AQA Chemistry A-level

Practical Skills Questions

Q1. This question is about a white solid, $MHCO_3$, that dissolves in water and reacts with hydrochloric acid to give a salt.

$$MHCO_3 + HCl \rightarrow MCl + H_2O + CO_2$$

A student was asked to design an experiment to determine a value for the Mr of $MHCO_3$. The student dissolved 1464 mg of $MHCO_3$ in water and made the solution up to 250 cm3.
25.0 cm3 samples of the solution were titrated with 0.102 mol dm^{-3} hydrochloric acid. The results are shown in the table.

	Rough	1	2	3
Initial burette reading / cm^3	0.00	10.00	19.50	29.25
Final burette reading / cm^3	10.00	19.50	29.25	38.90
Titre / cm^3	10.00	9.50	9.75	9.65

(a) Calculate the mean titre and use this to determine the amount, in moles, of HCl that reacted with 25.0 cm^3 of the $MHCO_3$ solution.

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(3)

(b) Calculate the amount, in moles, of $MHCO_3$ in 250 cm^3 of the solution.
Then calculate the experimental value for the Mr of $MHCO_3$.
Give your answer to the appropriate number of significant figures.

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(3)

(c) The student identified use of the burette as the largest source of uncertainty in the experiment.
Using the same apparatus, suggest how the procedure could be improved to reduce the percentage uncertainty in using the burette.
Justify your suggested improvement.
Suggestion ____________________________________

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Justification ____

(2)

(d) Another student is required to make up 250 cm3 of an aqueous solution that contains a known mass of MHCO3. The student is provided with a sample bottle containing the MHCO3. Describe the method, including apparatus and practical details, that the student should use to prepare the solution.

(6)
(Total 14 marks)

Q2. 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:

$$Na_2CO_3.10H_2O(s) \text{ ----> } Na_2CO_3(s) + 10H_2O(g)$$

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.
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)

Q3. A green solution, X, is thought to contain [Fe(H2O)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.

(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.

(5)
(Total 11 marks)

Q4. A sample of hydrated nickel sulfate ($NiSO_4.xH_2O$) with a mass of 2.287 g was heated to remove all water of crystallisation. The solid remaining had a mass of 1.344 g.
(a) Calculate the value of the integer x.
Show your working.

(4)

(b) Suggest how a student doing this experiment could check that all the water had been removed.

(2)
(Total 6 marks)

Q5. Propane-1,2-diol has the structure $CH_2(OH)CH(OH)CH_3$. It is used to make polyesters and is one of the main substances in electronic cigarettes (E-cigarettes).

A sample of propane-1,2-diol was refluxed with a large excess of potassium dichromate(VI) and sulfuric acid.

(a) Draw the skeletal formula of propane-1,2-diol.

(1)

(b) Write an equation for this oxidation reaction of propane-1,2-diol under reflux, using [O] to represent the oxidizing agent.

Show the displayed formula of the organic product.

(2)

(c) Draw a labelled diagram to show how you would set up apparatus for refluxing.

(2)

(d) Anti-bumping granules are placed in the flask when refluxing.
Suggest why these granules prevent bumping.

(1)

(e) Draw the structure of a different organic product formed when the acidified potassium dichromate(VI) is not in excess.

(1)
(Total 7 marks)

Q6. 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.

(5)
(Total 6 marks)

Q7. 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 H2SO4(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 H2SO4(aq).

Identity of Compound 2 ____

Explanation ____

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(3)

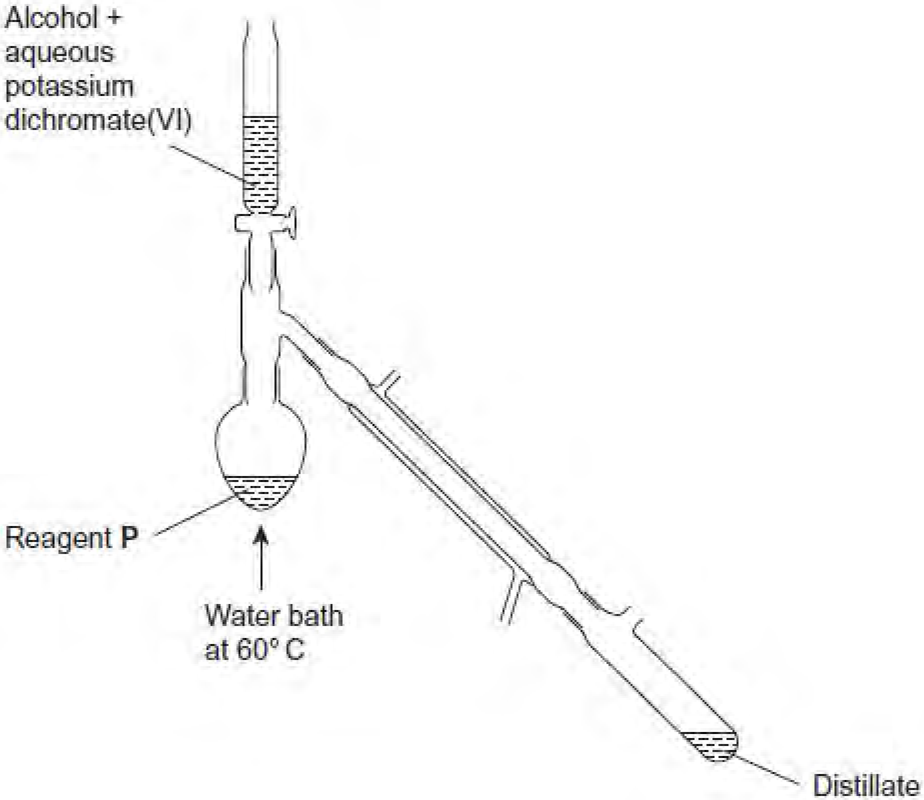
(c) Identify the compound that is strontium hydroxide.
Give an equation for the reaction of strontium hydroxide with sulfuric acid.

Compound ____

Equation ____

(2)
(Total 8 marks)

Q8. 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.

(1)

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

(1)

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

(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)

Q9. 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:

$$\mathrm{Ca(OH)2 + 2HCl\ CaCl2 + 2H2O}$$

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.

(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%.

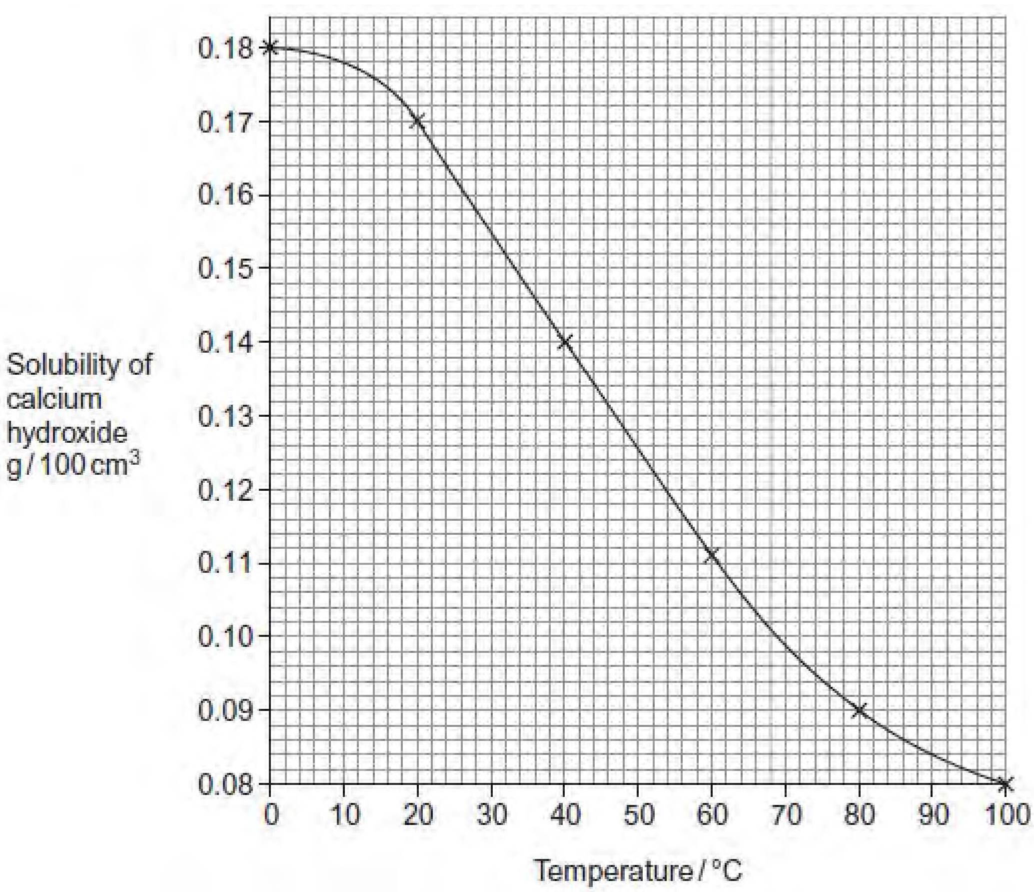
Calculate the mass of calcium sulfate formed. Give your answer to an appropriate number of significant figures.

Mass of calcium sulfate formed = ____________ g

(3)

(Total 11 marks)

Q10. 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.

(3)

(Total 6 marks)

Q11. 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. 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.

(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 cm3 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 ____

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(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)

Q12. 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 Rf 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.

(4)

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

(4)

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

(2)
(Total 10 marks)

Q13. Iodide ions are present in seawater but at very low concentrations. Certain types of seaweed are able to extract and concentrate iodide ions in their cells up to about 3% by mass. This seaweed could be a source of the element iodine (I_2).
The following is an account of a method that was used to extract I_2 from Laminaria seaweed.
The solvent tetrachloromethane (CCl_4) is no longer used because it is very toxic.

A. Collect and dry some seaweed. Heat it very strongly in a crucible until a small quantity of ash is formed.
B. Add distilled or deionised water to the cooled ash in a beaker. Boil the suspension for 5 minutes. Allow to cool.
C. Filter the suspension.
D. Gradually add dilute sulfuric acid to the filtrate until the solution is acidic.
E. Add hydrogen peroxide solution. A brown solution will be formed.
F. Transfer the solution to a separating funnel.
G. Add CCl_4 to the funnel. It forms a separate organic layer. This organic layer changes from a colourless liquid to a purple solution.
H. Add the organic layer to an evaporating basin and place this in a fume cupboard. Grey-black crystals of iodine will form as the solvent evaporates.

(a) In Step A of the method, explain how it could have been confirmed that the decomposition of the seaweed was complete.

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(2)

(b) The suspension was filtered in Step C.
Suggest an advantage of using vacuum filtration for this part of the method.

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(1)

(c) Describe how, in Step D, the solution could have been tested to show when it became acidic. Your method should not contaminate the solution.

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(2)

(d) Write an overall equation showing the oxidation of iodide ions to iodine in Step E using hydrogen peroxide solution in acidic conditions. (No oxygen is evolved in this reaction.)

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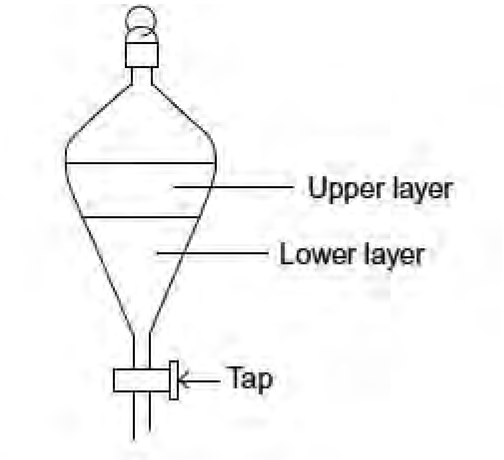
(1)

(e) A diagram of a separating funnel is shown below.



Aqueous solutions and tetrachloromethane are immiscible. When added to the separating funnel they form two layers as shown in the diagram. Prolonged shaking of the mixture allows iodine (dissolved in the aqueous layer) to pass into the tetrachloromethane layer. The densities of some liquids are shown in the table.

Liquid	**H_2O**	**Filtrate from Step C**	**CCl_4**	**Concentrated H_2SO_4**
Density / gcm^{-3}	1.0	1.2	1.6	1.8

Explain briefly whether the upper layer or the lower layer in the separating funnel is likely to show a purple colouration after Step G.

(1)

(f) The iodine in the separating funnel quickly establishes an equilibrium after shaking the contents. The concentrations of iodine in the aqueous layer and in the CCl_4 layer become constant. This is shown by the relationship

$$K = \frac{[I_2 \text{ in } CCl_4]}{[I_2 \text{ in aqueous layer}]}$$

A sample of Laminaria seaweed, mass 56.4 g, was processed by the method given. After Step H, 1.673 g of iodine remained in the evaporating basin. The volume of

each layer was 50.0 cm^3. The seaweed contains 3.00% iodine by mass.
Calculate the value of K from these data. Show your working.

(3)

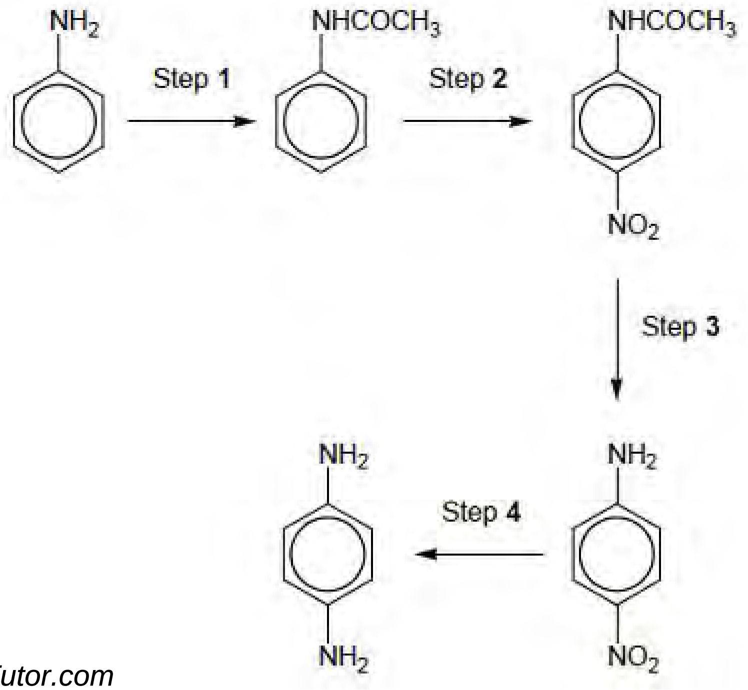
(g) It has been suggested that cyclohexene could be used to extract the iodine from the aqueous layer.
Explain why this would not be a suitable solvent.

(2)

(h) The iodine produced at the end of Step H is impure and needs to be recrystallised from a suitable inert solvent.
Explain the essential feature to consider when choosing a suitable inert solvent for this recrystallisation.

(2)
(Total 14 marks)

Q14. 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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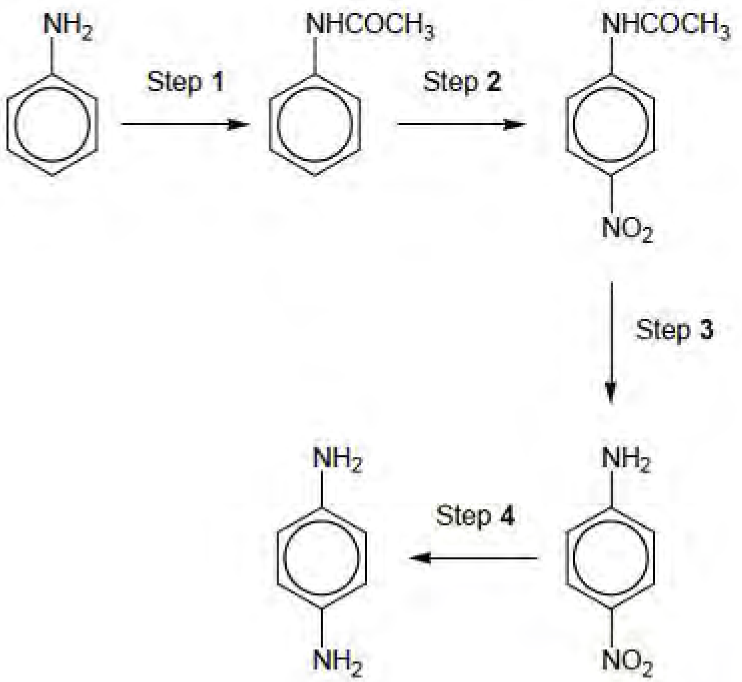
(2)

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.

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(1)

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

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(1)

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

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(1)

(h) Identify the reagents used in step 4.

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(1)

(Total 18 marks)

Q15. During the preparation of aspirin, it is necessary to filter the crude product under reduced pressure.

(a) 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)

Q16. 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 (Mr = 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.

(3)

(ii) In the preparation, the student produced 0.89 g of N−phenylethanamide.
Calculate the percentage yield for the reaction.

(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.

(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.

(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. ______________________________

2. ______________________________

(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.

(2)
(Total 15 marks)

Q17. Salicylic acid can be used to make aspirin. Before using a sample of salicylic acid to make aspirin, a student purified the acid by recrystallisation. The method for recrystallisation is outlined below.

Step 1: The sample is dissolved in a **minimum volume** of **hot water**.
Step 2: The solution is **filtered hot**.
Step 3: The filtrate is **cooled in ice** to form crystals.
Step 4: The crystals are collected by filtration, **washed with cold water** and left to dry.

Explain the purpose of each underlined point.

Minimum volume ______________________________

Hot water______________________________

Filtered hot______________________________

Cooled in ice ______________________________

Washed with cold water ____

(Total 5 marks)

Q18. An engineer was trying to develop a new fuel for a motorboat by blending mixtures of different alcohols in order to find out which mixture released the most energy when used in the engine.

The engineer had a number of alcohols in unlabelled bottles. It was decided to identify the alcohols by determining their enthalpies of combustion and comparing these values with those from a data book.

(a) Outline a simple practical experiment that the engineer could use, including the measurements to be taken, in order to determine the enthalpy of combustion for one of the unknown alcohols. You do not need to include details of any calculations.

(5)

(b) Other than heat loss to the surroundings, identify two major sources of error in the experiment. Do not refer to the precision of the equipment.

(2)

(c) The engineer found that the experimental values for the enthalpies of combustion of butan-1-ol and methylpropan-2-ol were very similar and so these values could not be used to distinguish between the two alcohols.

Identify a reagent that the engineer could use to distinguish between these two alcohols.

Give the observation in each case.

Reagent ____

Butan-1-ol ____

Methylpropan-2-ol ____

(3)

(d) The filter in the air intake for the engine in the motorboat may become partially blocked by dust and debris.
Explain with the aid of an equation why combustion of methylpropan-2-ol under these circumstances would be of economic and environmental concern to the engineer.

(3)
(Total 13 marks)

Q19. Sodium bromate(V) is a primary standard. This means that its solution can be used to check the concentration of other solutions.
(a) The half-equations for the reaction between bromate(V) ions and thiosulfate ions in the presence of acid are

$$2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e^-$$
$$BrO_3^- + 6H^+ + 6e^- \rightarrow Br^- + 3H_2O$$

Use these half-equations to deduce an overall equation for this reaction.

(1)

(b) A laboratory technician decided to use a 5.00×10^{-3} moldm^{-3} solution of sodium bromate(V) to check the concentration of a sodium thiosulfate solution that was labelled as 1.00×10^{-3} moldm^{-3}. The sodium bromate(V) solution was placed in the burette and 25.0 cm^3 of the sodium thiosulfate solution was pipetted into a conical flask.
Use the concentration of the sodium thiosulfate solution to calculate the expected titre value in this experiment.
Show your working.

(2)

(c) Consider the titre value that you have calculated in part (b).
Suggest one change to the experimental procedure in part (b) that would enable you to calculate a more accurate value for the concentration of the sodium thiosulfate solution.

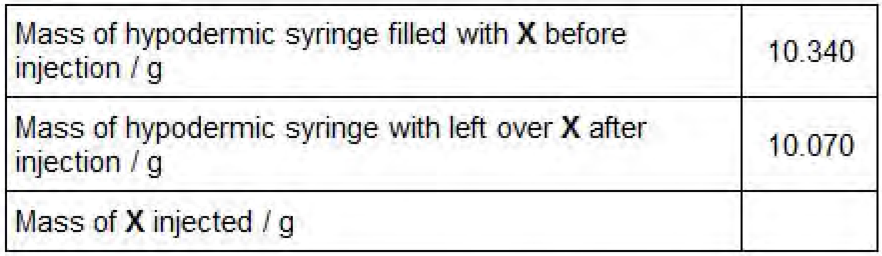
(1)
(Total 4 marks)

Q20. Silver cyanide can be precipitated from sodium cyanide solution by adding an excess of silver nitrate solution.
Describe how you would obtain a pure dry sample of silver cyanide from this mixture.

(Total 3 marks)

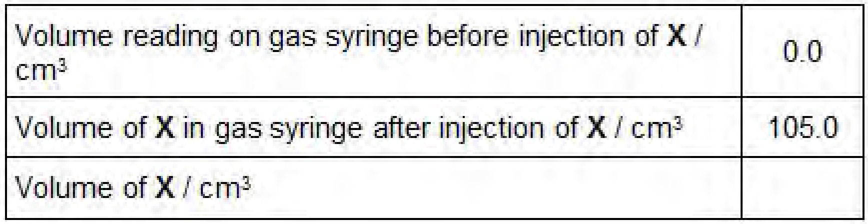
Q21. This question is about a toxic chloroalkane, X, that has a boiling point of 40 °C.
A student carried out an experiment to determine the Mr of X by injecting a sample of X from a hypodermic syringe into a gas syringe in an oven at 97 °C and 100 kPa. The student's results are set out in **Table 1** and **Table 2**.

Table 1



Mass of hypodermic syringe filled with **X** before injection / g	10.340
Mass of hypodermic syringe with left over **X** after injection / g	10.070
Mass of **X** injected / g	

Table 2



Volume reading on gas syringe before injection of **X** / cm^3	0.0
Volume of **X** in gas syringe after injection of **X** / cm^3	105.0
Volume of **X** / cm^3	

(a) Complete Table 1 and Table 2 by calculating the mass and volume of X.

(1)

(b) X is known to be one of the following chloroalkanes: CCl_4 $CHCl_3$ CH_2Cl_2 or CH_3Cl
Justify this statement by calculating a value for the Mr of X and use your answer to suggest the most likely identity of X from this list.
Give your answer for the Mr of X to an appropriate precision.

(The gas constant R = 8.31 J $K^{-1}mol^{-1}$)
Mr of X

Mr of X = ______________________

Identity of X
(If you have been unable to calculate a value for Mr, you may assume that the Mr value is 52. This is not the correct value).

Identity of X = __________________

(5)

(c) Suggest a reason, other than apparatus inaccuracy, why the Mr value determined from the experimental results differs from the actual Mr. Explain your answer.

(2)

(d) Suggest, with a reason, an appropriate safety precaution that the student should take when using the toxic chloroalkane, X, in the experiment.

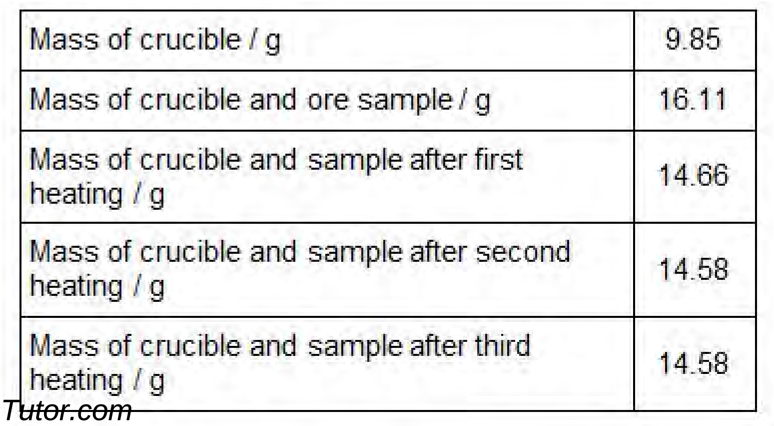
Safety precaution ____

Reason ____

(2)

(Total 10 marks)

Q22. A sample of strontium ore is known to contain strontium oxide, strontium carbonate and some inert impurities. To determine the mass of strontium carbonate present, a student weighed a sample of the solid ore and then heated it in a crucible for 5 minutes. The sample was allowed to cool and then reweighed. This heating, cooling and reweighing was carried out three times. The results are set out in the table.



Mass of crucible / g	9.85
Mass of crucible and ore sample / g	16.11
Mass of crucible and sample after first heating / g	14.66
Mass of crucible and sample after second heating / g	14.58
Mass of crucible and sample after third heating / g	14.58

(a) When strontium carbonate is heated it decomposes according to the following equation.

$$SrCO_3 \longrightarrow SrO + CO_2$$

Give a reason why the mass of the solid sample changed during the experiment.

____

____

____

(1)

(b) Use the data in the table to calculate the mass of strontium carbonate in the original ore sample. Give your answer to an appropriate precision.

Mass of strontium carbonate = ___ g

(5)

(c) Each balance reading has an uncertainty of ±5.00 mg.
Calculate the percentage error in the initial mass of ore used.

Percentage error = _____________ %

(1)

(d) The mass of inert impurities in the sample was 347 mg.
Deduce the mass of SrO in the sample and justify any assumption made in calculating your answer.
(If you have been unable to answer part (b), assume the mass of strontium carbonate was 4.85 g. This is not the correct answer.)

Mass of SrO = ________________

____

____

(2)

(e) Strontium metal can be extracted by heating strontium oxide with aluminium metal.
In this reaction, strontium vapour and solid aluminium oxide are formed.
Write an equation for the reaction and state the role of the aluminium in the process.

Explain why strontium forms a vapour but aluminium oxide is formed as a solid.
Equation

____

Role of aluminium ____

____

Explanation ____

____

____

____

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____

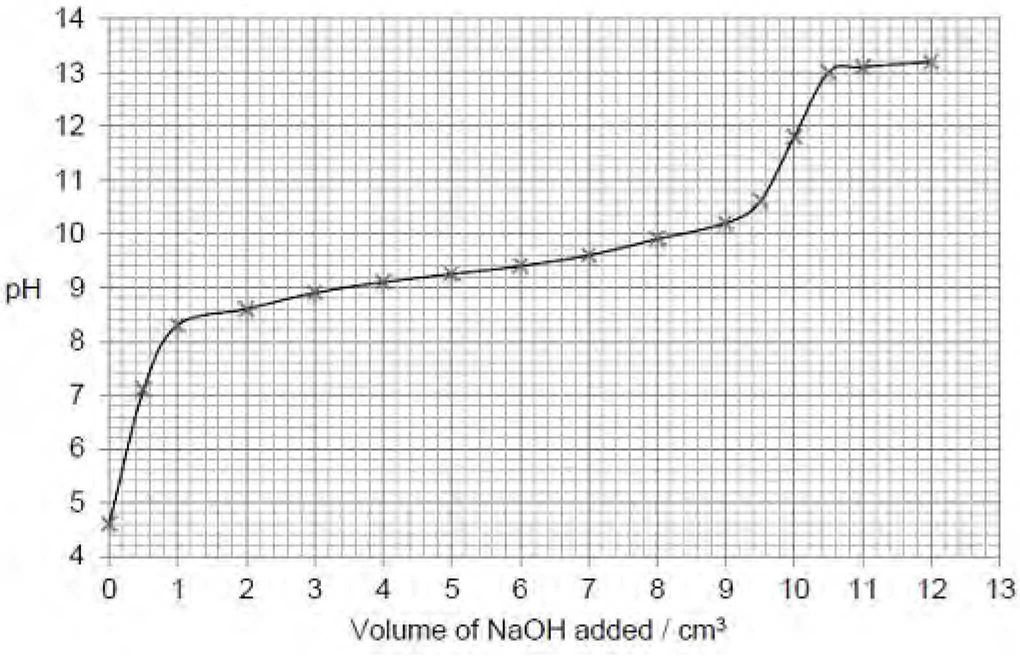
____

(5)
(Total 14 marks)

Q23. Ammonium chloride, when dissolved in water, can act as a weak acid as shown by the following equation.

$$NH_4^+(aq) \text{ ---> } NH_3(aq) + H^+(aq)$$

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 ____

(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.

(2)

(c) The pH at the end point of this reaction is 11.8.
Use this pH value and the ionic product of water, Kw = 1.0 × 10^{-14} mol^2dm^{-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 Ka.

Ka = _______________ mol dm−3

(3)

(e) A solution contains equal concentrations of ammonia and ammonium ions.
Use your value of Ka from part (d) to calculate the pH of this solution. Explain your working.
(If you were unable to calculate a value for Ka 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)

Q24. A student was given unlabelled samples of pentan-1-ol, pent-1-ene, pentanoic acid and pentanal.

(a) Name the reagent(s) that the student could use to identify the sample that was pent-1-ene.
Describe the observation(s) that the student would make to confirm this.

Reagent(s) ____

____

Observation(s) ____

(2)

(b) Name the reagent(s) that the student could use to identify the sample that was pentanoic acid.
Describe the observation(s) that the student would make to confirm this.

Reagent(s) ____

____

Observation(s) ____

(2)

(c) Name the reagent(s) that the student could use to identify the sample that was pentanal.
Describe the observation(s) that the student would make to confirm this.

Reagent(s) ____

____

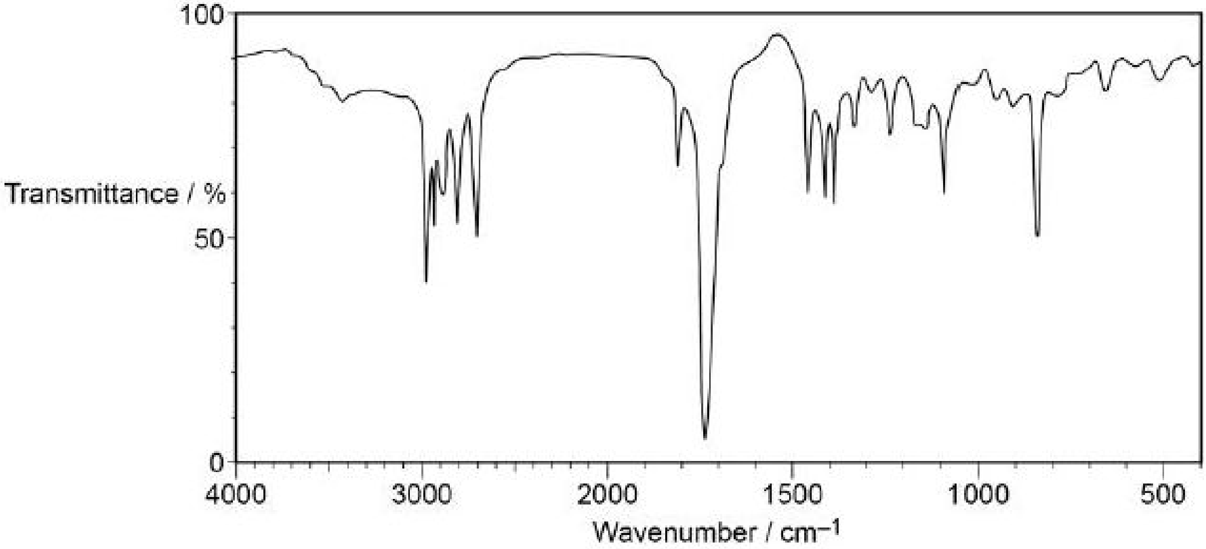
Observation(s) ____

____

____

(2)

(d) The student deduced that the spectrum in the image below was that of pentanal.



Justify this deduction and suggest why this spectrum cannot be that of pentan-1-ol, pentanoic acid or pent-1-ene.

(4)

(Total 10 marks)

Q25. (a) The iron(II) ions in well-water can be removed by oxidation using potassium manganate(VII) in **alkaline** solution. A mixture containing solid iron(III) hydroxide and solid manganese(IV) oxide is formed. These solid products can be removed by filtration under reduced pressure.

(i) Draw a diagram of the apparatus used for this filtration. Do **not** include the apparatus used to reduce the pressure.

(2)

(ii) An equation representing the oxidation reaction is given below.

$$3Fe^{2+}(aq) + KMnO_4(aq) + 5OH^-(aq) + 2H_2O(l) \longrightarrow 3Fe(OH)_3(s) + MnO_2(s) + K^+(aq)$$

Calculate the mass, in grams, of $KMnO_4$ required to react with the iron(II) ions in 1.00 dm^3 of well-water that has an iron(II) concentration of 0.225 mol dm^{-3}. Give your answer to the appropriate precision. Show your working.

(3)

(iii) In practice, a slight excess of potassium manganate(VII) is used to treat the well-water. Although this treated water is safe to drink, this excess of potassium manganate(VII) is undesirable. Suggest one reason, other than colour, why the excess is undesirable.

(1)

(b) Suggest one reason why the colour of potassium manganate(VII) solution can be a source of error when using a volumetric (graduated) flask to prepare a standard solution.

(1)

(Total 7 marks)

Q26. 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

(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.

(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.

(2)
(Total 11 marks)

Q27. (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.

(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.

(6)
(Total 11 marks)

Q28. A student calculated that a value for the enthalpy change of neutralisation is –51.2 kJ mol^{-1}.

The design of a possible hand-warmer using hydrochloric acid and sodium hydroxide was discussed. It was proposed that 500 cm^3 of hydrochloric acid should be used in a flexible, sealed plastic container with a breakable tube of solid sodium hydroxide also in the container. On breaking the tube, the sodium hydroxide would be released, react with the acid and produce heat. A 40 °C temperature rise was thought to be suitable.

(a) Calculate the heat energy, in J, required to raise the temperature of the reaction mixture by 40 °C. Assume that the reaction mixture has a density of 1.00 g cm^{-3} and a specific heat capacity of 4.18 J K^{-1} g^{-1}. Assume that all of the heat energy given out is used to heat the reaction mixture.

____

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____

____

(2)

(b) Use your answer from part (a) and the value for the enthalpy change of neutralisation of –51.2 kJ mol^{-1} to calculate the minimum amount, in moles, and hence the minimum mass of sodium hydroxide required in the breakable tube. (If you could not complete the calculation in part (a) assume that the heat energy required was 77 400 J. This is not the correct answer). Show your working.

Moles of NaOH ____

____

Mass of NaOH ____

____

(3)

(c) Use the amount, in moles, of sodium hydroxide from part (b) to calculate the minimum concentration, in mol dm^{-3}, of hydrochloric acid required in the 500 cm^3 of solution used in the sealed container.

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(1)

(d) Suggest one possible risk to a person who uses a hand-warmer containing sodium hydroxide and hydrochloric acid.

____

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(1)

(e) A commercial hand-warmer uses powdered iron sealed in a plastic container. A valve allows air to enter the container, and oxygen in the air reacts slowly with the iron to form solid iron(III) oxide. The heat released warms the container.

(i) Write an equation for this reaction between iron and oxygen to form iron(III) oxide.

____

(1)

(ii) One version of an iron-oxygen hand-warmer advertises that it is designed to stay warm for up to four hours. Other than by increasing the amount of iron in the container, state one change to the iron in the hand-warmer that would increase this time. Explain why this change to the iron might not be an advantage.

Change to the iron ____

____

Explanation ____

____

____

(3)

(f) Another type of hand-warmer uses sodium thiosulfate. Sodium thiosulfate is very soluble in water at 80 °C but is much less soluble at room temperature.

When a hot, concentrated solution of sodium thiosulfate is cooled it does not immediately crystallise. The sodium thiosulfate stays dissolved as a stable ’super-saturated’ solution until crystallisation is triggered. Heat energy is then released when the sodium thiosulfate crystallises.

(i) This type of hand-warmer is re-usable. Suggest one environmental advantage that a sodium thiosulfate hand-warmer has over the other two types.

____

(1)

(ii) Describe the two steps that you would take to make the sodium thiosulfate hand-warmer ready for re-use.

Step 1 ____

____

Step 2 ____

____

(2)

(Total 14 marks)

Q29. 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:

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

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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____
____
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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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____
____
____
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(3)
(Total 8 marks)

Q30. (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.
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 (Mr = 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.

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

____

____

____

____

(2)

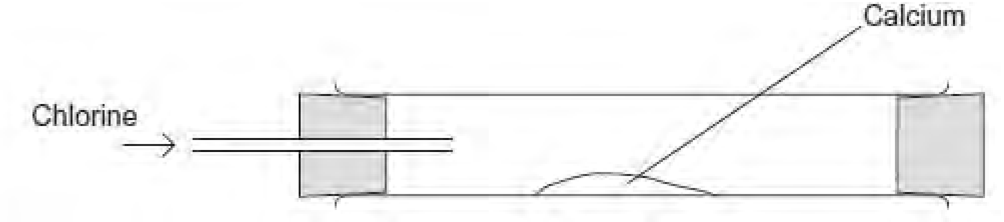
(h) Explain why it is important that the reaction mixture is stirred before recording each temperature.

____

____

(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.

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____

(1)

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

____

____

(1)

(Total 16 marks)

Q31. 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 I2
- 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 ____

____

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.

____

____

____

(1)

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

____

____

(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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____

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(1)

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

____

(1)
(Total 6 marks)

Q32. An equation for the decomposition of hydrogen peroxide is

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

(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)

Q33. A sample of pure $Mg(NO_3)_2$ was decomposed by heating as shown in the equation below.

$$2Mg(NO_3)_2(s) \longrightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

(a) A 3.74 × 10^{-2} g sample of $Mg(NO_3)_2$ was completely decomposed by heating.
Calculate the total volume, in cm^3, of gas produced at 60.0 °C and 100 kPa. Give your answer to the appropriate number of significant figures. The gas constant R = 8.31 J K^{-1} mol^{-1}.

Total volume of gas = ___________ cm^3

(5)

(b) The mass of MgO obtained in this experiment is slightly less than that expected from the mass of $Mg(NO_3)_2$ used. Suggest one practical reason for this.

(1)

(Total 6 marks)

Q34. 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 (Mr = 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)

Q35. 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)