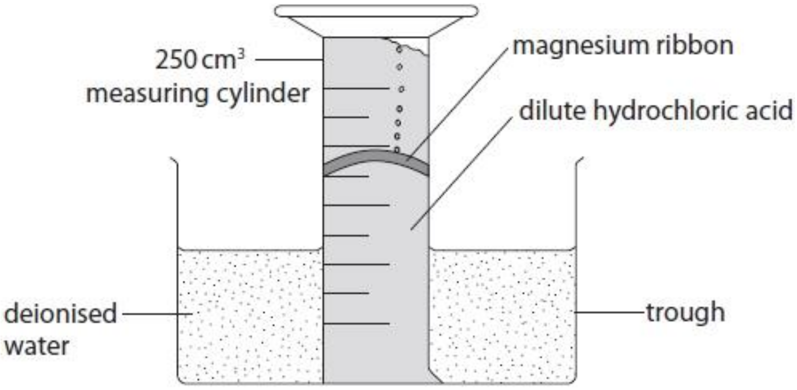
Questions

Q1.

A student used the apparatus in the diagram to determine the molar volume of a gas.



Assume clamps are in place to secure the apparatus

The student used a piece of magnesium ribbon, which was about 5 cm in length, and the dilute hydrochloric acid was in excess. The experiment was repeated three times at 24°C and the following results were obtained.

	Experiment 1	Experiment 2	Experiment 3
Mass of magnesium / g	0.04	0.04	0.04
Volume of hydrogen gas / cm³	31	25	32

The equation for the reaction is

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

(a) (i) Calculate the number of moles of magnesium used by the student in each experiment.

(1)

(ii) Use your answer from part (a)(i) to deduce the number of moles of hydrogen gas that should be produced.

(1)

(iii) Calculate, using the Ideal Gas Equation, the volume of hydrogen gas, in **cm^3**, that should be produced in each of these experiments.
[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1} $p = 101\ 000$ Pa]

(4)

(b) Give a reason why the student repeated the experiment three times.

(1)

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(c) Give three reasons for the difference between your calculated value in (a)(iii) and the actual volumes of hydrogen gas obtained by the student.

For each reason, identify a change to either the apparatus or the chemicals that could be made by the student to improve the result.

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(Total for question = 13 marks)

Q2.

Pineapple juice contains the weak acids citric acid ($C_6H_8O_7$) and ascorbic acid ($C_6H_8O_6$). The amount of each compound in a sample of 150 cm^3 of pineapple juice can be determined by titration.

Experiment **1** is designed to determine the total amount of acid. 10.0 cm^3 samples of pineapple juice are transferred to separate conical flasks and titrated with a solution of sodium hydroxide of known concentration.

The total amount of acid in the 150 cm^3 sample of pineapple juice is 8.00×10^{-3} mol.

(i) Give a reason why methyl orange would **not** be a suitable indicator to use in this titration.

(1)

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(ii) A student did not notice an air bubble in the tip of the burette **before** carrying out one of their accurate titrations. During this titration, the air bubble escaped.

Explain the effect this mistake would have on the value of this titre.

(2)

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(Total for question = 3 marks)

Q3.

(a) State what is meant by the term **molar volume of a gas**.

(1)

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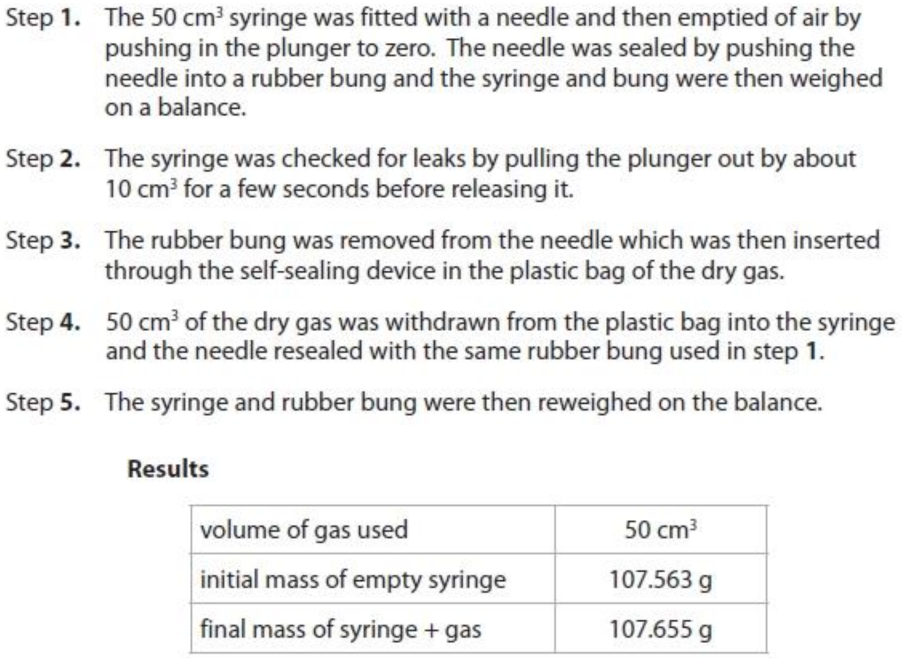
(b) The following steps were carried out by a student to find the molar mass of a gas. The experiment was carried out at 20 °C and one atmosphere pressure. The dry gas was supplied in a plastic bag fitted with a self-sealing device. The student had a choice of two different gas syringes. The student decided to use a 50 cm^3 syringe.



Step **1.** The 50 cm^3 syringe was fitted with a needle and then emptied of air by pushing in the plunger to zero. The needle was sealed by pushing the needle into a rubber bung and the syringe and bung were then weighed on a balance.

Step **2.** The syringe was checked for leaks by pulling the plunger out by about 10 cm^3 for a few seconds before releasing it.

Step **3.** The rubber bung was removed from the needle which was then inserted through the self-sealing device in the plastic bag of the dry gas.

Step **4.** 50 cm^3 of the dry gas was withdrawn from the plastic bag into the syringe and the needle resealed with the same rubber bung used in step **1**.

Step **5.** The syringe and rubber bung were then reweighed on the balance.

Results

volume of gas used	50 cm^3
initial mass of empty syringe	107.563 g
final mass of syringe + gas	107.655 g

(i) The gas syringe has a total uncertainty of ±0.5 cm^3.
Each reading on the balance has an uncertainty of ±0.0005 g.
Calculate the percentage uncertainty in the measurement of the volume and mass of gas used in this procedure.

(2)

(ii) The student repeated the experiment with 100 cm^3 of the gas using a 100 cm^3 syringe.
The total uncertainty for this larger syringe was also ±0.5 cm^3.
Determine the effect, if any, on the volume and mass uncertainties.

(2)

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(iii) Calculate the molar mass of the gas used in the procedure outlined in part (b). You may assume that one mole of gas occupies 24 000 cm^3 under these conditions. Give your answer to an appropriate number of significant figures and include units in your answer.

(2)

(iv) Explain how the student would know if the syringe had a leak in step **2** and what effect this leak would have on the molar mass determined in part (b)(iii).

(2)

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(c) If the temperature had been less than 20 °C and the pressure remained at one atmosphere, deduce the effect, if any, on the molar mass calculated in part (b)(iii).

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(d) Give a reason why the gas should be dry.

(1)

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(Total for question = 12 marks)

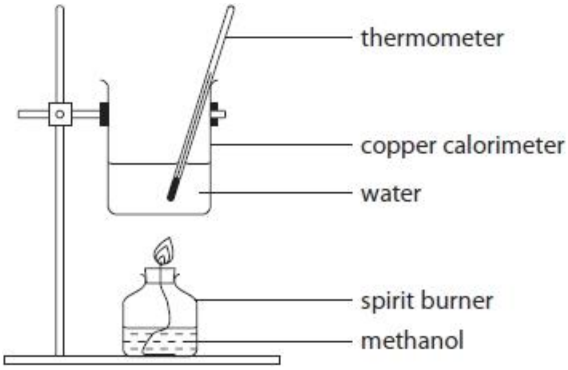
Q4.

This question is about the enthalpy change of combustion of methanol.

A teacher asked two students to carry out a practical task to determine the enthalpy change of combustion of methanol.
Both students were provided with the same apparatus and chemicals.
The following procedure was provided for the students.

Procedure

- Measure out 150 cm^3 of distilled water, using a 250 cm^3 measuring cylinder.
- Transfer the water to a copper calorimeter and note the initial temperature of the water (to the nearest 0.5°C) in **Table 1**.
- Weigh the spirit burner containing methanol and record its mass in **Table 1**.
- Place the spirit burner under the copper calorimeter, as shown in the diagram.
- Ignite the spirit burner and burn the methanol, whilst stirring the water with the thermometer.
- After heating the water for three minutes, extinguish the flame and immediately record the **highest** temperature reached by the water.
- As soon as possible, reweigh the spirit burner containing the methanol and record its mass in **Table 1**.



The results of Student 1 are recorded in **Table 1**.

Mass of spirit burner plus methanol before burning / g	213.47
Mass of spirit burner plus methanol after burning / g	211.87
Mass of methanol burned / g	
Highest temperature of the water / °C	64.5
Initial temperature of the water / °C	22.0
Temperature change of the water / °C	

Table 1

(a) Complete **Table 1**, giving the values to an appropriate number of decimal places.

(2)

(b) Write the equation that represents the reaction that occurs when the standard enthalpy change of combustion of methanol, $CH_3OH(l)$, is measured. Include state symbols.

(2)

(c) Use Student 1's result to calculate the enthalpy change of combustion of methanol in kJ mol^{-1}.
Give your answer to an appropriate number of significant figures.

Specific heat capacity of water = 4.18 J g^{-1} °C^{-1}
Density of water = 1.00 g cm^{-3}

(4)

(d) Student 1 compared the experimental value for the enthalpy change of combustion of methanol obtained in part (c) with the standard value given on the internet.
The student's value was **less exothermic** than the standard value.

Student 1 decided to evaluate the uncertainty in the measurements made in this experiment.

(i) Student 1 used a 250 cm^3 measuring cylinder to measure the volume of 150 cm^3 distilled water. The uncertainty in this volume measurement is ±1 cm^3.
Calculate the percentage uncertainty in the volume of distilled water that Student 1 measured in the experiment.

(1)

(ii) Compare and contrast the use of a 250 cm^3 measuring cylinder to measure out the 150 cm^3 distilled water with the use of a 25 cm^3 measuring cylinder (uncertainty ±0.2 cm^3 for each volume measurement) six times to measure the same volume.

(3)

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(iii) Student 1 calculated the uncertainties in the remaining measurements. However, Student 1 realised that the measurement uncertainties did **not** explain the difference between the experimental value for the enthalpy change of combustion of methanol calculated in part (c) and the value obtained from the internet.
Other than human error, give **three** reasons for the difference in the values.

(3)

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(e) Student 1 decided to repeat the experiment.

Student 1 used the copper calorimeter and water from the first experiment and recorded the initial temperature as 60.0°C.
Student 1 burned **exactly** the same mass of methanol as in the first experiment.
Explain, with a reason, how the value for the enthalpy change of combustion of methanol from this experiment would differ, if at all, from the value obtained in the first experiment.

(2)

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(f) Student 2 followed the **original** instructions provided, but extinguished the flame after **four** minutes rather than after three minutes.

Explain how the value calculated by Student 2 for the enthalpy change of combustion of methanol compared with that obtained in Student 1's first experiment.

(2)

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(g) Another student, Student 3, used the results from Student 1's first experiment to find the enthalpy change of combustion of methanol. Student 3 incorrectly used a value of 46.0 g mol^{-1} for the molar mass of methanol.

State and justify how this mistake would affect the calculated value for the enthalpy change of combustion of methanol.

(2)

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(Total for question = 21 marks)

Q5.

A student carried out an investigation to determine the value of ***x*** in hydrated magnesium nitrate(III), $Mg(NO_2)_2 \bullet xH_2O$, using three different methods.

Method 1

- The student prepared an aqueous solution by dissolving 1.15 g of $Mg(NO_2)_2 \bullet xH_2O$ in distilled water, making up the solution to 250.0 cm^3 in a volumetric flask and shaking the mixture.
- The student titrated this solution against 25.0 cm^3 portions of an acidified solution of 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$(aq).

Method 2

- The student mixed a solution of $Mg(NO_2)_2 \bullet xH_2O$ with an excess of aqueous sodium carbonate solution, Na_2CO_3(aq).
- The student obtained a precipitate of magnesium carbonate, $MgCO_3$(s), and determined the mass of this precipitate.

Method 3

- The student heated a known mass of $Mg(NO_2)_2 \bullet xH_2O$(s).
- The student determined the mass of the anhydrous residue formed.

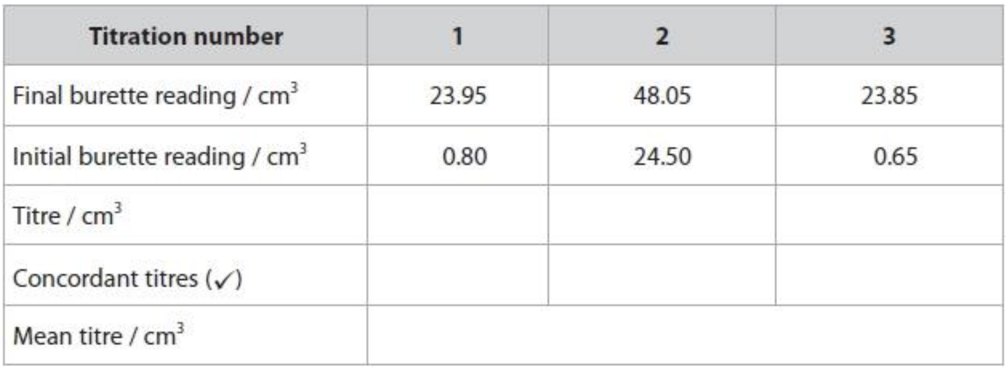
Method 1 – Titration

The student filled the burette with the solution made from $Mg(NO_2)_2 \bullet xH_2O$.

In each titration

- 25.0 cm^3 of 0.0200 mol dm^{-3} $KMnO_4$(aq) was transferred to a conical flask using a pipette.
- An excess of dilute sulfuric acid was added to the conical flask and the mixture heated.
- $Mg(NO_2)_2$(aq) was added from the burette until the end-point was reached.

The student's titration results are shown in the table (the rough titration results have **not** been included in the table).



Titration number	**1**	**2**	**3**
Final burette reading / cm^3	23.95	48.05	23.85
Initial burette reading / cm^3	0.80	24.50	0.65
Titre / cm^3			
Concordant titres (✓)			
Mean titre / cm^3			

(a) Complete the table.

(2)

(b) Deduce the colour change that the student would see at the end-point in this titration.

(1)

From .... to
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(c) In the titration reaction, 2 mol MnO_4^- react with 5 mol NO_2^-.

Calculate the number of moles of NO_2^-, in the 250 cm^3 of solution prepared by the student and hence the value of ***x*** in $Mg(NO_2)_2 \bullet xH_2O$.
Give your answer to the nearest whole number.

(5)

(d) The half-equations for the reaction in the titration are

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$

Use these half-equations to derive the overall ionic equation for the reaction between manganate(VII) and nitrate(III) ions in acidic conditions.
State symbols are not required.

(2)

Method 2 – Precipitation

The student used the following procedure.

- Dissolve a known mass of $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O$ in distilled water.
- Add an excess of aqueous sodium carbonate solution, $Na_2CO_3(aq)$, to obtain a precipitate of magnesium carbonate, $MgCO_3(s)$.

$$Mg^2+(aq) + CO_3^{2-}(aq) \rightarrow MgCO_3(s)$$

- Weigh a piece of filter paper.
- Filter the mixture from the above reaction through the pre-weighed filter paper.
- Wash the precipitate of $MgCO_3(s)$ with distilled water.
- Dry the filter paper and precipitate in a desiccator.
- Reweigh the filter paper and the precipitate.
- Calculate the value of ***x*** from the results obtained.

The student found that the value of ***x*** calculated using **Method 2** was different from that obtained using **Method 1**. This difference occurred despite having used a pure sample of the hydrated salt and without making any errors in technique during the experiment.

The student found out from a data book that the compound magnesium carbonate is very slightly soluble in water.

(e) Explain how, if at all, the very slight solubility of magnesium carbonate in water would affect the value calculated for ***x***.

(2)

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(f) The student planned to obtain any dissolved magnesium carbonate by evaporating the filtrate, and then weighing the residue.

Criticise this student's plan.

(2)

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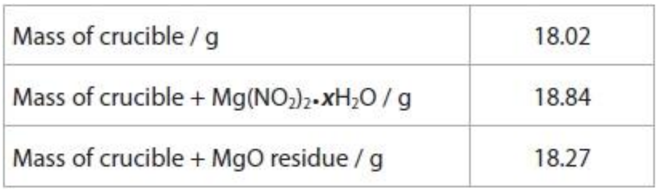
Method 3 – Thermal decomposition

NOTE: On heating, $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O(s)$ loses its water of crystallisation and **then** undergoes further decomposition to give magnesium oxide, MgO.

The student used the following procedure.

- Weigh an empty crucible.
- Add some $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O(s)$ and then reweigh the crucible plus contents.
- Heat the crucible plus contents and allow to cool.
- Weigh the crucible plus magnesium oxide residue.
- Use these data to calculate a value for ***x***.

The student's results are shown in the table.



Mass of crucible / g	18.02
Mass of crucible + $Mg(NO_2)_2 \bullet \boldsymbol{x}H_2O$ / g	18.84
Mass of crucible + MgO residue / g	18.27

(g) Identify how the student should ensure that the hydrated salt was fully decomposed.

(1)

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(h) The student carried out an evaluation of the results obtained from **Method 3**

Identify **two** modifications to the method that would enable the student to lower the percentage uncertainty in the measurement of the mass of the solid residue.

(2)

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(Total for question = 17 marks)

Q6.

The gas phase reaction between hydrogen and iodine is reversible.

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

(a) (i) Write the expression for the equilibrium constant, K_c, for this reaction.

(1)

(ii) If the starting concentration of both hydrogen and iodine was **a** mol dm^{-3} and it was found that 2**y** mol dm^{-3} of hydrogen iodide had formed once equilibrium had been established, write the K_c expression in terms of **a** and **y**.

(2)

(b) The expression for the equilibrium constant in (a)(ii) can be rearranged as shown.

$$\mathbf{y} = \frac{\mathbf{a}\sqrt{K_c}}{2 + \sqrt{K_c}}$$

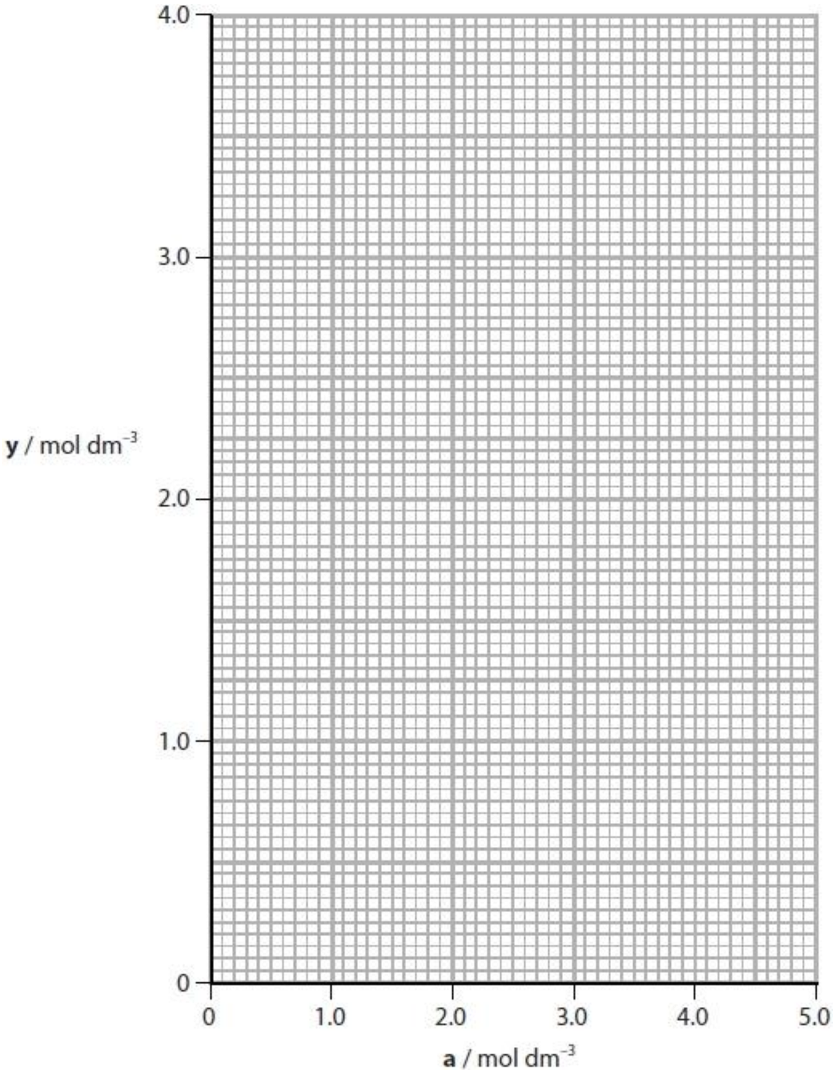
In an experiment, air was removed from a 1 dm^3 flask and amounts of hydrogen and iodine gases were mixed together such that their initial concentrations were both **a** mol dm^{-3}. This mixture was allowed to reach equilibrium at 760 K. The equilibrium concentration of iodine was then measured.
The experiment was repeated for various initial concentrations, **a** mol dm^{-3}, and the results recorded in the table.
(i) Complete the table to give the two remaining values of **y** mol dm^{-3}, to **two** decimal places.

(1)

a / mol dm^{-3}	$[I_2]_{eq}$ / mol dm^{-3}	y / mol dm^{-3}
0.20	0.02	0.18
0.80	0.25	0.55
1.50	0.37	
2.10	0.57	1.53
2.80	0.65	2.15
3.80	0.87	
4.90	1.15	3.75

(ii) Plot a graph to show how **y** mol dm^{-3} varies with the initial concentrations of hydrogen and iodine, **a** mol dm^{-3}.

(2)



(iii) Determine the gradient of your graph.
Show your working on the graph.

(2)

(iv) Use your answer to (b)(iii) and the expression $\mathbf{y} = \dfrac{\mathbf{a}\sqrt{K_c}}{2 + \sqrt{K_c}}$ to calculate the value of K_c.

(2)

(c) Identify a safety issue associated with this experiment.

(1)

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(d) One of the experiments in part (b) was repeated using the same molar quantities of hydrogen and iodine but in a 500 cm^3 flask instead of the 1 dm^3 flask.

Deduce the effect, if any, that this would have on the rate of reaction and on the value of K_c calculated.

(2)

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(e) The equation for the reaction between hydrogen and iodine is

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ $\Delta H = -9.6 \text{ kJ mol}^{-1}$

(i) Explain the effect, if any, on the value of K_c when the temperature is increased.

(2)

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(ii) On your graph in (b)(ii), draw and label the line you would expect if the experiment was carried out at 1000 K instead of 760 K.

(1)

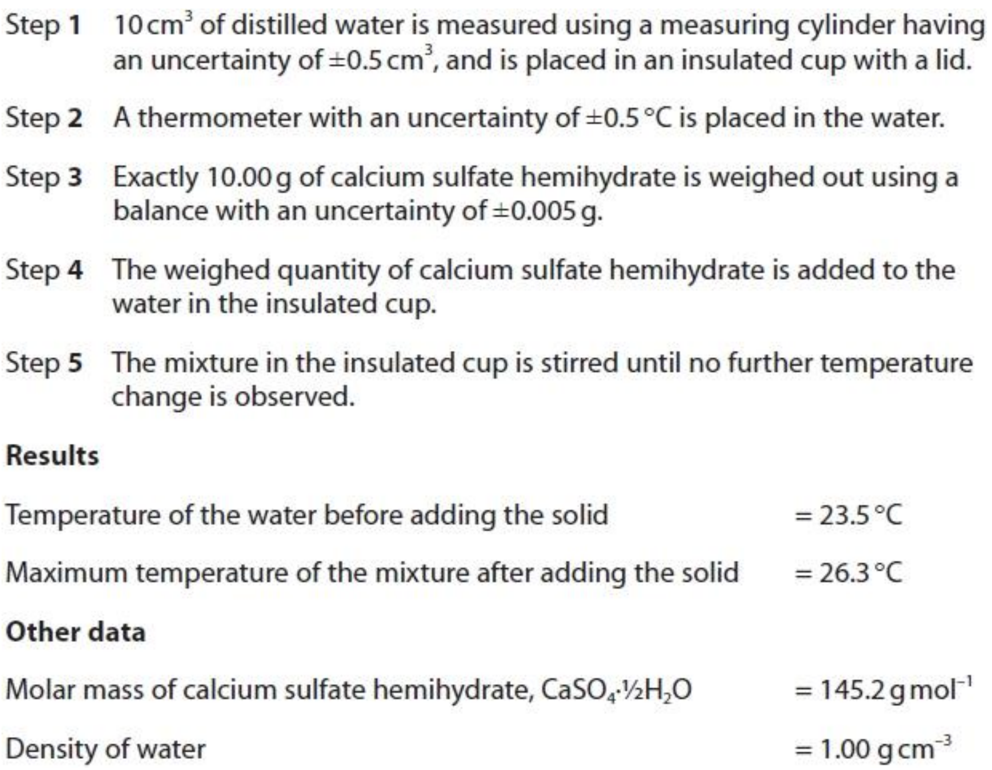
(Total for question = 16 marks)

Q7.

When solid calcium sulfate dihydrate, $CaSO_4{\cdot}2H_2O$, is heated in a crucible, it forms solid calcium sulfate hemihydrate, $CaSO_4{\cdot}\frac{1}{2}H_2O$.

When water is added to calcium sulfate hemihydrate, there is a rise in temperature.

A student decided to investigate this reaction using the following procedure:



Step 1 $10\,cm^3$ of distilled water is measured using a measuring cylinder having an uncertainty of $\pm0.5\,cm^3$, and is placed in an insulated cup with a lid.

Step 2 A thermometer with an uncertainty of ±0.5 °C is placed in the water.

Step 3 Exactly 10.00 g of calcium sulfate hemihydrate is weighed out using a balance with an uncertainty of ±0.005 g.

Step 4 The weighed quantity of calcium sulfate hemihydrate is added to the water in the insulated cup.

Step 5 The mixture in the insulated cup is stirred until no further temperature change is observed.

Results

Temperature of the water before adding the solid = 23.5 °C

Maximum temperature of the mixture after adding the solid = 26.3 °C

Other data

Molar mass of calcium sulfate hemihydrate, $CaSO_4{\cdot}\frac{1}{2}H_2O$ = $145.2\,g\,mol^{-1}$

Density of water = $1.00\,g\,cm^{-3}$

(i) Calculate the minimum volume of water needed to convert 10.00 g of $CaSO_4{\cdot}\frac{1}{2}H_2O$ into $CaSO_4{\cdot}2H_2O$.

(2)

(ii) Calculate the enthalpy change, in kJ mol^{-1}, for this reaction.
Include a sign in your answer and give your answer to an appropriate number of significant figures.

Assume that the liquid has a mass of 10.00 g and a specific heat capacity of 4.18 J g^{-1} $°C^{-1}$.

(4)

(iii) Deduce which measurement has the greatest uncertainty in this experiment. Justify your answer by calculating the percentage uncertainty of this piece of apparatus.

(2)

(Total for question = 8 marks)

Q8.

A group of students analysed a hydrated salt with the formula $KH_3(C_2O_4)_{\mathbf{y}}.\ \mathbf{z}H_2O$ where **y** and **z** are whole numbers.

The students carried out experiments to determine the values of **y** and **z**.

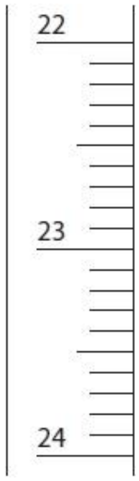
(a) Experiment 1 – to determine the value of **y**

One student was provided with a 0.0235 mol dm^{-3} solution of the salt.
25.0 cm^3 portions of the salt solution were acidified with excess dilute sulfuric acid and heated to about 60 °C.
Each portion was titrated with 0.0203 mol dm^{-3} potassium manganate(VII).
The results of four titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	23.85	47.20	24.05	48.10
Initial burette reading / cm^3	0.00	24.00	0.50	25.00
Titre / cm^3	23.85	23.20	23.55	23.10

(i) Complete the diagram to show the final burette reading in **Titration 1**.

(2)



(ii) Explain why this student should use a mean titre of 23.15 cm^3 and not 23.43 cm^3 in the calculation.

(2)

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(iii) The uncertainty in each burette reading is ±0.05 cm^3.
Calculate the percentage uncertainty in the titre volume of potassium manganate(VII) solution used in **Titration 2**.

(1)

(iv) The equation for the reaction is

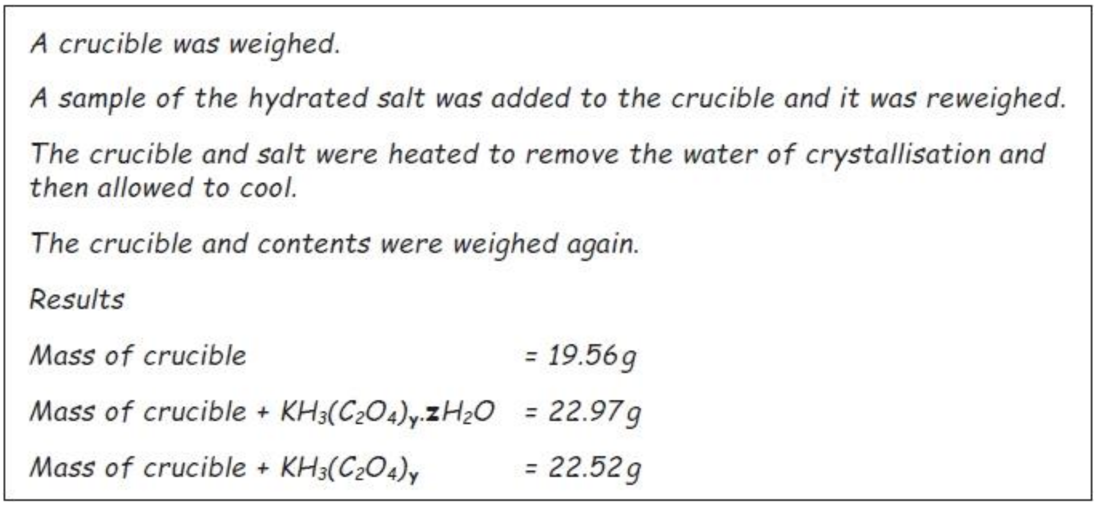
$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

Deduce, by calculation, the value of **y**, to the nearest whole number, in the formula $KH_3(C_2O_4)_{\mathbf{y}}.\ \mathbf{z}H_2O$.
Use the mean titre of 23.15 cm^3 and other data from **Experiment 1**.
You **must** show your working.

(4)

(b) **Experiment 2** – to determine the value of **z**

Another student wrote an account of the method for this experiment.



A crucible was weighed.

A sample of the hydrated salt was added to the crucible and it was reweighed.

The crucible and salt were heated to remove the water of crystallisation and then allowed to cool.

The crucible and contents were weighed again.

Results

Mass of crucible = 19.56g

Mass of crucible + $KH_3(C_2O_4)_\mathbf{y}.\mathbf{z}H_2O$ *= 22.97g*

Mass of crucible + $KH_3(C_2O_4)_\mathbf{y}$ *= 22.52g*

(i) Deduce, by calculation, the value of **z**, to the nearest whole number, in the formula $KH_3(C_2O_4)_\mathbf{y}.\ \mathbf{z}H_2O$.
You must use the data from **Experiment 2** and your value of **y** in (a)(iv).
You **must** show your working.

(3)

(ii) A third student carried out Experiment 2 and calculated a value of **z** that was lower than expected.

This student evaluated the experiment and gave two suggestions for **z** being lower.

Suggestion **1**

"Some of the crystals jumped out of the crucible while it was being heated."

Suggestion **2**

"It was difficult to tell when all the water of crystallisation had been lost."

Evaluate these two suggestions to decide whether they could account for the lower value of **z** obtained from the experimental results.

Include an explanation of the effect each suggestion would have on the calculated value of **z** and how the method could be improved to prevent these errors.

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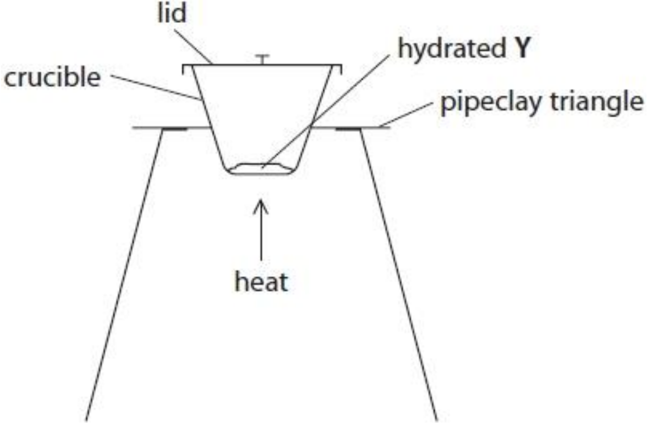
(Total for question = 17 marks)

Q9.

Y is identified as hydrated potassium carbonate, $K_2CO_3{\cdot}nH_2O$.
Two of the students were asked to determine the number of moles of water of crystallisation, *n*, in **Y** using the procedure shown:

- weigh a sample of hydrated **Y** into a pre-weighed crucible
- place a lid loosely on the crucible and heat it for five minutes to remove the water of crystallisation
- allow the crucible and lid to cool, remove the lid and then reweigh the crucible with its contents.



(i) The first student carried out the experiment but forgot to use the lid.

Explain how this mistake would affect the calculated value of *n*.

(2)

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(ii) The second student carried out the experiment but heated the apparatus for only **one** minute.

Explain how this mistake would affect the calculated value of *n*.

(2)

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(iii) In an accurate experiment, **Y** is found to consist of 71.9% K_2CO_3 by mass.

Calculate the value of *n*.

(3)

(Total for question = 7 marks)

Q10.

This question concerns alkenes and some halogen compounds.

The halogenoalkane chloroethene is used to make the important polymer poly(chloroethene), PVC.

(i) Draw a **displayed** formula of two repeat units of poly(chloroethene).

(1)

(ii) Some polymers are disposed of by incineration. Ignoring any economic considerations, explain why incineration is **not** a suitable method for the disposal of poly(chloroethene).

(2)

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(iii) Chloroethene has a boiling temperature of 260 K and is known to be carcinogenic. Use these facts to state **one** precaution that chemists should take when using this compound.

(1)

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(Total for question = 4 marks)

Q11.

This question is about redox chemistry.

(i) Bromine can be extracted from seawater containing bromide ions using chlorine.

Write the ionic equation for this reaction. State symbols are not required.

(1)

(ii) Identify **one** hazard associated with carrying out this reaction in a school laboratory and a safety precaution other than wearing a laboratory coat and eye protection.

(2)

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(Total for question = 3 marks)

Q12.

This question is about the identification of a Group 2 carbonate.

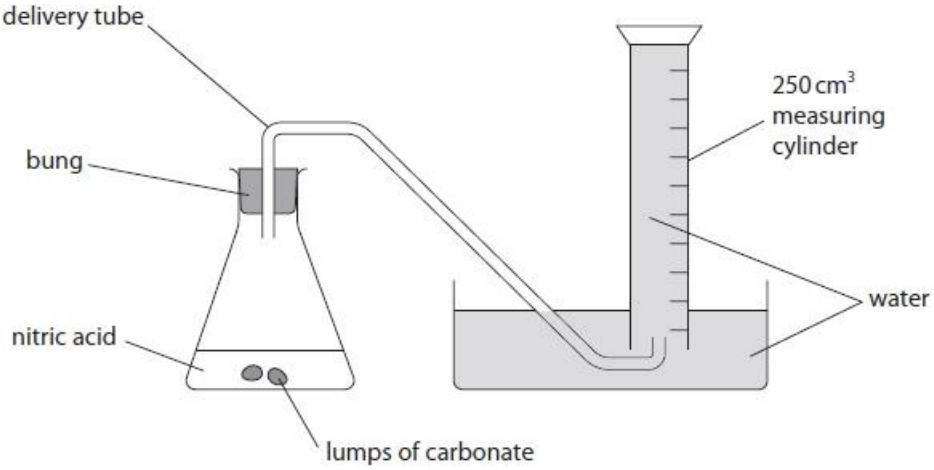
A chemistry teacher found a bottle containing lumps of a white solid. The original label was missing from the bottle. However, someone had written 'Group 2 carbonate' on the bottle. The lumps of the anhydrous white solid were pure and dry.

The chemistry teacher tried to identify the carbonate with the help of three students. The three students worked under identical conditions and shared the same weighing balance.

Student **1** recognised that if an acid is added to a carbonate, carbon dioxide is evolved. The student decided to measure the volume of carbon dioxide evolved when the Group 2 carbonate reacts with excess nitric acid.

The student knew that 1 mol of a Group 2 carbonate produces 1 mol of carbon dioxide.

Student **1** set up the apparatus shown below.



- Student **1** weighed out some of the Group 2 carbonate and added it to a 250 cm^3 conical flask.
- Student **1** then added 100 cm^3 of 0.200 mol dm^{-3} nitric acid to the conical flask and replaced the bung.
- Student **1** measured the volume of gas collected in the inverted measuring cylinder at room temperature and pressure (r.t.p.) when all the Group 2 carbonate had reacted.
- Student **1** obtained the results shown in Table 1.

Measurement		Value
Mass of weighing bottle and carbonate	/ g	13.247
Mass of empty weighing bottle	/ g	12.431
Mass of carbonate used	/ g	....
Volume of acid used	/ cm^3	100
Volume of gas collected	/ cm^3	225

Table 1

(a) Complete Table 1 to show the mass of the carbonate used.

(1)

(b) Calculate the amount, in moles, of carbon dioxide collected in the measuring cylinder at r.t.p.

(1)

(c) Calculate the molar mass of the Group 2 carbonate to an appropriate number of significant figures and hence deduce the identity of the Group 2 metal.

(4)

(d) Student **2** carried out the same experiment as Student **1**, using the same mass of the Group 2 carbonate.

Student **2** made no errors in their measurements or calculations but obtained a value for the molar mass which was 10 g mol^{-1} greater than the value obtained by Student **1**.
(i) Explain **one** procedural error which could have resulted in Student **2** obtaining a molar mass greater than that of Student **1**.

(2)

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(ii) It was later discovered that Student **2** had used 110 cm^3 of 0.200 mol dm^{-3} dilute nitric acid, instead of 100 cm^3 of 0.200 mol dm^{-3} dilute nitric acid.
Give a reason why this mistake would **not** have affected Student **2**'s result.
No calculation is required.

(1)

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(iii) The teacher noticed that Student **2** had used the Group 2 carbonate in powdered form rather than in lumps.

Explain how, if at all, this would affect the rate of reaction and the final volume of gas produced in the reaction.

(2)

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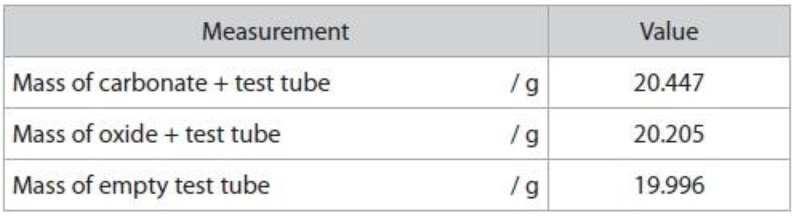
(e) Student **3** suggested a different experiment.

Student **3** realised that, by heating the carbonate, carbon dioxide would be lost and an oxide would remain.

Student **3** decided to measure the change in mass of the carbonate and to use this information to calculate its molar mass.

- Student **3** weighed an empty test tube.
- Using a spatula, Student **3** added some of the carbonate to the test tube.
- The test tube containing the carbonate was then weighed.
- The test tube and its contents were heated to constant mass.
- The results obtained by Student **3** are shown in Table 2.



Measurement		Value
Mass of carbonate + test tube	/ g	20.447
Mass of oxide + test tube	/ g	20.205
Mass of empty test tube	/ g	19.996

Table 2

(i) Write an equation, including state symbols, for the thermal decomposition of a Group 2 carbonate, MCO_3, where M represents the metal.

(1)

(ii) Using Student **3**'s results, calculate the molar mass of the Group 2 carbonate.

(3)

(f) Student **3** used the same balance as Student **1**.

Give a reason why the mass of the carbonate measured by Student **3** has a greater percentage uncertainty than that measured by Student **1**.

(1)

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(g) Student **3** noticed that on heating the test tube some solid was lost.

Explain how this would affect the calculated value for the molar mass of the Group 2 carbonate.

(2)

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(Total for question = 18 marks)

Q13.

This question is about the titration of a weak acid with a strong base.

The uncertainty in each burette reading is ± 0.05 cm^3. The uncertainty in the pipette volume is ± 0.06 cm^3.

(i) Calculate the percentage uncertainties for titre 4, and the pipette volume.

(2)

(ii) Which of the following changes would halve the percentage uncertainty in the volume of liquid measured by the burette?

(1)

- ☒ **A** halve the acid concentration and halve the acid volume
- ☒ **B** double the acid concentration and leave the acid volume unchanged
- ☒ **C** double the acid concentration and halve the acid volume
- ☒ **D** halve the acid concentration and leave the acid volume unchanged

(Total for question = 3 marks)

Q14.

Ammonia reacts with sodium to form sodium amide, $NaNH_2$, and hydrogen.

Give a possible reason why samples of sodium amide are stored in oil.

(1)

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(Total for question = 1 mark)

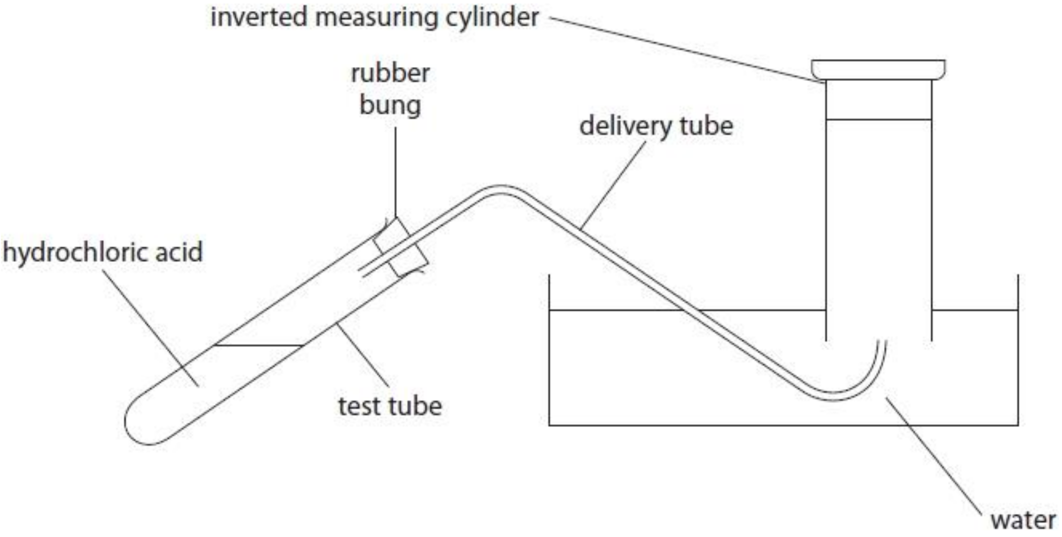
Q15.

(a) This question is about the reaction of magnesium with dilute hydrochloric acid.

Write an equation for the reaction of magnesium with hydrochloric acid. Include state symbols.

(2)

(b) The apparatus shown in the diagram can be used to collect the gas produced during the reaction of magnesium with dilute hydrochloric acid.



The following procedure was used.

Step **1** The apparatus was set up as shown in the diagram. The test tube contained 10.0 cm^3 of 0.20 mol dm^{-3} hydrochloric acid.

Step **2** A piece of magnesium ribbon was weighed. It had a mass of 0.12 g.

Step **3** The delivery tube and bung were removed from the test tube, the magnesium ribbon was added and the delivery tube and bung quickly replaced.

Step **4** When the reaction was complete, the final volume of gas was recorded.

(i) A measuring cylinder was used to measure the 10.0 cm^3 of dilute hydrochloric acid in Step **1**. The uncertainty for a volume measurement is ± 0.5 cm^3.
Calculate the percentage uncertainty in the volume of hydrochloric acid.

(1)

(ii) Determine which reactant is in excess by calculating the number of moles of magnesium and of hydrochloric acid used in the experiment.

(3)

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....

(iii) Calculate the maximum number of moles of gas that could be produced, using your answers to (a) and (b)(ii).

(1)

(iv) Under the conditions of the experiment, the temperature was 23°C and the pressure 98 000 Pa.
Calculate the maximum volume of gas, **in cm^3**, that could be produced using your answer in (b)(iii).
Give your answer to an appropriate number of significant figures.
[The ideal gas equation is $pV = nRT$. Gas constant (R) = 8.31 J mol^{-1} K^{-1}]

(4)

(c) (i) Deduce **two** possible reasons why the volume of gas collected in the experiment was smaller than that calculated in (b)(iv).

(2)

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(ii) Describe **two** changes to the procedure that would enable the volume of gas collected to be closer to that calculated in (b)(iv).

(2)

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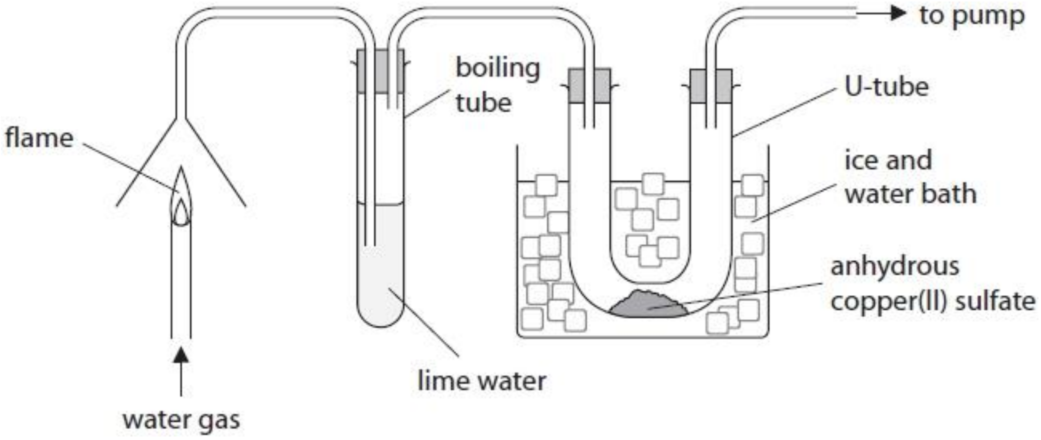
(Total for question = 15 marks)

Q16.

The complete combustion of water gas produces carbon dioxide and water.
A student drew a diagram of the apparatus to attempt to identify the combustion products.



Evaluate whether the student's apparatus is suitable for identifying both of the combustion products. Include any improvements needed.

(5)

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(Total for question = 5 marks)

Q17.

Malachite is a green mineral with the formula $Cu_2CO_3(OH)_2$. It has a molar mass of 221 g mol^{-1}.

(i) When malachite is heated to approximately 300 °C, water, carbon dioxide and copper(II) oxide are formed.

The equation for this decomposition is

$$Cu_2CO_3(OH)_2 \rightarrow 2CuO + CO_2 + H_2O$$

Calculate the maximum volume of carbon dioxide that could be produced when 0.810 g of malachite is thermally decomposed.
Assume that the gas is collected at a temperature of 25 °C and 101 kPa pressure.
Give your answer to an appropriate number of significant figures and state the units.
[The ideal gas equation is $pV = nRT$. Gas constant (R) = 8.31 J mol^{-1} K^{-1}]

(5)

(ii) The gas was collected in a gas syringe with a stated accuracy of ± 0.5 cm^3.

Calculate the percentage uncertainty in the volume of gas collected.

(1)

(iii) Malachite ore is a mixture of malachite and rock. A 0.810 g sample of malachite ore was thermally decomposed, producing 0.571 g of copper(II) oxide.

Calculate the percentage purity of this malachite ore sample. Give your answer to an appropriate number of significant figures.

(3)

(Total for question = 9 marks)

Q18.

This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

A student weighed about 4.00 g of sodium hydroxide pellets and added them to a beaker containing 50 cm^3 of deionised water.

The mixture was stirred with a glass rod to dissolve the pellets and to give a homogenous solution.

The solution was poured through a funnel into a 250.0 cm^3 volumetric flask and deionised water was added up to the mark and then the flask was shaken.

(i) Describe how you would ensure that all the sodium hydroxide was transferred to the volumetric flask.

(2)

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(ii) A student adds deionised water above the mark and shakes the flask.

State why the procedure has to be restarted rather than using a teat pipette to remove the excess water.

(1)

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(Total for question = 3 marks)

Q19.

This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

Two students each cleaned a burette, then poured sodium hydroxide solution into their burettes.

(i) Student 1 used a funnel to pour sodium hydroxide solution into the burette.

Give **two** steps needed before the student takes the initial burette reading.

(2)

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(ii) Student 2 cleaned the burette by rinsing it with deionised water immediately before filling it with the sodium hydroxide solution.

Give the effect, if any, on the value of the first titre. Justify your answer.

(1)

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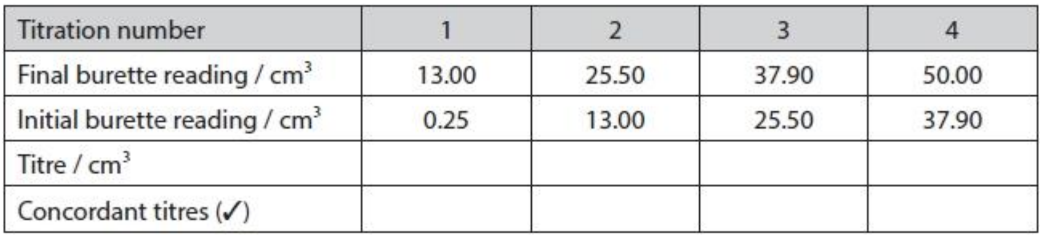
(Total for question = 3 marks)

Q20.

This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

Each student used a pipette to measure 25.0 cm^3 of the ethanoic acid solution into four separate conical flasks and added an indicator.

The results of one student's titrations are shown in the table.



Titration number	1	2	3	4
Final burette reading / cm^3	13.00	25.50	37.90	50.00
Initial burette reading / cm^3	0.25	13.00	25.50	37.90
Titre / cm^3				
Concordant titres (✓)				

(i) Complete the table.

(1)

(ii) The low titre for titration **4** was queried by the teacher. The student had wanted to refill the burette and continue the titration but had been told the measurement uncertainty would increase if this was done.

Calculate the total percentage measurement uncertainty if the burette had been refilled to 0.00, and then a further 0.30 cm^3 had been added from the burette, to the conical flask. The measurement uncertainty for each burette reading is ±0.05 cm^3.

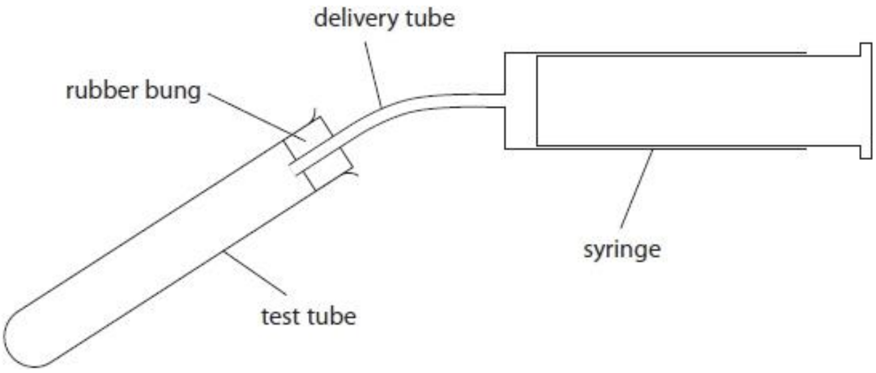
(1)

(Total for question = 2 marks)

Q21.

This question is about the molar volume of gases.

The apparatus shown was used to measure the volume of gas evolved when a weighed mass of sodium carbonate reacted with dilute hydrochloric acid.



The following procedure was used.

Step **1** Solid sodium carbonate was placed in a container and weighed accurately.

Step **2** The delivery tube and rubber bung were removed and the sodium carbonate was transferred to the test tube.

Step **3** The container was then reweighed.

Step **4** The syringe plunger was pushed in, to zero the syringe.

Step **5** 10.0 cm^3 of 0.400 mol dm^{-3} hydrochloric acid was then added to the sodium carbonate and the rubber bung and delivery tube rapidly replaced.

Step **6** The mixture was shaken and, when the reaction had finished, the reading of the syringe was noted.

Results

Mass of container and sodium carbonate before transfer = 20.135 g

Mass of container after transfer of the sodium carbonate = 19.893 g

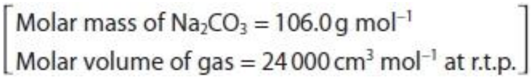
Mass of sodium carbonate used = 0.242 g

The equation for the reaction is

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

(i) Calculate the moles of hydrochloric acid and the moles of sodium carbonate used in this experiment.

Use your answers to decide which reactant is in excess.
Calculate the maximum volume of carbon dioxide which could be produced.



[Molar mass of Na_2CO_3 = 106.0 g mol^{-1}
Molar volume of gas = 24 000 cm^3 mol^{-1} at r.t.p.]

(5)

(ii) The actual volume of carbon dioxide collected was less than calculated.

Give **two** reasons for this.

(2)

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(Total for question = 7 marks)

Q22.

(a) This question is about the analysis of an unknown carboxylic acid **X** by three students.

The students analyse the mass spectrum of **X** and find that it has a molecular ion peak at *m* / *z* = 116.
The three students each propose a different structural formula for compound **X**.
Structure 1 HOOCCH==CHCOOH
Structure 2 $HOCH_2CH{=}{=}CHCH_2COOH$
Structure 3 $CH_3CH_2CH_2CH_2CH_2COOH$
The students are given the infrared spectrum of **X**.
(i) State **two** wavenumber ranges of the infrared absorptions providing evidence that compound **X** is a carboxylic acid. Include the bonds responsible.

(2)

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(ii) One of the students suggests that this infrared spectrum and the data in the Data Booklet **alone** could be used to identify which of the three proposed structures is **X**.
Show that this student's suggestion is correct. Include relevant infrared data in your answer.

(3)

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(b) The students decide to carry out an acid-base titration to obtain further information about compound **X**.

Each student uses solid sodium hydroxide, NaOH, to prepare a solution of concentration 0.140 mol dm^{-3}.
Calculate the mass, in grams, of solid sodium hydroxide that each student should weigh out to prepare 250.0 cm^3 of a 0.140 mol dm^{-3} solution.

(2)

(c) Each of the students makes up 250.0 cm^3 of 0.140 mol dm^{-3} sodium hydroxide solution in a volumetric flask and titrates this solution with the same solution of **X** of known concentration.

Student A

- correctly prepares the 0.140 mol dm^{-3} sodium hydroxide solution and pipettes a volume of 10.0 cm^3 of the solution into a conical flask
- fills a burette with the solution of **X** and carries out a titration
- repeats the procedure until obtaining concordant results
- obtains a mean titre of 10.20 cm^3.

Student B

- dissolves the sodium hydroxide in distilled water and transfers the solution to a volumetric flask
- adds more distilled water to the volumetric flask and mixes the solution
- notices that the volumetric flask has been filled with distilled water several cm^3 beyond the graduation mark
- realises the mistake, removes the extra solution and discards it
- pipettes 10.0 cm^3 of the sodium hydroxide solution into a conical flask and titrates this with the solution of **X**.

Student C

- correctly prepares the 0.140 mol dm^{-3} sodium hydroxide solution
- washes a conical flask thoroughly with distilled water and pipettes 10.0 cm^3 of the sodium hydroxide solution into the wet conical flask
- titrates the contents of the conical flask with the solution of **X**.

(i) Explain how, if at all, Student **B**'s mistake affects the value of the titre.

(2)

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(ii) Explain how, if at all, Student **C**'s use of a wet conical flask affects the value of the titre.

(2)

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(iii) Student **A** uses three pieces of apparatus to measure volumes in this experiment.

- The burette has an uncertainty of ±0.05 cm^3 for each volume reading
- The volumetric flask has an uncertainty of ±0.30 cm^3 for the volume
- The pipette has an uncertainty of ±0.04 cm^3 for the volume

Show by calculation which volume measurement has the lowest percentage uncertainty.

(3)

(d) Student **A** calculates the correct value for the molar mass of compound **X**, using the mean titre of 10.20 cm^3. The results indicate that **X** has **structure 1**.

Structure 1 $HOOCCH==CHCOOH$
Structure 2 $HOCH_2CH==CHCH_2COOH$
Structure 3 $CH_3CH_2CH_2CH_2CH_2COOH$

(i) Write the equation for the reaction between **structure 1** and sodium hydroxide solution. State symbols are not required.

(2)

(ii) Deduce the value that would have been obtained for the mean titre if the structural formula of **X** had been **structure 2**.
Justify your answer.

(2)

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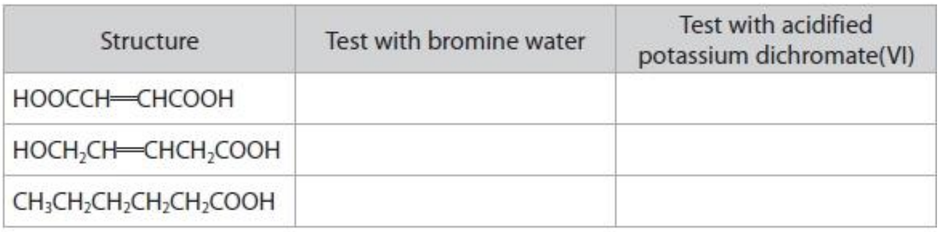
(e) The students could have identified the three structures using chemical tests.

Complete the table to show whether or not the suggested structures react with bromine water and when heated with acidified potassium dichromate(VI).
Use a tick (✓) if a reaction occurs.
Use a cross (✗) if no reaction occurs.

(2)



Structure	Test with bromine water	Test with acidified potassium dichromate(VI)
$HOOCCH=CHCOOH$		
$HOCH_2CH=CHCH_2COOH$		
$CH_3CH_2CH_2CH_2CH_2COOH$		

(f) The structure HOOCCH==CHCOOH has two stereoisomers.

(i) Draw the structures of these stereoisomers.

(2)

***E*-isomer**

***Z*-isomer**

(ii) State why HOOCCH==CHCOOH has *E*/*Z* isomers.

(2)

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(Total for question = 24 marks)

Q23.

Ethanedioic acid has two carboxylic acid groups.

(a) Ethanedioic acid, $H_2C_2O_4$, can be prepared from ethane-1,2-diol.

Give the reagents and condition required for this reaction.

(2)

Reagents

....

Condition

....

(b) The formula for ethanedioic acid crystals is $H_2C_2O_4.nH_2O$.

To determine the number of moles of water of crystallisation, n, in 1 mol of ethanedioic acid crystals, a student carried out the following procedure.

- Prepare 250.0cm^3 of a solution containing a known mass of about 1g of ethanedioic acid crystals.
- Titrate 25.0cm^3 portions of the ethanedioic acid solution with 0.103 mol dm^{-3} sodium hydroxide solution, using phenolphthalein as indicator.

The student obtained these results:
mass of ethanedioic acid crystals = 1.09g
mean titre = 16.20cm^3
The equation for the reaction is

$$H_2C_2O_4 + 2NaOH \rightarrow Na_2C_2O_4 + 2H_2O$$

(i) Describe how the student should prepare the 250.0 cm^3 of ethanedioic acid solution.

(4)

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(ii) Give the colour change at the end-point in this titration.

(1)

From .... to ....

(iii) Calculate a value of n in the formula $H_2C_2O_4.nH_2O$ from these data.

(5)

(iv) The student thought that the ethanedioic acid crystals used may have been slightly damp.

Explain the effect of using damp crystals on the titre and on the value of n.

(2)

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(Total for question = 14 marks)

Mark Scheme

Q1.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	• calculation of moles of magnesium	Example of calculation: (n= 0.04 ÷ 24.3 =) 0.001646 (mol) Allow 0.04 ÷ 24 = 0.001667 (mol) Ignore significant figures except 1	**(1)**

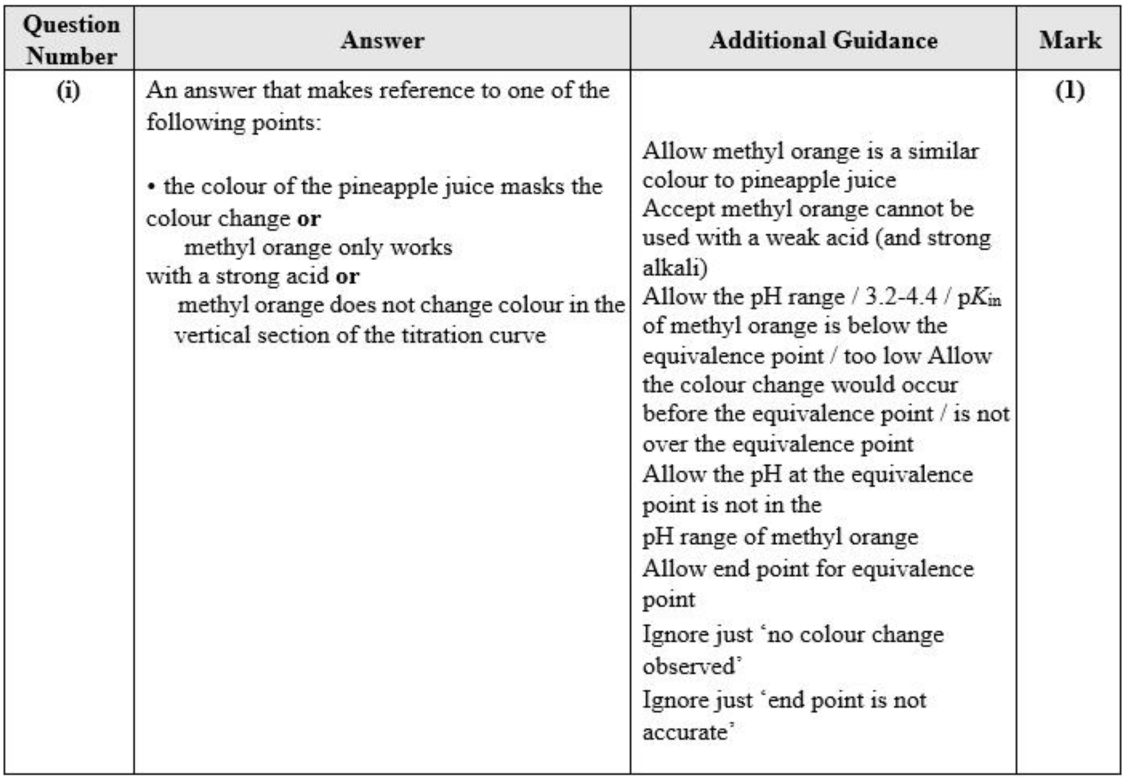
Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	• calculation of moles of hydrogen	Answer to (a)(i)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)		Example of calculation:	**(4)**
	• temperature changed to Kelvin **(1)**	24°C = 297 K	
	• rearrangement of equation so $V=nRT \div p$ and substituting the numbers **(1)**	$V = \frac{0.001646 \times 8.31 \times 297}{101000}$	
	• calculation of V in m^3 / dm^3 **(1)**	= 4.022×10^{-5} (m^3)	
	• answer converted in cm^3 and to a whole number **(1)**	= $4.022 \times 10^{-5} \times 10^{6}$ = 40 cm^3	

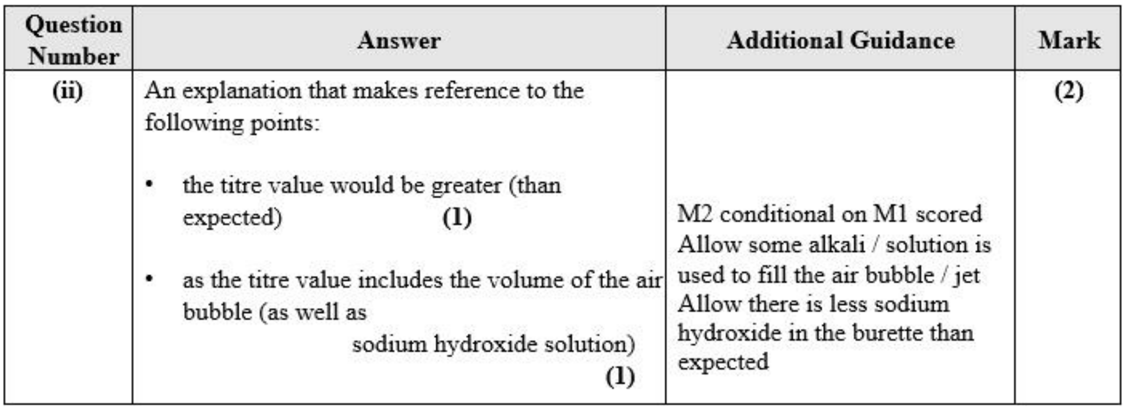
Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	An answer that making reference to any of the following: • To identify anomalies **and** discard • To identify random errors **and** discard • Identify precise results **and** use them • Identify imprecise results **and** discard them	Allow To improve reliability/ reproducibility Ignore reference to confidence in the results Ignore 'make results more precise' Do not award "to improve accuracy"	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	An answer that makes reference to three of the following linked pairs: • **issue:** hydrogen escapes from the apparatus **(1)** • **improvement:** use a sealed apparatus with a gas syringe /use a conical flask / bung with a gas syringe **(1)** • **issue:** magnesium ribbon covered with oxide **(1)** • **improvement:** clean with abrasive before weighing **(1)** • **issue**: mass of magnesium may be less than 0.04 g (i.e. as low as 0.035 g) **or** mass of magnesium required is too small to be measured accurately by the balance available **(1)** • **improvement:** use more precise balance/ use larger mass (so percentage error is less) **(1)** • **issue:** large measuring cylinder cannot measure volume accurately (as the graduations are too far apart)	Maximum **three** marks for issues identified Maximum **three** marks for improvement identified which must be linked with associated issue identified or near-miss Do not award impurities in magnesium Allow measurement uncertainty for measurement accuracy	**(6)**
	(1) • **improvement:** use a smaller measuring cylinder/burette/ conical flask / bung with a gas syringe **(1)**	If more than three issues are given, then maximum 4 marks if incorrect chemistry is stated e.g. reference to 'not all the magnesium reacting' Ignore reference to: The solubility of hydrogen gas Changes in temperature Changes in acid concentration Air already in the apparatus Measuring the length of Mg	

Q2.

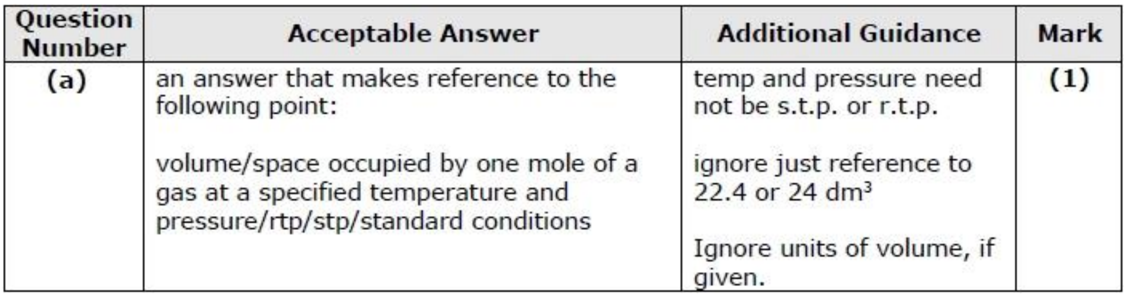


Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to one of the following points: • the colour of the pineapple juice masks the colour change **or** methyl orange only works with a strong acid **or** methyl orange does not change colour in the vertical section of the titration curve	Allow methyl orange is a similar colour to pineapple juice Accept methyl orange cannot be used with a weak acid (and strong alkali) Allow the pH range / 3.2-4.4 / pK_{in} of methyl orange is below the equivalence point / too low Allow the colour change would occur before the equivalence point / is not over the equivalence point Allow the pH at the equivalence point is not in the pH range of methyl orange Allow end point for equivalence point Ignore just 'no colour change observed' Ignore just 'end point is not accurate'	**(1)**



Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • the titre value would be greater (than expected) **(1)** • as the titre value includes the volume of the air bubble (as well as sodium hydroxide solution) **(1)**	M2 conditional on M1 scored Allow some alkali / solution is used to fill the air bubble / jet Allow there is less sodium hydroxide in the burette than expected	**(2)**

Q3.



Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	an answer that makes reference to the following point: volume/space occupied by one mole of a gas at a specified temperature and pressure/rtp/stp/standard conditions	temp and pressure need not be s.t.p. or r.t.p. ignore just reference to 22.4 or 24 dm^3 Ignore units of volume, if given.	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	(% volume uncertainty =)1% **(1)** (% mass uncertainty =) 1/1.1/1.09/1.08696 % **(1)**	example of calculation 0.5 cm^3 in 50 cm^3 % uncertainty = $\frac{0.5}{50}$ x 100 = 1% mass of gas = 107.655 – 107.563 = 0.092 g uncertainty = 0.0005 x 2 0.001 g in 0.092 g % uncertainty = $\frac{0.001}{0.092}$ x 100 = 1/1.1/1.09/1.08696 % Ignore uncertainties added together Do not award calculation of uncertainty in each mass reading (often added together +1) eg 0.0004644 + 0.0004648 + 1 = 1.000928	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(ii)	an answer that makes reference to the following points: halves the % volume uncertainty /0.5 cm^3 in 100 cm^3 = 0.5% **(1)** (volume of gas is doubled so mass of gas doubles), % mass uncertainty (also) halves. **(1)**	TE for answer to (b)(i) ÷ 2 TE for answer to (b)(i) ÷ 2 Allow 1 mark for both uncertainties decrease	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iii)	• mass of gas and expression for molar mass **(1)** • molar mass to 2 or 3 SF and correct units **(1)**	example of calculation mass of gas = 107.655 – 107.563 = 0.092 g and molar mass = 0.092 x 24000 /50 = 44.16 Allow any other correct alternative calculation TE from M1 to M2 for incorrect mass only 44.2/44 **g mol^{-1}** Correct answer to 2/3 SF with/without working gets 2 marks	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iv)	an explanation that makes reference to the following points: • plunger does not return (to zero/original position) when released **(1)** • molar mass will decrease **because** 'air' has a lower molar mass (than 44/carbon dioxide) **(1)**	Mark independently There must be some reference to air	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points: • the calculated molar mass would be greater **(1)** • at a lower temperature there would be more molecules/moles/mass in the same volume /density is greater. **(1)**	Points to be marked independently Standalone mark Do not award for answers that refer to smaller volume Ignore smaller molar volume Ignore particles/molecules/atoms closer together	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(d)	an answer that makes reference to the following point: water (vapour) would decrease/affect molar mass OR gas is now a mixture so would decrease/affect molar mass	Ignore gas may dissolve in water Do not award water may react with gas in syringe Do not award wet gas is heavier Ignore answers that refer to molar volume	**(1)**

Q4.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• 1.60 **(1)** • (+) 42.5 **(1)**	Do not award MP1 for "1.6" (must be to 2 D.P.) Do not award MP2 for "42.50" (must be to 1 D.P.) Penalise D.P. error once only	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	$CH_3OH(l) + 1.5O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$		**(2)**
	• Balanced equation **(1)**	Do not award multiples (enthalpy change is for the complete combustion of one mole) for MP1	
	• State symbols all correct **(1)**	MP2 depends on the award of MP1 or correct species	

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)		<u>Example of calculation</u>	**(4)**
	• Calculation of energy change **(1)**	(= $mc\Delta T$ = 150 x 4.18 x 42.5 =) 26647.5 (J)	
	• Calculation of moles of CH_3OH **(1)**	Moles CH_3OH = 1.60/32 (= 0.05(00))	
	• Calculation of energy ÷ moles CH_3OH **(1)**	$\frac{26647.5}{0.05(00)}$ = 532950 (J mol^{-1}) Ignore any signs at this stage	
	• ΔH final answer in kJ mol^{-1} **and** negative sign included **and** ΔH final answer to 2 or 3 S.F. **(1)**	−533 (kJ mol^{-1}) **Or** −530 (kJ mol^{-1}) Correct answer with no working gains full marks Penalise incorrect units for MP4 only Allow TE at each stage Allow correct rounding to 2SF or more at each stage	

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	(±)0.7 (%)	Allow from 1 SF up to calculator value correctly rounded where (% uncertainty =) (±) $\frac{1}{150}$ x 100 = 0.66666…7 (%) Allow $0.\dot{6}$ or $\frac{2}{3}$ Do not award 0.66/0.6	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to the following points: • Calculation of the % uncertainty using the 25 cm^3 measuring cylinder **(1)** **Then any two from:** • % uncertainty with use of 25 cm^3 measuring cylinder is greater **(1)** • Repeated use of the small measuring cylinder will lead to greater transfer losses **(1)** • Repeated use will take more time **(1)**	Needs to show combined error in using the 25 cm^3 six times is greater than using 250 cm^3 measuring cylinder once only Award MP1 EITHER if multiplies errors: 100 x (0.2 /25) x 6 = 4.8% OR If adds errors 100 x (1.2 /150) = 0.8% Do not award (0.2 / 25) x 100 = 0.8 % Do not award 'easier' to use larger measuring cylinder	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	An answer that makes reference to any **three** of the following points: • heat/energy loss (to the surroundings) **(1)** • evaporation of methanol / water from the calorimeter **(1)** • incomplete combustion (of methanol) **(1)** • (specific) heat capacity of the calorimeter/apparatus has been ignored **(1)**	Ignore experiment carried out under non-standard conditions Ignore just 'no lid' Allow calorimeter has not been calibrated	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to the following points: • The second value will be less exothermic / less negative **(1)** • Some energy will be used to boil the water/boiling water is endothermic Water can only be heated to 100°C/ Temperature rise (measured) can only be (a maximum) of 40°C Greater heat losses in the 60°C to 100°C range **(1)**	Allow 'more positive' or 'smaller in magnitude' Do not accept 'greater' or 'smaller' for 'less negative' Do not award **just** "the water boils" Mark points M1 and M2 independently	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	An explanation that makes reference to the following points: Either • student 2's value will be similar / the same **(1)** • (As) both the energy change **and** moles/mass (of methanol) burned will be higher/ Ratio of energy change to moles/mass (of methanol) burned will be the same/ The energy change is proportional to the moles/mass (of methanol) burned **(1)** Or • student 2's value will be less negative/ less exothermic **(1)** • greater heat loss because higher temperature/heated for longer **(1)**	Allow 'temperature change' for 'energy change' Allow 'more positive' or 'smaller in magnitude' or 'smaller' for 'less negative' Mark points MP1 and MP2 independently within each route	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(g)	An answer that makes reference to the following points: • (Calculated) value of moles (of methanol) burned will be less / too small **(1)** • The calculated value will be more exothermic / more negative **(1)**	Allow **both** marks for a calculation using M_r of 46.0 (instead of 32.0), giving a final ΔH value (approx.) of −766 (kJ mol^{-1}) Allow 'increase' or 'greater' for 'more negative' MP2 depends on MP1	**(2)**

Q5.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• 23.15 **and** 23.55 **and** 23.20 completed in table **(1)** • ✓ beneath titres **1 and 3** **and** mean titre = 23.18 (cm^3) **(1)**	All three titres must be shown to 2 D.P. Allow 23.2 or 23.175 (cm^3)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	(From)(pale) pink/purple (to) colourless	**Both** colours needed for the mark Do not award mauve or magenta or violet for pink/purple Ignore references to 'clear'	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)		Example of calculation	**(5)**
	• calculation of moles of MnO_4^- in 25.0 cm^3 **(1)**	Moles MnO_4^- = $\frac{0.02(00) \times 25.0}{1000}$ = $5(.00) \times 10^{-4}$ / 0.0005(00) (mol)	
	• calculation of moles of NO_2^- in mean titre **(1)**	Moles NO_2^- in mean titre = 2.5 x moles MnO_4^- = 1.25×10^{-3} / 0.00125 (mol)	
	• calculation of moles of NO_2^- in 250 cm^3 **(1)**	Moles NO_2^- in 250 cm^3 = moles NO_2^- in mean titre x $\frac{250}{\text{mean titre from (a)}}$ = $1.25 \times 10^{-3} \times \frac{250}{23.18}$ = 0.013481449 = 0.0135 (mol) Allow TE on mean titre from (a) Ignore SF except 1 SF	
	• calculation of molar mass **(1)**	• Molar mass = 2 x $\frac{1.15}{0.0135}$ = 170.3703704 (g mol^{-1}) = 170.4 (g mol^{-1}) Allow TE	
	• calculation of ***x*** correctly to the nearest whole number: **(1)**	• $x = \frac{170.4 - 116.3}{18(.0)}$ x = 3.005555556 x = 3 (**must** be to nearest whole number) Allow TE from molar mass calculated Allow alternative correct methods for MP4 and MP5 Correct value of ***x*** with no working scores (1)	

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)	$2MnO_4^- + 5NO_2^- + 6H^+ \rightarrow 2Mn^{2+} + 5NO_3^- + 3H_2O$ - evidence of multiplying 1st equation by 2 **and** 2nd equation by 5 **(1)** - overall equation correct with H^+ and H_2O and $e^{(-)}$ cancelled as appropriate **(1)**	Each of the following equations score **(1)** mark overall: $2MnO_4^- + 5NO_2^- + 16H^+ + 5H_2O \rightarrow 2Mn^{2+} + 5NO_3^- + 8H_2O + 10H^+$ OR $2MnO_4^- + 5NO_2^- + 6H^+ + 5H_2O \rightarrow 2Mn^{2+} + 5NO_3^- + 8H_2O$ OR $2MnO_4^- + 5NO_2^- + 16H^+ \rightarrow 2Mn^{2+} + 5NO_3^- + 10H^+ + 3H_2O$ Ignore state symbols, even if incorrect Allow multiples	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to the following: **Either** - the (calculated) value of ***x*** would be too high **(1)** - The moles of $MgCO_3$ would be too low / the moles of $Mg(NO_2)_2 \cdot xH_2O$ would be too low / the M_r of $Mg(NO_2)_2 \cdot xH_2O$ would be too high **(1)** **Or** - (So) the (calculated) value of ***x*** would be unchanged (so this does not explain the discrepancy) **(1)** - Only a small amount/mass of $MgCO_3$ would dissolve because it is very slightly soluble **(1)**	Allow 'amount' or 'mass' for 'moles' MP2 depends on MP1 MP2 depends on MP1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	An answer that makes reference to the following points: • the $MgCO_3$ would decompose / the residue would contain $NaNO_2$ / the residue would contain (the excess) Na_2CO_3 **(1)** • (so) the (proposed) method is not valid / appropriate / suitable **(1)**	Ignore references to just 'impurities' M2 dependent on M1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(g)	An answer that makes reference to the following point: • heat (the sample) to constant mass	Allow repetition of heating and weighing until there is no change in mass (of the sample) Ignore references to 'brown gas' etc	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(h)	An answer that makes reference to the following points: • use a larger mass (of the hydrated salt) **(1)** • Use a balance that weighs to 3 D.P. (rather than 2 D.P.) **(1)**	Ignore references to repeat measurements Allow statements such as 'use a balance that weighs to more decimal places' /'greater resolution' / ' a more precise/sensitive balance' Do not allow 'more accurate'	**(2)**

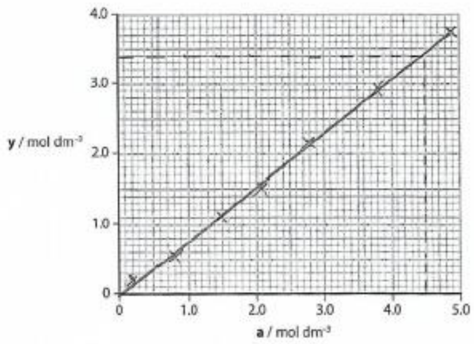
Q6.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	$(K_c =) \dfrac{[HI(g)]^2}{[H_2(g)][I_2(g)]}$	Ignore missing state symbols or units Do not award round brackets	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	$(K_c =) \dfrac{4y^2}{(a - y)^2}$ • Numerator term correct **(1)** • Denominator term correct **(1)**	Allow square brackets Allow $(2y)^2$ Allow $(a^2 - 2ay+y^2)$ or $(a-y)(a-y)$	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• both values correct to 2 DP	1.13 2.93	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• All 7 points plotted correctly **(1)** • Appropriate straight line of best fit, drawn through the origin **(1)**	Allow TE for incorrect values from 9(b)(i) Do not allow all points above or below the line of best fit Allow line of best fit to intersect one square either side of the origin	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	• co-ordinates correctly read off the line on graph **(1)**  • gradient correctly calculated **(1)**	At least 1 line must be shown on the graph to indicate selection of co-ordinates <u>Example of calculation</u> $\dfrac{3.40 - 0.00}{4.50 - 0.00}$ = gradient of graph Gradient = 0.76 Ignore SF except 1SF Do not allow units for the gradient Allow a value from 0.71 to 0.81 inclusive	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iv)	• $\frac{\sqrt{K_c}}{2 + \sqrt{K_c}}$ = gradient / $\frac{y}{a}$ **(1)** • re-arrangement of expression and calculation of K_c **(1)**	Example of calculation $\frac{\sqrt{K_c}}{2 + \sqrt{K_c}} = 0.76$ K_c = 40.1 /40 (no units) Allow TE on gradient from part (iii) $K_c = [(2 \text{ x grad})/(1\text{-grad})]^2$ Correct answer with no working scores (2)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	• hydrogen is flammable / explosive	Allow iodine vapour damages eyes /toxic Allow hydrogen iodide is corrosive / acidic / irritant (if qualified) / lachrymator Ignore references to high pressure Ignore references to safety precautions	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)	• Faster rate of reaction / increased rate **(1)** • K_c unchanged **(1)**	Ignore references to shifting position of equilibrium	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(i)	An explanation that makes reference to the following points: • (K_c is) smaller / decreases / gets less **(1)** • (forward) reaction is exothermic **(1)**	Allow reverse/backwards reaction is endothermic MP2 dependent on MP1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(ii)	• straight line drawn on the graph with a less steep gradient (and goes through the origin)	Do not allow if lines cross	**(1)**

Q7.

Question Number	Answer	Additional Guidance	Mark
(i)	• calculation of moles of $CaSO_4 \cdot \frac{1}{2}H_2O$ (1) • calculation of volume (or mass) of water required (1)	<u>Example of calculation</u> 10.00 g $CaSO_4 \cdot \frac{1}{2}H_2O$ = 10.00 ÷ 145.2 mol = 0.06887 mol Allow 0.069 (moles of water required = 0.06887 x 1.5 = 0.1033 mol) volume of water required = 0.1033 x 18 ÷ 1.00 = 1.86 cm^3 Allow 1.86 g Ignore SF except 1 SF Correct answer with no working scores (2) Allow calculation using multiples of these moles (still gets same final answer scores 2) Allow alternative correct calculations: e.g. comparison of moles of $CaSO_4 \cdot \frac{1}{2}H_2O$ with moles of water in 10.00 g.	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of ΔT (1) • use of $mc\Delta T$ to find Q (1) • calculation of $\Delta_r H$ (1) • correct final answer, with sign and 2 or 3 SF (1)	<u>Example of calculation</u> ΔT = 2.8 °C m = 10.00 g, c = 4.18 J g^{-1} $°C^{-1}$ Q = $mc\Delta T$ = 117.04 J / 0.11704 kJ Allow M1 and M2 if figure of 117.04 J is seen Ignore units unless converted to kJ 117.04 ÷ 0.06887 = −1699.4 (J mol^{-1}) −1.70 / −1.7 (kJ mol^{-1}) Correct answer with no working scores (4) Allow TE throughout and from 4ci (for moles $CaSO_4 \cdot \frac{1}{2}H_2O$)	(4)

Question Number	Answer	Additional Guidance	Mark
(iii)	• selection of thermometer (1) • calculation of percentage uncertainty (1)	<u>Example of calculation</u> $\frac{2 \times 0.5 \times 100}{2.8}$ = 35.7 / 36 / 40 (%) Allow selection of measuring cylinder **and** percentage uncertainty is 5%, scores (1) mark Do not award selection of balance Ignore SF	(2)

Q8.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	• bottom of meniscus between 23.8 and 23.9 (cm^3) **(1)** • meniscus curved downwards **(1)**	Example of diagram  Ignore shading below the meniscus Do not award M2 if there is shading above the meniscus	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a) (ii)	An explanation that makes reference to the following points:	Allow other descriptions of concordant e.g. titres within 0.1 / 0.2 cm^3 Allow (23.1(0) + 23.2(0))/2 = 23.15 (cm^3)	**(2)**
	• 23.15 (cm^3) should be used as it is the mean of the concordant titres / titres 2 and 4 /23.10 and 23.20 (cm^3) **(1)**	Allow only the concordant titres / titres 2 and 4 / 23.20 and 23.20 (cm^3) should be used / are used(in the mean)	
	• 23.43 (cm^3) should not be used as it includes the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) **(1)**	Allow the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) should not be used / are used (in the mean)	

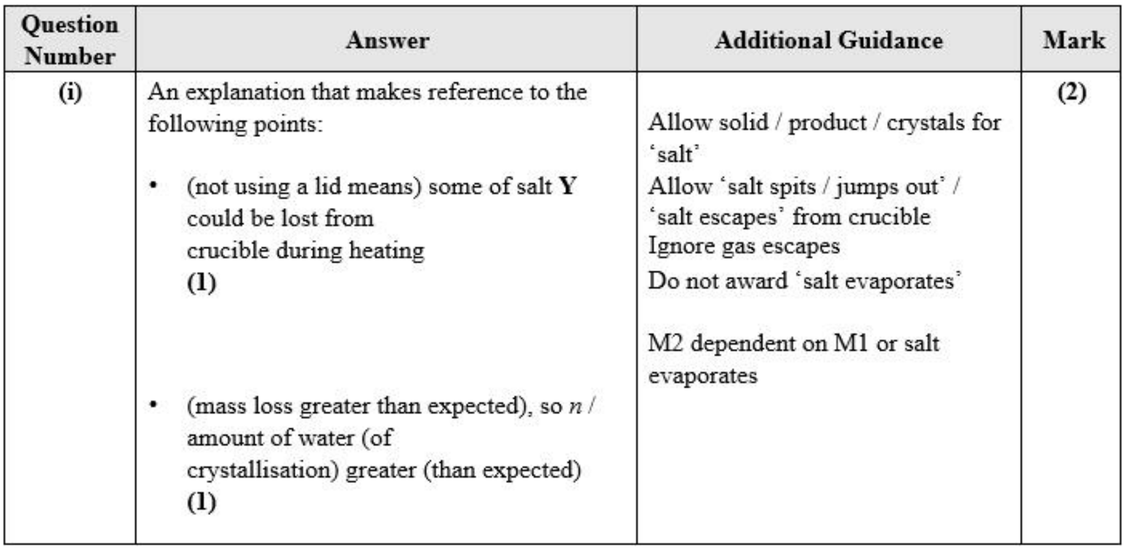
Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	• calculation of percentage uncertainty	Example of calculation $\frac{2 \times 0.05}{23.20} \times 100$ = (±)0.431 / 0.43 / 0.4 (%) Ignore SF including 1 SF Correct answer with no working scores (1)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a) (iv)	• calculation of moles of MnO_4^- **(1)**	Example of calculation moles MnO_4^- = 23.15 x 0.0203/1000 = 0.00046995 / 4.6995 x 10^{-4} (mol)	**(4)**
	• calculation of moles $C_2O_4^{2-}$ in 25.0 cm^3 **(1)**	moles $C_2O_4^{2-}$ in 25.0 cm^3 = 4.6995 x 10^{-4} x 5/2 = 0.0011749 / 1.1749 x 10^{-3} (mol) TE on moles MnO_4^-	
	• calculation of moles $C_2O_4^{2-}$ in 1.00 dm^3 **(1)**	moles $C_2O_4^{2-}$ in 1.00 dm^3 = 1.1749 x 10^{-3} x $\frac{1000}{25.0}$ = 0.046995 / 4.6995 x 10^{-2} (mol) TE on moles $C_2O_4^{2-}$ in 25.0 cm^3	
	• calculation of **y** to nearest whole number **(1)**	Ratio moles salt : moles $C_2O_4^{2-}$ = 0.0235 : 0.046995 = 1 : 1.9998 **y** = 2 TE on moles $C_2O_4^{2-}$ in 1.00 dm^3 Alternative method for M3 and M4 moles salt in 25.0 cm^3 = 0.0235 x 25.0/1000 = 5.875 x 10^{-4} (1) Ratio moles salt : moles $C_2O_4^{2-}$ = 5.875 x 10^{-4} : 1.1749 x 10^{-3} = 1 : 1.9998 **y** = 2 TE on moles salt and $C_2O_4^{2-}$ in 25.0 cm^3 (1) Ignore SF in working except 1 SF Correct answer with no working scores (1) Allow M4 for correct answer using charges on ions	

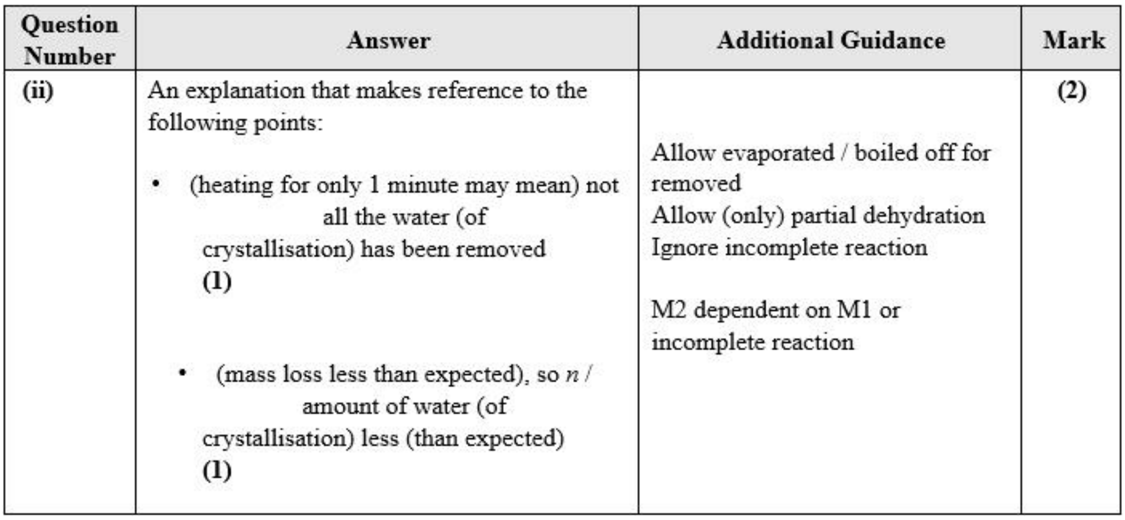
Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• calculation of mol of anhydrous salt **(1)** • calculation of mol H_2O **(1)** • calculation of ***z*** to nearest whole number **(1)**	Example of calculation mol anhydrous salt = 2.96/218.1 = 0.013572 / 1.3572×10^{-2} (mol) TE on M_r of anhydrous salt from value of **y** in (a)(iv) or an assumed value of ***y*** Allow 0.013578 from M_r 218 mol H_2O (= 0.45/18) = 0.025 / 2.5×10^{-2} (mol) Ratio mol salt : mol H_2O = 0.013572 : 0.025 = 1 : 1.842 **z** = 2 TE on moles anhydrous salt and moles H_2O Ignore SF in working except 1 SF Correct answer with some working scores (3) Penalise **y** and **z** not given to nearest whole number once only in (a)(iv) and (b)(i) Allow alternative correct methods	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	An answer which includes the following points: Crystals jumped out of crucible • value of ***z*** increases **and** because it appears that more mass / mol / water is lost (than expected) **(1)** • (this can be prevented by) placing a lid on the crucible **or** heat more gently / carefully **(1)** Not all water of crystallisation lost • less mass / mol /water is lost (than expected) **(1)** • (this can be prevented by) heating to constant mass **or** description of heating to constant mass **(1)** • so this accounts for the lower value of ***z*** / value of ***z*** decreases **(1)**	Ignore just 'loss in mass / mol' Stand alone mark Allow just 'cover the crucible' Ignore use an electrical heater / larger crucible / evaporating basin / conical flask / test tube etc Do not award add anti-bumping granules Stand alone mark Ignore just 'heat for longer' Do not award the idea of repeating the experiment / using a drying agent Conditional on M3	**(5)**

Q9.



Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • (not using a lid means) some of salt **Y** could be lost from crucible during heating **(1)** • (mass loss greater than expected), so *n* / amount of water (of crystallisation) greater (than expected) **(1)**	Allow solid / product / crystals for 'salt' Allow 'salt spits / jumps out' / 'salt escapes' from crucible Ignore gas escapes Do not award 'salt evaporates' M2 dependent on M1 or salt evaporates	**(2)**



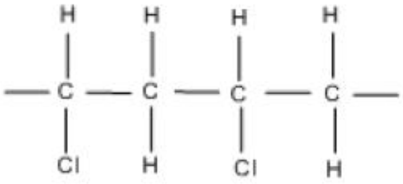
Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • (heating for only 1 minute may mean) not all the water (of crystallisation) has been removed **(1)** • (mass loss less than expected), so *n* / amount of water (of crystallisation) less (than expected) **(1)**	Allow evaporated / boiled off for removed Allow (only) partial dehydration Ignore incomplete reaction M2 dependent on M1 or incomplete reaction	**(2)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>(iii)</td>
<td>•
• calculation of moles of K_2CO_3 (1)
• calculation of moles of H_2O (1)
deduction of n (1)</td>
<td>Example of calculation
<table>
<tr><th></th><th>K_2CO_3</th><th>H_2O</th></tr>
<tr><td>Moles =</td><td>71.9 / (138.2)
= 0.52026</td><td>(100 - 71.9) / 18
= 1.56111</td></tr>
<tr><td>Ratio =</td><td>= 0.52026 / 0.52026
= 1</td><td>= 1.56111 / 0.52026
= 3</td></tr>
<tr><td>n =</td><td>3</td><td></td></tr>
</table>
Accept use of 0.719 / 0.281 in M1
Allow TE from M1
Allow use of 138 for M_r of K_2CO_3 – gives 0.52101
Ignore SF including 1SF in M1 and M2
M3 must be 1 SF

Accept alternative methods e.g.
$\frac{138.2}{138.2 + 18n} = 0.719$ (1)
38.8342 = 12.942n (1) so n = 3 (1) or
M_r of hydrated salt = $\frac{138.2}{0.719}$ = 192.2 (1)
mass of water = 192.2 – 138.2 = 54 (1) n = 54/18 = 3 (1) or
138.2 = 71.9% so 28.1% is water (1) $\frac{138.2}{71.9}$ x 28.1 = 54 (1) n = 54/18 = 3 (1)

Correct answer with no working scores (1)
Correct answer with some correct working scores (3)</td>
<td>(3)</td>
</tr>
</table>

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)		must show **two** repeat units fully displayed allow head to head, head to tail, tail to tail, syndiotactic and isotactic stuctures do not award any other type of formula ignore brackets and n	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following: • (incineration produces) HCl/chlorinated molecules **(1)** • which are corrosive/toxic /cause acid rain **(1)**	M2 is dependent on M1 allow chlorine ignore carbon dioxide and its consequences allow adverse effect on ozone layer	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following: any appropriate precautions to deal with toxic vapours/use fume cupboard etc.	allow good ventilation required allow gas mask/respirator do not award just mask ignore gloves, lab coat	**(1)**

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	$Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$	Allow multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • chlorine/bromine toxic/poisonous **(1)** • (Carry out the experiment in a) fume cupboard **(1)** OR • bromine corrosive **(1)** • wear gloves **(1)**	2nd mark dependent on first. Do not award harmful, but allow MP2 if correct for toxic.	**(2)**

Q12.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	0.816 / 8.16 x 10^{-1} (g)		(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	• calculation of moles of CO_2	Example of calculation: (moles CO_2 = $\frac{225}{24000}$ =) 0.009375 Allow 9.375 x 10^{-3} / 9.38 x 10^{-3} / 9.4 x 10^{-3} Ignore SF except 1SF	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	• moles of MCO_3 **(1)**	Example of calculation: Moles of MCO_3 = moles CO_2 = 0.009375 (mol)	(4)
	• method for calculation of molar mass of MCO_3 **(1)**	Molar mass of MCO_3 = $\frac{0.816}{0.009375}$ (= 87.04 (g mol^{-1})) M2 subsumes mark for M1	
	• molar mass final answer to 1, 2 or 3 SF **(1)**	= 87.0 / 87 / 90 (g mol^{-1}) NOTE M3 mark subsumes mark for M2 and M1	
	• consequential identification of Group 2 metal by name or formula **(1)**	(87.0 – 60) = 27 **AND** Mg / Magnesium / $MgCO_3$ Allow TE on answers to parts (a) and (b), with Metal consequential on calculated molar mass but M must be a Group 2 element	
	NOTE Alternative method can score 3 MAX Calculation of moles of CO_3^{2-} **(1)**	Moles CO_3^{2-} = 0.009375	
	(Calculation of mass of CO_3^{2-}) Deduction of mass of M by subtraction **(1)**	(Mass of CO_3^{2-} = 0.009375 x 60 = 0.5625 g) Mass of M = 0.2535 g	
	Calculation of Ar of M to 1, 2 or 3 SF **AND** Identification of group 2 metal **(1)**	Ar = 0.2535/0.009375 = 27.0 / 27 / 30 (g mol^{-1}) **AND** Mg / Magnesium / $MgCO_3$	

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	An explanation that makes reference to the following points: • the bung was not replaced quickly enough **(1)** • (So) CO_2 / gas lost (to the surroundings) **(1)**	Allow bung not fitting tightly resulting in leaks Ignore references to CO_2 dissolving Ignore references to other types of gas leak Allow 'smaller volume of gas collected' / lower reading of gas volume Mark points M1 and M2 independently	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to the following point: The acid was (already) in excess (and more acid won't affect this)	Allow The carbonate is the limiting reactant / the acid is not the limiting reactant	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	An explanation that makes reference to the following points: • rate of reaction is faster **and** powder has greater surface area **(1)** • no effect on (final) volume of gas **and** moles of (metal) carbonate are unchanged **or** because the rate is faster more gas will be lost before the bung is replaced so the (final) volume will be less **(1)**	Mark points M1 and M2 independently Both parts of statement needed Both parts of statement needed Allow mass / amount for moles Allow reactant for metal carbonate	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(i)	• balanced equation with state symbols	Example of equation: $MCO_3(s) \rightarrow MO(s) + CO_2(g)$ Allow a correct equation for the decomposition of any Group 2 carbonate	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(ii)	- subtractions to obtain masses **(1)**	Example of calculation: (mass of CO_2 = 20.447 − 20.205) = 0.242 **AND** (mass of MCO_3 = 20.447 − 19.996) = 0.451	**(3)**
	- calculation of moles of CO_2 **(1)**	moles of $CO_2 = \frac{0.242}{44}$ = 0.0055(0) (mol) / 5.5(0) x 10^{-3} (mol) ALLOW TE from M2 to M3	
	- calculation of molar mass of MCO_3 **(1)**	Mr of $MCO_3 = \frac{0.451}{0.0055(0)}$ = 82 (g mol^{-1}) Correct answer with or without working scores 3 Ignore SF except 1 Ignore attempts to identify the metal	

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	An answer that makes reference to the following point: Student 3 used a smaller mass / less (and the uncertainty of the balance was the same) **or** Student 1 used a larger mass / more (and the uncertainty of the balance was the same)	Allow calculations comparing the two percentage errors: e.g. Student 1:- (0.001/0.816) x 100% = 0.12% **and** Student 3:- 0.001/0.451 x 100% = 0.22%	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(g)	An explanation that makes reference to the following points: • more CO_2 (would appear to be) given off **(1)** • (So) calculated molar mass is smaller **(1)**	 M2 dependent on M1	**(2)**
	OR • Less MO would appear to have been formed **(1)** • Calculated molar mass would be greater **(1)**	 M2 dependent on M1	

Q13.

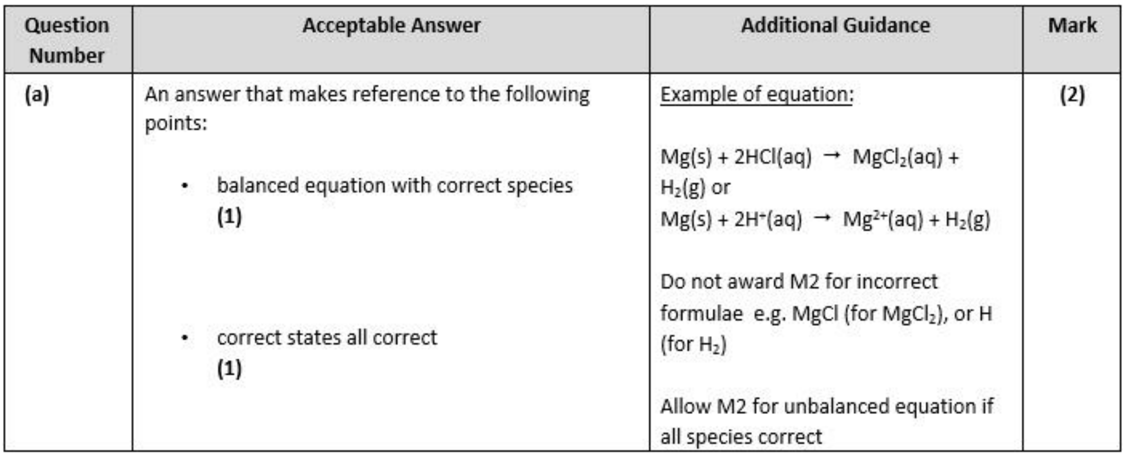
Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	- burette uncertainty **(1)** - pipette uncertainty **(1)**	Example of calculations 0.05 x 2 x 100/ 17.65 = (±)0.567/0.57/0.6(%) 0.06 x 100/25 = (±)0.24/0.2(%) ignore addition of the two uncertainties ignore SF	**(2)**

Question Number	Acceptable Answer	Mark
(ii)	**The only correct answer is B** ***A*** *is not correct because the volume of NaOH needed is divided by 4, uncertainty is x4* ***C*** *is not correct because moles of acid is the same and uncertainty is the same.* ***D*** *is not correct because moles of acid halved and uncertainty doubled.*	**(1)**

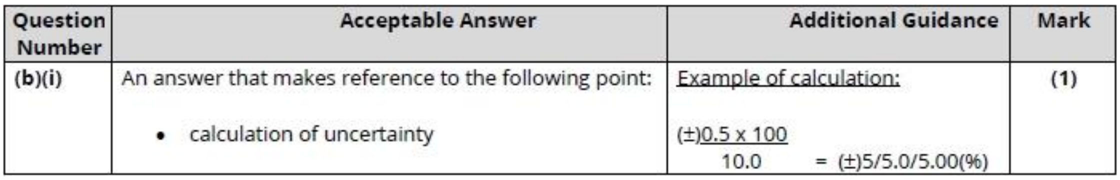
Q14.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following point: - sodium amide reacts (vigorously / violently) with water / oxygen	Allow reacts with air Allow will oxidise if not stored in oil / if stored in air Do not award sodium reacts with water / oxygen / air	(1)

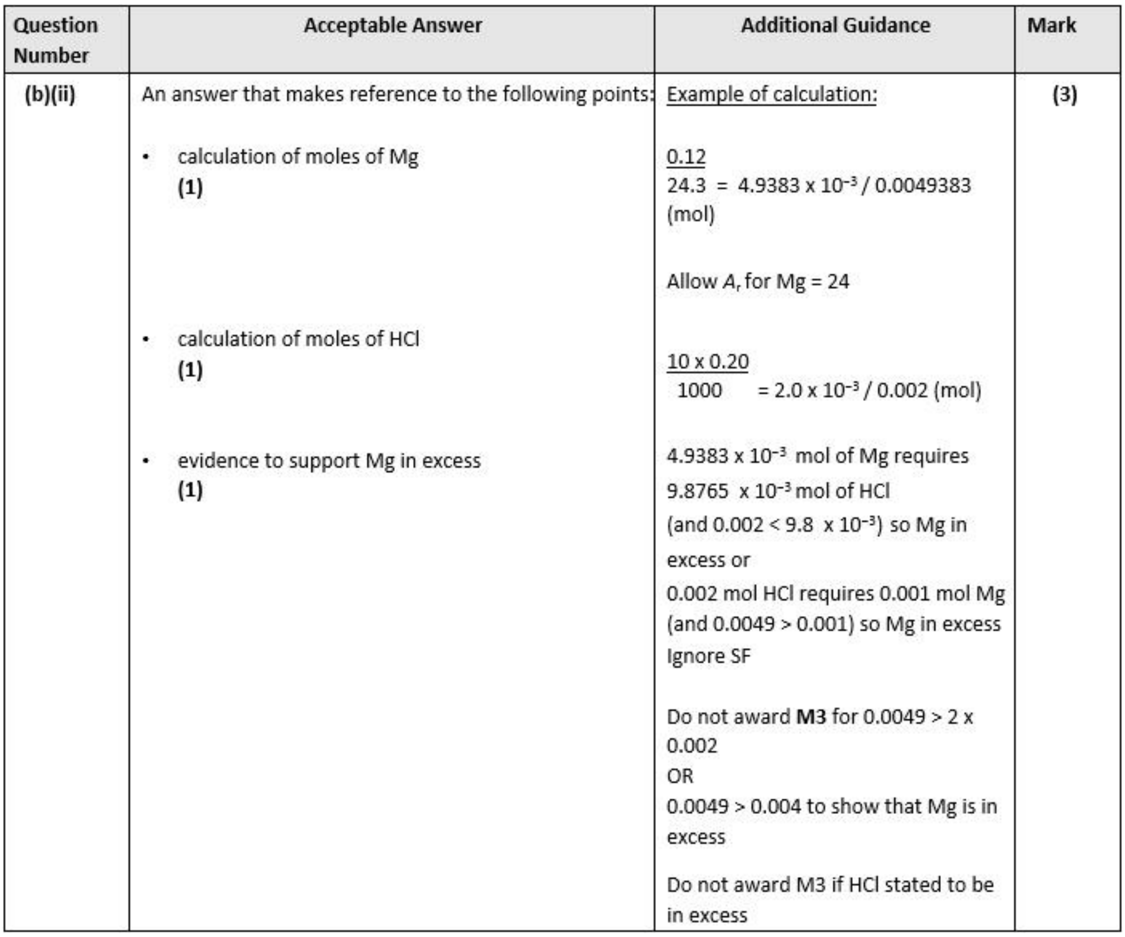
Q15.



Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • balanced equation with correct species **(1)** • correct states all correct **(1)**	Example of equation: $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ or $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ Do not award M2 for incorrect formulae e.g. MgCl (for $MgCl_2$), or H (for H_2) Allow M2 for unbalanced equation if all species correct	**(2)**



Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	An answer that makes reference to the following point: • calculation of uncertainty	Example of calculation: $\frac{(\pm)0.5 \times 100}{10.0} = (\pm)5/5.0/5.00(\%)$	**(1)**

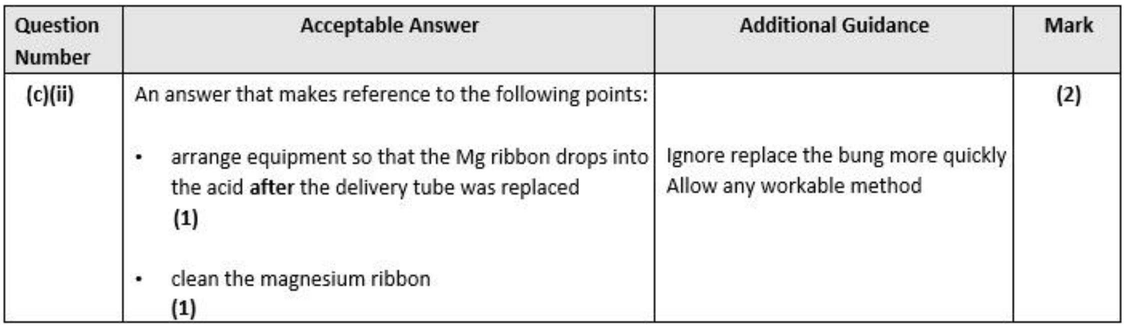


Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(ii)	An answer that makes reference to the following points: • calculation of moles of Mg **(1)** • calculation of moles of HCl **(1)** • evidence to support Mg in excess **(1)**	Example of calculation: $\frac{0.12}{24.3} = 4.9383 \times 10^{-3} / 0.0049383$ (mol) Allow A_r for Mg = 24 $\frac{10 \times 0.20}{1000} = 2.0 \times 10^{-3} / 0.002$ (mol) 4.9383×10^{-3} mol of Mg requires 9.8765×10^{-3} mol of HCl (and $0.002 < 9.8 \times 10^{-3}$) so Mg in excess or 0.002 mol HCl requires 0.001 mol Mg (and 0.0049 > 0.001) so Mg in excess Ignore SF Do not award **M3** for 0.0049 > 2 x 0.002 OR 0.0049 > 0.004 to show that Mg is in excess Do not award M3 if HCl stated to be in excess	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iii)	calculation of moles of gas	Example of calculation 0.002 ÷ 2 = 0.001 or 1 x 10^{-3} Allow TE from (a) and (b)(ii)	**(1)**

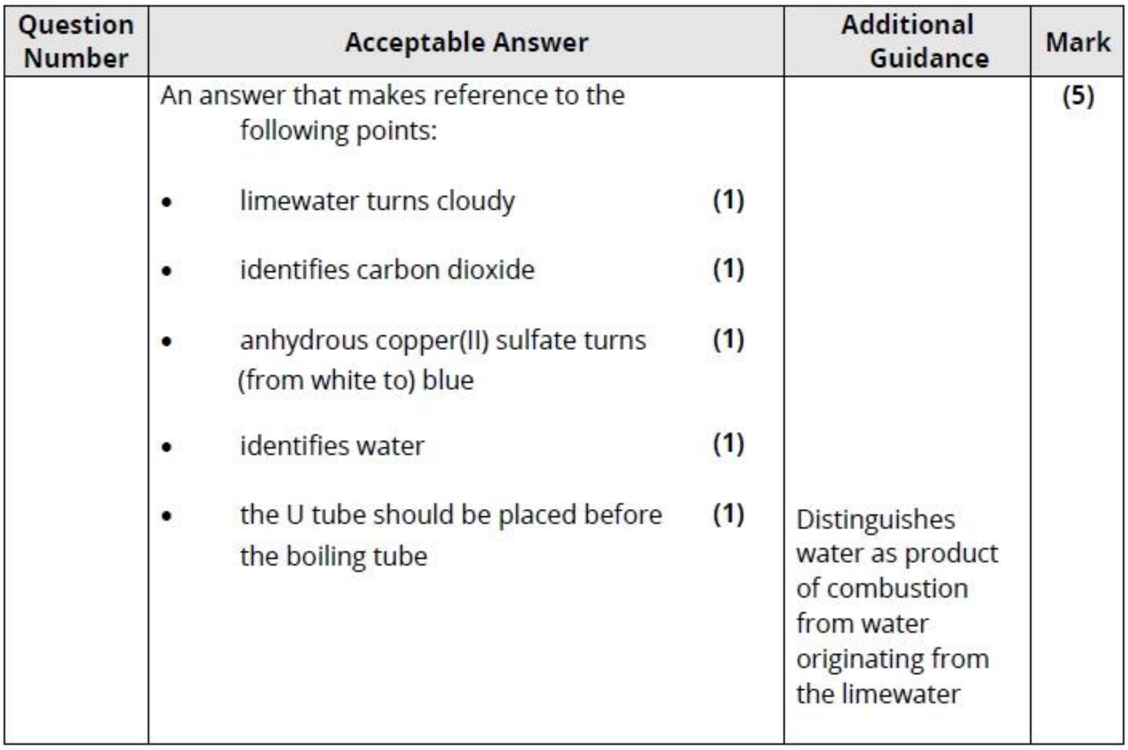
Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iv)		Example of calculation:	
	• Rearrangement of ideal gas equation **(1)**	pV = nRT rearrange $V = \frac{nRT}{p}$ Allow M1 if equation rearrangement not explicitly shown but used correctly in M3	
	• conversion of °C to K **(1)**	(273 + 23) = 296 Allow M2 if (273 + 23) used in equation	
	• calculation of volume in m$_3$ **(1)**	$V = \frac{1.0 \times 10^{-3} \times 8.31 \times (273 + 23)}{98\,000}$ = 2.51 x 10^{-5} (m^3) = 25 allow 25.1 (cm^3)	
	• calculation of volume in cm$_3$ **(1)**	Allow TE from (b)(iii) and TE at each stage Allow **2 or 3** SF for final answer **ECF values from (b)(iii)** For 0.002 mol H_2, V = 50.2 cm^3 For 0.00494 mol H_2, V = 124 cm^3 For 0.00894 mol H_2, V = 224 cm^3 For 0.004 mol H_2, V = 100 cm^3	

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)(i)	An answer that makes reference to the following points:		**(2)**
	• gas lost before the bung replaced **(1)**	Ignore 'generic' gas leakages from apparatus Do not award gas may dissolve (in water or acid)	
	• the magnesium was coated with oxide (so water was formed instead of hydrogen) **(1)**	Ignore 'generic' references to impurity Ignore references to incomplete reaction	



Question Number	Acceptable Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following points: • arrange equipment so that the Mg ribbon drops into the acid **after** the delivery tube was replaced **(1)** • clean the magnesium ribbon **(1)**	Ignore replace the bung more quickly Allow any workable method	**(2)**

Q16.



Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • limewater turns cloudy **(1)** • identifies carbon dioxide **(1)** • anhydrous copper(II) sulfate turns (from white to) blue **(1)** • identifies water **(1)** • the U tube should be placed before the boiling tube **(1)**	Distinguishes water as product of combustion from water originating from the limewater	**(5)**

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• moles of malachite / carbon dioxide **(1)** • convert temperature to kelvin **(1)** • convert pressure to Pa **(1)** • rearrange the expression for V and substitute the candidate's values **(1)** • calculation of V with units and answer to 2 or 3 SF **(1)**	Example of calculation: 0.810/ 221 = 3.66(5158371) x 10^{-3} (mol) temperature = 298 (K) allow for correct temperature in K shown in the calculation Pressure = 101000 (Pa) Allow use of 101 (kPa) if answer given in dm^3 $V = nRT/p$ = 3.66(5158371) x 10^{-3} x 8.31 x 298 ÷ 101000 Correct use of rearranged equation scores M4 =8.98(6460284) x 10^{-5} m^3 =8.99 x 10^{-5} m^3 /9.0 x 10^{-5} m^3/ 0.0899 dm^3 /0.090 dm^3/89.9 cm^3 / 90 cm^3 Use of 300°C / 573 K gives 1.73 x 10^{-4} m^3 Use of 25° gives 7.54 x 10^{-6} m^3 Allow equivalent answers in standard or nonstandard form . Allow TE throughout Correct answer with no working scores 5 marks	**(5)**

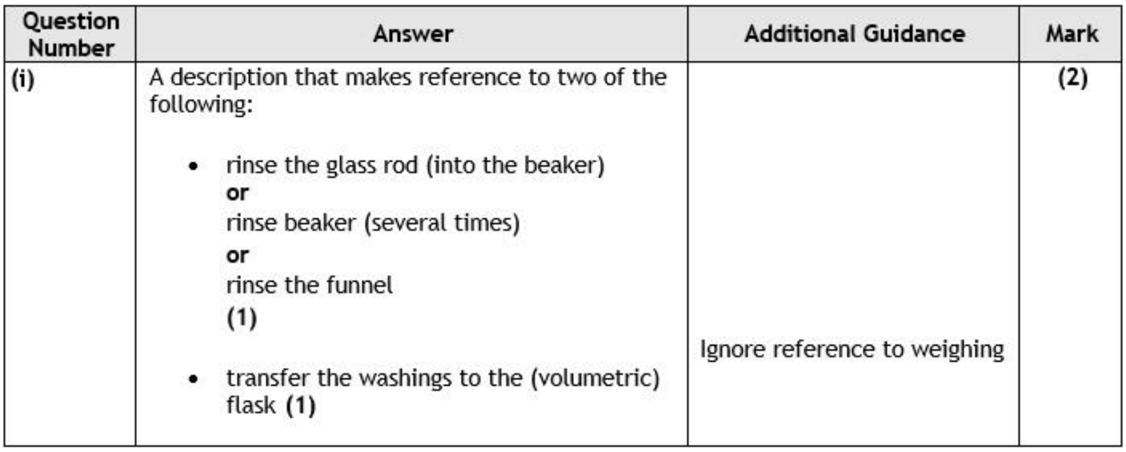
Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• 0.556 (%) / 0.56 (%) / 0.6 (%)	Example of calculation: 0.5/89.9 x 100 = 0.556 (%) Allow TE from answer to 6(d)(i) Ignore SF	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• moles of copper(II) oxide expected (from 0.810 g pure malachite) **(1)** • mass of copper(II) oxide expected (from 0.810 g pure malachite) **(1)** • evaluation of answer **(1)**	Example of calculation: 2 x 3.66(5158371) x 10^{-3}= 7.33(0316742) x 10^{-3} (mol) 7.33(0316742) x 10^{-3} x 79.5 = 0.582(760181) (g) (0.583 (g) scores M1 and M2) % purity = $\frac{\text{actual mass x100}}{\text{expected mass}}$ = $\frac{0.571 \times 100}{0.582(760181)}$ =	**(3)**

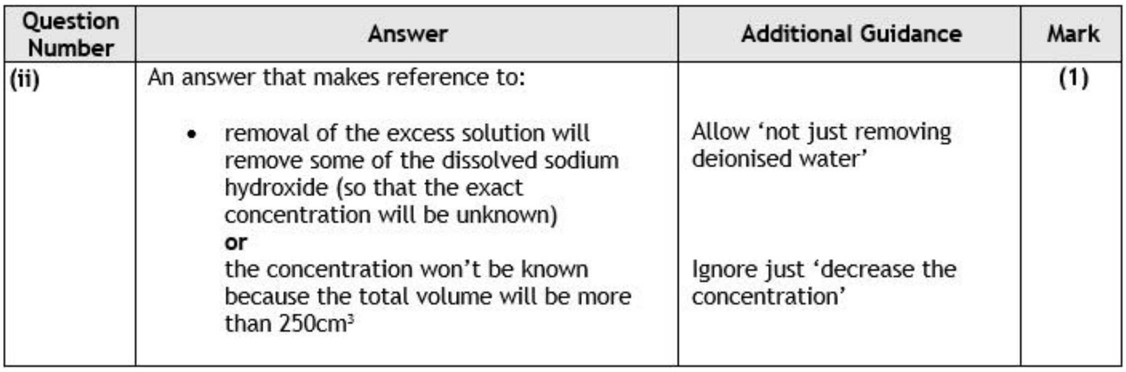
		97.981(98618) = 98.0(%)/ 98(%)	
	OR		
	• moles of copper(II) oxide in 0.571 g **(1)**	$\frac{0.571}{79.5}$ = 7.18(2389937) x 10^{-3} (mol)	
	• moles of copper(II) oxide expected from 0.810 g pure malachite **(1)**	2 x 3.66(5158371) x 10^{-3}= 7.33(0316742) x 10^{-3} (mol)	
	• evaluation of answer **(1)**	$\frac{7.18(2389937) \times 10^{-3} \times 100}{7.33(0316742) \times 10^{-3}}$ = 97.9(8198618) = 98.0(%) / 98(%)	
	OR		
	• calculate mass of CO_2 from decomposition of 0.810 g malachite **and** calculate mass of H_2O from decomposition of 0.810 g malachite **(1)**	3.66(5158371) x 10^{-3} x 44 = 0.161(2669683) (g) 3.66(5158371) x 10^{-3} x 18 = 0.0659(7285068) (g)	
	• calculate total mass of products **(1)**	0.161 + 0.066 + 0.571 = 0.798(239819) (g)	
	• evaluation of answer **(1)**	$\frac{0.798(239819) \times 100}{0.810}$ = 98.5 (481258) / 99(%)	
		0.571/ 79.5 = 7.18 x 10^{-3} (mol)	

	OR		
	• calculate moles of CuO in 0.571 g **(1)**	Moles of malachite = 7.18 x 10^{-3} ÷ 2 = 3.59119 x 10^{-3} (mol)	
	• calculate mass of malachite to produce 0.571 g CuO **(1)**	Mass of malachite = 3.59119 x 10^{-3} x 221 = 0.79365 (g)	
	• calculate % **(1)**	Purity = 0.79365 x 100/0.810 = 97.98198618 (%) =98 / 98.0(%) Allow TE throughout Correct answer with no working scores 3 marks	

Q18.

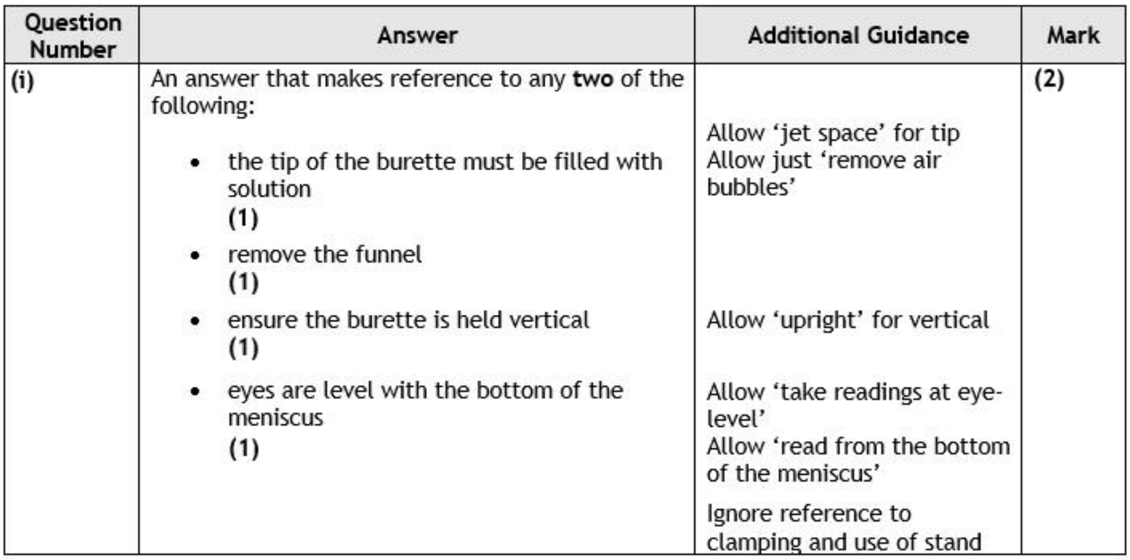


Question Number	Answer	Additional Guidance	Mark
(i)	A description that makes reference to two of the following: • rinse the glass rod (into the beaker) **or** rinse beaker (several times) **or** rinse the funnel **(1)** • transfer the washings to the (volumetric) flask **(1)**	Ignore reference to weighing	**(2)**

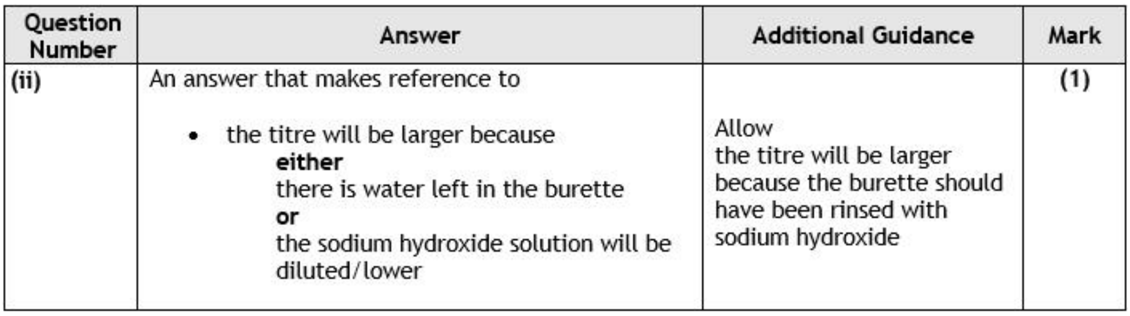


Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to: • removal of the excess solution will remove some of the dissolved sodium hydroxide (so that the exact concentration will be unknown) **or** the concentration won't be known because the total volume will be more than 250cm^3	Allow 'not just removing deionised water' Ignore just 'decrease the concentration'	**(1)**

Q19.

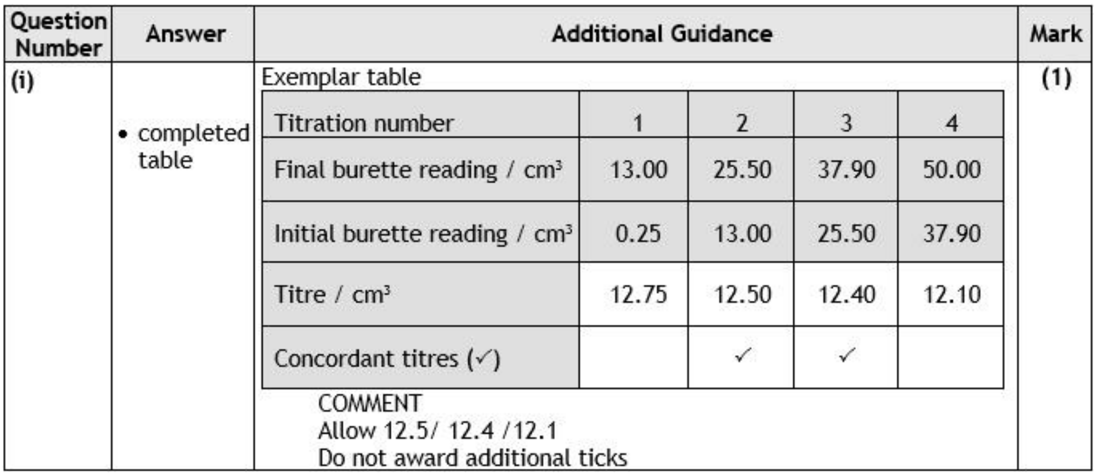


Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to any **two** of the following: • the tip of the burette must be filled with solution **(1)** • remove the funnel **(1)** • ensure the burette is held vertical **(1)** • eyes are level with the bottom of the meniscus **(1)**	Allow 'jet space' for tip Allow just 'remove air bubbles' Allow 'upright' for vertical Allow 'take readings at eye-level' Allow 'read from the bottom of the meniscus' Ignore reference to clamping and use of stand	**(2)**



Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to • the titre will be larger because **either** there is water left in the burette **or** the sodium hydroxide solution will be diluted/lower	Allow the titre will be larger because the burette should have been rinsed with sodium hydroxide	**(1)**

Q20.



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<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(i)</td><td>• completed table</td><td>Exemplar table
<table>
<tr><td>Titration number</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>Final burette reading / cm^3</td><td>13.00</td><td>25.50</td><td>37.90</td><td>50.00</td></tr>
<tr><td>Initial burette reading / cm^3</td><td>0.25</td><td>13.00</td><td>25.50</td><td>37.90</td></tr>
<tr><td>Titre / cm^3</td><td>12.75</td><td>12.50</td><td>12.40</td><td>12.10</td></tr>
<tr><td>Concordant titres (✓)</td><td></td><td>✓</td><td>✓</td><td></td></tr>
</table>
COMMENT
Allow 12.5/ 12.4 /12.1
Do not award additional ticks</td><td>(1)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
(ii)	- calculation of percentage measurement uncertainty	Example of calculation (%= ((0.05 x 4) ÷ 12.40 x 100) = 1.6%/1.61% / 2% Ignore SF Do not award 1.65% rounded to 2%	(1)

Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	- calculates moles of acid **(1)**	Example of calculation moles of acid =10.0 x 0.400/1000 =4(.0) x 10^{-3} /0.004 (mol)	
	- calculates moles of sodium carbonate **(1)**	moles of sodium carbonate =0.242/106.0 = 2.283 x 10^{-3}/0.002283 (mol)	
	- recognises that (sodium) carbonate is in excess **(1)**		
	- evidence for excess sodium carbonate in terms of moles **(1)**	recognition of HCl:Na_2CO_3 = 2:1 gets M4 4.0 x10^{-3} mol acid requires 2.0 x 10^{-3} mol sodium carbonate OR 2.283 x 10^{-3} mol of sodium carbonate requires 4.566 x 10^{-3} mol of acid	
	- correct volume of gas calculated with units **(1)**	moles CO_2 = 2.0 x 10^{-3} (mol) volume of gas = 2.0 x 10^{-3} x 24 000 = 48 cm^3 /0.048 dm^3 TE on incorrect moles CO_2 correct answer with no working scores 1 mark if the moles of sodium carbonate are not calculated, only M1, M4 and M5 can be awarded. ignore SF except 1 for M5	**(5)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following reasons: • some gas escaped before the bung/delivery tube was replaced **(1)** • the gas / carbon dioxide is (slightly) soluble in water/ acid / solution **(1)**	ignore references to change in volume when the bung is pushed into the test tube allow 'temperature less than 25°C/298 K/room temperature' as alternative to either answer do not award an incomplete reaction do not award leaky apparatus/sticking syringe	**(2)**

Q22.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: • 3300 — 2500 (cm^{-1}) **and** O-H (bond) **(1)** • 1725 — 1700 (cm^{-1}) **and** C=O (bond) **(1)**	Allow any value(s) within the range 3300 — 2500 (cm^{-1}) Allow -OH Allow any value(s) within the range 1725 — 1700 (cm^{-1}) Allow 1320 – 1210 (cm^{-1}) **and** C-O	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: • structures 1 and 2 will have an absorption at Either C=C at 1669 — 1645 (cm^{-1}) **or** C—H in an alkene at 3095 — 3010 (cm^{-1}) **(1)** • only structure 2 will have an absorption due to the presence of an alcohol / O—H at 3750 —3200 (cm^{-1}) **(1)** • structure 3 will have none of these absorptions / will not show C=C absorption / C-H absorption for an alkene **(1)**	Reject C=C at 3010 (cm^{-1})	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	- calculation of moles of NaOH **(1)** - calculation of mass of NaOH **(1)**	Example of calculation: (moles NaOH = 0.140 x 250) 1000 = 0.035(0) (mol) = 40(.0) x 0.035(0) = 1.4(0) (g) Correct answer with or without working scores 2 marks Allow TE for M2 on moles of NaOH Alternative route, allow M1 for conversion of concentration to 5.6 g dm^{-3} Ignore SF	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	An explanation that makes reference to the following points: - (because the) sodium hydroxide has been diluted **(1)** - (the titre will be) smaller **(1)**	Allow Fewer moles of sodium hydroxide present / some sodium hydroxide will have been removed M2 dependent on M1	**(2)**

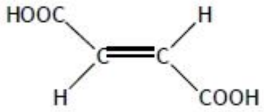
Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	An explanation that makes reference to the following points: M1 no effect (on the titre) **(1)** M2 because the (number of) moles of sodium hydroxide is unaffected **(1)**	M2 depends on M1 Allow base / alkali / hydroxide (ions) Allow amount / mass of sodium hydroxide is unaffected	**(2)**

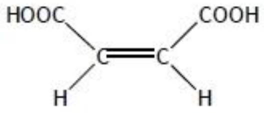
Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(iii)	- calculation of percentage uncertainty in burette volume **(1)** - calculation of percentage uncertainty in volumetric flask volume **and** in pipette volume **(1)** - identification of volume with the lowest percentage uncertainty **(1)**	Example of calculation: $\frac{2 \times (\pm)0.05}{10.20} \times 100\% = (\pm)0.980392156\%$ $\frac{(\pm)0.30}{250.0} \times 100\% = (\pm)0.12\%$ **and** $\frac{(\pm)0.040}{10.0} \times 100\% = (\pm)0.4\%$ Volumetric flask has the lowest uncertainty Allow TE for identification in M3 Allow ANY number of SF in answer, from 1 SF up to calculator value	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	- left-hand side of equation correct **(1)** - right-hand side of equation correct **(1)**	Example of equation HOOCCH=CHCOOH + 2NaOH → NaOOCCH=CHCOONa + $2H_2O$ ALLOW use of molecular formulae or ionic equation: $C_4H_4O_4 + 2NaOH \rightarrow Na_2C_4H_2O_4 + 2H_2O$ HOOCCH=CHCOOH + $2OH^-$ (+ $2Na^+$) → $^-$OOCCH=CHCOO$^-$ + $2H_2O$ (+ $2Na^+$) ALLOW Multiples Correct charges Do not award if O−Na covalent bond drawn IGNORE State symbols, even if incorrect	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to the following points: - (New mean titre) = 20.4(0) (cm^3) / double (the original value) **(1)** - For structure 2, mole ratio / reacting ratio is 1:1 (with NaOH) **(1)**	Mark M1 and M2 independently Allow structure 2 has 1 COOH / 1 acid group	**(2)**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(e)</td><td>
<table>
<tr><th>Structure</th><th>Test with Br_2 water</th><th>Test with acidified $K_2Cr_2O_7$</th></tr>
<tr><td>HOOCCH=CHCOOH</td><td>✓</td><td>x</td></tr>
<tr><td>$HOCH_2CH=CHCH_2COOH$</td><td>✓</td><td>✓</td></tr>
<tr><td>$CH_3CH_2CH_2CH_2CH_2COOH$</td><td>x</td><td>x</td></tr>
</table>
Left hand column correct (1)
Right hand column correct (1)</td><td>3 correct ticks with no crosses scores 1
Ignore descriptions of result in terms of colour (changes) / reactions occurring</td><td>(2)</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(f)(i)</td><td>• <i>E</i>-isomer:


(1)
• <i>Z</i>-isomer:


(1)</td><td>ALLOW skeletal or displayed structures
ALLOW $-CO_2H$
IGNORE
Connectivity to the −COOH group
IGNORE
bond angles
Award one mark if correct structures are drawn, but <i>E</i>- and <i>Z</i>-isomers labelled the wrong way round
Award 1 mark if incorrect molecule used but <i>E</i> - and <i>Z</i>- isomers are correct</td><td>(2)</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(f)(ii)</td><td>An answer that makes reference to the following points:
• restricted / limited rotation (about the C=C double bond)(1)
• each carbon atom in the double bond is attached to (two) different atoms / different groups (of atoms) / to a H (atom) and a COOH group (1)</td><td>Allow “no rotation”
Do not award the carbons are attached to 2 “different molecules”
Mark points M1 and M2 independently</td><td>(2)</td></tr>
</table>

Q23.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• potassium dichromate((VI))/$K_2Cr_2O_7$ <u>and</u> sulfuric acid/H_2SO_4 **or** sodium dichromate((VI))/$Na_2Cr_2O_7$ <u>and</u> (dilute) sulfuric acid/H_2SO_4 **(1)**	Allow $Cr_2O_7^{2-}$ <u>and</u> H^+ / acidified (potassium / sodium) dichromate((VI)) If name and formula given, both must be correct Ignore concentration of acid Do not allow hydrochloric acid / HCl / nitric acid / HNO_3	**(2)**
	• heat/reflux **(1)**	Conditional on correct reagents or near miss, provided dichromate or (per)manganate((VII)) is mentioned Allow a specified temperature in the range 60 – 150°C Ignore distillation / warm Allow answers written on either dotted line	

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	A description that makes reference to the following points:	Ignore heat	**(4)**
	• **Flask** - use of a volumetric / graduated flask **(1)**	Do not allow just 'flask' / conical flask	
	• **Weighing** - weigh the ethanedioic acid (in a weighed container and record the exact mass) **(1)**	Ignore just 'put 1 /1.0 /1.09 g solid in beaker'	
	• **Dissolve, transfer and washings** – allow these in any order depending on the method used **(1)**	Distilled / deionised water must be mentioned once in M3 or M4 Allow pure water	
	• **Mark and mix** - make up to the mark / 250 cm^3 <u>and</u> then mix **(1)**	Allow any indication of mixing eg swirl / invert the flask	

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• (From) colourless (to) pink	Allow (to) red Do not allow purple / pink/purple Do not allow clear	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)		Correct answer of 2.2582/2.258/2.26/2.3 without working scores 5 Final answer of 2, with working, resulting from a number between 2.2 and 2.3, scores 5 If no other mark is scored, an answer of just 2 scores 1	**(5)**
	• calculation of moles of NaOH **(1)**	Example of calculation moles NaOH = 16.2 x 0.103/1000 = 1.6686×10^{-3}	
	• calculation of moles of $H_2C_2O_4$ in 25 cm^3 **(1)**	moles $H_2C_2O_4$ in 25 cm^3 = $1.6686 \times 10^{-3}/2 = 8.343 \times 10^{-4}$ TE on mole NaOH	
	• calculation of moles of $H_2C_2O_4$ in 250 cm^3 **(1)**	moles $H_2C_2O_4$ in 250 cm^3 = $8.343 \times 10^{-4} \times 10 = 8.343 \times 10^{-3}$ TE on moles $H_2C_2O_4$ in 25 cm^3	
	• calculation of M_r of crystals **(1)**	M_r of crystals = $1.09/8.343 \times 10^{-3}$ = 130.648 /130.65 / 130.6 TE on moles $H_2C_2O_4$ in 250 cm^3 For first 4 marking points ignore SF except 1 SF	
	• calculation of value of n **(1)**	130.65 = (2 + (2x12) + (4x16)) + 18n n = 2.2582/ 2.258/2.26/2.3/2 TE on M_r of crystals, provided n is positive	

	Alternative method for M4 and M5 • calculation of moles of H_2O **(1)**	mass $H_2C_2O_4$ = $8.343 \times 10^{-3} \times 90$ = 0.75087 (g) mass H_2O = 1.09 – 0.75087 = 0.3391 (g) moles H_2O = 0.3391/18 = 0.01884	
	• calculation of value of n **(1)**	mole ratio $H_2C_2O_4$: H_2O = 1 : $0.01884/8.343 \times 10^{-3}$ = 1 : 2.2582/ 2.258/2.26/2.3/2	

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iv)	An explanation that makes reference to the following points: • (damp crystals will have more water so) lower mass / moles / concentration of $H_2C_2O_4$ **(1)** • so titre will be lower and the value of n will be higher **(1)**		**(2)**