves in excess of NaOH	white precipitate, bubbles of a gas	no change observed
S	white precipitate	no change observed	brown precipitate	brown precipitate, bubbles of a gas	yellow solution

(a) Identify each of compounds **Q**, **R** and **S**.
You are **not** required to explain your answers.

Identity of **Q** ....

....

Identity of **R** ....

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Identity of **S** ....

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(6)

(b) Write ionic equations for each of the positive observations with **S**.

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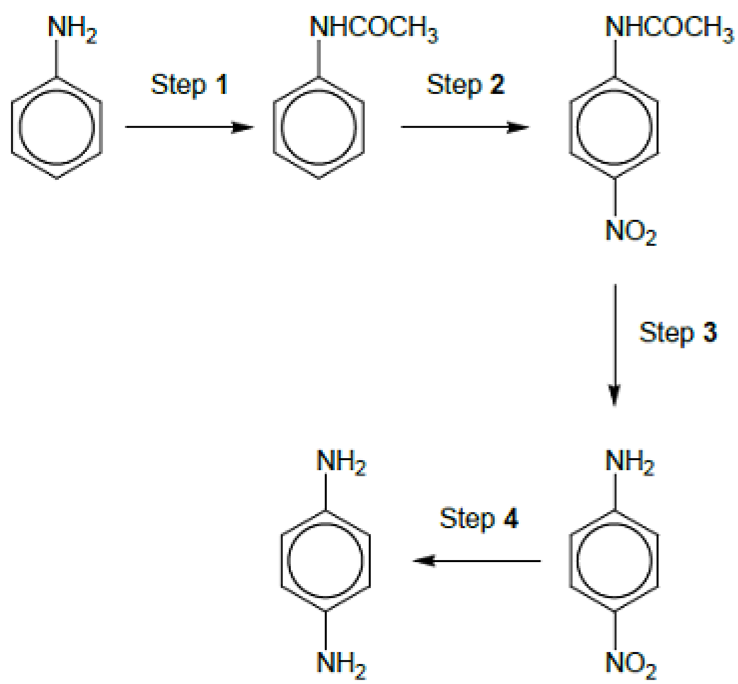
(4)
(Total 10 marks)

23 1,4-diaminobenzene is an important intermediate in the production of polymers such as Kevlar and also of polyurethanes, used in making foam seating.

A possible synthesis of 1,4-diaminobenzene from phenylamine is shown in the following figure.



(a) A suitable reagent for step **1** is CH_3COCl

Name and draw a mechanism for the reaction in step **1**.

Name of mechanism ....

Mechanism

(5)

(b) The product of step **1** was purified by recrystallisation as follows.

The crude product was dissolved in **the minimum quantity of hot water** and the hot solution was filtered through a hot filter funnel into a conical flask. This filtration removed any insoluble impurities. The flask was **left to cool to room temperature**.
The crystals formed were filtered off using a Buchner funnel and a clean cork was used **to compress the crystals in the funnel. A little cold water was then poured through the crystals.**
After a few minutes, the crystals were removed from the funnel and weighed.
A small sample was then used to find the melting point.

Give reasons for each of the following practical steps.

The minimum quantity of hot water was used

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The flask was cooled to room temperature before the crystals were filtered off

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The crystals were compressed in the funnel

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A little cold water was poured through the crystals

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(4)

(c) The melting point of the sample in part (b) was found to be slightly lower than a data-book value.

Suggest the most likely impurity to have caused this low value and an improvement to the method so that a more accurate value for the melting point would be obtained.

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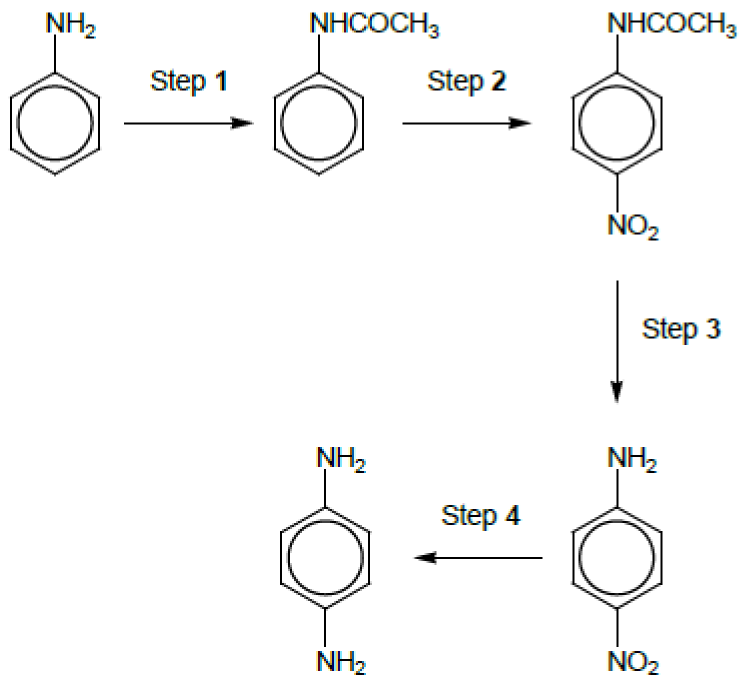
(2)

The figure above is repeated here to help you answer the following questions.



(d) In an experiment starting with 5.05 g of phenylamine, 4.82 g of purified product were obtained in step **1**.

Calculate the percentage yield in this reaction.
Give your answer to the appropriate number of significant figures.

Percentage yield = ...%

(3)

(e) A reagent for step **2** is a mixture of concentrated nitric acid and concentrated sulfuric acid, which react together to form a reactive intermediate.

Write an equation for the reaction of this intermediate in step **2**.

....

(1)

(f) Name a mechanism for the reaction in step **2**.

....

(1)

(g) Suggest the type of reaction occurring in step **3**.

....

(1)

(h) Identify the reagents used in step **4**.

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(1)
(Total 18 marks)

24 Ethanol can be oxidised by acidified potassium dichromate(VI) to ethanoic acid in a two-step process.

$$\text{ethanol} \longrightarrow \text{ethanal} \longrightarrow \text{ethanoic acid}$$

(a) In order to ensure that the oxidation to ethanoic acid is complete, the reaction is carried out under reflux.

Describe what happens when a reaction mixture is refluxed and why it is necessary, in this case, for complete oxidation to ethanoic acid.

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(3)

(b) Write a half-equation for the overall oxidation of ethanol into ethanoic acid.

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(1)

(c) The boiling points of the organic compounds in a reaction mixture are shown in the following table.

Compound	ethanol	ethanal	ethanoic acid
Boiling point / °C	78	21	118

Use these data to describe how you would obtain a sample of ethanal from a mixture of these three compounds. Include in your answer a description of the apparatus you would use and how you would minimise the loss of ethanal. Your description of the apparatus can be either a description in words or a labelled sketch.

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(5)

(d) Use your knowledge of structure and bonding to explain why it is possible to separate ethanal in this way.

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(2)

(e) A student obtained a sample of a liquid using the apparatus in part **(c)**.

Describe how the student could use chemical tests to confirm that the liquid contained ethanal and did **not** contain ethanoic acid.

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(5)
(Total 16 marks)

25 A peptide is hydrolysed to form a solution containing a mixture of amino acids. This mixture is then analysed by silica gel thin-layer chromatography (TLC) using a toxic solvent. The individual amino acids are identified from their R_f values.

Part of the practical procedure is given below.

1. **Wearing plastic gloves to hold a TLC plate**, draw a pencil line 1.5 cm from the bottom of the plate.
2. Use a capillary tube to apply a very small drop of the solution of amino acids to the mid-point of the pencil line.
3. Allow the spot to dry completely.
4. In the developing tank, add the developing solvent to **a depth of not more than 1 cm**.
5. Place your TLC plate in the developing tank.
6. Allow the developing solvent to rise up the plate **to the top**.
7. Remove the plate and quickly mark the position of the solvent front with a pencil.
8. Allow the plate to dry **in a fume cupboard**.

(a) Parts of the procedure are in bold text.

For each of these parts, consider whether it is essential and justify your answer.

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(4)

(b) Outline the steps needed to locate the positions of the amino acids on the TLC plate and to determine their R_f values.

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(4)

(c) Explain why different amino acids have different R_f values.

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(2)
(Total 10 marks)

26 The correct technique can improve the accuracy of a titration.

(a) State why it is important to fill the space below the tap in the burette with solution **A** before beginning an accurate titration.

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(1)

(b) Suggest **one** reason why a 250 cm^3 conical flask is preferred to a 250 cm^3 beaker for a titration.

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(1)

(c) During a titration, a chemist rinsed the inside of the conical flask with deionised water. The water used for rinsing remained in the conical flask.

(i) Give **one** reason why this rinsing can improve the accuracy of the end-point.

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(1)

(ii) Explain why the water used for rinsing has **no** effect on the accuracy of the titre.

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(1)

(d) Suggest **one** reason why repeating a titration makes the value of the average titre more reliable.

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(1)
(Total 5 marks)

27 (a) Strontium chloride is used in toothpaste for sensitive teeth.
Both strontium carbonate and strontium sulfate are white solids that are insoluble in water.

(i) Write an equation for the reaction between strontium chloride solution and sodium sulfate solution.
Include state symbols in your equation.

....

(1)

(ii) Strontium carbonate reacts with nitric acid to produce a solution of strontium nitrate. Strontium sulfate does not react with nitric acid.

Describe briefly how you could obtain strontium sulfate from a mixture of strontium carbonate and strontium sulfate.
You are **not** required to describe the purification of the strontium sulfate.

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(2)

(b) A solution of magnesium sulfate is sometimes given as first aid to someone who has swallowed barium chloride.

Explain why drinking magnesium sulfate solution is effective in the treatment of barium poisoning.

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(1)

(c) Medicines for the treatment of nervous disorders often contain calcium bromide.
Silver nitrate, acidified with dilute nitric acid, can be used together with another reagent to test for the presence of bromide ions in a solution of a medicine.

Describe briefly how you would carry out this test and state what you would observe.

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(3)
(Total 7 marks)

28 (a) Anhydrous strontium chloride is not used in toothpaste because it absorbs water from the atmosphere. The hexahydrate, $SrCl_2.6H_2O$, is preferred.

A chemist was asked to determine the purity of a sample of strontium chloride hexahydrate. The chemist weighed out 2.25 g of the sample and added it to 100 cm^3 of water. The mixture was warmed and stirred for several minutes to dissolve all of the strontium chloride in the sample. The mixture was then filtered into a conical flask. An excess of silver nitrate solution was added to the flask and the contents swirled for 1 minute to make sure that the precipitation was complete.

The silver chloride precipitate was separated from the mixture by filtration. The precipitate was washed several times with deionised water and dried carefully. The chemist weighed the dry precipitate and recorded a mass of 1.55 g.

(i) Calculate the amount, in moles, of AgCl in 1.55 g of silver chloride (M_r = 143.4).

....

(1)

(ii) The equation for the reaction between strontium chloride and silver nitrate is

$$SrCl_2 + 2AgNO_3 \longrightarrow 2AgCl + Sr(NO_3)_2$$

Use your answer from part (i) and this equation to calculate the amount, in moles, of $SrCl_2$ needed to form 1.55 g of silver chloride.

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(1)

(iii) Use data from the Periodic Table to calculate the M_r of strontium chloride hexahydrate. Give your answer to 1 decimal place.

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(1)

(iv) Use your answers from parts (a)(ii) and (a)(iii) to calculate the percentage by mass of strontium chloride hexahydrate in the sample. Show your working.
Give your answer to the appropriate precision.

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(2)

(v) Several steps in the practical procedure were designed to ensure an accurate value for the percentage by mass of strontium chloride hexahydrate in the sample.

1 Explain why the solution of strontium chloride was filtered to remove insoluble impurities before the addition of silver nitrate.

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(1)

2 Explain why the precipitate of silver chloride was washed several times with deionised water.

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(1)

(b) Magnesium hydroxide and magnesium carbonate are used to reduce acidity in the stomach. Magnesium hydroxide can be prepared by the reaction of solutions of magnesium chloride and sodium hydroxide.

(i) Write the **simplest ionic** equation for the reaction that occurs between magnesium chloride and sodium hydroxide.
Include state symbols in your equation.

....

(1)

(ii) Other than cost, explain one advantage of using magnesium hydroxide rather than magnesium carbonate to reduce acidity in the stomach.

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....

(1)

(c) Calcium ethanoate, $(CH_3COO)_2Ca$, is used in the treatment of kidney disease.
Thermal decomposition of calcium ethanoate under certain conditions gives propanone and **one** other product.

Write an equation for the thermal decomposition of calcium ethanoate.

....

(1)

(d) Salts containing the chromate(VI) ion are usually yellow in colour.
Calcium chromate(VI) is soluble in water.
Strontium chromate(VI) is insoluble in water, but will dissolve in a solution of ethanoic acid.
Barium chromate(VI) is insoluble in water and is also insoluble in a solution of ethanoic acid.

Describe a series of tests using solutions of sodium chromate(VI) and ethanoic acid that would allow you to distinguish between separate solutions of calcium chloride, strontium chloride and barium chloride.
State what you would observe in each test.

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(3)

(e) The strontium salt of ranelic acid is used to promote bone growth. Analysis of a pure sample of ranelic acid showed that it contained 42.09% of carbon, 2.92% of hydrogen, 8.18% of nitrogen, 37.42% of oxygen and 9.39% of sulfur by mass.

Use these data to calculate the empirical formula of ranelic acid.
Show your working.

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(2)
(Total 15 marks)

29 The alcohol 2-methylpropan-2-ol, $(CH_3)_3COH$, reacts to form esters that are used as flavourings by the food industry. The alcohol can be oxidised to produce carbon dioxide and water.

A student carried out an experiment on a pure sample of 2-methylpropan-2-ol to determine its enthalpy of combustion. A sample of the alcohol was placed into a spirit burner and positioned under a beaker containing 50 cm^3 of water. The spirit burner was ignited and allowed to burn for several minutes before it was extinguished.

The results for the experiment are shown in **Table 1**.

Table 1

Initial temperature of the water / °C	18.1
Final temperature of the water / °C	45.4
Initial mass of spirit burner and alcohol / g	208.80
Final mass of spirit burner and alcohol / g	208.58

(a) Use the results from **Table 1** to calculate a value for the heat energy released from the combustion of this sample of 2-methylpropan-2-ol.

The specific heat capacity of water is 4.18 J K^{-1} g^{-1}.
Show your working.

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(2)

(b) Calculate the amount, in moles, of 2-methylpropan-2-ol burned in the experiment.

Hence calculate a value, in kJ mol^{-1}, for the enthalpy of combustion of 2-methylpropan-2-ol.
Show your working.

(If you were unable to calculate an answer to part (a), you should assume that the heat energy released was 5580 J. This is **not** the correct value.)

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(3)

(c) An equation for the combustion of 2-methylpropan-2-ol is

$$(CH_3)_3COH(l) + 6O_2(g) \longrightarrow 4CO_2(g) + 5H_2O(l)$$

Table 2 contains some standard enthalpy of formation data.

Table 2

	$(CH_3)_3COH(l)$	$O_2(g)$	$CO_2(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–360	0	–393	–286

Use the data from **Table 2** to calculate a value for the standard enthalpy of combustion of 2-methylpropan-2-ol. Show your working.

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(3)

(d) An accurate value for the enthalpy of combustion of 2-methylpropan-2-ol in which water is formed as a gas is –2422 kJ mol^{-1}.

Use this value and your answer from part (b) to calculate the overall percentage error in the student's experimental value for the enthalpy of combustion of 2-methylpropan-2-ol.

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(1)

(e) Suggest **one** improvement that would reduce errors due to heat loss in the student's experiment.

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(1)

(f) Suggest **one** other source of error in the student's experiment. Do **not** include heat loss, apparatus error or student error.

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(1)

(Total 11 marks)

30 A sample of 2-methylpropan-2-ol was contaminated with butan-2-ol. The student separated the two alcohols using chromatography.

Identify a reagent or combination of reagents that the student could use to distinguish between these alcohols. State what would be observed for each alcohol.

Reagent(s) ....

Observation with 2-methylpropan-2-ol ....

....

....

Observation with butan-2-ol ....

....

....

(Total 3 marks)

31 A student investigated how the initial rate of reaction between sulfuric acid and magnesium at 20 °C is affected by the concentration of the acid.

The equation for the reaction is

$$H_2SO_4(aq) + Mg(s) \longrightarrow MgSO_4(aq) + H_2(g)$$

(a) The student made measurements every 20 seconds for 5 minutes. The student then repeated the experiment using double the concentration of sulfuric acid.

State a measurement that the student should make every 20 seconds. Identify the apparatus that the student could use to make this measurement.

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(2)

(b) State **one** condition, other than temperature and pressure, that would need to be kept constant in this investigation.

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(1)

(c) When the student had finished the investigation, an excess of sodium hydroxide solution was added to the reaction mixture. This was to neutralise any unreacted sulfuric acid. The student found that a further reaction took place, producing magnesium hydroxide.

(i) Draw a diagram to show how the student could separate the magnesium hydroxide from the reaction mixture.

(2)

(ii) Suggest **one** method the student could use for removing soluble impurities from the sample of magnesium hydroxide that has been separated.

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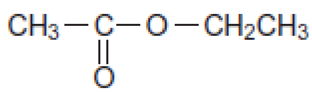
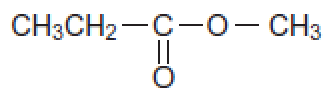
(1)
(Total 6 marks)

32 (a) **Ester 1** and **Ester 2** were studied by ^{1}H n.m.r. spectroscopy.

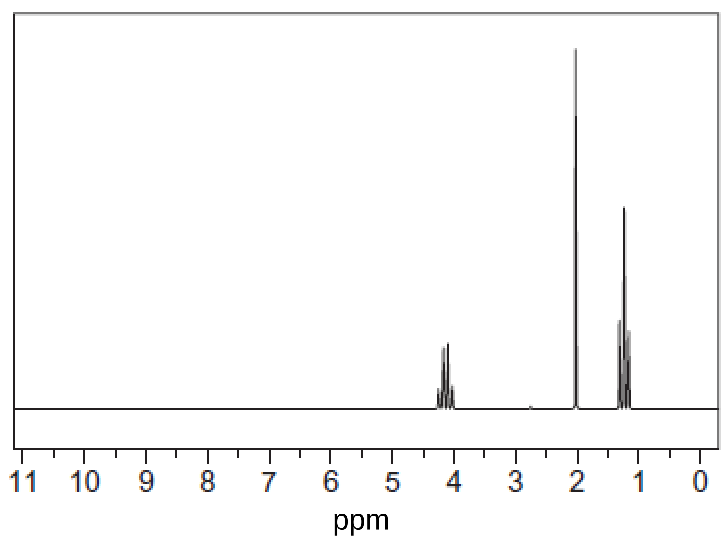


Ester 1



Ester 2

One of the two esters produced this spectrum.



Deduce which of the two esters produced the spectrum shown. In your answer, explain the position and splitting of the quartet peak at δ = 4.1 ppm in the spectrum.

Predict the δ value of the quartet peak in the spectrum of the other ester.

Use **Table B** on the Data Sheet.

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(4)

(b) Cetrimide is used as an antiseptic.

$$[CH_3(CH_2)_{15}N(CH_3)_3]^+ Br^-$$

cetrimide

Name this type of compound.

Give the reagent that must be added to $CH_3(CH_2)15NH_2$ to make cetrimide and state the reaction conditions.

Name the type of mechanism involved in this reaction.

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(4)

(c) Give a reagent that could be used in a test-tube reaction to distinguish between benzene and cyclohexene.
Describe what you would see when the reagent is added to each compound and the test tube is shaken.

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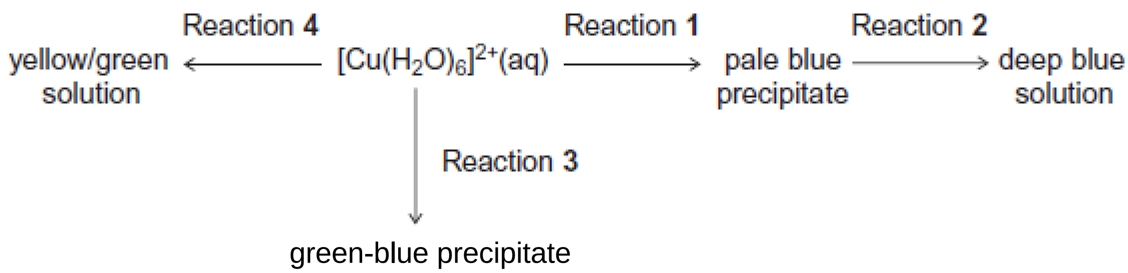
(3)
(Total 11 marks)

33 Consider the following reaction scheme that starts from aqueous $[Cu(H_2O)6]^{2+}$ ions.



For each of the reactions **1** to **4**, identify a suitable reagent, give the formula of the copper-containing species formed and write an equation for the reaction.

(a) Reaction **1**

Reagent ....

Copper-containing species ....

Equation ....

(3)

(b) Reaction **2**

Reagent ....

Copper-containing species ....

Equation ....

(3)

(c) Reaction **3**

Reagent ....

Copper-containing species ....

Equation ....

(3)

(d) Reaction **4**

Reagent ....

Copper-containing species ....

Equation ....

(3)

(Total 12 marks)

34 In an experiment to determine the acid dissociation constant (K_a) of a weak acid, 25.0 cm^3 of an approximately 0.1 mol dm^{-3} solution of this acid were titrated with a 0.10 mol dm^{-3} solution of sodium hydroxide.

The pH was measured at intervals and recorded. The table below shows the results.

Volume of NaOH / cm^3	0.0	1.0	2.0	3.0	4.0	5.0	10.0	15.0
pH	5.1	7.8	8.1	8.7	8.4	8.5	8.9	9.3

Volume of NaOH / cm^3	20.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0
pH	9.7	10.0	10.2	11.0	11.3	11.4	11.5	11.6

(a) On the grid below, plot the values from the table above on a graph of pH (y-axis) against volume of NaOH.
You should start your y-axis at pH 4.0.
Draw a curve that represents the curve of best fit through these points. Ignore any anomalous points.

(4)

(b) Deduce the volume of the sodium hydroxide solution that would have been added at the half-neutralisation point of this experiment. This is the point where half the amount of the weak acid has been neutralised.

....

(1)

(c) When half of the weak acid has been neutralised, the pH of the mixture at this point is equal to the pK_a of the weak acid.

Use your answer to part (b) and your graph to determine the pK_a of the weak acid and, hence, its K_a value.

pK_a ....

K_a ....

(2)

(d) State the pH value for the anomalous point on your graph.
Suggest **one** reason for this anomaly. Assume that the reading on the pH meter is correct.

pH ....

Reason for anomaly ....

....

....

(1)

(e) Suggest how the experimental procedure could be slightly modified in order to give a more reliable value for the end-point.

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(1)
(Total 9 marks)

35 Ethanoic acid, propyl ethanoate and propan-1-ol are all colourless liquids. Esters do **not** give a positive result with any of the usual tests for functional groups.

State how you could use chemical tests to show the presence of ethanoic acid and propan-1-ol in a mixture of the acid, the alcohol and the ester.

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(Total 4 marks)

36 In a test, aqueous iron(III) ions are reduced to aqueous iron(II) ions by iodide ions.
This reaction could be used to provide electrical energy in a cell.

(a) The standard electrode potential for the reduction of iron(III) ions into iron(II) ions can be measured by connecting a suitable electrode to a standard hydrogen electrode.
Draw a clearly labelled diagram to show the components and reagents, including their concentrations, in this Fe(III)/Fe(II) electrode.
Do **not** draw the salt bridge or the standard hydrogen electrode.

(3)

(b) A salt bridge is used to complete the cell. This could be prepared using potassium nitrate solution and filter paper.

State the purpose of the salt bridge. State **one** essential requirement of the soluble ionic compound used to make the salt bridge.

Purpose of salt bridge ....

....

Requirement ....

....

(2)

(Total 5 marks)

37 One cell that has been used to provide electrical energy is the Daniell cell. This cell uses copper and zinc.

(a) The conventional representation for the Daniell cell is

$$Zn(s) \mid Zn^{2+}(aq) \mid \mid Cu^{2+}(aq) \mid Cu(s)$$

The e.m.f. of this cell under standard conditions is +1.10 V.

Deduce the half-equations for the reactions occurring at the electrodes.

At Zn electrode ....

At Cu electrode ....

(2)

(b) A Daniell cell was set up using 100 cm^3 of a 1.0 mol dm^{-3} copper(II) sulfate solution. The cell was allowed to produce electricity until the concentration of the copper(II) ions had decreased to 0.50 mol dm^{-3}.

Calculate the decrease in mass of the zinc electrode. Show your working.

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(3)

(c) You are provided with the Daniell cell referred to in part (b), including a zinc electrode of known mass.

Briefly outline how you would carry out an experiment to confirm your answer to part (b).

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(3)
(Total 8 marks)

38 When iodine molecules are dissolved in aqueous solutions containing iodide ions, they react to form triiodide ions (I_3^-).

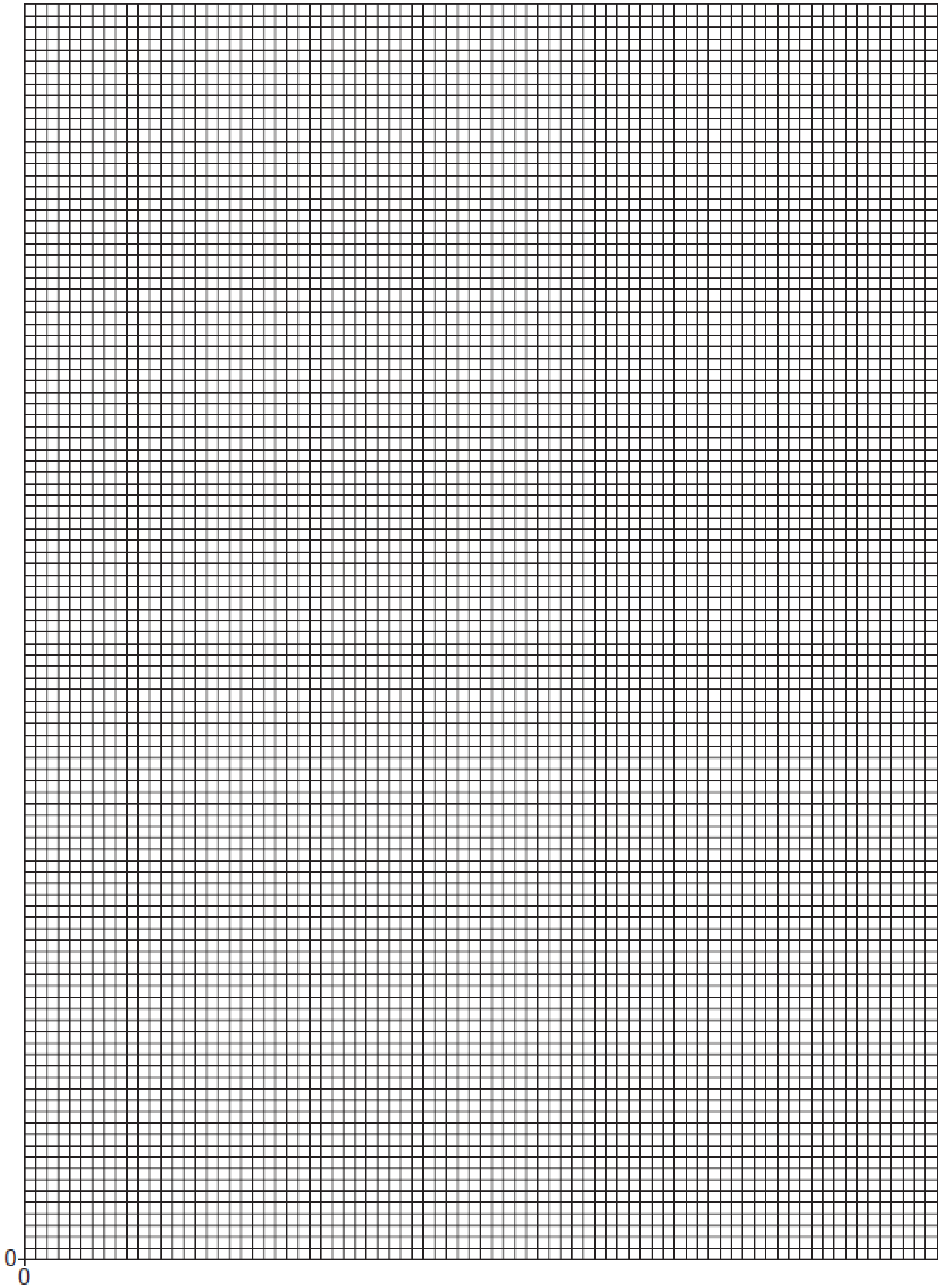
$$I_2 + I^- \longrightarrow I_3^-$$

The rate of the oxidation of iodide ions to iodine by peroxodisulfate(VI) ions ($S_2O_8^{2-}$) was studied by measuring the concentration of the I_3^- ions at different times, starting at time = 0, when the reactants were mixed together. The concentration of the I_3^- ions was determined by measuring the absorption of light using a spectrometer.

The table below shows the results.

Time / s	**Concentration of I_3^- / mol dm^{-3}**
10	0.23
20	0.34
30	0.39
40	0.42
50	0.47
60	0.44
70	0.45

(a) Plot the values of the concentration of I_3^- (y-axis) against time on the grid below.



(2)

(b) A graph of these results should include an additional point. On the grid, draw a ring around this additional point.

(1)

(c) Draw a best-fit curve on the grid, **including the extra point from part (b)**.

(2)

(d) Draw a tangent to your curve at time = 30 seconds. Calculate the slope (gradient) of this tangent and hence the rate of reaction at 30 seconds. Include units with your final answer. Show your working.

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....

(4)
(Total 9 marks)

39 (a) During the preparation of aspirin, it is necessary to filter the crude product under reduced pressure.

Draw a diagram to show the apparatus you would use to filter the crude product under reduced pressure. (Do **not** include the vacuum pump.)

(2)

(b) You are provided with a small sample of pure aspirin in a melting point tube. Describe briefly how you would determine an accurate value for the melting point of aspirin.

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....

....

(2)
(Total 4 marks)

40 In a titration, it is important to wash the inside of the titration flask with distilled or deionised water as you approach the end-point.

(a) Suggest **one** reason why it is important to wash the inside of the flask.

....

....

....

(1)

(b) Washing with water decreases the concentration of the reagents in the titration flask.

Suggest why washing with water does **not** affect the titre value.

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(1)
(Total 2 marks)

41 The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair, give a suitable reagent that could be added separately to each compound to distinguish between them.
Describe what you would observe in each case.

(a) $AgBr(s)$ and $AgI(s)$

Reagent ....

Observation with $AgBr(s)$..

....

Observation with $AgI(s)$ ....

....

(3)

(b) $HCl(aq)$ and $HNO_3(aq)$

Reagent ....

Observation with $HCl(aq)$ ....

....

Observation with $HNO_3(aq)$ ....

....

(3)

(c) Cyclohexane and cyclohexene

Reagent ....

Observation with cyclohexane ....

....

Observation with cyclohexene ....

....

(3)

(d) Butanal and butanone

Reagent ....

Observation with butanal ....

....

Observation with butanone ....

....

(3)
(Total 12 marks)

42 There is an experimental method for determining the number of water molecules in the formula of hydrated sodium carbonate. This method involves heating a sample to a temperature higher than 300 °C and recording the change in mass of the sample. The equation for the reaction taking place is

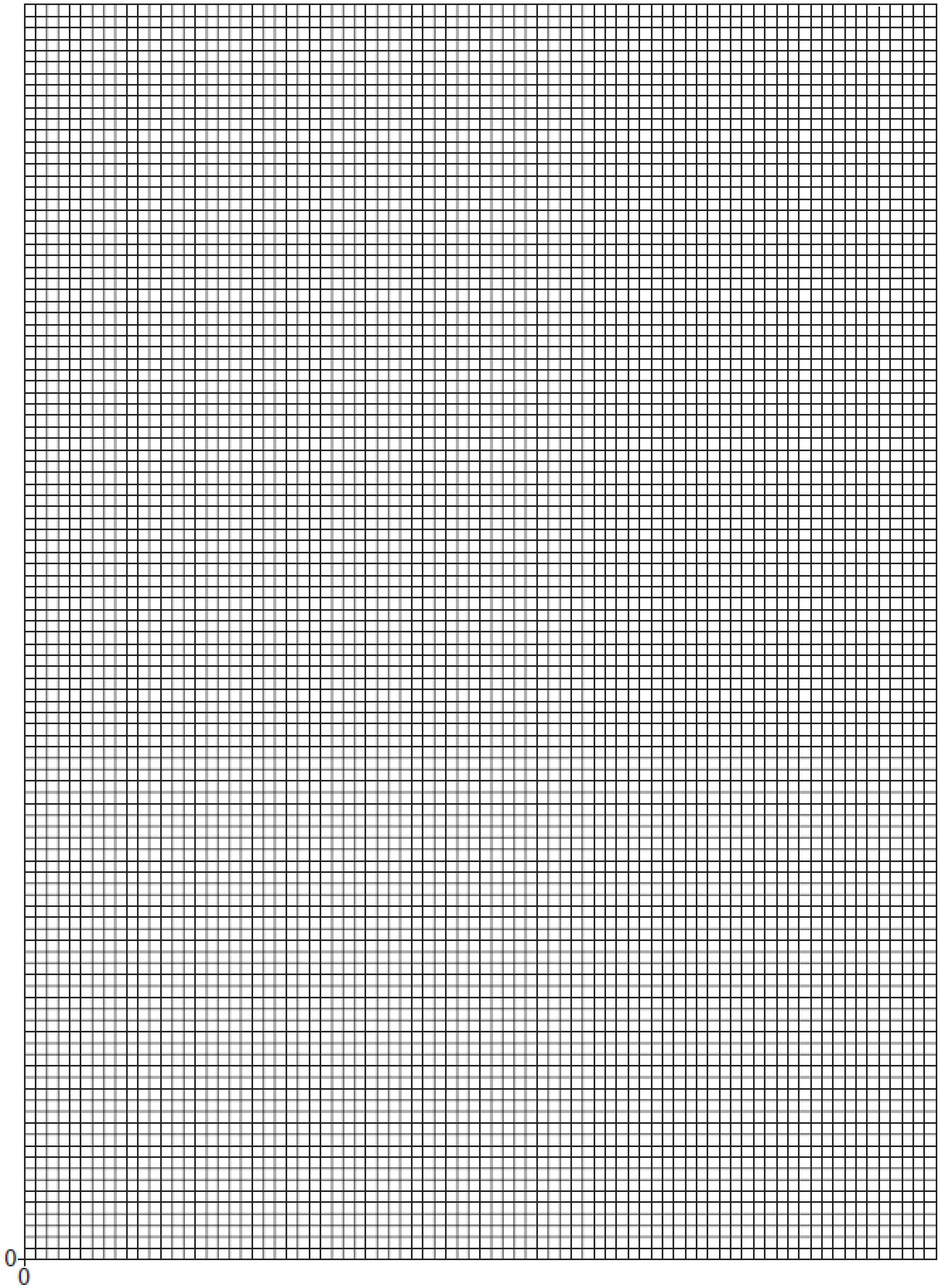
$$Na_2CO_3.10H_2O(s) \longrightarrow Na_2CO_3(s) + 10H_2O(g)$$

A group of six students carried out this experiment. They each weighed out a sample of hydrated sodium carbonate. They then heated their sample to a temperature higher than 300 °C in a crucible for ten minutes and recorded the final mass after the crucible had cooled. Their results are summarised in the table.

Student	1	2	3	4	5	6
Initial mass / g	2.43	1.65	3.58	1.09	2.82	1.95
Final mass / g	0.90	0.61	1.53	0.40	1.15	0.72

(a) Plot the values of **Initial mass** (*y*-axis) against **Final mass** on the grid below.

A graph of these results should include an additional point.
Draw a circle on the grid around the additional point that you should include.



(4)

(b) Draw a best-fit straight line for these results that includes your additional point.

(1)

(c) Identify each student whose experiment gave an anomalous result.

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(1)

(d) All the students carried out the experiment exactly according to this method.
Explain why a student that you identified in part (c) obtained an anomalous result.

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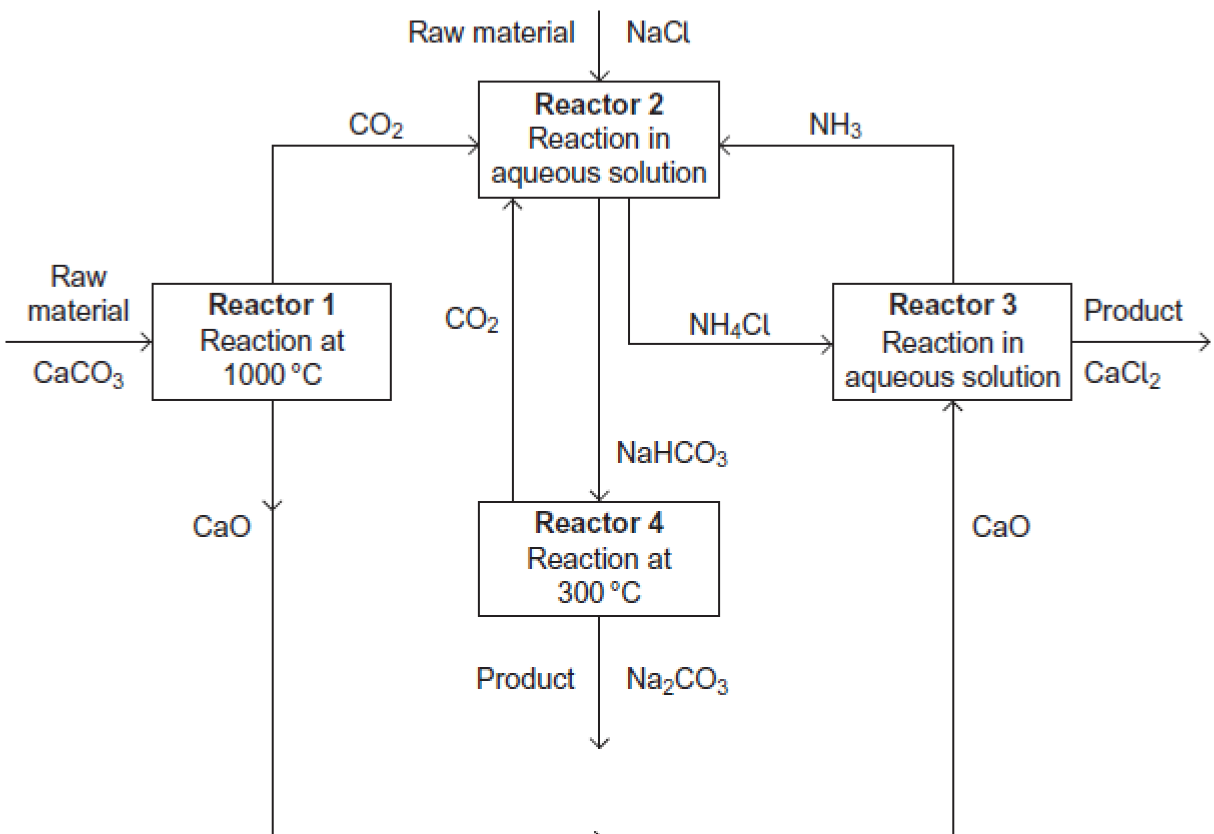
(2)
(Total 8 marks)

43 Sodium carbonate is manufactured by the Solvay Process.

The separate stages involved in this process are shown in this diagram.



(a) In **Reactor 1**, calcium carbonate is decomposed into calcium oxide and carbon dioxide. Despite no significant leakage of carbon dioxide from this decomposition, this part of the process results in an increase in carbon dioxide in the atmosphere.

State why this increase in carbon dioxide occurs.

....

....

(1)

(b) In **Reactor 2**, sodium chloride solution, carbon dioxide and ammonia react to form sodium hydrogencarbonate and ammonium chloride.

Write an equation for this reaction.

....

(1)

(c) Use information from the diagram to deduce an equation for the reaction taking place in **Reactor 3**.

....

....

(1)

(d) An equation for the overall reaction in the Solvay Process is

$$2NaCl(aq) + CaCO_3(s) \longrightarrow Na_2CO_3(s) + CaCl_2(aq)$$

(i) Calculate the percentage atom economy of this reaction to produce sodium carbonate. Show your working.

....

....

....

(2)

(ii) State what could be done to improve the percentage atom economy of the Solvay Process.

....

....

(1)

(e) Use information from the diagram to suggest why ammonia is **not** regarded as a raw material in the Solvay Process.

....

....

(1)
(Total 7 marks)

44 Baking powder contains sodium hydrogencarbonate and an acid or a mixture of acids. One acid that may be in baking powder is 2,3-dihydroxybutanedioic acid. This has the molecular formula $C_4H_6O_6$ and it is often referred to as tartaric acid.

(a) Draw the structural formula of tartaric acid.

(1)

(b) Write an equation for the reaction of tartaric acid ($C_4H_6O_6$) with sodium hydrogencarbonate to form a salt, carbon dioxide and water.

....

(1)

(c) Substances that contain carbonate or hydrogencarbonate ions can be used to confirm the presence of an acid.

Identify **one** other substance that could be used to confirm the presence of acid groups in tartaric acid.
State the observation you would make when this other substance is added to an aqueous solution of tartaric acid.

Substance ....

Observation ....

....

....

(2)

(d) It is known that tartaric acid contains alcohol and carboxylic acid functional groups only. A test can be used to show that tartaric acid contains secondary alcohol groups, **not** tertiary alcohol groups.

(i) Identify a reagent for this test and state the observation you would make for each type of alcohol.

Reagent ....

....

Observation for secondary alcohol ....

....

Observation for tertiary alcohol ....

....

(3)

(ii) Suggest why this test **cannot** be used to distinguish between a primary alcohol and a secondary alcohol.

....

....

(1)

(e) Baking powder usually contains starch. Starch is added to absorb any water vapour that may come into contact with the baking powder when the container is opened.

Deduce a reason why this water vapour needs to be absorbed.

....

....

....

....

(1)

(f) Sodium hydrogencarbonate in baking powder forms carbon dioxide during the production of bread and cakes.

Suggest **one** advantage of having an acid in baking powder.

....

....

(1)

(g) Safety information indicates that tartaric acid and its salts can act as muscle toxins. These can cause paralysis and possible death.

Suggest **one** reason why the use of tartaric acid in baking powder is **not** a hazard to health.

....

....

(1)
(Total 11 marks)

45 Read the following instructions that describe how to make up a standard solution of a solid in a volumetric flask.
Answer the questions which follow.

'Take a clean 250 cm ^{3} volumetric flask. Use the balance provided and a clean, dry container, to weigh out the amount of solid required. Tip the solid into a clean, dry 250 cm^3 beaker and add about 100 cm^3 of distilled water. Use a stirring rod to help the solid dissolve, carefully breaking up any lumps of solid with the rod. When the solid has dissolved, pour the solution into the flask using a filter funnel. Add water to the flask until the level rises to the graduation mark.'

(a) Suggest **three** further instructions that would improve the overall technique in this account.

1 ....

....

....

2 ....

....

....

3 ....

....

....

(3)

(b) In a series of titrations using the solution made up in part (a), a student obtained the following titres (all in cm^3).

Rough	1	2
25.7	25.20	25.35

State what this student must do in order to obtain an accurate average titre in this experiment.

....

....

....

....

(2)
(Total 5 marks)

46 Barium chloride solution was added, dropwise, to magnesium sulfate solution until no more white precipitate was formed. The mixture was filtered.

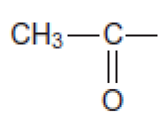
Give the formulae of the **two** main ions in the filtrate.

....

....

(Total 1 mark)

47 The triiodomethane reaction is often used as a test for aldehydes and ketones that contain the CH_3CO group shown.



The aldehyde or ketone is reacted with an alkaline solution of iodine. Triiodomethane (CHI_3) is formed as a precipitate. Compounds that contain a group that can be oxidised to the CH_3CO group will also give a positive result in this test.

(a) State, with a reason, whether or not ethanol will give a positive result in the triiodomethane reaction.

....

....

....

(1)

(b) The equation for the reaction of ethanal with an alkaline solution of iodine is

$CH_3CHO + 3I_2 + 4NaOH \longrightarrow CHI_3 + HCOONa + 3NaI + 3H_2O$

In an experiment using this reaction, the yield of triiodomethane (CHI_3) obtained by a student was 83.2%.

Calculate the minimum mass of iodine that this student would have used to form 10.0 g of triiodomethane.
Give your answer to the appropriate precision.
Show your working.

....

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....

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....

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....

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....

....

(5)

(c) Triiodomethane can be separated from the reaction mixture by filtration.
State **one** reason why the solid residue is then washed with water after the filtration.

....

....

(1)

(d) State **one** reason, other than cost or availability, why water is suitable for washing this solid residue after the filtration.

....

....

(1)
(Total 8 marks)

48 In order to obtain a pH curve, you are provided with a conical flask containing 25.0 cm^3 of a 0.100 mol dm^{-3} carboxylic acid solution and a burette filled with 0.100 mol dm^{-3} sodium hydroxide solution. You are also provided with a calibrated pH meter.

(a) State why calibrating a pH meter just before it is used improves the accuracy of the pH measurement.

....

....

(1)

(b) Describe how you would obtain the pH curve for the titration.

....

....

....

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....

....

(5)
(Total 6 marks)

49 Iron(II) ethanedioate is another insoluble solid used as a pigment in paints and glass. It occurs as a dihydrate ($FeC_2O_4.2H_2O$). One procedure used for the preparation of iron(II) ethanedioate is outlined below.

Procedure

A 6.95 g sample of hydrated iron(II) sulfate ($FeSO_4.7H_2O$) was added to 100 cm^3 of water in a beaker and stirred until all of the solid dissolved. A 150 cm^3 volume of 0.20 mol dm^{-3} sodium ethanedioate solution was added to the beaker. The mixture was stirred until precipitation was complete. After filtration, 3.31 g of the dihydrate ($FeC_2O_4.2H_2O$) were collected.

(a) Write an equation for the reaction between iron(II) sulfate and sodium ethanedioate.

....

(1)

(b) Calculate the amount, in moles, of $FeSO_4.7H_2O$ in 6.95 g of hydrated iron(II) sulfate. Show your working.

....

....

....

(2)

(c) Calculate the amount, in moles, of sodium ethanedioate in 150 cm^3 of 0.20 mol dm^{-3} sodium ethanedioate solution.

....

....

(1)

(d) Calculate the percentage yield of iron(II) ethanedioate dihydrate (M_r = 179.8) formed in this reaction.
Give your answer to the appropriate precision. Show your working.

....

....

....

....

(2)

(e) In this experiment, no side reactions take place, the reagents are pure and the reaction goes to completion.

Suggest **one** reason why the yield of iron(II) ethanedioate dihydrate in this experiment is less than 100%.

....

....

....

(1)

(f) When dissolved in dilute sulfuric acid, the number of moles of ethanedioate ions in a pigment can be determined by titration with acidified potassium manganate(VII).

Explain why the titration of a sample of iron(II) ethanedioate would require a different amount of potassium manganate(VII) than a titration of an equimolar amount of copper(II) ethanedioate.

....

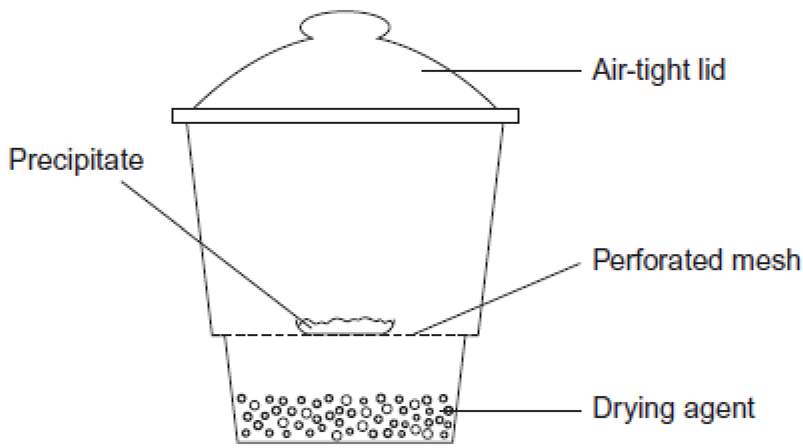
....

....

....

(2)
(Total 9 marks)

50 A desiccator can be used to dry precipitates as shown in the diagram.



(a) Explain briefly how the precipitate in the desiccator becomes dry.

....

....

(1)

(b) Anhydrous cobalt(II) chloride is blue. It is often added to the drying agent to indicate the amount of moisture in the drying agent.

State the colour change of this cobalt compound that you would observe as the drying process takes place.

....

(1)
(Total 2 marks)

51 An equation for the decomposition of hydrogen peroxide is

$$2H_2O_2 \longrightarrow 2H_2O \quad + \quad O_2$$

(a) The rate of reaction can be determined by collecting the oxygen formed and measuring its volume at regular intervals.

Draw a diagram to show the apparatus that you would use to collect and measure the volume of the oxygen formed.

(2)

(b) Explain how you could use your results from the experiment in part (a) to determine the initial rate of this reaction.

....

....

....

....

....

(2)

(c) The rate of decomposition of hydrogen peroxide is increased by the addition of cobalt(II) ions.

Outline the essential features of an additional experiment to show that the rate of decomposition is increased by the addition of cobalt(II) chloride. Use the same method and the same apparatus as in part (a).

....

....

....

....

....

(2)
(Total 6 marks)

52 An experiment was carried out to measure the e.m.f. of this cell.

$$Al(s) \mid Al^{3+}(aq) \parallel H^{+}(aq) \mid H_2(g) \mid Pt(s)$$

(a) The aluminium used as the electrode is rubbed with sandpaper prior to use.

Suggest the reason for this.

....

....

....

(1)

(b) Draw a labelled diagram of a suitable apparatus for the right-hand electrode in this cell. You do **not** need to include the salt bridge or the external electrical circuit.

(2)

(c) A simple salt bridge can be prepared by dipping a piece of filter paper into potassium carbonate solution. Explain why such a salt bridge would **not** be suitable for use in this cell.

....

....

....

....

(2)
(Total 5 marks)

53 Ammonia and methylamine were dissolved in separate samples of water. The two solutions had equal molar concentrations.

State **one** simple method, other than smell, of distinguishing these solutions.
State what you would observe.

Method ....

Observation ....

....

....

(Total 2 marks)

54 A student investigated the chemistry of the halogens and the halide ions.

(a) In the first two tests, the student made the following observations.

Test	**Observation**
1. Add chlorine water to aqueous potassium iodide solution.	The colourless solution turned a brown colour.
2. Add silver nitrate solution to aqueous potassium chloride solution.	The colourless solution produced a white precipitate.

(i) Identify the species responsible for the brown colour in Test **1**.

Write the **simplest ionic** equation for the reaction that has taken place in Test **1**.

State the type of reaction that has taken place in Test **1**.

....

....

....

....

....

(Extra space) ....

....

(3)

(ii) Name the species responsible for the white precipitate in Test **2**.

Write the **simplest ionic** equation for the reaction that has taken place in Test **2**.

State what would be observed when an excess of dilute ammonia solution is added to the white precipitate obtained in Test **2**.

....

....

....

....

....

(Extra space) ....

....

(3)

(b) In two further tests, the student made the following observations.

Test	Observation
3. Add concentrated sulfuric acid to solid potassium chloride.	The white solid produced misty white fumes which turned blue litmus paper to red.
4. Add concentrated sulfuric acid to solid potassium iodide.	The white solid turned black. A gas was released that smelled of rotten eggs. A yellow solid was formed.

(i) Write the **simplest ionic** equation for the reaction that has taken place in Test **3**.

Identify the species responsible for the misty white fumes produced in Test **3**.

....

....

(Extra space) ....

....

(2)

(ii) The student had read in a textbook that the equation for one of the reactions in Test **4** is as follows.

$$8H^+ + 8I^- + H_2SO_4 \longrightarrow 4I_2 + H_2S + 4H_2O$$

Write the **two** half-equations for this reaction.

State the role of the sulfuric acid and identify the yellow solid that is also observed in Test **4**.

....

....

....

....

....

....

(Extra space) ....

....

(4)

(iii) The student knew that bromine can be used for killing microorganisms in swimming pool water.
The following equilibrium is established when bromine is added to cold water.

$$Br_2(l) + H_2O(l) \rightleftharpoons HBrO(aq) + H^+(aq) + Br^-(aq)$$

Use Le Chatelier's principle to explain why this equilibrium moves to the right when sodium hydroxide solution is added to a solution containing dissolved bromine.

Deduce why bromine can be used for killing microorganisms in swimming pool water, even though bromine is toxic.

....

....

....

....

....

....

(Extra space) ....

....

(3)
(Total 15 marks)

55 During a titration a chemist may rinse the inside of the conical flask with distilled or deionised water. The water used for rinsing remains in the conical flask.

(a) Explain why this rinsing can improve the accuracy of the end-point.

....

....

(1)

(b) Explain why the addition of water during rinsing does **not** give an incorrect result.

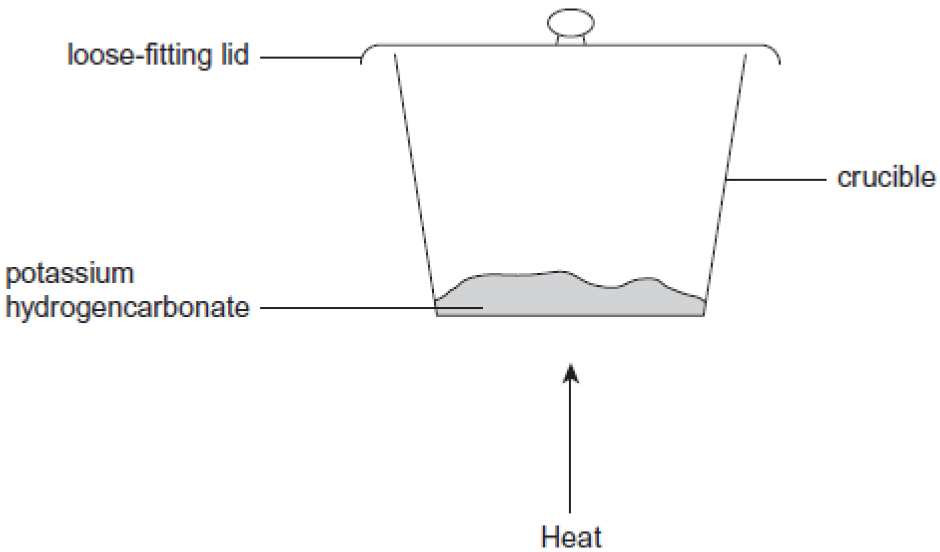
....

....

(1)
(Total 2 marks)

56 (a) Potassium carbonate can also be prepared by the decomposition of potassium hydrogencarbonate. The equation for the reaction is shown below with a diagram of the apparatus used.

$$2KHCO_3 \longrightarrow K_2CO_3 + CO_2 + H_2O$$



A student was asked to check the purity of a sample of potassium hydrogencarbonate. The student weighed a clean, dry crucible, and transferred 1.00 g of the potassium hydrogencarbonate to the crucible. A lid was placed on the crucible and the crucible was then heated for a few minutes. After cooling, the mass of the crucible and its contents was recorded.

(i) Explain why the use of a wet crucible would give an inaccurate result.

....

....

....

(1)

(ii) Give **one** reason why the use of a lid improves the accuracy of the experiment.

....

....

....

(1)

(iii) State **one** reason why the use of a very small amount of potassium hydrogencarbonate could lead to a less accurate result.

....

....

(1)

(b) In another experiment, the decomposition of a 1.00 g sample of pure potassium hydrogencarbonate gave 0.81 g of solid in the crucible.

(i) Calculate the mass of potassium carbonate that can be formed from 1.00 g of potassium hydrogencarbonate.
Show your working.

....

....

....

....

....

(3)

(ii) In this experiment the mass of solid remaining in the crucible was greater than expected. Suggest **one** reason for this result.

....

....

(1)
(Total 7 marks)

57 (a) Anhydrous calcium chloride is not used as a commercial de-icer because it reacts with water. The reaction with water is exothermic and causes handling problems.

A student weighed out 1.00 g of anhydrous calcium chloride. Using a pipette, 25.0 cm^3 of water were measured out and transferred to a plastic cup. The cup was placed in a beaker to provide insulation. A thermometer was mounted in the cup using a clamp and stand. The bulb of the thermometer was fully immersed in the water.

The student recorded the temperature of the water in the cup every minute, stirring the water before reading the temperature. At the fourth minute the anhydrous calcium chloride was added, but the temperature was not recorded. The mixture was stirred, then the temperature was recorded at the fifth minute. The student continued stirring and recording the temperature at minute intervals for seven more minutes.

The student's results are shown in the table below.

Time / minutes	0	1	2	3	4
Temperature / °C	19.6	19.5	19.5	19.5	

Time / minutes	4	5	6	7	8	9	10	11	12
Temperature / °C		24.6	25.0	25.2	24.7	24.6	23.9	23.4	23.0

Plot a graph of temperature (y-axis) against time on the grid below.
Draw a line of best fit for the points before the fourth minute.
Draw a second line of best fit for the appropriate points after the fourth minute.
Extrapolate both lines to the fourth minute.

(5)

(b) Use your graph to determine an accurate value for the temperature of the water at the fourth minute (**before** mixing).

Temperature before mixing ....

(1)

(c) Use your graph to determine an accurate value for the temperature of the reaction mixture at the fourth minute (**after** mixing).

Temperature after mixing ....

(1)

(d) Use your answers from parts (b) and (c) to determine an accurate value for the temperature rise at the fourth minute.
Give your answer to the appropriate precision.

Temperature rise ....

(1)

(e) Use your answer from part (d) to calculate the heat given out during this experiment.
Assume that the water has a density of 1.00 g cm^{-3} and a specific heat capacity of 4.18 JK^{-1} g^{-1}. Assume that all of the heat given out is used to heat the water.
Show your working.

....

....

....

....

(2)

(f) Calculate the amount, in moles, of $CaCl_2$ in 1.00 g of anhydrous calcium chloride (M_r = 111.0).

....

(1)

(g) Use your answers from parts (e) and (f) to calculate a value for the enthalpy change, in kJ mol^{-1}, for the reaction that occurs when anhydrous calcium chloride dissolves in water.

$$CaCl_2(s) + aq \longrightarrow CaCl_2(aq)$$

....

....

....

....

(2)

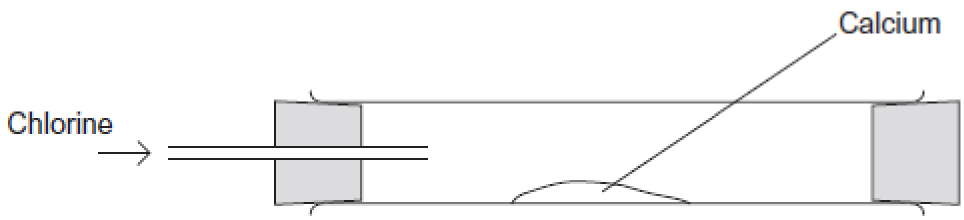
(h) Explain why it is important that the reaction mixture is stirred before recording each temperature.

....

....

(1)

(i) Anhydrous calcium chloride can be prepared by passing chlorine over heated calcium. To prevent unreacted chlorine escaping into the atmosphere, a student suggested the diagram of the apparatus for this experiment shown below.



(i) Suggest **one** reason why the student wished to prevent unreacted chlorine escaping into the atmosphere.

....

....

(1)

(ii) Suggest **one** hazard of using the apparatus as suggested by the student for this experiment.

....

....

(1)
(Total 16 marks)

1 (a) **M1** acidified potassium dichromate or $K_2Cr_2O_7$ / H_2SO_4

OR $K_2Cr_2O_7$ / H^+ ***OR*** acidified $K_2Cr_2O_7$

M2 (orange to) green solution ***OR*** goes green

M3 (solution) remains orange or no reaction or no (observed) change

*If no reagent or incorrect reagent in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

If incomplete / inaccurate attempt at reagent e.g. "dichromate" or "dichromate(IV)" or incorrect formula or no acid, ***penalise M1 only and mark on***

*For **M2** ignore dichromate described as "yellow" or "red"*

*For **M3** ignore "nothing (happens)" or "no observation"*

Alternative using $KMnO_4$ / H_2SO_4

M1 acidified potassium manganate(VII) / potassium permanganate or $KMnO_4$ / H_2SO_4

OR $KMnO_4$ / H^+ ***OR*** acidified $KMnO_4$

M2 colourless solution ***OR*** goes colourless

M3 (solution) remains purple or no reaction or no (observed) change

*For **M1***

If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, ***penalise M1 only and mark on***

*Credit alkaline $KMnO_4$ for possible full marks but **M2** gives brown precipitate or solution goes green*

3

(b) **M1** (Shake with) Br_2 ***OR*** bromine (water) ***OR*** bromine (in CCl_4 / organic solvent)

M2 (stays) orange / red / yellow / brown / the same

OR no reaction ***OR*** no (observed) change

M3 decolourised / goes colourless / loses its colour / orange to colourless

*If no reagent or incorrect reagent in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

*If incomplete / inaccurate attempt at reagent (e.g. Br), **penalise M1 only and mark on***

*No credit for combustion observations; **CE = 0***

*For **M2 in every case***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear"

***OR* as alternatives**

Use $KMnO_4$ / H_2SO_4

M1 acidified potassium manganate(VII) / potassium permanganate ***OR*** $KMnO_4$ / H_2SO_4

OR $KMnO_4$ / H^+ ***OR*** acidified $KMnO_4$

M2 (stays) <u>purple</u> or no reaction or no (observed) change

M3 decolourised / goes colourless / loses its colour

Use iodine

M1 iodine or I_2 / KI or iodine solution

M2 no change

M3 decolourised / goes colourless / loses its colour

Use concentrated sulfuric acid

M1 <u>concentrated</u> H_2SO_4

M2 no change

M3 brown

***For M1**, it must be a whole reagent and / or correct formula*

For M1** penalise incorrect attempt at correct formula, but mark **M2** and **M3

With potassium manganate(VII)

*If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*Credit alkaline / neutral $KMnO_4$ for possible full marks but **M3** gives <u>brown precipitate</u> or solution goes <u>green</u>*

Apply similar guidance for errors in the formula of iodine or concentrated sulfuric acid reagent as those used for other reagents.

3

(c) **M1** Any soluble chloride including hydrochloric acid (ignore concentration)

M2 white precipitate or white solid / white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 Any soluble iodide including HI

M2 yellow precipitate or yellow solid / yellow suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 Any soluble bromide including HBr

M2 cream precipitate or cream solid / cream suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 NaOH or KOH or any soluble carbonate

M2 brown precipitate or brown solid / brown suspension with NaOH / KOH (white precipitate / solid / suspension with carbonate)

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

*If no reagent or incorrect reagent or insoluble chloride in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

Allow chlorine water

*If incomplete reagent (e.g. chloride ions) or inaccurate attempt at formula of chosen chloride, or chlorine, **penalise M1 only and mark on***

*For **M2** require the word "white" and some reference to a solid. Ignore "cloudy solution" OR "suspension" (similarly for the alternatives)*

*For **M3***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear" on its own

Ignore "dissolves"

3

(d) **M1** Any soluble sulfate including (dilute or aqueous) sulfuric acid

M2 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

M3 white precipitate or white solid / white suspension

If no reagent or incorrect reagent or insoluble sulfate in ***M1**, **CE = 0*** *and no marks for* ***M1**, **M2*** *or* ***M3***

Accept $MgSO_4$ and $CaSO_4$ but not barium, lead or silver sulfates

If concentrated sulfuric acid or incomplete reagent (e.g. sulfate ions) or inaccurate attempt at formula of chosen sulfate, ***penalise M1 only and mark on***

For ***M3 (or M2 in the alternative)*** *require the word "white" and some reference to a solid.*

Ignore "cloudy solution" OR "suspension"

For ***M2 (or M3 in the alternative)***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear" on its own

Ignore "dissolves"

***OR* as an alternative**

M1 NaOH or KOH

M2 white precipitate or white solid / white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

If incomplete reagent (e.g. hydroxide ions) or inaccurate attempt at formula of chosen hydroxide, ***penalise M1 only and mark on***

If ***M1*** *uses NH_3 (dilute or concentrated)* ***penalise M1 only and mark on***

3

[12]

2 (a) (i) Uses sensible scales.

*Lose this mark if the **plotted points** do not cover half of the paper.*

Lose this mark if the graph plot goes off the squared paper

Lose this mark if volume is plotted on the x-axis

1

All points plotted correctly

Allow ± one small square.

1

Smooth curve from 0 seconds to at least 135 seconds − the line must pass through or close to all points (± one small square).

Make some allowance for the difficulties of drawing a curve but do not allow very thick or doubled lines.

1

(ii) Any value in the range 91 to 105 s

Allow a range of times within this but not if 90 quoted.

1

(b) (i) Using $pV = nRT$

This mark can be gained in a correctly substituted equation.

1

$100\ 000 \times 570 \times 10^{-6} = n \times 8.31 \times 293$

Correct answer with no working scores one mark only.

1

n = 0.0234 mol

Do not penalise precision of answer but must have a minimum of 2 significant figures.

1

(ii) Mol of $ZnCO_3$ = 0.0234

Mark consequentially on Q6

M1

1

Mass of $ZnCO_3$ = M1 × 125.4 = 2.9(3) or 2.9(4) g

If 0.0225 used then mass = 2.8(2) g

M2

1

(iii) Difference = (15.00 / 5) − Ans to b

If 2.87 g used then percentage is 4.3

M1

1

Percentage = (M1 / 3.00) × 100

Ignore precision beyond 2 significant figures in the final answer

If 2.82 g used from (ii) then percentage = 6.0

M2

1

(c) A reaction vessel which is clearly airtight round the bung

1

Gas collection over water or in a syringe

Collection vessel must be graduated by label or markings

Ignore any numbered volume markings.

1

[13]

3 (a) (To make chewing the tablets) more palatable

Tastes better / sweet taste / mask the taste of the $Mg(OH)_2$

Do not allow 'to aid digestion'.

1

(b) The indicator is acidic

1

(c) They produce CO_2 gas that may produce 'wind' / a bloated feeling.

1

[3]

4 (a) The value of the titre would be higher (than the true value.)

1

(b) It should have no effect.

1

The first titration can be ignored / subsequent titrations would be accurate

Allow references to the first titration being a 'rough' or 'trial' value.

1

[3]

5 (a) Compound 1

If M1 incorrect, CE = 0

M1

1

No visible change with H_2SO_4

M2

1

Gives white ppt with NaOH

M3

1

(b) $BaCO_3$

1

The carbonate ion releases CO_2

1

but the $BaSO_4$ formed is highly insoluble.

1

(c) Compound 4

1

$Sr(OH)_2 + H_2SO_4 \rightarrow SrSO_4 + 2H_2O$

Allow ionic equation; ignore state symbols

1

[8]

6 (a) 0.155 g per 100 cm^3

M1

Allow 0.153 − 0.157

1

(0.155 / 74.1) × 10 = 0.0209 mol dm^{-3}

M2

Allow 0.0206 − 0.0212

1

Answer to 3 significant figures

M3

The correct answer only loses M1

1

(b) Take a known volume of the saturated solution

1

Evaporate the filtrate to dryness

Allow titrate with dilute HCl or HNO_3 .....

1

Weigh the residue

.....of known / specified concentration

Ignore any references to indicators

1

[6]

7 Increase in volume

If a volume is quoted it must be less than 300

1

Smaller increase in T above room temperature
Or increased contact between calorimeter and water
Or smaller heat loss by evaporation / from the surface

1

[2]

8 (a) H_2SO_4

Allow H_3PO_4 or HCl

1

(b) Dichromate / Cr(VI) reduced or Cr(III) formed.

Allow Cr^{6+} and Cr^{3+}

1

(c) The alcohol is flammable

Allow enables temperature to be controlled

1

(d) Tollens'

1

Silver mirror
OR Fehling's
Red precipitate
OR Benedict's
Red precipitate

1

[5]

9 (a) $Cr(OH)_3 + 3H_2O + 3H^+ \rightarrow [Cr(H_2O)_6]^{3+}$

Can start with $Cr(H_2O)_3(OH)_3$ for each equation

Ignore any unnecessary preliminary preparation of $Cr(OH)_3$

1

Green / grey−green solid

Mark colours independently from equations

Allow green ppt.

1

Forms green / purple / ruby / violet solution

ignore shades of colours

1

$Cr(OH)_3 + 2H_2O + OH^- \rightarrow [Cr(H_2O)_2(OH)_4]^-$

Allow with 5 or 6 OH^- provided complex has co−ordination number of 6

Penalise complex ions with incorrect charges overall or if shown on ligand.

1

Forms green solution

Note that for each equation final complex must be 6 co−ordinate

1

(b) $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$

Allow two correct equations via intermediate hydroxide in both cases even if first equation uses OH^- instead of NH_3

1

Blue (solution)

Mark colours independently from equations

1

Dark / deep / royal blue solution

1

$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$

1

pink / red (solution)

1

Brown / straw / yellow solution

ignore darkens in air / with time

1

[11]

10 (a) $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow Fe(H_2O)_4(OH)_2 + 2NH_4^+$

Allow equation with OH^- provided equation showing formation of OH^- from NH_3 given

1

Green precipitate

1

$[Fe(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow FeCO_3 + 6H_2O$

1

Green precipitate

effervescence incorrect so loses M4

1

(b) (i) Colourless / (pale) green changes to pink / purple (solution)

Do not allow pale pink to purple

1

Just after the end−point MnO_4^- is in excess / present

1

(ii) $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$

1

Moles $KMnO_4$ = 18.7 × 0.0205 / 1000 = (3.8335 × 10^{-4})

Process mark

1

Moles Fe^{2+} = 5 × 3.8335 × 10^{-4} = 1.91675 × 10^{-3}

Mark for M2 × 5

1

Moles Fe^{2+} in 250 cm^3 = 10 × 1.91675 × 10^{-3} = 0.0191675 moles in 50 cm^3

Process mark for moles of iron in titration (M3) × 10

1

Original conc Fe^{2+} = 0.0191675 × 1000 / 50 = 0.383 mol dm^{-3}

Answer for moles of iron (M4) × 1000 / 50

Answer must be to at least 2 sig. figs. (0.38)

1

[11]

11 (a) (i) M_r N−phenylethanamide = 135.0

1

Theoretical yield = 135.0 × 2 (1.15 / 284.1) = 1.09 g

1

Answer recorded to 3 significant figures.

1

(ii) $\frac{0.89}{\text{Ans to (a)}} \times 100$

= 81.4 %

Mark consequentially to (a)
Allow 81 to 82

1

(b) (i) Dissolve the product in the **minimum** volume of water / solvent (in a boiling tube / beaker)

If dissolving is not mentioned, CE = 0 / 4

1

Hot water / solvent

Steps must be in a logical order to score all 4 marks

1

Allow the solution to cool and allow crystals to form.

1

Filter off the pure product under reduced pressure / using a Buchner funnel and side arm flask

Ignore source of vacuum for filtration (electric pump, water pump, etc.)

1

(ii) Measure the melting point

1

Use of melting point apparatus or oil bath

1

Sharp melting point / melting point matches data source value

1

(iii) Any **two** from:

Product left in the beaker or glassware

Sample was still wet

Sample lost during recrystallisation.

Do not allow "sample lost" without clarification.

2 Max

(c) An identified hazard of ethanoyl chloride

E.g. "Violent reaction", "harmful", "reacts violently with water"

Do not allow "toxic", "irritant" (unless linked with HCl gas).

1

HCl gas / fumes released / HCl not released when ethanoic anhydride used

1

[15]

12 (a) As a droplet from the funnel could enter the burette / affect volume / readings / titre

1

(b) Air bubble in jet or wtte

Do not allow misreading burette or overshooting end point.

1

(c) Ensures **all** reagents are able to react / mix / come into contact

Accept no reagent is left unreacted on sides of flask

Do not allow any reference to 'removal' of the solution unless it is clear that it is added to the flask.

1

(d) The added water does not affect the mols / amount of reagents / reactants / solution Z

Do not allow mols of solution or mols in the flask.

Allow water does not react with the reagents / water is not one of the reactants

Do not allow 'water is not involved'

1

[4]

13 Pipette = 0.05 × 100 / **25.0** = 0.2%

Ignore precision

1

Burette = 0.15 × 100 / 24.25 cm^3

Must show working

Allow one mark for two correct answers with no working

1

[2]

14 (a) (Biocide) reacts with bacteria / used up killing bacteria

Max two marks

Chlorine given off / evaporates

Do not allow "chlorine has reacted with water" alone.

Chlorine has reacted with water to form (HCl and) O_2

Do not allow products of HCl and HOCl alone

2

(b) the concentration of the remaining solution (after a sample has been removed) is unchanged.

1

(c) So that all chlorine was reacted / reduced

*Do **not** allow 'all of the iodide was oxidised'*

1

(d) The E^o value for the iodine half-equation is more positive than that for the thiosulfate

Allow = 0.45

Must refer to values

1

(e) $S_2O_3^{2-} + \frac{1}{2} I_2 \rightarrow I^- + \frac{1}{2} S_4O_6^{2-}$

Allow multiples

1

[6]

15 (a) <u>164.0</u>

Must be 1 decimal place

1

(b) 17.1(%) (= 28.0 × 100 / Qa)

Consequential on their (a)

Ignore precision but must be to at least 2 sig fig.

(i.e. accept 17 or 17.07)

1

(c) (i) <u>*Absorption*</u> depends on (proportional to) path length / distance travelled through solution

Do not allow size.

1

(ii) To select the colour / frequency / wavelength that is (most strongly) absorbed (by the sample)

Allow the filter is chosen to complement the colour of the solution

1

(iii) Quicker to analyse extracted samples than by titration / uses smaller volumes of solution

1

[5]

16 (a) Multiply volume of propan−1−ol by density

Allow measure the mass of the volume added

Any reference to concentration of propan−1−ol CE = 0

1

Divide the mass by the M_r of propan−1−ol

1

(b) Titrate a measured volume of the concentrated HCl added initially to determine moles of HCl used in the experiment

Allow addition of $AgNO_3$ to form AgCl precipitate. Use mass of precipitate to calculate initial moles of HCl added.

1

Subtract this number of moles of HCl from the total moles of acid at equilibrium

1

(c) M1 ester will evaporate / escape

Allow reactants / products will evaporate

1

M2 incorrect values used (to determine K_c)

Allow the system will no longer be at equilibrium

Do not allow references to equilibrium position shifting alone

1

[6]

17 (a) $2NaBr + 2H_2SO_4 \longrightarrow Na_2SO_4 + Br_2 + SO_2 + 2H_2O$

Allow ionic equation

$2Br^- + 2H_2SO_4 \longrightarrow Br_2 + SO_4^{2-} + SO_2 + 2H_2O$

1

Br^- ions are bigger than Cl^- ions

1

Therefore Br^- ions more easily oxidised / lose an electron more easily (than Cl^- ions)

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3

All stages are covered and the explanation of each stage is generally correct and virtually complete. Stages 1 and 2 are supported by correct equations.

Answer communicates the whole process coherently and shows a logical progression from stage 1 to stage 2 and then stage 3. The steps in stage 3 are in a logical order.

5–6 marks

Level 2

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression through the stages. Some steps in each stage may be out of order and incomplete.

3–4 marks

Level 1

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1–2 marks

Level 0

Insufficient correct chemistry to warrant a mark.

0 marks

Indicative chemistry content

Stage 1*: formation of precipitates*

- *Add silver nitrate*
- *to form precipitates of AgCl and AgBr*
- $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$
- $AgNO_3 + NaBr \rightarrow AgBr + NaNO_3$

Stage 2*: selective dissolving of AgCl*

- *Add excess of dilute ammonia to the mixture of precipitates*
- *the silver chloride precipitate dissolves*
- $AgCl + 2NH_3 \rightarrow Ag(NH_3)_2^+ + Cl^-$

***Stage 3**: separation and purification of AgBr*

- *Filter off the remaining silver bromide precipitate*
- *Wash to remove soluble compounds*
- *Dry to remove water*

6

(c) $Cl_2 + 2HO^- \longrightarrow OCl^- + Cl^- + H_2O$

1

OCl^- is +1

Cl^- is –1

Both required for the mark

1

[11]

18 (a) Stage 1: appreciation that the acid must be in excess and calculation of amount of solid that permits this

Statement that there must be an excess of acid

1

Moles of acid = 50.0 × 0.200 / 1000 = 1.00×10^{-2} mol

1

2 mol of acid react with 1 mol of calcium hydroxide therefore moles of solid weighed out must be less than half the moles of acid = $0.5 \times 1.00 \times 10^{-2} = 5.00 \times 10^{-3}$ mol

1

Mass of solid must be < $5.00 \times 10^{-3} \times 74.1$ = < 0.371 g

1

Stage 2: Experimental method

Measure out 50 cm^3 of acid using a pipette and add the weighed amount of solid in a conical flask

1

Titrate against 0.100 (or 0.200) mol dm^{-3} NaOH added from a burette and record the volume (v) when an added indicator changes colour

1

Stage 3: How to calculate M_r from the experimental data

Moles of calcium hydroxide = 5.00×10^{-3} – (v/2 × conc NaOH) / 1000 = z mol

1

M_r = mass of solid / z

1

Extended response

Maximum of 7 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

(b) Moles of calcium chloride = 3.56 / 111.1 = 3.204×10^{-2}

1

Moles of calcium sulfate = $3.204 \times 10^{-2} \times 83.4 / 100 = 2.672 \times 10^{-2}$

1

Mass of calcium sulfate = $2.672 \times 10^{-2} \times 136.2 = 3.6398 = 3.64$ (g)

Answer must be to 3 significant figures

1

[11]

19 (a) Measured volume would be greater

1

Level in burette falls as tap is filled before any liquid is delivered

1

(b) Drop sizes vary

Allow percentage error for amount of oil will be large as the amount used is so small

1

(c) Use a larger single volume of oil

1

Dissolve this oil in the organic solvent

1

Transfer to a conical flask and make up to 250 cm^3 with more solvent

1

Titrate (25 cm^3) samples from the flask

1

(d) Stage 1

Mass of oil = $0.92 \times (5.0 \times 10^{-2} \times 5) = 0.23$ (g)

1

Mol of oil = $0.23 / 885 = 2.6 \times 10^{-4}$

1

Extended response calculation

To gain 4 or 5 marks, students must show a logical progression from stage 1 and stage 2 (in either order) to stage 3

Stage 2

Mol bromine = $2.0 \times 10^{-2} \times 39.4 / 1000 = 7.9 \times 10^{-4}$

1

Stage 3

Ratio oil : bromine

2.6×10^{-4} : 7.9×10^{-4}

Simplest ratio = $2.6 \times 10^{-4} / 2.6 \times 10^{-4} : 7.9 \times 10^{-4} / 2.6 \times 10^{-4}$

= 1 : 3

1

Hence, 3 C=C bonds

M5 cannot be awarded unless working for M4 is shown

1

[12]

20 (a) Burette

1

Because it can deliver variable volumes

1

(b) The change in pH is gradual / not rapid at the end point

1

An indicator would change colour over a range of volumes of sodium hydroxide

Allow indicator would not change colour rapidly / with a few drops of NaOH

1

(c) $[H^+] = 10^{-pH} = 1.58 \times 10^{-12}$

1

$K_w = [H^+][OH^-]$ therefore $[OH^-] = K_w / [H^+]$

1

Therefore, $[OH^-] = 1 \times 10^{-14} / 1.58 \times 10^{-12} = 6.33 \times 10^{-3}$ (mol dm^{-3})

Allow 6.31–6.33 × 10^{-3} (mol dm^{-3})

1

(d) At this point, $[NH_3] = [H^+]$

Therefore $K_a = \dfrac{[H^+]^2}{[NH_4^+]}$

1

$[H^+] = 10^{-4.6} = 2.51 \times 10^{-5}$

1

$K_a = (2.51 \times 10^{-5})^2 / 2 = 3.15 \times 10^{-10}$ (mol dm^{-3})

Allow 3.15 – 3.16 × 10^{-10} (mol dm^{-3})

1

(e) When $[NH_3] = [NH_4^+]$, $K_a = [H^+]$ therefore $-\log K_a = -\log [H^+]$

Answer using alternative value

1

Therefore pH = $-\log_{10}(3.15 \times 10^{-10}) = 9.50$

M2 pH = $-\log_{10}(4.75 \times 10^{-9}) = 8.32$

Allow consequential marking based on answer from part (d)

1

[12]

21 (a) Start a clock when KCl is added to water

1

Record the temperature every subsequent minute for about 5 minutes

Allow record the temperature at regular time intervals until some time after all the solid has dissolved for M2

1

Plot a graph of temperature vs time

1

Extrapolate back to time of mixing = 0 and determine the temperature

1

(b) Heat taken in = $m \times c \times \Delta T = 50 \times 4.18 \times 5.4 = 1128.6$ J

Max 2 if 14.6 °C used as ΔT

1

Moles of KCl = 5.00 / 74.6 = 0.0670

1

Enthalpy change per mole = +1128.6 / 0.0670 = 16 839 J mol^{-1}

1

= +16.8 (kJ mol^{-1})

Answer must be given to this precision

1

(c) $\Delta H_{solution} = \Delta H_{lattice}$ + ΔH(hydration of calcium ions) + 2 × ΔH(hydration of chloride ions)

$\Delta H_{lattice} = \Delta H_{solution}$ – ΔH(hydration of calcium ions) –2 ×ΔH(hydration of chloride ions)

1

$\Delta H_{lattice} = -82-9 - (-1650 + 2 \times -364) = +2295$ (kJ mol^{-1})

1

(d) Magnesium ion is smaller than the calcium ion

1

Therefore, it attracts the chloride ion more strongly / stronger ionic bonding

1

[12]

22 (a) **Q** is calcium or magnesium

1

bromide

1

R is aluminium 1

chloride 1

S is iron(III) 1

sulfate 1

Mark this question independently

(b) $Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$ 1

$[Fe(H_2O)_6]^{3+} + 3OH^- \longrightarrow Fe(H_2O)_3(OH)_3 + 3H_2O$ 1

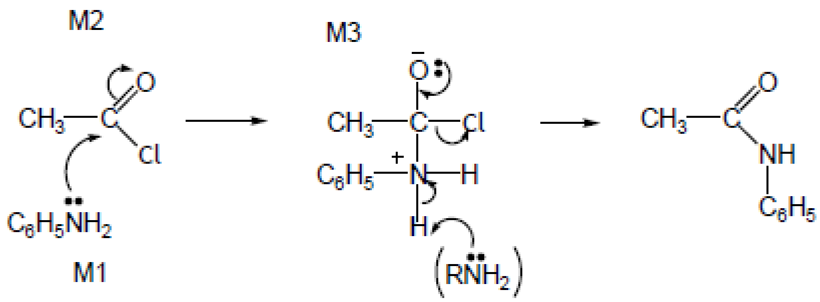
$2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \longrightarrow 2Fe(H_2O)_3(OH)_3 + 3H_2O + 3CO_2$ 1

$[Fe(H_2O)_6]^{3+} + 4Cl^- \longrightarrow [FeCl_4]^- + 6H_2O$ 1

[10]

23 (a) (nucleophilic) addition-elimination

Not electrophilic addition-elimination 1



M4 for 3 arrows and lp

Allow C_6H_5 or benzene ring

Allow attack by $:NH_2C_6H_5$

M2 not allowed independent of M1, but allow M1 for correct attack on C+

M3 for correct structure <u>with charges</u> but lone pair on O is part of M4

M4 (for three arrows and lone pair) can be shown in more than one structure

4

(b) **The minimum quantity of hot water was used:**

To ensure the hot solution would be saturated / crystals would form on cooling

1

The flask was left to cool before crystals were filtered off:

Yield lower if warm / solubility higher if warm

1

The crystals were compressed in the funnel:

Air passes through the sample not just round it

Allow better drying but not water squeezed out

1

A little cold water was poured through the crystals:

To wash away soluble impurities

1

(c) Water

Do not allow unreacted reagents

1

Press the sample of crystals between filter papers

Allow give the sample time to dry in air

1

(d) M_r product = 135.0

1

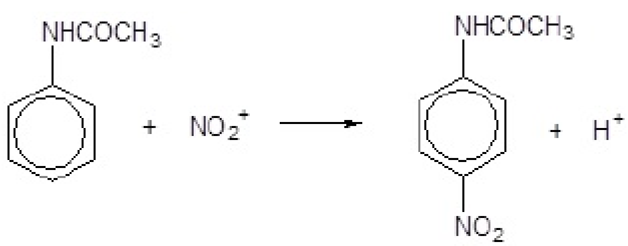
Expected mass = $5.05 \times \frac{135.0}{93.0} = 7.33$ g

1

Percentage yield = $\frac{4.82}{7.33} \times 100 = 65.75 = 65.8(\%)$

Answer must be given to this precision

(e)



OR

$C_6H_5NHCOCH_3 + NO_2^+ \rightarrow C_6H_4(NHCOCH_3)NO_2 + H^+$

1

(f) Electrophilic substitution

1

(g) Hydrolysis

1

(h) Sn / HCl

Ignore acid concentration; allow Fe / HCl

1

[18]

24 (a) A mixture of liquids is heated to boiling point for a prolonged time

1

Vapour is formed which escapes from the liquid mixture, is changed back into liquid and returned to the liquid mixture

1

Any ethanal and ethanol that initially evaporates can then be oxidised

1

(b) $CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$

1

(c) Mixture heated in a suitable flask / container

A labelled sketch illustrating these points scores the marks

1

With still head containing a thermometer

1

Water cooled condenser connected to the still head and suitable <u>cooled</u> collecting vessel

1

Collect sample at the boiling point of ethanal

1

Cooled collection vessel necessary to reduce evaporation of ethanal

1

(d) Hydrogen bonding in ethanol and ethanoic acid or no hydrogen bonding in ethanal

1

Intermolecular forces / dipole-dipole are weaker than hydrogen bonding

1

(e) Reagent to confirm the presence of ethanal:

Add Tollens' reagent / ammoniacal silver nitrate / aqueous silver nitrate followed by 1 drop of aqueous sodium hydroxide, then enough aqueous ammonia to dissolve the precipitate formed

OR

Add Fehling's solution

1

Warm

M2 and M3 can only be awarded if M1 is given correctly

1

Result with Tollen's reagent:

Silver mirror / black precipitate

OR

Result with Fehling's solution:

Red precipitate / orange-red precipitate

1

Reagent to confirm the absence of ethanoic acid

Add sodium hydrogencarbonate or sodium carbonate

1

Result; no effervescence observed; hence no acid present

1

M5 can only be awarded if M4 is given correctly

OR

Reagent; add ethanol and concentrated sulfuric acid and warm

Result; no sweet smell / no oily drops on the surface of the liquid,

hence no acid present

[16]

25 (a) **Wear plastic gloves:**

Essential – to prevent contamination from the hands to the plate

1

Add developing solvent to a depth of not more than 1 cm^3:

Essential – if the solvent is too deep it will dissolve the mixture from the plate

1

Allow the solvent to rise up the plate to the top:

Not essential – the R_f value can be calculated if the solvent front does not reach the top of the plate

1

Allow the plate to dry in a fume cupboard:

Essential – the solvent is toxic

Allow hazardous

1

(b) Spray with developing agent or use UV

1

Measure distances from initial pencil line to the spots (*x*)

1

Measure distance from initial pencil line to solvent front line (*y*)

1

R_f value = *x* / *y*

1

(c) Amino acids have different polarities

1

Therefore, have different retention on the stationary phase or different solubility in the developing solvent

1

[10]

26

(a) Space will fill during titration / titres or volumes added are too high

Do not allow 'to improve accuracy' without qualification.

Do not allow 'incorrect end-point' without qualification.

Do not allow 'titres or volumes added are too low'.

Ignore 'titres or volumes added are different'.

1

(b) Less chance of losing liquid on swirling / liquid doesn't splash on swirling

Do not accept 'easier to swirl' on its own.

1

(c) (i) Returns reagent on the sides of the flask to the reaction mixture (to ensure that all of the acid / alkali reacts)

Do not allow 'to improve accuracy' without qualification.

Ignore reference to cleaning.

1

(ii) This does not change the number of moles of reagents / water is not a reagent / water is one of the products

Do not allow 'water does not affect the titration' without qualification.

Ignore 'water is neutral / has a pH of 7'.

1

(d) Idea that a single titration could be flawed / anomalous

Do not accept 'will improve reliability / reproducibility / accuracy' without further qualification.

Allow 'to obtain concordant results'.

1

[5]

27 (a) (i) $SrCl_2(aq) + Na_2SO_4(aq) \rightarrow SrSO_4(s) + 2NaCl(aq)$

Allow multiples, including fractions.

Allow ionic equations.

Lose this mark if any of the state symbols are missing or incorrect.

1

(ii) Add nitric acid to the mixture (until in excess)

Do not allow any suggestion that the solution is an emetic.

1

Filter (to isolate strontium sulfate)

1

(b) Insoluble barium sulfate is formed

Allow 'removes barium ions as a precipitate' .

1

(c) Add silver nitrate, then dilute ammonia (solution) **M1**

Do not allow answers which imply silver nitrate and ammonia are added at the same time.

Allow 'add silver nitrate, then concentrated ammonia (solution)'.

*Can score **M1** in the answer for **M3***

1

Cream precipitate **M2**

Allow 'off white precipitate'.

1

No visible change or precipitate dissolves slightly in dilute ammonia **M3**

Allow 'soluble / colourless solution / precipitate dissolves in concentrated ammonia'.

Allow 3 marks for:

*Add dilute ammonia (solution), then silver nitrate **M1***

*No visible change **M2***

*Cream / off white precipitate with silver nitrate **M3***

1

[7]

28 (a) (i) 1.08×10^{-2}

Do not penalise precision but must be to at least 2 significant figures.

Do not accept 1×10^{-2}

1

(ii) $5.4(0) \times 10^{-3}$

Allow (i) / 2

Do not penalise precision but must be to at least 2 significant figures.

1

(iii) 266.6

Lose this mark if answer not given to 1 decimal place.

1

(iv) mass = 5.4(0) × 10^{-3} × 266.6 = 1.44 g **M1**

Allow (ii) × (iii).

1

percentage = 1.44 × 100 / 2.25 = 64.0 **M2**

*Allow consequential answer from **M1***

Lose this mark if answer not given to 3 significant figures.

*Correct answer with no working scores **M2** only.*

1

(v) 1 Would give an incorrect / too large mass (of silver chloride)

Do not allow 'to get an accurate result' without qualification.

1

2 To remove soluble impurities / excess silver nitrate (solution) / strontium nitrate (solution)

Do not allow 'to remove impurities'.

Do not allow 'to remove excess strontium chloride solution'.

1

(b) (i) $Mg^{2+}(aq) + 2OH^{-}(aq) \rightarrow Mg(OH)_2(s)$

Allow $Mg^{2+}(aq) + 2OH^{-}(aq) \rightarrow Mg^{2+}(OH^{-})_2(s)$

Allow multiples, including fractions.

Lose mark if state symbols are missing or incorrect.

Lose mark if incorrect charge on an ion.

1

(ii) Does not produce CO_2 / gas which distends stomach / does not produce wind / does not increase pressure in stomach

Allow 'prevents flatulence' and 'prevents burping'.

Do not allow 'gas' without qualification.

1

(c) $(CH_3COO)_2Ca \rightarrow CH_3COCH_3 + CaCO_3$

Allow multiples.

Allow propanone as C_3H_6O

Allow $(CH_3COO^{-})_2Ca^{2+} \rightarrow CH_3COCH_3 + Ca^{2+}CO_3^{2-}$

1

(d) Ca (salt) - no visible change with sodium chromate(VI) **M1**

Allow 'yellow solution formed' or 'no ppt. forms'.

*Allow **M1** and **M2** in any order.*

1

Sr and Ba (salts) give (yellow) precipitate with sodium chromate(VI) **M2**

Lose this mark if precipitate has an incorrect colour.

1

Sr precipitate (chromate(VI)) dissolves in ethanoic acid / Ba precipitate (chromate(VI)) does not dissolve in ethanoic acid **M3**

*If ethanoic acid is added first, allow access to **M1** and **M3**.*

1

(e) C 42.09 / 12, H 2.92 / 1, N 8.18 / 14, O 37.42 / 16 and S 9.39 / 32.1

Accept any other correct method of working.

If relative atomic mass has been divided by the percentage composition is used then CE = 0 / 2

1

$C_{12}H_{10}N_2O_8S$

Correct answer with no working scores 1 mark only.

1

[15]

29 (a) ($Q = mc\Delta T$)

$= 50 \times 4.18 \times 27.3$

If incorrect (eg mass = 0.22 or 50.22 g) ***CE = 0 / 2***

1

= **5706 J** (accept 5700 and 5710)

Accept 5.7 kJ with correct unit. Ignore sign.

1

(b) M_r of 2-methylpropan-2-ol = 74(.0)

For incorrect M_r, lose M1 but mark on.

1

Moles = mass / M_r

= 0.22 / 74(.0)

= **0.00297 moles**

1

$\Delta H = –5706 / (0.002970 \times 1000)$

= **–1921 (kJ mol$^{–1}$)**

If 0.22 is used in part (a), answer = –8.45 kJ mol$^{–1}$ scores 3

(Allow –1920, –1919)

If uses the value given (5580 J), answer = –1879 kJ mol$^{–1}$ scores 3

Answer without working scores M3 only.

Do not penalise precision.

Lack of negative sign loses M3

1

(c) $\Delta H = \Sigma\Delta H$ products – $\Sigma\Delta H$ reactants
OR a correct cycle

Correct answer with no working scores 1 mark only.

1

$\Delta H = -(-360) + (4 \times -393) + (5 \times -286)$

M2 also implies M1 scored.

1

$\Delta H =$ **–2642** (kJ mol^{-1}) This answer only.

Allow 1 mark out of 3 for correct value with incorrect sign.

1

(d) (–2422 – part (b)) × 100 / –2422

Ignore negative sign.

Expect answers in region of 20.7

If error carried forward, 0.22 allow 99.7

If 5580 J used earlier, then allow 22.4

1

(e) Reduce the distance between the flame and the beaker / put a sleeve around the flame to protect from drafts / add a lid / use a copper calorimeter rather than a pyrex beaker / use a food calorimeter

Any reference to insulating material around the beaker must be on top.

Accept calibrate the equipment using an alcohol of known enthalpy of combustion.

1

(f) Incomplete combustion

1

[11]

30 Acidified potassium dichromate

Accept words or formulae.

Accept acidified potassium permanganate.

Accept Lucas reagent (conc HCl, $ZnCl_2$) (cloudy in 5 mins for 2°, instantly for 3°).

Mark on for incomplete reagent.

Incorrect reagent CE = 0 / 3

Inclusion of Tollen's etc with acidified potassium dichromate is incorrect reagent.

Not no reaction.

Either

Obs with 2-methylpropan-2-ol

No visible change

1

Obs with butan-2-ol

Orange to green (both colours needed)

1

or

Obs with 2-methylpropan-2-ol orange

Obs with butan-2-ol green

[3]

31 (a) (Measure the) volume of gas / mass of the container + contents

1

Suitable named piece of equipment

Gas syringe (or inverted burette or measuring cylinder, as long as student has referred to the cylinder being filled with water) / balance.

Equipment must be correct for the measurement stated.

1

(b) Any **one** of:

- Mass of magnesium
  Allow amount of magnesium.
- Surface area of magnesium

1

(c) (i) Gravity: Conical flask or beaker and funnel /

Vacuum: Sealed container with a side arm and Buchner or Hirsch funnel

Must be either gravity filtration (with a V-shaped funnel) or vacuum filtration (with a side-arm conical flask) appropriately drawn.

1

Filter paper

Must show filter paper as at least two sides of a triangle (V-shaped) for gravity filtration or horizontal filter paper for vacuum filtration.

1

(ii) Wash with / add (a small amount of cold) water

Ignore filtering.

1

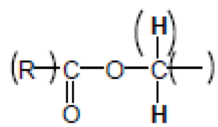
[6]

32 (a) M1 Ester **1**

If Ester 2, can score M3 only.

1

M2 peak at δ = 4.1 due to



When marking M2 and M3, check any annotation of structures in the stem at the top of the page.

1

M3 (δ = 4.1 peak is) quartet as <u>adjacent / next to / attached to CH_3</u>

1

M4 Other spectrum quartet at δ = 2.1-2.6 (or value in this range)

1

(b) M1 <u>Quaternary</u> (alkyl) <u>ammonium salt / bromide</u>

1

M2 CH_3Br or bromomethane

Penalise contradictory formula and name.

1

M3 Excess (CH_3Br or bromomethane)

Mention of acid eg H_2SO_4 OR alkali eg NaOH loses both M2 and M3.

1

M4 Nucleophilic substitution

Can only score M3 if reagent correct.

Ignore alcohol or ethanol (conditions) or Temp.

1

(c)

	Bromine (penalise Br but mark on)	Acidified $KMnO_4$ (Penalise missing acid but mark on)

Wrong reagent = no marks.

If bromine colour stated it must be red, yellow, orange, brown or any combination, penalise wrong starting colour.

1

Benzene	no reaction / colour remains / no (visible) change	no reaction / colour remains / no (visible) change

Ignore 'clear', 'nothing'.

Allow colour fades slowly.

Allow 'nvc' for no visible change.

1

cyclohexene	(Bromine) decolourised	(Acidified $KMnO_4$) decolourised

1

[11]

33 (a) **Reaction 1**

General principles in marking this question

Square brackets are not essential

Penalise charges on individual ligands rather than on the whole complex

Reagent and species can be extracted from the equation

Ignore conditions such as dilute, concentrated, excess

Reagent must be a compound NOT just an ion

Equations must start from $[Cu(H_2O)_6]^{2+}$ *except in part (b)*

Mark reagent, species and equation independently

ammonia (NH_3) (solution) / NaOH

1

$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Cu(H_2O)_4(OH)_2] + 2NH_4^+$ /

$[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow [Cu(H_2O)_4(OH)_2] + 2H_2O$

Do not allow OH^- *for reagent*

Product 1, balanced equation 1

Allow either equation for ammonia

2

(b) **Reaction 2**

Ammonia (conc / xs)

1

$[Cu(H_2O)_4(OH)_2] + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 2H_2O + 2OH^-$

Product 1, balanced equation 1

Note that the equation must start from the hydroxide $[Cu(H_2O)_4(OH)_2]$

2

(c) **Reaction 3**

Na_2CO_3 / any identified soluble carbonate / $NaHCO_3$

Do not allow $NaCO_3$ *or any insoluble carbonate but mark on*

1

$[Cu(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CuCO_3 + 6H_2O$

OR $[Cu(H_2O)_6]^{2+} + Na_2CO_3 \rightarrow CuCO_3 + 6H_2O + 2Na^+$

OR $2[Cu(H_2O)_6]^{2+} + 2CO_3^{2-} \rightarrow Cu(OH)_2.CuCO_3 + 11H_2O + CO_2$

OR with $NaHCO_3$

$[Cu(H_2O)_6]^{2+} + HCO_3^- \rightarrow CuCO_3 + 6H_2O + H^+$

Product 1, balanced equation 1

2

(d) **Reaction 4**

HCl (conc / xs) / NaCl

Allow any identified soluble chloride

1

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$

Product 1, balanced equation 1

2

[12]

34 (a) Correct orientation of graph (pH on *y*-axis)

1

Scale – plotted points cover at least half the grid and *y*-axis should start at pH 4

1

All points plotted correctly

+ / – one small square.

1

<u>Curve</u> of best fit drawn correctly

Allow some leniency here with a complex graph – it is important that the section between pH 8.5 and 9.7 is close to linear.

Lose this mark if the line is pulled towards the anomaly at 3.0 cm^3.

Lose this mark if first point at pH 5.1 is treated as an anomaly.

Do not accept doubled lines but allow some slight discontinuity where the curve changes direction.

1

(b) 11.6-11.9 (cm^3) only

Do not mark consequentially to student's graph.

1

(c) pK_a = value of pH related to part (b) **M1**

Mark consequentially on student's graph – ideally 9.0-9.1

Do not penalise precision of answer.

1

$K_a = 10^{-pKa}$ **M2**

Ideally 1.0×10^{-9} to 7.9×10^{-10}

*Ignore precision of answer but lose **M2** for 1 significant figure here.*

1

(d) pH 8.7

Ineffective stirring / swirling of the mixture

Both points needed for this mark.

Do not allow pH 5.1

Do not allow 'overshooting (at 3 cm^3 addition)'.

1

(e) Take more pH readings around the end-point / add smaller volumes of NaOH near the end-point

Do not allow 'use a more accurate / reliable pH meter / probe'.

Do not allow the use of a thermostatted mixture.

1

[9]

35 Identification of acid by suitable method eg named indicator, named carbonate, specified reactive metal

Ignore any reference to the smell of the ester.

1

with expected results

Do not allow the use of any instrumental method eg i.r. or n.m.r.; must be a <u>chemical</u> test.

1

Identification of alcohol by suitable method eg oxidation by acidified potassium dichromate(VI)

1

with expected results

1

[4]

36 (a) Platinum electrode

1

Solution in beaker is a mixture of named soluble iron(II) compound <u>and</u> named soluble iron(III) compound

Allow correct formulae for the iron compounds.

1

Concentrations of Fe(II) <u>and</u> Fe(III) ions are both 1 mol dm^{-3}

Ignore any references to temperature.

If eg $Fe_2(SO_4)_3$ used then concentration must be 0.5

1

(b) Purpose: Allow movement <u>of ions</u> between electrodes

Allow to maintain an electric circuit.

Do not allow reference to movement of electrons in salt bridge.

1

Requirement: Must not react with the electrolyte / ions in solution

Do not allow 'must not react' without further qualification.

1

[5]

37 (a) $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

*If equations reversed, allow **M1** only.*

1

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Ignore state symbols.

1

(b) Moles of copper(II) reacted = (100 / 1000) × 0.5 = 0.05

1

Moles of zinc reacted = 0.05

1

Mass of zinc lost = 0.05 × 65.4 = 3.27 g

*Correct final answer without working scores **M3** only.*

1

(c) Allow cell to discharge until $[Cu^{2+}]$ is 0.5

Alternative: Allow cell to discharge completely.

1

Confirmed by colorimetric measurement or other suitable method

Solution colourless or use of chemical test to determine absence of copper(II)

1

Weigh the Zn electrode before and after the experiment

Weigh Zn electrodes before and after and halve the mass change.

1

[8]

38 (a) Sensible scales

Plotted points (including 0,0) must cover more than half the graph paper.

If axis wrong way round lose this mark but mark on consequentially.

Do not allow broken axis.

1

Plots points correctly

1

(b) Ring around the origin

1

(c) Line through points is smooth

Line must pass within ± 1 small square of each plotted point except the anomaly (allow one plot ± 2 small square – at 40 or 60s).

1

Line through points is best fit and ignores anomaly (allow one plot ± 2 small square)

Lose this mark if student's line is doubled.

Kinked line loses this mark.

Lose this mark if the line does not pass through the origin + / – 1 small square.

Lose this mark if the line deviates to anomaly.

1

(d) Draws suitable tangent

Must touch the curve at 30s and must not cross the curve.

Lose this mark if the tangent is unsuitable but mark on.

1

Chooses appropriate x and y values from their graph

Mark consequentially if axes plotted the wrong way around.

Allow information clearly shown on graph.

1

Correctly calculates y / x

Difference in x values and y values must be at least 10 small squares in either direction.

1

Gives answer with correct units (mol dm^{-3} s^{-1}) or correct variant

Lose this mark if answer not to minimum of 2 significant figures and no units or incorrect units are given.

If student has used axis the wrong way round, the unit mark can be awarded for either the correct unit based on their graph or for the correct unit for rate.

1

[9]

39 (a) Side-arm flask / side-arm test tube

Do not allow sealed side-arm flask.

1

Flat-bottomed filter funnel with filter paper clearly shown

Either Buchner or Hirsch versions are suitable.

Allow Hirsch funnel and <u>horizontal</u> filter paper.

Allow three-dimensional filter funnels.

Do not allow standard Y-shaped funnel.

Do not allow sealed funnel.

If it is not clearly air-tight between the funnel and the flask, maximum 1 mark.

1

(b) Heat melting point tube in an oil bath

Accept 'melting point apparatus' or Thiele tube.

Do not accept water bath.

1

<u>slowly near the melting point</u>

Ignore any additional correct details.

Apply list principle for additional incorrect details.

1

[4]

40 (a) To make sure all the solutions (from both the burette and pipette) react with each other / are in the flask

Penalise 'solid' or 'residue'.

Do not allow any suggestion of removal of species.

1

(b) Water does not change the number of moles <u>of either reagent / reactants</u>

Water is not a reagent / does not react with either reactant.

Do not allow 'water is not involved in the reaction'.

Apply list principle.

1

[2]

41 (a) M1 <u>concentrated sulfuric acid OR c(onc) H_2SO_4</u>

*If no reagent or incorrect reagent in **M1, CE= 0** and no marks for **M2** or **M3***

M2 (cream solid) turns orange
OR <u>orange / red / brown fumes / gas / vapour</u>

*If <u>dilute</u> sulfuric acid **OR** "aq" <u>(alone)</u> **CE=0***

M3 (yellow solid) turns black
OR <u>purple fumes / gas / vapour</u>
OR correct reference to H_2S <u>observation (eg bad egg smell)</u>

*If H_2SO_4 / sulfuric acid given but not stated whether dilute or concentrated, penalise **M1** and mark on for **M2** and **M3***
*If incorrect formula for the acid, penalise **M1** but mark **M2** and **M3***

***OR* as an alternative**

M1 <u>concentrated ammonia</u> ***OR*** <u>c(onc) NH_3</u>

*If NH_3 / ammonia / aq ammonia given, but not stated as <u>concentrated</u> **OR** if <u>dilute</u> ammonia given, penalise **M1** but mark on for **M2** and **M3***
*Ignore "partially" and ignore "clear" in **M2***

M2 (cream solid) dissolves / solution formed

M3 precipitate remains / does not dissolve / insoluble
OR no reaction / no change / (yellow solid) turns to white solid

*If incorrect formula for ammonia, penalise **M1** but mark **M2** and **M3***

*In **M3** for ammonia.*
ignore "nothing (happens)".
ignore "no observation".

3

(b) M1 $AgNO_3$ ***OR*** silver nitrate ***OR*** any soluble silver salt

If no reagent ***OR*** *incorrect reagent in* ***M1***, ***CE= 0*** *and no marks for* ***M2 OR M3***

M2 <u>white precipitate</u> or <u>white solid / white suspension</u>

An insoluble silver salt OR Tollens' ***OR*** *Ag* ***OR*** *ammoniacal silver nitrate or HCl / $AgNO_3$* ***CE= 0*** *for the clip.*

M3 remains colourless ***OR*** no reaction ***OR*** no (observed) change ***OR*** no precipitate

For ***M1***
*Credit acidified (**OR** HNO_3) silver nitrate for* ***M1*** *and mark on.*
If silver ions or incorrect formula for silver nitrate, penalise ***M1*** *but mark* ***M2*** *and* ***M3***

Credit alternative test for nitrate ions

For ***M2***
Ignore "cloudy solution" ***OR*** *"suspension".*

For ***M3***
Ignore "nothing (happens)".
Ignore "no observation".
Ignore "clear".
Ignore "dissolves".

3

(c) M1 Br_2 ***OR*** bromine (water) ***OR*** bromine (in CCl_4 / organic solvent)

*If no reagent or incorrect reagent in **M1**, **CE= 0** and no marks for **M2** or **M3***

Either Order

M2 (stays) Orange / red / yellow / brown / the same

OR no reaction ***OR*** no (observed) change

OR reference to colour going to cyclohexane layer

*No credit for combustion observations; **CE=0***
*For **M2 in every case**.*
Ignore "nothing (happens)".
Ignore "no observation".
Ignore "clear".

M3 decolourised / goes colourless / loses its colour

With bromine (water)
***For M1**, it must be a whole reagent and / or correct formula.*
If oxidation state given in name, it must be correct.
For M1** penalise incorrect formula, but mark **M2** and **M3

***OR* as an alternative**

Use $KMnO_4/H_2SO_4$

M1 acidified potassium manganate(VII) or $KMnO_4/H_2SO_4$

OR $KMnO_4$/ H^+ ***OR*** acidified $KMnO_4$

M2 (stays) <u>purple</u> or no reaction or no (observed) change

With potassium manganate(VII)
For M1

M3 <u>purple to colourless</u> solution ***OR*** goes <u>colourless</u>

*If "manganate" or "manganate(IV)" or incorrect formula or no acid, penalise **M1** but mark **M2** and **M3***

Credit alternative test using **iodine** (for **M1**)

M2 (brown) to purple or accept no change, M3 colourless

Credit alternative test using <u>concentrated</u> $H_2\ SO_4$

M2 no change, M3 brown

*Credit alkaline / neutral $KMnO_4$ for possible full marks but **M3** gives <u>brown precipitate</u> or solution goes <u>green</u>.*

3

(d) M1 Tollens' (reagent) OR ammoniacal silver nitrate OR a description of making Tollens'

(Ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3)

M2 silver mirror

OR black solid / precipitate (Ignore silver precipitate)

M3 (stays) colourless or no reaction or no (observed) change

*If no reagent or incorrect reagent in **M1**, **CE= 0** and no marks for **M2** or **M3***

For M3 in every case
Ignore "nothing (happens)".
Ignore "no observation".

Alternative using Fehling's (solution)

M1 Fehling's (solution) or Benedict's solution

(Ignore Cu^{2+}(aq) or $CuSO_4$ on their own, but mark M2 and M3)

M2 Red solid / precipitate (Credit Orange or brown solid)

M3 (stays) blue or no reaction or no (observed) change

With potassium dichromate(VI)
For M1
*If "dichromate" or "(potassium) dichromate(IV)" or incorrect formula or no acid, penalise **M1** but mark **M2** and **M3***

Alternative using $K_2Cr_2O_7/H_2SO_4$

M1 acidified potassium dichromate or $K_2Cr_2O_7/H_2SO_4$

OR $K_2Cr_2O_7/H^+$ ***OR*** acidified $K_2Cr_2O_7$

M2 (Orange to) green solution OR goes green

M3 (stays) Orange or no reaction or no (observed) change

*For **M3***
Ignore dichromate described as "yellow" or "red".

With potassium manganate(VII)
For M1
If "manganate" or "(potassium manganate(IV)" or incorrect formula or no acid, penalise M1 but mark M2 and M3

Alternative using $KMnO_4/H_2SO_4$

M1 acidified potassium manganate(VII) or $KMnO_4/H_2SO_4$

OR $KMnO_4/H^+$ ***OR*** acidified $KMnO_4$

M2 purple to colourless solution OR goes colourless

M3 (stays) purple or no reaction or no (observed) change

*Credit alkaline / neutral $KMnO_4$ for possible full marks but **M2** gives brown precipitate or solution goes green.*

3

[12]

42 (a) 'Initial mass' must be the *y*-axis

If axis unlabelled, use data to decide that 'Initial mass' is on the y-axis.

1

Sensible scale

Do not award this mark if ***plotted points*** *do not cover at least half of the grid.*

Do not award this mark if any plotted point is outside the grid.

1

All points plotted correctly

Allow ± one small square.

1

Point at (0,0) is ringed

1

(b) Best-fit straight line that goes through the origin ± ½ small square

Mark consequentially to plotted points but the line must still go through the origin ± ½ small square.

Lose this mark if the line is doubled or kinked.

If the points are plotted correctly, lose this mark if the line deviates towards the anomalies.

1

(c) Students 3 and 5

Allow masses of 1.15 and 1.53 or 2.82 and 3.58

Mark consequentially to plot.

1

(d) Samples 3 or 5 have not lost all their water

Allow reaction / decomposition incomplete.

1

Sample not heated for enough time / larger masses will take a longer time to dehydrate / decompose

1

[8]

43 (a) (CO_2 from) burning (fossil) fuels

1

(b) $NaCl + CO_2 + NH_3 + H_2O \rightarrow NaHCO_3 + NH_4Cl$

Allow multiples, including fractions.

Ignore state symbols.

1

(c) $CaO + 2NH_4Cl \rightarrow CaCl_2 + 2NH_3 + H_2O$

Allow multiples, including fractions.

Allow ionic equations.

Do not allow equations involving NH_4OH *or* NH_4^+ *on the right hand side.*

Ignore state symbols.

1

(d) (i) = (106) × 100 / (117 + 100(.1))

Do not penalise precision but must be to minimum of two significant figures.

1

= 48.8

This answer without working scores 1 mark only.

1

(ii) The percentage atom economy cannot be improved

OR

Sell the by-product / $CaCl_2$ (solution)

Do not accept answers which refer to improving the efficiency of the process.

1

(e) It is used up but then regenerated later in the cycle / No overall consumption of NH_3

Allow 'can act as a catalyst'.

1

[7]

44 (a) HOOC—CHOH—CHOH—COO

Any suitable structural formula.

Displayed formula not required but bond sequences must be correct if shown.

1

(b) $C_4H_6O_6 + NaHCO_3 \rightarrow C_4H_5O_6Na + CO_2 + H_2O$

OR

$C_4H_6O_6 + 2NaHCO_3 \rightarrow C_4H_4O_6Na_2 + 2CO_2 + 2H_2O$

Allow equations based on the structural formula.

Allow multiples including fractions.

Allow any structure for C_4H_6O or $C_4H_5O_6Na$

1

(c) Suitable named indicator (eg litmus, methyl orange, Universal Indicator) / identified reactive metal (Mg, Zn or Fe)

Do not allow phenolphthalein without explanation of how a colour change would be seen.

Incorrect reagent, chemical error = 0 / 2

1

Appropriate colour in acid (eg red) / gas evolved

1

(d) (i) Reagent: <u>Acidified potassium dichromate</u> (solution)

If incomplete (correct) reagent, lose M1 but mark on.

Incorrect reagent, chemical error = 0 / 3

Allow acidified potassium manganate(VII)

1

Obs: orange to green

Purple to colourless (solution).

1

Obs: no (visible) change

Allow 'no visible reaction', but do not allow 'no reaction' without qualification.

1

(ii) Both would give the same result / both oxidised by reagent / both react with the reagent or similar

Allow consequential answer from (i).

Chemical error if reagent in (i) is incorrect, 0 / 1

1

(e) The water would allow the tartaric acid and sodium hydrogencarbonate to react (before use)

Ignore any reference to water reacting with the ingredients.

Ignore references to prevention of 'caking' or 'clumping'.

Ignore references to shelf life without qualification.

1

(f) Acid reacts (with $NaHCO_3$ / Na_2CO_3) to form CO_2

Allow 'neutralises ($NaHCO_3$ / Na_2CO_3) to form CO_2'.

1

(g) It is only used in very small quantities

Allow 'decomposes in the reaction'.

Do not allow 'reacts' without qualification.

Ignore reference to formation of salts.

1

[11]

45 (a) Any **three** from:

A method of weighing by difference / wash the solid from its weighing container into the beaker

If the nature of any washing is imprecise penalise once only.

Wash the (wet) rod into the flask / beaker after use

Do not allow a method where the solution is made up directly in the flask.

Wash the (wet) beaker into the flask after transfer

Ignore any instructions that refer to rinsing equipment (before use) or use of deionised water.

Wash the filter funnel (after transfer) into the flask

Use a teat pipette to make up to the mark on the volumetric flask

Ensure the <u>bottom of the (liquid) meniscus</u> is on the graduation mark

Mix / shake the final solution in the flask / invert flask

Max 3

(b) Do (a) further titration(s)

Mark these points independently.

1

To obtain concordant results

Allow results with ± 0.1

1

[5]

46 Mg^{2+} and Cl^{-}

Do not allow names.

[1]

47 (a) Yes, because it is oxidised to ethanal / CH_3CHO
OR it is oxidised to a compound that contains CH_3CO group

Ignore 'primary alcohols are oxidised to aldehydes'.

Need 'yes' and an explanation to be awarded the mark.

1

(b) M_r CHI_3 = 393.7 **(M1)**

Allow if clearly shown in a calculation.

Allow 394

1

Moles CHI_3 = 10 / 393.7 = 2.54×10^{-2} **(M2)**

Allow a consequential answer on an incorrect M_r.

*2.54×10^{-2} scores **M1** and **M2**.*

1

Moles I_2 = 7.62 × 10^{-2} **(M3)**

*Allow 3 × **M2**.*

1

Mass I_2 = 7.62 × 10^{-2} × 253.8 = 19.34g **(M4)**

*Allow **M3** × 253.8 or **M3** × 254*

1

Scaling 19.34 / 0.832 = 23.2g **(M5)**

*Allow **M4** / 0.832*

Lose this mark if the answer is not given to 3 significant figures.

*Answer without working scores **M5** only.*

Allow any chemically correct alternative method.

Calculations which combine several steps in one expression can score the marks for all of these individual steps.

1

(c) Remove soluble impurities

Allow 'remove excess sodium hydroxide / iodine'.

Allow 'remove excess sodium methanoate / sodium iodide'.

Allow 'remove excess reagents'.

1

(d) Will not dissolve solid / solid is insoluble in water

Allow 'will not react with solid'.

1

[8]

48 (a) Over time / after storage meter does not give accurate readings

Do not allow 'to get an accurate reading' or 'reading drifts' on its own.

Allow 'temperature variations affect readings'.

1

(b) Any **five** from:

Ignore references to the use of the pipette, the filling of the burette and the calibration of the pH meter.

- Measure pH (of the acid)
- Add alkali in known small portions

  Allow 1 – 2cm^3.
- Stir mixture
- Measure pH (after each addition)
- Repeat until alkali in excess

  Allow 27 – 50cm^3.
- Add in smaller increments near endpoint

  Allow 0.1 – 0.5cm^3.

  To score full marks, the sequence must follow a logical order.

5 max

[6]

49 (a) $FeSO_4 + Na_2C_2O_4 \rightarrow FeC_2O_4 + Na_2SO_4$

Allow multiples, including fractions.

Allow $Fe^{2+} + C_2O_4^{2-} \rightarrow FeC_2O_4$

Allow correct equation which includes water of crystallisation.

1

(b) M_r $FeSO_4.7H_2O$ = 277.9

Allow if shown clearly in the calculation.

Allow 278

1

Moles = 6.95 / 277.9 = 2.5(0) × 10^{-2}

Do not penalise precision but must be to a minimum of two significant figures.

Allow correct calculation using incorrect M_r.

Correct answer without working scores this mark only.

1

(c) 3(.00) × 10^{-2}

1

(d) Theoretical mass = 2.50 × 10^{-2} × 179.8 = 4.50g
as long as 2.50 × 10^{-2} is the smaller of parts (b) and (c) **(M1)**

Allow consequential answer from parts (b) and (c).

Allow theoretical mass = (smaller of parts (b) and (c)) × 179.8

If larger of parts (b) and (c) used, lose ***M1*** *but can score* ***M2****.*

Allow answers based on moles of reactant and product.

1

Yield = 3.31 × 100 / 4.50 = 73.6% **(M2)**

Award this mark only if answer given to 3 significant figures.

Correct answer without working scores this mark only, provided answer given to 3 significant figures.

1

(e) Some left in solution / some lost during filtration

Do not allow 'incomplete reaction'.

Do not allow 'reaction is reversible'.

1

(f) MnO_4^- will oxidise the iron(II) ion and the ethanedioate ion

1

MnO_4^- does not oxidise the Cu^{2+} ion / larger volume needed for iron(II) ethanedioate

1

[9]

50 (a) Water in the gaseous state from the precipitate absorbed by drying agent

OR

Water vapour from the precipitate absorbed by drying agent

Allow 'water vapour reacts with drying agent'.

Do not allow 'absorb water' without qualification.

1

(b) (Blue to) pink / pink colour observed

1

[2]

51 (a) Stoppered flask or similar with side arm

Allow gas outlet through stopper.

1

Calibrated container for collection eg gas syringe

Allow collection over water, but must use calibrated vessel for collection.

Lose 1 mark if apparatus is not gas tight.

1

(b) Plot a graph of 'volume (of gas)' against 'time'

1

Determine the slope (gradient) at the beginning

1

(c) Repeat with same volume **or** concentration of hydrogen peroxide and at the same temperature

Ignore references to results.

Do not allow 'keep everything the same' or words to that effect.
Must mention volume or concentration and temperature.

1

Add cobalt(II) chloride to one experiment

1

[6]

52 (a) To remove the oxide layer on the aluminium

Do not allow 'cleaning' or 'removal of grease'.

Do not allow 'removal of impurities' without qualification.

1

(b) An appropriate method for delivering H_2 gas over a Pt electrode

Need H_2 gas and Pt electrode labelled (allow gas delivered directly below the electrode).

1

The Pt electrode must clearly be in contact with a solution of a named acid.

Ignore any concentration or pressure values.

Ignore absence of bubbles.

Allow if electrode is below outer acid level.

1

(c) The carbonate ion reacts with the acid (in the SHE) / reaction between carbonate and Al^{3+}

Lose this mark if aluminium carbonate formed but mark on.

1

Reaction given (either equation or products specified)

OR H^+ / Al^{3+} concentrations change / cell e.m.f. altered

1

[5]

53 Measure pH with a meter

Chemical indicators not allowed for M1 (allow mark for M2 if student describes differences in pHs but not for differences in colours).

1

Methylamine would have a higher pH / ammonia would have a lower pH

Use of $CuSO_4$ not allowed.

1

[2]

54 (a) (i) **M1** iodine ***OR*** I_2 OR I_3^-

Ignore state symbols

*Credit **M1** for "iodine solution"*

M2 $Cl_2 + \mathbf{2}I^- \longrightarrow \mathbf{2}Cl^- + I_2$

OR

$\frac{1}{2} Cl_2 + I^- \longrightarrow Cl^- + \frac{1}{2} I_2$

Penalise multiples in M2 except those shown

***M2** accept correct use of I_3^-*

M3 redox or reduction-oxidation or displacement

3

(ii) **M1** (the white precipitate is) silver chloride

__M1__ must be named and for this mark ignore incorrect formula

M2 $Ag^+ + Cl^- \longrightarrow AgCl$

For __M2__ ignore state symbols

Penalise multiples

M3 (white) precipitate / it dissolves

OR colourless solution

Ignore references to "clear" alone

3

(b) (i) **M1** $H_2SO_4 + \mathbf{2}Cl^- \longrightarrow \mathbf{2}HCl + SO_4^{2-}$

For __M1__ ignore state symbols

OR $H_2SO_4 + Cl^- \longrightarrow HCl + HSO_4^-$

Penalise multiples for equations and apply the list principle

OR $H^+ + Cl^- \longrightarrow HCl$

M2 hydrogen chloride ***OR*** HCl ***OR*** hydrochloric acid

2

(ii) **M1 and M2 in either order**

For __M1__ and __M2__, ignore state symbols and credit multiples

M1 $\mathbf{2}I^- \longrightarrow I_2 + \mathbf{2}e^-$

OR

$\mathbf{8}I^- \longrightarrow \mathbf{4}I_2 + \mathbf{8}e$ –

Do not penalise absence of charge on the electron

Credit electrons shown correctly on the other side of each equation

M2 $H_2SO_4 + \mathbf{8}H^+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$

OR

$SO_4^{2-} + \mathbf{10}H+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$

Additional equations should not contradict

M3 oxidising agent / oxidises the iodide (ions)

OR

electron acceptor

M4 sulfur ***OR*** S ***OR*** S_2 ***OR*** S_8 ***OR*** sulphur

4

(iii) **M1** The NaOH / OH^- / (sodium) hydroxide reacts with / neutralises the H^+ / acid / HBr (lowering its concentration)

OR a correct neutralisation equation for H^+ or HBr with NaOH or with hydroxide ion

Ignore reference to NaOH reacting with bromide ions

Ignore reference to NaOH reacting with HBrO alone

M2 Requires a correct statement for M1

The (position of) equilibrium moves / shifts(from L to R)

- to replace the H^+ / acid / HBr that has been removed / lost
- ***OR*** to increase the H^+ / acid / HBr concentration
- ***OR*** to make more H^+ / acid / HBr / product(s)
- ***OR*** to oppose the loss of H^+ / loss of product(s)
- ***OR*** to oppose the decrease in concentration of product(s)

*In **M2**, answers must refer to the (position of) equilibrium shifts / moves and is not enough to state simply that it / the system / the reaction shifts to oppose the change.*

M3 The (health) benefit outweighs the risk or wtte

OR

a clear statement that once it has done its job, little of it remains

OR

used in (very) dilute concentrations / small amounts / low doses

3

[15]

55 (a) (Returns) reagent on the sides of the flask to the reaction mixture (to ensure that all of the acid / alkali reacts)

Do not allow 'to get a better result' without qualification.

Do not allow 'to ensure that all of the acid / alkali reacts' without qualification.

1

(b) Water is not a reagent / water one of the products / does not change the number of moles of reagents

Do not allow 'water does not affect the titration' without qualification.

1

[2]

56 (a) (i) Mass loss would be too large / water would be lost when heating (so mass incorrect)

Do not allow 'to improve accuracy' without qualification.

Do not allow 'water is a product of the reaction'.

Do not allow 'mass of crucible incorrect / too high'.

1

(ii) Prevents loss of <u>solid / potassium carbonate / potassium hydrogencarbonate</u> (from the crucible)

Do not allow 'to improve accuracy' without qualification.

Do not allow 'stops anything escaping'.

1

(iii) Errors in <u>weighing</u> are too high / percentage errors in (obtaining) the <u>mass</u> are too high

Do not allow 'hard to / can't weigh very small amounts' without further qualification.

1

(b) (i) M_r of $KHCO_3$ is 100(.1)

Do not penalise precision.

1

moles $K_2CO_3 = 1 / (M_r \times 2) = 0.005$

If factor of 2 missing can only score first mark (M1).

Allow consequential answer on incorrect M_r of $KHCO_3$

1

mass of $K_2CO_3 = 0.005 \times 138.2 = 0.69(0)$

Correct mass without working scores one mark only (M3).

1

(ii) Reaction / decomposition incomplete

Do not allow 'a wet crucible was used'.

Ignore references to impurity and / or experimental errors.

1

[7]

57 (a) Temperature on *y*-axis

If axes unlabelled use data to decide that temperature is on y-axis.

1

Uses sensible scales

*Lose this mark if the **plotted points** do not cover half of the paper.*

Lose this mark if the temperature axis starts at 0 °C.

1

Plots **all** of the points correctly ± one square

Lose this mark if the graph plot goes off the squared paper.

1

Draws two best-fit lines

*Candidate must draw **two** correct lines.*

Lose this mark if the candidate's line is doubled or kinked.

1

Both extrapolations are correct to the 4^{th} minute

Award this mark if the candidate's extrapolations are within one square of your extrapolations of the candidate's best-fit lines at the 4^{th} minute.

1

(b) 19.5 (°C)

Accept this answer only.

1

(c) 26.5 ± 0.2 (°C)

Do not penalise precision.

1

(d) (c) – (b)

*Only award this mark if temperature rise is recorded to **1 d.p.***

1

(e) Uses $mc\Delta T$ equation

Allow use of this equation with symbols or values for M1 even if the mass is wrong.

1

Correct value using 25 × 4.18 × (d)

7.0 gives 732 J.

Correct answer with no working scores one mark only.

Do not penalise precision.

Allow answer in J or kJ.

Ignore sign of enthalpy change.

1

(f) $9.0(1) \times 10^{-3}$

Do not allow 0.01

Allow 9×10^{-3} or 0.009 in this case.

1

(g) If answer to (e) in J, then (e) / (1000 × (f))

or

If answer to (e) in kJ, then (e) / (f)

7.0 and 9.01×10^{-3} gives 81.2 kJ mol^{-1}

If answer to (e) is in J must convert to kJ mol^{-1} correctly to score mark.

1

Enthalpy change has negative sign

Award this mark independently, whatever the calculated value of the enthalpy change.

1

(h) The idea that this ensures that all of the solution is at the same temperature

Do not allow 'to get an accurate reading' without qualification.

1

(i) (i) Chlorine is <u>toxic / poisonous / corrosive</u>

Do not allow 'harmful'.

1

(ii) Explosion risk / apparatus will fly apart / stopper will come out

Ignore 'gas can't escape' or 'gas can't enter the tube'.

1

[16]