Q1.

Calcium sulfide reacts with calcium sulfate as shown.

$$CaS + 3\ CaSO_4 \rightarrow 4\ CaO + 4\ SO_2$$

2.50 g of calcium sulfide are heated with 9.85 g of calcium sulfate until there is no further reaction.

Show that calcium sulfate is the limiting reagent in this reaction.

Calculate the mass, in g, of sulfur dioxide formed.

M_r (CaS) = 72.2
M_r ($CaSO_4$) = 136.2

Mass of sulfur dioxide ____________________ g

(Total 5 marks)

Q2.

A student is provided with a 5.60 g sample of ethanoic acid (CH_3COOH) contaminated with sodium ethanoate (CH_3COONa).

The student dissolves the sample in deionised water and makes the volume up to 200 cm^3

The student removes 25.0 cm^3 samples of the solution and titrates them with 0.350 mol dm^{-3} sodium hydroxide solution.

The table below shows the results of these titrations.

	Rough	**1**	**2**	**3**
Final volume / cm^3	20.85	41.10	20.50	40.80
Initial volume / cm^3	0.00	20.85	0.00	20.50
Titre / cm^3	20.85	20.25	20.50	20.30

(a) Use the results in the table above to calculate the mean titre value.

Use the mean titre to calculate the percentage by mass of sodium ethanoate in the original sample.

Mean titre value ________________ cm^3

Percentage by mass ______________________

(6)

(b) The student rinses the burette with deionised water before filling with sodium hydroxide solution.

State and explain the effect, if any, that this rinsing will have on the value of the titre.

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(2)

(Total 8 marks)

Q3.

This question is about two experiments on gases.

(a) In the first experiment, liquid **Y** is injected into a sealed flask under vacuum.
The liquid vaporises in the flask.
The table below shows data for this experiment.

Mass of **Y**	717 mg
Temperature	297 K
Volume of flask	482 cm^3
Pressure inside flask	51.0 kPa

Calculate the relative molecular mass of **Y**.

Show your working.

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

Relative molecular mass of **Y** ______________________

(5)

(b) In the second experiment, another flask is used for a combustion reaction.

Method

- Remove all the air from the flask.
- Add 0.0010 mol of 2,2,4-trimethylpentane (C_8H_{18}) to the flask.
- Add 0.0200 mol of oxygen to the flask.
- Spark the mixture to ensure complete combustion.
- Cool the mixture to the original temperature.

The equation is

$$C_8H_{18}(g) + 12\frac{1}{2}\ O_2(g) \rightarrow 8\ CO_2(g) + 9\ H_2O(l)$$

Calculate the amount, in moles, of gas in the flask after the reaction.

Amount of gas ______________________________ mol

(2)

(Total 7 marks)

Q4.

A compound contains 40.0% carbon, 6.7% hydrogen and 53.3% oxygen by mass.

Which could be the molecular formula of this compound?

A $C_2H_2O_2$ ☐

B C_2H_2O ☐

C $C_2H_4O_2$ ☐

D C_2HO_2 ☐

(Total 1 mark)

Q5.

When driving a car, a legal limit for ethanol (M_r = 46.0) is 80 mg per 100 cm^3 of blood.

What is this concentration in mol dm^{-3}?

A 1.74×10^{-1} ☐

B 1.74×10^{-2} ☐

C 1.74×10^{-3} ☐

D 1.74×10^{-4} ☐

(Total 1 mark)

Q6.

What is the percentage atom economy for the production of ethanol from glucose?

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

A 25.6%

B 27.1%

C 51.1%

D 54.2%

(Total 1 mark)

Q7.

Nitration of 1.70 g of methyl benzoate (M_r = 136.0) produces methyl 3-nitrobenzoate (M_r = 181.0). The percentage yield is 65.0%

What mass, in g, of methyl 3-nitrobenzoate is produced?

A 0.830

B 1.10

C 1.47

D 2.26

(Total 1 mark)

Q8.

Which compound needs the greatest amount of oxygen for the complete combustion of 1 mol of the compound?

A ethanal

B ethanol

C ethane-1,2-diol

D methanol

(Total 1 mark)

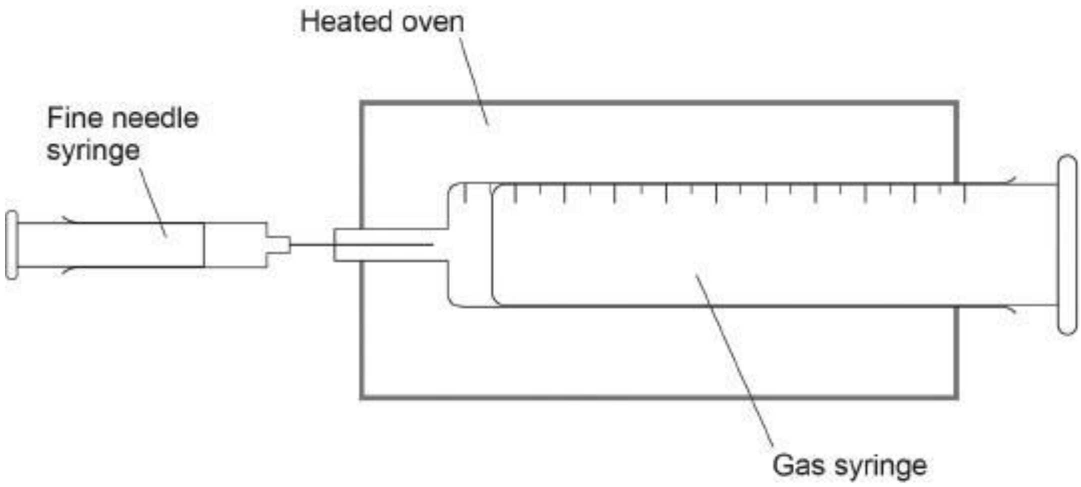
Q9.

This question is about a volatile liquid, **A**.

(a) A student does an experiment to determine the relative molecular mass (M_r) of liquid **A** using the apparatus shown in the figure below.

The student injects a sample of **A** into a gas syringe in an oven.

At the temperature of the oven, liquid **A** vaporises.



The table shows the student's results.

Mass of fine needle syringe and contents before injecting	11.295 g
Mass of fine needle syringe and contents after injecting	10.835 g
Volume reading on gas syringe before injecting	0.0 cm^3
Volume reading on gas syringe after injecting	178.0 cm^3
Pressure of gas in syringe	100 kPa
Temperature of oven	120 °C

Calculate the M_r of **A**.

Give your answer to 3 significant figures.

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

M_r ________________

(4)

(b) The student noticed that some of the liquid injected into the gas syringe did **not** vaporise.

Explain the effect that this has on the M_r calculated by the student.

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(2)

The table is repeated here.

Mass of fine needle syringe and contents before injecting	11.295 g
Mass of fine needle syringe and contents after injecting	10.835 g
Volume reading on gas syringe before injecting	0.0 cm^3
Volume reading on gas syringe after injecting	178.0 cm^3
Pressure of gas in syringe	100 kPa
Temperature of oven	120 °C

(c) Each reading on the balance used to record the mass of the fine needle syringe and contents had an uncertainty of ±0.001 g

Calculate the percentage uncertainty in the mass of liquid **A** injected in this experiment.

Percentage uncertainty ________________

(1)

(Total 7 marks)

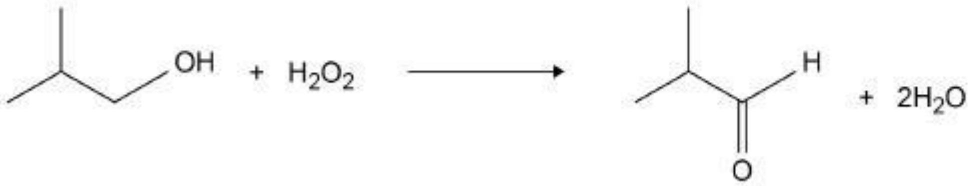
Q10.

A student investigates two experimental methods of making methylpropanal. The equations for these two methods are shown.

Method 1

M_r = 116.0 M_r = 72.0

Method 2



M_r = 74.0 M_r = 72.0

In each method, the student uses 1.00 g of organic starting material.

The yield of methylpropanal obtained using each method and other data are included in the table.

	Method 1	Method 2
Yield of methylpropanal / mg	552	778
Percentage yield		80.0%
Percentage atom economy	62.1%	

Calculate the percentage yield for Method 1.

Calculate the percentage atom economy for Method 2.

State the importance of percentage yield and percentage atom economy when choosing the method used to make a compound.

% yield _______________

Importance of percentage yield ___________________________________

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% atom economy ______________

Importance of percentage atom economy ___________________________

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(Total 6 marks)

Q11.

A student does an experiment to determine the percentage by mass of sodium chlorate(I), NaClO, in a sample of bleach solution.

Method:

- Dilute a 10.0 cm^3 sample of bleach solution to 100 cm^3 with distilled water.
- Transfer 25.0 cm^3 of the diluted bleach solution to a conical flask and acidify using sulfuric acid.
- Add excess potassium iodide to the conical flask to form a brown solution containing I_2(aq).
- Add 0.100 mol dm^{-3} sodium thiosulfate solution ($Na_2S_2O_3$) to the conical flask from a burette until the brown solution containing I_2(aq) becomes a colourless solution containing I^-(aq).

The student uses 33.50 cm^3 of sodium thiosulfate solution.

The density of the original bleach solution is 1.20 g cm^{-3}

The equations for the reactions in this experiment are

$$ClO^-(aq) + 2\ H^+(aq) + 2\ I^-(aq) \rightarrow Cl^-(aq) + H_2O(l) + I_2(aq)$$

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

(a) Use all the information given to calculate the percentage by mass of NaClO in the original bleach solution.

Give your answer to 3 significant figures.

Percentage by mass _______________

(7)

(b) The total uncertainty from two readings and an end point error in using a burette is ± 0.15 cm^3

What is the total percentage uncertainty in using the burette in this experiment?

Tick (✓) **one** box.

0.45%	☐
0.90%	☐
1.34%	☐

(1)

(Total 8 marks)

Q12.

The equation below represents the complete combustion of butane.

$$C_4H_{10}(g) + 6\frac{1}{2}O_2(g) \rightarrow 4CO_2(g) + 5H_2O(g)$$

20 cm^3 of butane are completely burned in 0.20 dm^3 of oxygen.
Which statement is correct?

All volumes are measured at the same temperature and pressure.

A 40 cm^3 of carbon dioxide are formed ⬭

B 0.065 dm^3 of oxygen react ⬭

C 70 cm^3 of oxygen remain ⬭

D 0.50 dm^3 of steam are formed ⬭

(Total 1 mark)

Q13.

The heat released when 1.00 g of ethanol (M_r = 46.0) undergoes complete combustion is 29.8 kJ

What is the heat released by each molecule, in joules, when ethanol undergoes complete combustion?

(the Avogadro constant $L = 6.022 \times 10^{23}$ mol^{-1})

A 2.28×10^{-18} J ⬭

B 4.95×10^{-20} J ⬭

C 2.28×10^{-21} J ⬭

D 4.95×10^{-23} J ⬭

(Total 1 mark)

Q14.

This question is about sodium fluoride (NaF).

Some toothpastes contain sodium fluoride.
The concentration of sodium fluoride can be expressed in parts per million (ppm).
1 ppm represents a concentration of 1 mg in every 1 kg of toothpaste.

(a) A 1.00 g sample of toothpaste was found to contain 2.88×10^{-5} mol of sodium fluoride.

Calculate the concentration of sodium fluoride, in ppm, for the sample of toothpaste.
Give your answer to 3 significant figures.

Concentration of sodium fluoride ________________________________ ppm

(4)

(b) Sodium fluoride is toxic in high concentrations.
Major health problems can occur if concentrations of sodium fluoride are greater than 3.19×10^{-2} g per kilogram of body mass.

Deduce the maximum mass of sodium fluoride, in mg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of sodium fluoride ________________________________ mg

(1)

(c) The concentration of sodium fluoride in a prescription toothpaste is 2800 ppm.

Use your answer to Question (b) to deduce the mass of toothpaste, in kg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of toothpaste ________________________________ kg

(1)

(d) Identify the diagram in the figure below that shows the correct relative sizes of the ions in sodium fluoride.
Justify your answer.

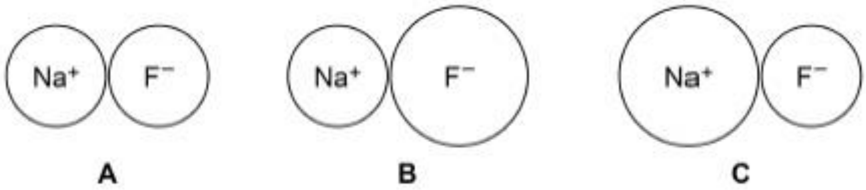

Diagram ___________

Justification

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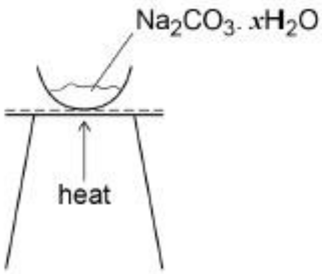
(3)
(Total 9 marks)

Q15.

A student heated a solid sample of $Na_2CO_3 . xH_2O$ for 1 minute to remove water and determine a value for x
The diagram shows the apparatus used. The table shows the results recorded.



Mass of empty evaporating basin	24.35 g
Mass of evaporating basin and solid before heating	25.47 g
Mass of evaporating basin and solid after heating for 1 minute	24.92 g

(a) Use the data in the table to calculate a value for x in the formula $Na_2CO_3 . xH_2O$ Give your answer to 2 decimal places.

Value for x ____________________

(5)

(b) The correct value for x is 10.

Suggest a reason for the difference between the experimental value for x and the correct value.

(If you were unable to calculate an experimental value for x assume it was 8.05.
This is **not** the correct experimental value.)

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(1)

(c) Suggest how the procedure could be improved, using the same apparatus, to give a more accurate value for x
Justify your answer.

Suggestion

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Justification

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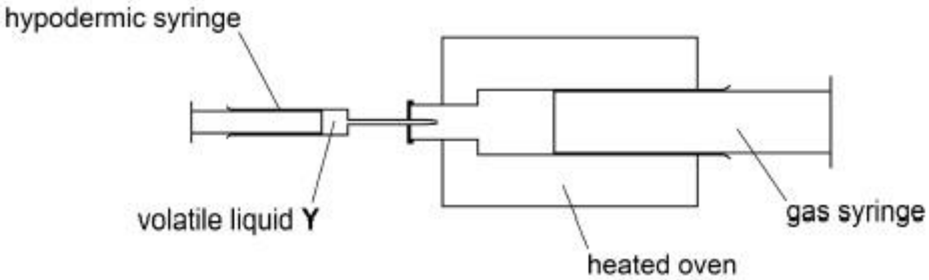
(2)
(Total 8 marks)

Q16.

A student determined the relative molecular mass, M_r, of an unknown volatile liquid Y in an experiment as shown in the diagram.
The student used a hypodermic syringe to inject a sample of liquid Y into a gas syringe in an oven.
At the temperature of the oven, liquid Y vaporised.

The student's results are shown in the table.



Mass of hypodermic syringe and liquid Y before injection	10.91 g
Mass of hypodermic syringe and liquid Y after injection	10.70 g
Oven temperature	98.1 °C
Atmospheric pressure	102 kPa
Increase in volume in gas syringe after injection of Y	85.0 cm^3

(a) Define the term relative molecular mass (M_r).

Use the experimental results in the table to determine the relative molecular mass of Y.
The gas constant R = 8.31 J K^{-1} mol^{-1}

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(5)

(b) Some of the liquid injected did not evaporate because it dripped into the gas syringe nozzle outside the oven.

Explain how this would affect the value of the M_r of Y calculated from the experimental results.

(2)
(Total 7 marks)

Q17.

How many protons are there in 6.0 g of nitrogen gas?

Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

A 1.3×10^{23}

B 9.0×10^{23}

C 1.8×10^{24}

D 3.6×10^{24}

(Total 1 mark)

Q18.

A 30 cm^3 sample of nitrogen was reacted with a 60 cm^3 sample of fluorine according to the equation

$$\frac{1}{2}N_2(g) + \frac{3}{2}F_2(g) \rightarrow NF_3(g)$$

What is the volume of the gas mixture after the reaction, at constant temperature and pressure?

A 20 cm^3 ○

B 30 cm^3 ○

C 40 cm^3 ○

D 50 cm^3 ○

(Total 1 mark)

Q19.

Citric acid, $C_3H_5O(COOH)_3$, occurs naturally in many fruits and can also be synthesised in the laboratory for use as a food flavouring. A student analysed a sample of citric acid to determine its percentage purity.

The student dissolved 784 mg of impure citric acid in water to prepare 250 cm^3 of solution in a volumetric flask.

The student titrated 25.0 cm^3 samples of this solution with 0.0500 mol dm^{-3} sodium hydroxide solution using phenolphthalein as the indicator.

$$C_3H_5O(COOH)_3(aq) + 3NaOH(aq) \rightarrow C_3H_5O(COO)_3Na_3(aq) + 3H_2O(l)$$

(a) The student rinsed the burette before filling it with the sodium hydroxide solution.

State why the student should use sodium hydroxide solution rather than water for the final rinse of the burette.

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(1)

(b) The student carried out several titrations. The results are shown in the table.

Complete the table to show the titre in each titration.

Titration	**Rough**	**1**	**2**	**3**
Final reading / cm^3	25.2	23.95	47.65	24.10
Start reading / cm^3	0.0	0.05	23.95	0.10
Titre / cm^3				

(1)

(c) Calculate the mean titre using the concordant results.

Give your answer to the appropriate number of significant figures.

Mean titre ____________________ cm^3

(2)

(d) The total uncertainty when using the burette is ±0.15 cm^3. This is the combination of uncertainties in the start reading, final reading and the determination of the end point.

Use your answer to part (c) to calculate the percentage uncertainty for the use of the burette in this experiment.

Percentage uncertainty ____________________ %

(1)

(e) Use your answer to part (c) to find the mass, in mg, of citric acid dissolved in 250 cm^3 of the solution.

The relative molecular mass (M_r) of citric acid is 192.0

mass ____________________ mg

(3)

(f) Calculate the percentage purity of this sample of citric acid.

Percentage purity ____________________ %

(1)

(Total 9 marks)

Q20.

A student added 627 mg of hydrated sodium carbonate ($Na_2CO_3.xH_2O$) to 200 cm^3 of 0.250 mol dm^{-3} hydrochloric acid in a beaker and stirred the mixture. After the reaction was complete, the resulting solution was transferred to a volumetric flask, made up to 250 cm^3 with deionised water and mixed thoroughly. Several 25.0 cm^3 portions of the resulting solution were titrated with 0.150 mol dm^{-3} aqueous sodium hydroxide. The mean titre was 26.60 cm^3 of aqueous sodium hydroxide.

Calculate the value of x in $Na_2CO_3.xH_2O$
Show your working.
Give your answer as an integer.

Value of x ____________________

(Total 7 marks)

Q21.

Copper can be produced from rock that contains $CuFeS_2$

(a) Balance the equations for the two stages in this process.

.....$CuFeS_2$ + ...O_2 + ...SiO_2 ⟶ .....Cu_2S + ...Cu_2O + ...SO_2 + ...$FeSiO_3$

.....Cu_2S + ...Cu_2O ⟶ .....Cu + ...SO_2

(2)

(b) Suggest two reasons why the sulfur dioxide by-product of this process is removed from the exhaust gases.

Reason 1

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Reason 2

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(2)

(c) A passenger jet contains 4050 kg of copper wiring.

A rock sample contains 1.25% $CuFeS_2$ by mass.

Calculate the mass, in tonnes, of rock needed to produce enough copper wire for a passenger jet. (1 tonne = 1000 kg)

Mass of rock ____________________ tonnes

(4)

(d) Copper can also be produced by the reaction of carbon with copper(II) oxide according to the equation

$$2CuO + C \longrightarrow 2Cu + CO_2$$

Calculate the percentage atom economy for the production of copper by this process.

Give your answer to the appropriate number of significant figures.

Percentage atom economy ____________________

(2)

(Total 10 marks)

Q22.

Which of these contains the greatest number of atoms?

A 127 mg of iodine ○

B 1.54×10^{-4} kg of phosphorus ○

C 81.0 mg of carbon dioxide ○

D 1.70×10^{-4} kg of ammonia ○

(Total 1 mark)

Q23.

A 20.0 cm^3 sample of a 0.400 mol dm^{-3} aqueous solution of a metal bromide (MBr_n) reacts exactly with 160 cm^3 of 0.100 mol dm^{-3} aqueous silver nitrate.

What is the formula of the metal bromide?

A MBr ○

B MBr_2 ○

C MBr_3 ○

D MBr_4 ○

(Total 1 mark)

Q24.

An experiment was carried out to determine the relative molecular mass (M_r) of a volatile hydrocarbon **X** that is a liquid at room temperature.

A known mass of **X** was vaporised at a known temperature and pressure and the volume of the gas produced was measured in a gas syringe.

Data from this experiment are shown in the table.

Mass of **X**	194 mg
Temperature	373 K
Pressure	102 kPa
Volume	72 cm^3

(a) Calculate the relative molecular mass of **X**.

Show your working.

Give your answer to the appropriate number of significant figures.

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

Relative molecular mass ________________________________

(5)

(b) Analysis of a different hydrocarbon **Y** shows that it contains 83.7% by mass of carbon.

Calculate the empirical formula of **Y**.

Use this empirical formula and the relative molecular mass of **Y** (M_r = 86.0) to calculate the molecular formula of **Y**.

Empirical formula

____

Molecular formula ______________________________

(4)
(Total 9 marks)

Q25.

Ethanedioic acid ($H_2C_2O_4$) is a diprotic acid. Beekeepers use a solution of this acid as a pesticide.

A student carried out a titration with sodium hydroxide solution to determine the mass of the acid in the solution. The student repeated the titration until concordant titres were obtained.

$$H_2C_2O_4(aq) + 2NaOH(aq) \longrightarrow Na_2C_2O_4(aq) + 2H_2O(l)$$

(a) The student found that 25.0 cm^3 of the ethanedioic acid solution reacted completely with 25.30 cm^3 of 0.500 mol dm^{-3} sodium hydroxide solution.

Calculate the mass, in mg, of the acid in 25.0 cm^3 of this solution.

Mass of acid = ______________________ mg

(4)

(b) The student used a wash bottle containing deionised water when approaching the end-point to rinse the inside of the conical flask.

Explain why this improved the accuracy of the titration.

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(1)

(c) Give the meaning of the term concordant titres.

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(1)
(Total 6 marks)

Q26.

This question is about a toxic chloroalkane, **X**, that has a boiling point of 40 °C.

A student carried out an experiment to determine the M_r of **X** by injecting a sample of **X** from a hypodermic syringe into a gas syringe in an oven at 97 °C and 100 kPa. The student's results are set out in **Table 1** and **Table 2**.

Table 1

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

Table 2

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

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

(1)

(b) **X** is known to be one of the following chloroalkanes: CCl_4 $CHCl_3$ CH_2Cl_2 or CH_3Cl

Justify this statement by calculating a value for the M_r of **X** and use your answer to suggest the most likely identity of **X** from this list.

Give your answer for the M_r of **X** to an appropriate precision.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

M_r of **X**

M_r of **X** = ______________________

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

Identity of **X** = ___________________

(5)

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

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(2)

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

Safety precaution

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Reason

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(2)
(Total 10 marks)

Q27.

What is the volume of 0.200 mol dm^{-3} $Ba(OH)_2$ (aq) required to neutralise exactly 30.0 cm^3 of 0.100 mol dm^{-3} HCl(aq)?

A 150.0 cm^3 ○

B 75.0 cm^3 ○

C 15.0 cm^3 ○

D 7.50 cm^3 ○

(Total 1 mark)