Pearson Edexcel

EDEXCEL AS LEVEL

TOPICAL QUESTIONS

FORMULAE, EQUATIONS & AMOUNT OF SUBSTANCE

Complied by :

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1 A sample of nitrogen gas occupied 108 cm^3 at a temperature of 25 °C and a pressure of 1.36 × 10^5 Pa.

Using the ideal gas equation, calculate the number of moles of nitrogen gas in this sample.

[$pV = nRT$ $R = 8.31\ J\,mol^{-1}\,K^{-1}$]

(4)

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2 This question is about compounds containing chlorine.

(a) A precipitate of silver chloride is formed when silver nitrate solution reacts with sodium chloride solution.

A student wrote an ionic equation for the reaction.

$$Ag^{2+}(l) + 2Cl^{-}(l) \rightarrow AgCl_2(s)$$

Explain why this equation is incorrect, even though it is balanced.

(2)

(b) A sample of a compound is analysed and found to contain **only** 3.09 g carbon, 0.26 g hydrogen and 9.15 g chlorine.
The molar mass of the compound is 97.0 g mol^{-1}.

Calculate the molecular formula of this compound.
You **must** show your working.

(3)

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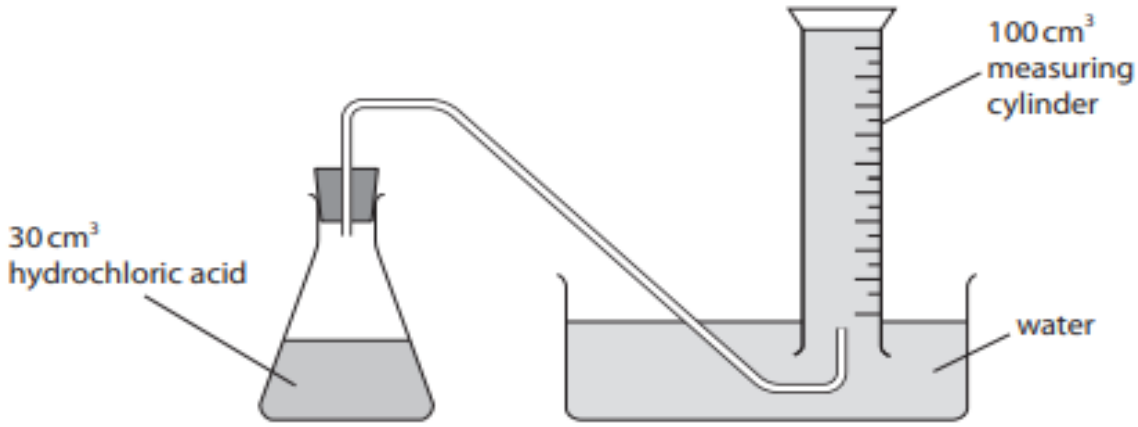
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3 Magnesium carbonate powder reacts with hydrochloric acid.

(a) Complete the equation for this reaction by adding state symbols. (1)

$$MgCO_3(\quad) + 2HCl(\quad) \rightarrow MgCl_2(\quad) + H_2O(\quad) + CO_2(\quad)$$

(b) A student carried out an investigation to determine the molar volume of carbon dioxide using this apparatus.



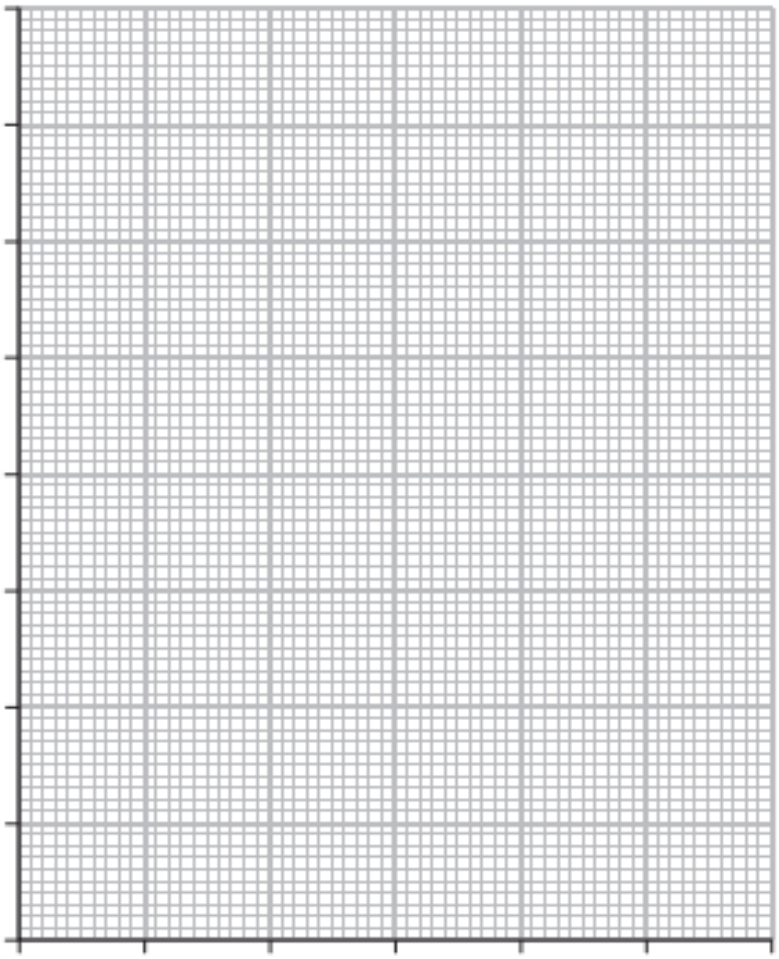
The student carried out five experiments, adding a different mass of magnesium carbonate each time.

The results are shown in the table.

Mass of magnesium carbonate / g	Volume of gas collected / cm^3
0.05	11
0.10	27
0.15	38
0.20	54
0.25	63

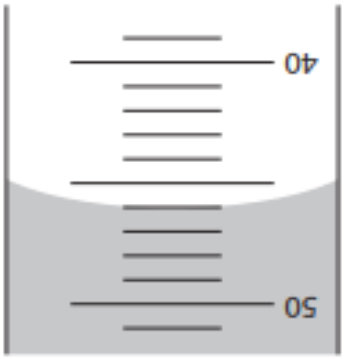
(i) Plot a graph of these results.

(3)



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(ii) A student carried out a further experiment using a different mass of magnesium carbonate.



Give the volume of gas collected using the **inverted** measuring cylinder.

(1)

(iii) Determine the mass of magnesium carbonate added in the experiment in (b)(ii), using your graph.

[1]

(iv) Calculate the molar volume of carbon dioxide using your answers to parts (b)(ii) and (b)(iii). Give your value to an appropriate number of significant figures and include units.

[A_r values: Mg = 24.3 C = 12.0 O = 16.0]

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(v) The acid must be in excess for each experiment.

Calculate the **minimum** concentration of hydrochloric acid needed for 30 cm^3 of acid to completely react with 0.25 g of magnesium carbonate.

$$MgCO_3 + 2HCl + MgCl_2 + H_2O + CO_2$$

(2)

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(c) The value of molar volume calculated in (b)(iv) was lower than the student expected.

Give **two** reasons for the value being lower than expected.

Assume that the correct amounts of hydrochloric acid and magnesium carbonate were used.

(2)

4 Calculate, using the ideal gas equation, the volume in **cm^3** occupied by 0.0200 mol of ClF_3 gas at a temperature of 60 °C and a pressure of 1.28×10^5 Pa. Give your answer to an appropriate number of significant figures.

[$pV = nRT$ $R = 8.31\,J\,mol^{-1}\,K^{-1}$]

(4)

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5 This question is about the compound ammonium dichromate(VI), $(NH_4)_2Cr_2O_7$.

(a) $(NH_4)_2Cr_2O_7$ breaks down at around 180 °C, producing an oxide of chromium, nitrogen and water as the only products.

(i) Write an equation for the reaction.
State symbols are not required.

(2)

(ii) Give a name for this type of reaction.

(1)

(b) When 0.00100 mol of ammonium dichromate(VI) was heated, 25.2 cm^3 of nitrogen gas, measured at laboratory temperature, was formed.

Calculate the temperature in the laboratory, in degrees Celsius, using the ideal gas equation. Use atmospheric pressure = 101 kPa.

$[pV = nRT \quad R = 8.31\ J\,mol^{-1}\,K^{-1}]$

(4)

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6 The element iron forms two chlorides: iron(II) chloride, $FeCl_2$, and iron(III) chloride, $FeCl_3$.

(a) A known mass of iron powder is added to 200 cm^3 of a hot solution of iron(III) chloride with a concentration of 0.500 mol dm^{-3}. When the reaction is complete, the solution only contains iron(II) chloride.
The unreacted iron is filtered, dried and weighed.

Initial mass of iron powder = 6.17 g
Final mass of iron powder = 3.38 g

(i) Calculate the number of moles of iron that react.

(2)

(ii) Calculate the number of moles of iron(III) chloride that react.

(2)

(iii) Use your answers to (a)(i) and (a)(ii) to write the **ionic** equation for the reaction of iron with iron(III) chloride. Include state symbols.
You **must** show your working.

(3)

(b) The concentration of the solution obtained in (a) is increased by heating it gently to remove some of the water. The solution is allowed to cool and pale green crystals of a hydrated iron(II) chloride, $FeCl_2 \cdot xH_2O$, form.
Analysis shows that these crystals contain 28.1% by mass of iron.

Calculate the number of moles of water of crystallisation, x, per mole of hydrated iron(II) chloride.

(4)

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7 Organic waste may be disposed of by landfill or incineration.
Both processes produce gases.

(a) The main gases produced from a typical landfill are shown in the table.

Gas	Percentage by volume / %
methane	50
carbon dioxide	45
nitrogen	4
sulfur compounds	1

(i) One tonne of landfill waste produces approximately 12.5 dm^3 of landfill gases per day.

Calculate the mass of carbon dioxide produced in a year by a typical landfill site which contains 90 000 tonnes of waste.
Assume that the gas volume is measured at room temperature and pressure (r.t.p.). [Molar volume of gas at r.t.p. = 24.0 $dm^3\ mol^{-1}$]

(3)

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8 (a) Germane is a compound with the formula GeH_4.

It can be formed by the reaction shown.

$$Na_2GeO_3 + NaBH_4 + H_2O \rightarrow GeH_4 + 2NaOH + NaBO_2$$

Germane is toxic and the maximum permitted concentration is $0.640\ mg\ m^{-3}$ in air.

Calculate the maximum number of germane molecules permitted in a laboratory with a volume of $231\ m^3$.

[Avogadro constant (L) = $6.02 \times 10^{23}\ mol^{-1}$]

[Ar of Ge = 72.6]

(4)

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(b) A halide of germanium, GeX_4, reacts with water as shown.

$$GeX_4 + 2H_2O \rightarrow GeO_2 + 4HX$$

1.50 g of GeX_4 was added to excess water.
The insoluble GeO_2 was removed by filtration.
The solution of hydrogen halide formed was then added to excess magnesium carbonate, forming 335.5 cm^3 of carbon dioxide at room temperature and pressure (r.t.p.).

$$MgCO_3 + 2HX \rightarrow MgX_2 + CO_2 + H_2O$$

[Molar volume of a gas at r.t.p. = 24 000 $cm^3 mol^{-1}$]

(i) Calculate the number of moles of carbon dioxide formed.

(1)

(ii) Deduce the number of moles of HX formed when GeX_4 reacted with the excess water.

(1)

(iii) Deduce the number of moles of GeX_4 that reacted with the excess water.

(1)

(iv) Calculate the molar mass of GeX_4 and hence identify X.

(2)

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9 (a) Barium chloride, $BaCl_2$, can be prepared by the reaction of barium carbonate with hydrochloric acid.

$$BaCO_3(s) + 2HCl(aq) \rightarrow BaCl_2(aq) + CO_2(g) + H_2O(l)$$

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

(1)

(ii) Calculate the atom economy by mass for this preparation of barium chloride.

[A_r values: H = 1.0 C = 12.0 O = 16.0 Cl = 35.5 Ba = 137.3]

(2)

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(b) Barium chloride reacts with Group 1 sulfates, M_2SO_4.

$$M_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2MCl(aq)$$

A solution is made by dissolving 7.98 g of a Group 1 sulfate in deionised water.

Excess aqueous barium chloride is added to this solution and the precipitate is filtered, dried and weighed.

The mass of the barium sulfate precipitate is 10.72 g.

Identify the Group 1 element.

[A_r values: Ba = 137.3 S = 32.1 O = 16.0]

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(4)

10 Butane, C_4H_{10}, is found in the refinery gases fraction of crude oil.
It is used as a propellant in pharmaceutical inhalers.
An inhaler that provides a total of 120 doses contains 1.55 g of butane.

Calculate the volume, in cm^3, of propellant used for each dose at 25 °C and 100 kPa.

Use the ideal gas equation and give your answer to an appropriate number of significant figures.

[$pV = nRT$ $R = 8.31\ J\,K^{-1}\,mol^{-1}$]

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11 Bisabolenes are a group of compounds found in plants and fungi.
Bisabolene molecules contain several carbon–carbon double bonds.

5.51 g of α-bisabolene reacted with 1873 cm^3 of hydrogen gas, H_2.
The reaction occurred at a temperature of 150 °C and a pressure of 152 000 Pa.

[*M*, value: α-bisabolene = 204.0]

(i) Calculate the amount, in mol, of α-bisabolene in 5.51 g.

(2)

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(ii) Calculate the amount, in mol, of hydrogen gas that reacted with α-bisabolene.
Use the ideal gas equation, $pV = nRT$.

[$R = 8.31\ J\,mol^{-1}\,K^{-1}$]

(3)

12 Another basic carbonate found in minerals contains the metal element **X** and is formed by the reaction shown.

$$2\mathbf{X}SO_4 + 2Na_2CO_3 + H_2O \rightarrow \mathbf{X}_2CO_3(OH)_2 + 2Na_2SO_4 + CO_2$$

1.995 g of $\mathbf{X}SO_4$ is reacted with excess Na_2CO_3 forming 150.0 cm^3 of carbon dioxide gas, CO_2, at room temperature and pressure, r.t.p.

[Molar volume of a gas at r.t.p. = 24.0 $dm^3\,mol^{-1}$]

(i) Calculate the relative formula mass of $\mathbf{X}SO_4$, using these data.

(ii) Deduce the identity of **X**, using your answer to (c)(i).

(1)

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13 Aluminium chloride is a solid at room temperature.
At the relatively low temperature of 453 K it sublimes.

(i) A sample of 5.00 g of aluminium chloride was heated to 455 K at a pressure of 1.01×10^5 Pa.
When all the aluminium chloride had vaporised, the final volume of gas was 700 cm^3.

Show that the data is consistent with the formula of aluminium chloride in the gas phase being Al_2Cl_6.

[Gas constant $R = 8.31\ J\ mol^{-1}\ K^{-1}$ Ideal gas equation $pV = nRT$]

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1 How many **atoms** are there in 10 g of methane?

[A_r values: H = 1.0 C = 12.0 $L = 6.02 \times 10^{23}\,mol^{-1}$]

- ☐ **A** 3.76×10^{23}
- ☐ **B** 9.63×10^{23}
- ☐ **C** 1.88×10^{24}
- ☐ **D** 4.82×10^{24}

2 What is the maximum volume of butane that can be completely burned in 39 cm^3 of oxygen at room temperature and pressure?

$$C_4H_{10}(g) + 6.5O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

- ☐ **A** 6.0 cm^3
- ☐ **B** 12 cm^3
- ☐ **C** 24 cm^3
- ☐ **D** 45 cm^3

This question is about the production of ethanol by fermentation of glucose or by hydration of ethene.

3 What is the percentage atom economy by mass for the production by fermentation?

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$$

(1)

- ☒ **A** 24.4%
- ☒ **B** 25.6%
- ☒ **C** 48.9%
- ☒ **D** 51.1%

4 What is the percentage atom economy by mass for the production by hydration?

$$C_2H_4 + H_2O \rightarrow CH_3CH_2OH$$

(1)

- ☒ **A** 39.1%
- ☒ **B** 60.9%
- ☒ **C** 78.2%
- ☒ **D** 100%

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5 Which is the simplest ionic equation for an alkali reacting with an acid?

- ☐ **A** $2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$
- ☐ **B** $H^+(aq) + OH^-(aq) \rightarrow H_2O(aq)$
- ☐ **C** $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
- ☐ **D** $2H^+(aq) + O^{2-}(aq) \rightarrow H_2O(l)$

6 How many oxygen **atoms** are there in 0.0100 mol of H_2SO_4?

[Avogadro constant, $L = 6.020 \times 10^{23}\ mol^{-1}$]

- ☐ **A** 6.020×10^{21}
- ☐ **B** 1.204×10^{22}
- ☐ **C** 2.408×10^{22}
- ☐ **D** 4.214×10^{22}

7 Two identical sealed flasks, containing different gases, are side by side. Each flask contains one gas, with the gases at the same temperature and pressure.

Flask **A** contains 4.0×10^{-3} mol of methane.

Flask **B** contains 160 mg of a different gas.

Which could be the gas in Flask **B**?

- ☐ **A** argon
- ☐ **B** carbon dioxide
- ☐ **C** helium
- ☐ **D** neon

8 Diphosphane, P_2H_4, reacts spontaneously with oxygen.

$$xP_2H_4 + yO_2 \rightarrow P_4O_{10} + zH_2O$$

The equation for this reaction is balanced when

- ☐ **A** x = 1 y = 6 z = 2
- ☐ **B** x = 2 y = 6 z = 2
- ☐ **C** x = 2 y = 7 z = 4
- ☐ **D** x = 4 y = 9 z = 8

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9 Copper metal can displace silver from silver nitrate solution according to the equation shown.

$$Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$$

10 g of copper metal was added to an excess of silver nitrate solution.

The silver metal was collected, washed with deionised water and left to dry.

What is the mass of silver metal collected, assuming a 100 % yield?

- ☐ **A** between 10 g and 20 g
- ☐ **B** 20 g
- ☐ **C** between 20 g and 40 g
- ☐ **D** more than 40 g

10 This question is about the thermal decomposition of calcium nitrate.

$$2Ca(NO_3)_2 \rightarrow 2CaO + 4NO_2 + O_2$$

What volume of gas is produced by the complete decomposition of 0.050 mol of calcium nitrate at room temperature and pressure (r.t.p.)?

[Molar volume of a gas at r.t.p. = 24 $dm^3 mol^{-1}$]

- ☐ **A** 600 cm^3
- ☐ **B** 1.20 dm^3
- ☐ **C** 3.00 dm^3
- ☐ **D** 6.00 dm^3

11 Ethanol is formed from glucose during fermentation.

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

What is the atom economy by mass for the formation of ethanol in this reaction?

- ☐ **A** 26 %
- ☐ **B** 49 %
- ☐ **C** 51 %
- ☐ **D** 96 %

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1 kg of seawater contains 64 mg of bromide ions.

[A_r of Br = 80 Avogadro constant, $L = 6.0 \times 10^{23}$ mol^{-1}]

12 What is the concentration of bromide ions in parts per million (ppm) by mass?

- ☐ **A** 0.80
- ☐ **B** 64
- ☐ **C** 800
- ☐ **D** 64 000

(1)

13 How many bromide ions are in 500 g of the sample?

- ☐ **A** 2.4×10^{20}
- ☐ **B** 4.8×10^{20}
- ☐ **C** 1.9×10^{22}
- ☐ **D** 3.8×10^{22}

(1)

14 0.15 mol of aluminium is added to 120 cm^3 of 1.50 mol dm^{-3} hydrochloric acid.

$$2Al(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2(g)$$

The amount of **unused** reactant is

- ☐ **A** 0.06 mol aluminium
- ☐ **B** 0.09 mol aluminium
- ☐ **C** 0.03 mol hydrochloric acid
- ☐ **D** 0.13 mol hydrochloric acid

(1)

15 An organic compound contains 24.2% carbon, 4.00% hydrogen and 71.8% chlorine by mass.

[A_r values: H = 1.0 C = 12.0 Cl = 35.5]

What is the empirical formula of the compound?

- ☐ **A** CHCl
- ☐ **B** CH_2Cl
- ☐ **C** $C_2H_4Cl_2$
- ☐ **D** $C_4H_4Cl_4$

(1)

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16 Excess calcium carbide and 10 g of water react to form the hydrocarbon ethyne, C_2H_2.

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$$

What is the mass of ethyne that forms, assuming a yield of 100 %?

[M_r values: $H_2O = 18.0$ $C_2H_2 = 26.0$]

(1)

- ☐ **A** 7.22 g
- ☐ **B** 14.4 g
- ☐ **C** 23.4 g
- ☐ **D** 28.9 g

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Concentrations in mixtures can be given in units of parts per million (ppm).

17 A sample of a gaseous mixture contains 2.19 % carbon dioxide by mass.

What is the concentration of carbon dioxide in parts per million (ppm) by mass in this sample?

(1)

- ☐ **A** 2.19×10^6
- ☐ **B** 2.19×10^4
- ☐ **C** 2.19×10^{-4}
- ☐ **D** 2.19×10^{-6}

18 A solution of lead nitrate has a concentration of 15 ppm by mass.

What is the mass of lead nitrate in 400 g of this solution?

(1)

- ☐ **A** 6.00×10^{-3} g
- ☐ **B** 6.00×10^{-6} g
- ☐ **C** 6.00×10^{-3} kg
- ☐ **D** 6.00×10^{0} kg

19 Which solution contains chloride ions with a concentration of 0.0500 mol dm^{-3}?

[A_r values: Ca = 40.1 Cl = 35.5 Na = 23.0]

	Solute	Mass of solute / g	Volume of solution / cm^3
☐ **A**	calcium chloride	1.39	250
☐ **B**	calcium chloride	1.39	500
☐ **C**	sodium chloride	1.46	250
☐ **D**	sodium chloride	1.46	1000

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20 A sample of nitrogen gas contains 1.204×10^{22} molecules.

What is the mass of this sample?

[A_r N = 14.0 Avogadro constant (L) = 6.02×10^{23} mol^{-1}]

☐ **A** 0.14 g

☐ **B** 0.28 g

☐ **C** 0.56 g

☐ **D** 1.12 g

21 When magnesium oxide reacts with dilute sulfuric acid the equation is

$$MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$$

What is the ionic equation for the reaction?

☐ **A** $MgO(s) + 2H^+(aq) + SO_4^{2-}(aq) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq) + H_2O(l)$

☐ **B** $MgO(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(l)$

☐ **C** $Mg^{2+}(s) + SO_4^{2-}(aq) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq)$

☐ **D** $O^{2-}(s) + 2H^+(aq) \rightarrow H_2O(l)$

22 A mass of 4.08 g of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, was dissolved in deionised water to form 250 cm^3 of solution.

What is the concentration of the copper(II) sulfate solution formed, in mol dm^{-3}?

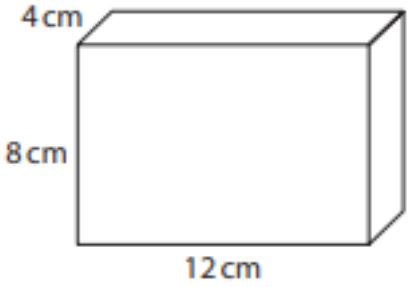
☐ **A** 0.0163

☐ **B** 0.0256

☐ **C** 0.0654

☐ **D** 0.102

23 A piece of copper is shown.



How many moles of copper atoms are there in this piece of copper?

[Density of copper = 8.96 g cm^{-3}]

- ☐ **A** 0.675
- ☐ **B** 1.48
- ☐ **C** 6.05
- ☐ **D** 54.2

24 A mass of 2.50 g of sodium chloride reacts with excess lead(II) nitrate solution forming lead(II) chloride with a yield of 95 %.

What is the mass of lead(II) chloride, $PbCl_2$, formed?

$$2NaCl + Pb(NO_3)_2 \rightarrow PbCl_2 + 2NaNO_3$$

[M_r values: NaCl = 58.5 $PbCl_2$ = 278.2]

- ☐ **A** 5.65 g
- ☐ **B** 5.94 g
- ☐ **C** 11.3 g
- ☐ **D** 11.9 g

25 Which of these gases occupies 6.0 dm^3 at room temperature and pressure (r.t.p.)?

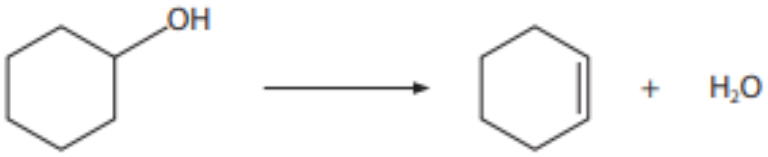
[molar volume of gas at r.t.p. = 24.0 dm^3 mol^{-1}

A_r values: He = 4.0 C = 12.0 N = 14.0 O = 16.0]

- ☐ **A** 2.0 g of helium
- ☐ **B** 4.0 g of oxygen
- ☐ **C** 11.0 g of carbon dioxide
- ☐ **D** 14.0 g of nitrogen

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26 Cyclohexene may be prepared by the dehydration of cyclohexanol.



cyclohexanol
$M_r = 100$

cyclohexene
$M_r = 82$

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What mass of cyclohexene can be made from 12.5 g of cyclohexanol if the yield is 51.2 %?

- ☐ **A** 5.25 g
- ☐ **B** 6.40 g
- ☐ **C** 7.80 g
- ☐ **D** 10.25 g

27 An oxide of lead contains 90.7 % by mass of lead.

What is the formula of this oxide?

[A_r values: O = 16.0 Pb = 207.2]

- ☐ **A** PbO
- ☐ **B** PbO_2
- ☐ **C** Pb_2O_3
- ☐ **D** Pb_3O_4

28 Propane burns completely in oxygen as shown.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

100 cm^3 of propane was mixed with 600 cm^3 of oxygen and the mixture was ignited.

What is the **total** volume, in cm^3, of the gas mixture at the end of the reaction?
All gas volumes were measured at room temperature and pressure.

- ☐ **A** 300
- ☐ **B** 400
- ☐ **C** 700
- ☐ **D** 800

1

Question number	Answer	Additional guidance	Mark
	• conversion of volume to m^3 **(1)** • conversion of temperature to K **(1)** • rearrangement of ideal gas equation **(1)** • evaluation to give n **(1)**	Example of calculation: volume of $N_2 = \frac{108}{1 \times 10^6} = 1.08 \times 10^{-4}$ m^3 temperature = 25 + 273 = 298 K $n = \frac{pV}{RT}$ **or** $n = \frac{1.36 \times 10^5 \times 1.08 \times 10^{-4}}{8.31 \times 298}$ TE on volume and temperature $n = 5.9312 \times 10^{-3}$ / 0.0059312 (mol) Conditional on correctly rearranged equation in M3 Ignore SF except 1SF Correct answer with no working scores full marks	(4)

2

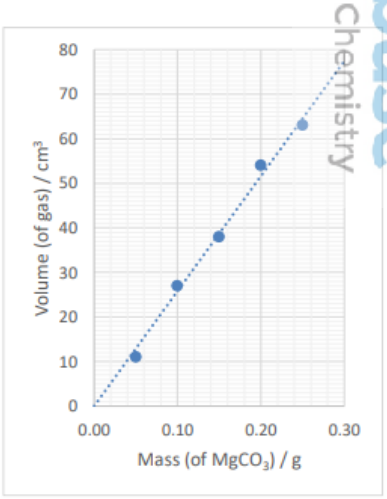
Question number	Answer	Additional guidance	Mark
(a)	An explanation that makes reference to the following points: • (l) is incorrect because the solutions are aqueous **or** the ions are (in the) aqueous (state) **or** the state symbols should be (aq) instead of (l) **(1)** • silver ions should have one positive charge / Ag^+ **or** silver chloride is AgCl **(1)**	Allow silver nitrate and sodium chloride are aqueous Do not award if incorrect state symbol for one of the species in the equation e.g. Ag is (s) / AgCl is (aq) Ignore just the charge on the silver ion is incorrect / the formula of silver chloride is incorrect	(2)

Question number	Answer	Additional guidance	Mark
(b)	• calculation of mol of C, H and Cl **(1)** • calculation of empirical formula **(1)** • calculation of molecular formula **(1)**	Example of calculation: C : H : Cl mol $\frac{3.09}{12} : \frac{0.26}{1} : \frac{9.15}{35.5}$ = 0.2575 : 0.26 : 0.2577 (ratio 1 : 1 : 1) Empirical formula is CHCl molar mass CHCl = 12 + 1 + 35.5 = 48.5 $\frac{\text{molar mass } (CHCl)_n}{\text{molar mass CHCl}} = \frac{97}{48.5} = 2$ Molecular formula is $C_2H_2Cl_2$ Allow symbols in any order Do not award 2CHCl Ignore SF in mol and ratio Correct molecular formula with some working scores (3)	(3)

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Question Number	Answer	Additional guidance	Mark
(a)	• all correct state symbols	$MgCO_3$(**s**) + 2HCl(**aq**) → $MgCl_2$(**aq**) + H_2O(**l**) + CO_2(**g**) Allow capital letters Ignore extra brackets	(1)

Question Number	Answer	Additional guidance	Mark
(b)(i)	• suitable choice of scale so that the points cover at least 50% of the grid in both directions and correct choice of axes i.e. mass on x axis, suitably labelled including units **(1)** • all points plotted correctly (within ½ square) **(1)** • **straight** line of best fit (passes through the origin) **(1)**	Example of graph:  Allow no origin Allow units in brackets e.g. (g) instead of / g Any extrapolated line should pass within 2 squares of origin. Straight best fit lines that are not extrapolated are not penalised. If axes are the wrong way round, only MP1 is penalised.	(3)

Question Number	Answer	Additional guidance	Mark
(b)(ii)	• 46 (cm^3)	Allow 46.0(cm^3) Ignore units even if incorrect	(1)

Question Number	Answer	Additional guidance	Mark
(b)(iii)	• 0.18 (g)	Accept answers from 0.17 (g) to 0.19 (g) Ignore SF TE on (b)(ii) and the graph, eg 54 (cm^3) gives 0.215 (g) Ignore units even if incorrect	(1)

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Question Number	Answer	Additional guidance	Mark
(b)(iv)	• calculation of molar mass of magnesium carbonate **(1)** • calculation of moles of magnesium carbonate **(1)** • calculation of molar volume **(1)** • answer given to **2 or 3 SF and** units **(1)** M4 dependent on award of M3	Example of calculation: 84.3 OR expression used correctly: [24.3 + 12 + (3×16)] n= 0.18 ÷ 84.3 = 0.0021352 / 2.1352 x 10^{-3} (mol) 46 ÷ 0.0021352 = 21 543 / 2.1543 x 10^{4} (cm^3) = 22 dm^3 (mol^{-1}) / 22 000 cm^3 (mol^{-1}) Or 21.5 dm^3 (mol^{-1}) / 21 500 cm^3 (mol^{-1}) TE on any reasonable pair of values obtained from the candidates' graph or table provided eg 54cm^3 and 0.215(g) →2.5504 ×10^{-3} (mol) →21 200 cm^3 Correct answer scores 4 marks Final answer must not be given as a fraction to get MP4 Ignore units except for MP4	(4)

Question Number	Answer	Additional guidance	Mark
(b)(v)	• moles of magnesium carbonate and moles of acid in 30 cm^3 **(1)** • calculation of minimum concentration with units **(1)**	Example of calculation: n = 0.25 / 84.3 n = 0.0029655 or 0.00297 **and** 1:2 stoichiometry ∴0.00593 (moles acid) Accept 0.00594 from 0.00297 (0.00593 / 30) × 1000 = 0.198 mol dm^{-3} Accept answers from 0.198 to 0.200 mol dm^{-3} Allow TE throughout e.g. M_r from 21(b)(iv) Ignore SF Correct answer with no working scores 2	(2)

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Question Number	Answer	Additional guidance	Mark
(c)	An answer that makes reference to any two of the following points: • loss of gas before the bung is inserted / other named reason **(1)** • some carbon dioxide dissolved in the water **(1)** • temperature of the lab was <u>lower</u> than standard temperature. **(1)**	Do not allow "loss of gas" unless a reason is given eg delivery tube not positioned correctly so not all goes into measuring cylinder, badly fitting bung Ignore leaks Allow gas for carbon dioxide Ignore higher pressure Do not award higher temperature / lower pressure / suck-back Ignore impurities in $MgCO_3$ Ignore incomplete reaction **Comment:** Apply the list principle ie • 1 correct answer and 1 do not award answer scores 1 • 2 correct answers and 1 do not award answer scores 1 • 2 correct answers and 2 do not award answers scores 0 • 2 correct answers and 1 ignore scores 2	(2)

4

Question number	Answer	Additional guidance	Mark
	• conversion of temperature to K (1) • rearrangement of Ideal Gas Equation (1) • evaluation to give volume (1) • conversion of volume to cm^3 **and** answer given to 2 or 3 SF (1)	Example of calculation: temperature = 60 + 273 = 333 K $V = \frac{nRT}{P}$ or $V = \frac{0.0200 \times 8.31 \times 333}{1.28 \times 10^5}$ $V = 4.3238 \times 10^{-4}$ (m^3) TE on temperature volume = $4.3238 \times 10^{-4} \times 1 \times 10^6$ = (432.38) = 432 / 430 / 4.32×10^2 / 4.3×10^2 (cm^3) TE on volume in M3 Penalise rounding to 1SF once only in M1, M2 and M3 Correct answer with no working scores full marks	**(4)**

5

Question Number	Answer	Additional guidance	Mark
(a)(i)	• $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4H_2O + Cr_2O_3$	1 mark for Cr_2O_3 1 mark for all the rest being correct Allow multiples Marks are standalone	**(2)**

Question Number	Answer	Additional guidance	Mark
(a)(ii)	• (thermal) decomposition **or** redox	Ignore oxidation or reduction on their own	**(1)**

Question Number	Answer		Additional guidance	Mark
(b)	• conversion of units for *P* and *V*	(1)	Example of calculation: $P = 101000 / 1.01 \times 10^5$ Pa $V = 0.0000252 / 2.52 \times 10^{-5}$ m^3 Allow incorrect use standard form e.g. 10.1×10^4 Pa	(4)
	• substitution in equation and rearrange	(1)	$T = \frac{101000 \times 0.0000252}{0.001 \times 8.31}$	
	• answer in **K**	(1)	T = 306.28 (K)	
	• convert to °C	(1)	T = 33.3(°C) (33.1°C if 273.15 is used for conversion of kelvin to Celsius)	
			Ignore SF except 1 SF on final answer	
			TE throughout but only award for MP4 if final answer in °C is between 0 and 50°C	
			Units if given must be correct	
			Comment: *Correct answer with no working scores 4* *306.28(K) scores 3* *30.85℃ scores 3* *33.7℃ scores 3 as they have used R as 8.3* *33.55℃ scores 3 using 8.3 and 273.15* *306.7K scores 2 as they have used R as 8.3*	

6

Question number	Answer		Additional guidance	Mark
(a)(i)	• calculation of mass of iron and use of A_r(Fe)	(1)	Example of calculation: mol $= \frac{6.17 - 3.38}{55.8} = \frac{2.79}{55.8}$	**2**
	• evaluation of moles of iron	(1)	mol iron = 5×10^{-2} / 0.05 (mol) Allow A_r of Fe = 56 when mol Fe =0.0498 Ignore SF Correct answer with some working scores 2 Use of incorrect mass for 1 mark TE e.g. 6.17g gives 0.11(057) 3.38g gives 0.06(0057) Dividing 2.79g by an incorrect A_r gets 1 mark	

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Question number	Answer	Additional guidance	Mark
(a)(ii)	• expression for concentration and substitute values (1) • evaluation of moles of iron(III) chloride (1)	Example of calculation: $\text{concentration} = \frac{\text{mol}}{\text{vol in dm}^3}$ $0.500 = \frac{\text{mol}}{200/1000}$ mol = 0.500 × 200/1000 = 0.1 (mol) Correct answer with some working scores 2 Ignore SF	2

Question number	Answer	Additional guidance	Mark
(a)(iii)	• calculation of whole number ratio (1) • ionic equation (1) • all three states correct (1)	Example of calculation: 0.1 mol Fe^{3+} (or $FeCl_3$) reacts with 0.05 mol Fe so 2 mol Fe^{3+} (or $FeCl_3$) reacts with 1 mol Fe (0.1 ÷ 0.05 or 1 : 0.5 is enough for M1, not 2:1 alone) TE on incorrect i & ii e.g. 1:1 $Fe(s) + 2Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq)$ Allow multiples Allow correct states on species in the reaction Allow correct states on compounds, Cl^- must be (aq) M2 and M3 standalone marks Comment: If no working shown max 2 marks	3

Question number	Answer	Additional guidance	Mark
(b)	• calculation of relative formula mass of $FeCl_2.xH_2O$ (1) • calculation of relative formula mass of $FeCl_2$ (1) • calculation of moles of H_2O in crystals (1) • calculation of moles of H_2O per mole of $FeCl_2$ (1)	Example of calculation: RFM(1) = $\frac{55.8}{28.1} \times 100 = 198.58$ RFM(2) = 55.8 + 2 × 35.5 = 126.8 RFM(1) − RFM(2) = 71.777 71.777 / 18 = 3.988 = 4 so x = 4 M4 is only awarded for final answer of 4 Allow A_r of Fe = 56 Correct answer with some appropriate working scores 4 Ignore SF <u>Alternative:</u> M1 mol Fe (in 100g hydrated salt) = 28.1/55.8 = 0.50358 M2 mass of Cl (in 100g hydrated salt) = 0.50384 × 2 × 35.5 = 35.75(448)g M3 mass of H_2O (in 100g hydrated salt) = 100 – 28.1 – 35.75 = 36.15g moles H_2O = 36.15/18 = 2.008 M4 Ratio $FeCl_2$: H_2O = 0.5(0384):2(.008) = 1:4, so x = 4 (55.8)/(55.8 + 71 + 18x) = 0.281 is another valid way of getting to x = 4	4

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Question number	Answer		Additional guidance	Mark
	• calculation of annual volume of carbon dioxide	(1)	Example of calculation = (45 ÷ 100) × 365 × 90000 × 12.5 = = 1.8478×10^8 (dm^3)	3
	• calculation of moles of carbon dioxide	(1)	= $1.8478 \times 10^8 \div 24(.0) = 7.6992 \times 10^6$ (mol)	
	• calculation of mass of carbon dioxide	(1)	= $7.6992 \times 10^6 \times 44 = 3.3877 \times 10^8$ (g) / 3.3877×10^2 tonnes / 338.77 tonnes Answers not in grams must have units for M3 TE at each stage Allow 365.25 / 366 days Ignore SF except 1 SF Correct answer with some working scores (3)	

8

Question Number	Acceptable Answers		Additional Guidance	Mark
(a)	• calculation of maximum mass of germane in laboratory in mg	**(1)**	Example of calculation 0.640 × 231 = 147.84 (mg)	**4**
	• conversion of mass from mg to g	**(1)**	147.84 ÷ 1000 = 0.14784 (g) Allow TE from M1 to M2	
	• calculation of moles of germane	**(1)**	= 0.14784 ÷ 76.6 = 1.9300×10^{-3} (mol) Allow TE from M2 to M3	
	• calculation of maximum number of germane molecules in laboratory	**(1)**	$1.9300 \times 10^{-3} \times 6.02 \times 10^{23}$ = 1.1619×10^{21} (molecules)	
	NOTE – do not award M1 and M2 if there is evidence that candidates believe the values 147.84 / 0.14784 are moles. Such answers are likely to only be able to access M4		Allow TE from M3 to M4 Allow use of 76.7 for 76.6 giving 1.1604×10^{21} Correct answer with no working scores 4 marks Ignore SF except 1 SF	

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Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• calculation of moles of carbon dioxide	(335.5 ÷ 24000) = 0.013979 / 1.3979 × 10^{-2} (mol) Ignore SF except 1 SF	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• answer to (i) × 2	(0.013979 × 2) = 0.027958 / 2.7958 × 10^{-2} (mol) Ignore SF except 1 SF Allow TE from (i)	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	• answer to (ii) ÷ 4	(0.027958 ÷ 4) = 0.0069896 / 6.9896 × 10^{-3} (mol) Ignore SF except 1 SF Allow TE from (ii)	1

Question Number	Acceptable Answers		Additional Guidance	Mark
(b)(iv)	• 1.50 ÷ (answer to (iii))	**(1)**	1.50 ÷ 6.9897 × 10^{-3} = 214.6 (g mol^{-1})	2
	• identification of X	**(1)**	214.6 – 72.6 = 142.01 142.01 ÷ 4 = 35.501 ; so X = Cl Allow TE from (iii) Must be some correct working to score M2	

9

Question Number	Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following point: • $BaCO_3 + 2H^+ \rightarrow Ba^{2+} + CO_2 + H_2O$	Ignore state symbols even if incorrect	(1)

Question Number	Answer		Additional Guidance	Mark
(a)(ii)	• calculation of M_r of barium chloride and total M_r of reactants / products	(1)	Example of calculation 137.3 + 71 (= 208.3) **and** 208.3 + 44 +18 (= 270.3)	(2)
	• $\frac{M_r \text{ barium chloride}}{\text{total } M_r \text{ of reactants / products}} \times 100$	(1)	(208.3 ÷ 270.3) × 100 = 77.063% Ignore SF except 1 SF Correct answer with no working scores 2 No TE on atom economy of incorrect product Allow TE on incorrect A_r/ Mr/ transcription error	

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Question Number	Answer		Additional Guidance	Mark
(b)			Example of calculation	(4)
	• calculation of M_r $BaSO_4$	(1)	137.3 + 32.1 + 64 (= 233.4)	
	• calculation of amount of $BaSO_4$	(1)	10.72 ÷ 233.4 = 0.045930 (mol)	
	• calculation of mass of Group 1 metal	(1)	7.98 – (0.045930 × 96.1) = 7.98 – 4.4138 = 3.5662 / 3.57 (g)	
	• calculation of A_r of Group 1 metal **and** identification of metal	(1)	$\frac{3.5662 \div 0.045930}{2}$ = (38.822) = 38.8/39 **and** potassium / K	
			Alternative Scheme for M3 and M4 M_r M_2SO_4 = 7.98 ÷ 0.04593 = 173.7 (1) $\frac{173.7 - 96.1}{2}$ = 38.8 / 39 **and** potassium / K	
			Alternative scheme 96.1 ÷ 233.4 × 10.72 = 4.414 g SO_4^{2-} scores M1, M2 7.98 −4.414 = 3.5662/3.57 scores M3 Then M4 as above Ignore SF except 1 SF TE throughout	

10

Question Number	Answer		Additional Guidance	Mark
			Example of calculation	(5)
	• calculation of amount of butane	(1)	1.55 ÷ 58 = 0.026724 / 2.6724 × 10^{-2} (mol)	
	• convert T from °C to K **and** kPa to Pa	(1)	25 + 273 = 298 (K) **and** 100 × 1000 = 100 000 / 1 × 10^5 (Pa)	
	• correct rearrangement of the ideal gas equation and substitution of values	(1)	$V = \frac{nRT}{P} = \frac{0.026724 \times 8.31 \times 298}{1 \times 10^5} = 6.6179 \times 10^{-4}$ (m^3)	
	• conversion of m^3 to cm^3	(1)	6.6179 × 10^{-4} × 10^6 = 661.79 (cm^3)	
	• volume / dose in cm^3 to 2/3 SF	(1)	661.79 ÷ 120 = 5.5149 = 5.51 (cm^3)	
			Answer to 2/3 SF Penalise incorrect units in final answer only	
			M4 conversion to cm^3 and M5 calculation of volume of single dose can be credited at any stage Allow TE throughout	

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Question Number	Answer	Additional Guidance	Mark
(i)	• calculation of number of moles	Example of calculation 5.51 ÷ 204 = 0.027010 (mol) Correct answer with no working scores 1 Ignore SF except 1SF Ignore incorrect units	(1)

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Question Number	Answer	Additional Guidance	Mark
(ii)	• rearrangement of ideal gas equation **(1)** • conversion of temperature and volume to appropriate units **(1)** • calculation of moles of hydrogen **(1)**	Example of calculation $n = pV \div RT$ M1 may be subsumed in M3 423 (K), 1873 x 10^{-6} (m^3) Allow 423 (K), 1873 x 10^{-3} (dm^3) , 152 (kPa) Allow 423.15K (which gives final answer of 0.080963) $= \frac{(152 \times 10^3) \times (1873 \times 10^{-6})}{8.31 \times 423}$ = 0.080992 / 0.08099 / 0.0810 / 0.081 (mol) Correct answer with no working scores 1 Allow TE from M2 to M3 Ignore SF except 1SF Penalise use of 1 SF once only in (c)(i) and (c)(ii)	(3)

12

Question Number	Answer	Additional Guidance	Mark
(i)	• conversion of volume of CO_2 into dm^3 **(1)** • calculation of moles of CO_2 **(1)** • calculation of moles of XSO_4 using ratio from equation **(1)** • calculation of the relative formula mass of XSO_4 **(1)** Comment Allow conversion of molar gas volume to 24000 cm^3 mol^{-1} and use of 150 cm^3 for M1 and M2	Example of calculation 150 ÷ 1000 = 0.15 (dm^3) 0.15 ÷ 24 = 6.25 × 10^{-3} (mol) 6.25 × 10^{-3} × 2 = 0.0125 (mol) 1.995 ÷ 0.0125 = 159.6 Ignore units for RFM Allow TE throughout Ignore SF except 1 SF Correct answer with some working scores (4) Correct answer with **no** working scores M4 only	**(4)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• Deduction of identity of **X**	Example of calculation 159.6 – (32.1 + 64) = 63.5 so Cu / Cu^{2+} If 159.6 given in (c)(i) then allow just Cu / Cu^{2+} Allow TE from (c)(i) for any element consistent with calculated RFM – 96.1 e.g. failure to multiply by 2 in (i) leads to a RFM of 319.2, which is consistent with Fr in (ii)	**(1)**

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Question Number	Answer		Additional Guidance	Mark
(i)	• calculate % oxygen **and** mol / mol fraction of K, C, H and O	(1)	Example of calculation: 100 – (20.8 + 25.5 + 2.66) = 51.04 K: 20.8 ÷ 39.1 = 0.532; C: 25.5 ÷ 12 = 2.13; H: 2.66 ÷ 1 = 2.66; O: 51.04 ÷ 16 = 3.19 0.532 ÷ 0.532 = 1; 2.13 ÷ 0.532 = 4; 2.66 ÷ 0.532 = 5; 3.19 ÷ 0.532 = 6 $KC_4H_5O_6$; Elements in any order Correct answer with some working scores (2) Ignore SF except 1 SF TE from M1 to M2 or KC_4H_5 (O_2 omitted)	(2)
	• (calculate smallest whole number ratio and) give the empirical formula	(1)		

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1)	C
2)	A
3)	D
4)	D
5)	C
6)	C
7)	A
8)	C
9)	C
13)	C
11)	C
12)	B
13)	A
14)	B
15)	B
16)	B
17)	B
18)	A
19)	B
20)	C
21)	B
22)	C
23)	D
24)	A
25)	C
26)	A
27)	D
28)	B


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