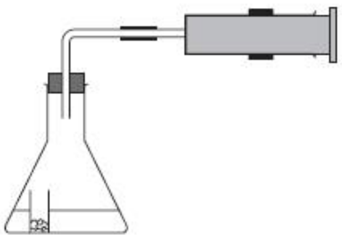
Questions

Q1.

A student wanted to measure the volume of a gas and use the results to find the volume occupied by one mole of the gas. The following method was used.

- A sample of calcium carbonate was weighed out in a small plastic container.
- 20 cm^3 of hydrochloric acid of concentration 2.00 mol dm^{-3} was added to a conical flask. A small pinch of calcium carbonate was added to the acid.
- The container was placed in the conical flask and a gas syringe was connected to the top of the conical flask.
- The flask was carefully shaken so that the small plastic container fell over, allowing the acid and calcium carbonate to mix.

The apparatus set up is shown.



The student repeated the experiment five times using different masses of calcium carbonate on each occasion, with the concentration and volume of the hydrochloric acid constant.

Experiment number	Mass / g	Volume of CO_2 / cm^3
1	0.10	23
2	0.20	44
3	0.30	67
4	0.40	96
5	0.50	115

(a) (i) Write the equation for the reaction between calcium carbonate and hydrochloric acid. Include state symbols.

(2)

(ii) Calculate the molar mass of calcium carbonate.

(1)

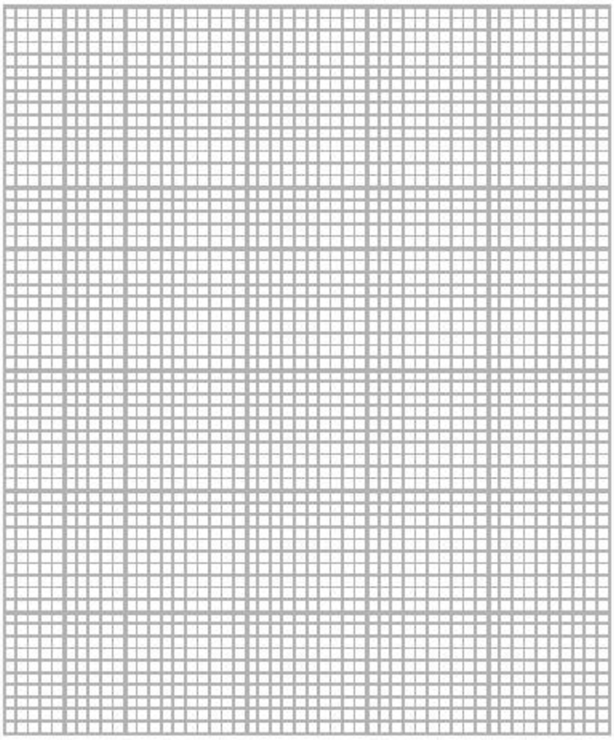
.... g mol^{-1}

(iii) Show that, in each experiment, the hydrochloric acid is in excess.

(2)

(b) (i) Plot a graph of volume of carbon dioxide produced against mass of calcium carbonate on the grid. Include a line of best fit.

(2)



(ii) State how your graph supports the idea that the volume of gas produced depends directly on the mass of calcium carbonate added.

(1)

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(c) Calculate the volume, under these conditions, of one mole of carbon dioxide gas from these data. Give your answer in dm^3 to **two** significant figures.

(2)

(d) Give a reason why the student added a small pinch of calcium carbonate to the acid before starting the reaction.

(1)

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(Total for question = 11 marks)

Q2.

This question is about some reactions of chlorine and hydrogen chloride.

When hydrogen gas and chlorine gas are mixed and passed over a hot platinum catalyst, hydrogen chloride gas is formed.

The equation for this reaction is

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

In an experiment, 20 cm^3 of dry hydrogen gas was reacted with 20 cm^3 of dry chlorine gas. All gas volumes were measured at room temperature and pressure (r.t.p.).

Calculate the number of gas molecules in the product at r.t.p.

[Molar volume of a gas at r.t.p. = 24 000 $cm^3\ mol^{-1}$
Avogadro constant (L) = 6.02 × 1023 mol^{-1}]

(2)

(Total for question = 2 marks)

Q3.

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**.

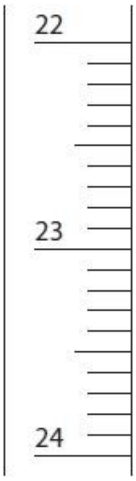
(a) Experiment 1 – to determine the value of **y**

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	= 19.56 g
Mass of crucible + $KH_3(C_2O_4)_\mathbf{y}.\mathbf{z}H_2O$	= 22.97 g
Mass of crucible + $KH_3(C_2O_4)_\mathbf{y}$	= 22.52 g

(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.

(5)

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(Total for question = 17 marks)

Q4.

This question is about equilibrium systems.

Sulfur dioxide and oxygen form an equilibrium with sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The composition of an equilibrium mixture at 698 K and a total pressure of 2.40 atm is shown in the table.

Substance	$SO_2(g)$	$O_2(g)$	$SO_3(g)$
Number of moles /mol	0.0160	0.0120	0.772

(i) Calculate the value of K_p at this temperature.

Include units, if appropriate.

(5)

(ii) Calculate the number of sulfur dioxide molecules present in this equilibrium mixture.

(1)

(iii) Deduce, by referring to K_p, how the number of sulfur dioxide molecules will change if more oxygen is added to the equilibrium mixture.

(2)

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(Total for question = 8 marks)

Q5.

An ionic compound contains a metal cation and a non-metal anion in a 1 : 1 ratio, and water of crystallisation. The compound can be represented as $MN.xH_2O$, where x is the number of moles of water of crystallisation per mole of MN.

A sample of $MN.xH_2O$ was dissolved in distilled water to produce a colourless solution, with a concentration of about 0.5 mol dm^{-3}. 2 cm^3 of the resulting solution was transferred to each of two test tubes.

The following tests were carried out to identify the ions present.

(a) **Test 1**

(i) Addition of a few drops of a solution of barium chloride to one of the test tubes gave a white precipitate.

Identify, by name or formula, **two** possible anions that would give this result.

(1)

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(ii) Addition of 1 cm^3 of dilute hydrochloric acid to the test tube in (a)(i) resulted in no further change.

Give the **formula** of the anion.

(1)

....

(iii) What is the charge on the cation?

(1)

- ☐ **A** +1
- ☐ **B** −1
- ☐ **C** +2
- ☐ **D** −2

(b) **Test 2**

A flame test on a sample of solid $MN.xH_2O$ gave no change in the flame colour.
Give a possible identity of the cation, M.

(1)

....

(c) Heating the hydrated compound results in the formation of the anhydrous ionic solid MN by the following reaction:

$$MN.xH_2O(s) \rightarrow MN(s) + xH_2O(g)$$

Heating a sample of the hydrated compound reduced the mass to 48.9 % of its original value.
Use this information and your answer to (a)(ii) and (b) to calculate the value of x.

[*Note: If you have been unable to identify MN, you may use this hydrated compound,* $CoCl_2.yH_2O$ *in which the sample reduced in mass to 54.6% of its original value. Use this information to calculate the value of y.*]

(4)

(Total for question = 8 marks)

Q6.

This question is about some reactions of chlorine and hydrogen chloride.

Chlorine reacts with hot concentrated aqueous sodium hydroxide to produce sodium chlorate(V) as one of the products.

The equation for this reaction is

$$3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$$

(i) Explain, using oxidation numbers, why this is a disproportionation reaction.

(2)

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(ii) Calculate the atom economy, by mass, of sodium chlorate(V) in this reaction.

(3)

(Total for question = 5 marks)

Q7.

Many vehicles are fitted with airbags which provide a gas-filled safety cushion to protect the occupant of the vehicle if there is a crash.

(a) The first reaction in airbags is the thermal decomposition of sodium azide, NaN_3, to form sodium and nitrogen gas.

(i) Write the equation for this decomposition of sodium azide.
State symbols are not required.

(1)

(ii) In the reaction in (i), a typical airbag is inflated by about 67 dm^3 of gas.
Calculate the **minimum mass** of sodium azide, in grams, needed to produce this volume of gas. Use the Ideal Gas Equation and give your answer to an appropriate number of significant figures.
For the purpose of this calculation, assume that the temperature is 300 °C and the pressure is 140 000 Pa.

(4)

(b) The second reaction in the airbag is between the sodium produced in the reaction (a)(i) and potassium nitrate.

$$\ldots\ldots Na + \ldots\ldots KNO_3 \rightarrow \ldots\ldots K_2O + \ldots\ldots Na_2O + \ldots\ldots N_2$$

Balance the above equation, justifying your answer in terms of the changes in oxidation numbers.

(3)

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(c) The third reaction in the airbag is between the metal oxides and silicon dioxide.

State the type of reaction taking place and justify why this reaction is necessary.

(3)

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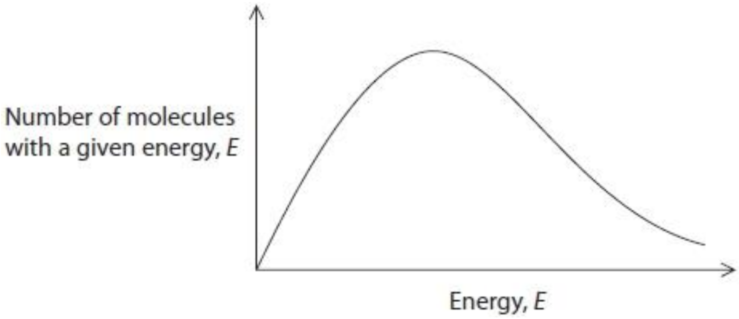
(d) The Maxwell-Boltzmann distribution diagram shows the molecular energies for the gaseous system immediately after the airbag has been deployed.



What is the change in shape of the curve when the airbag **cools**?

(1)

- ☐ **A** the peak would shift to the left and be higher
- ☐ **B** the peak would shift to the left and be lower
- ☐ **C** the peak would shift to the right and be higher
- ☐ **D** the peak would shift to the right and be lower

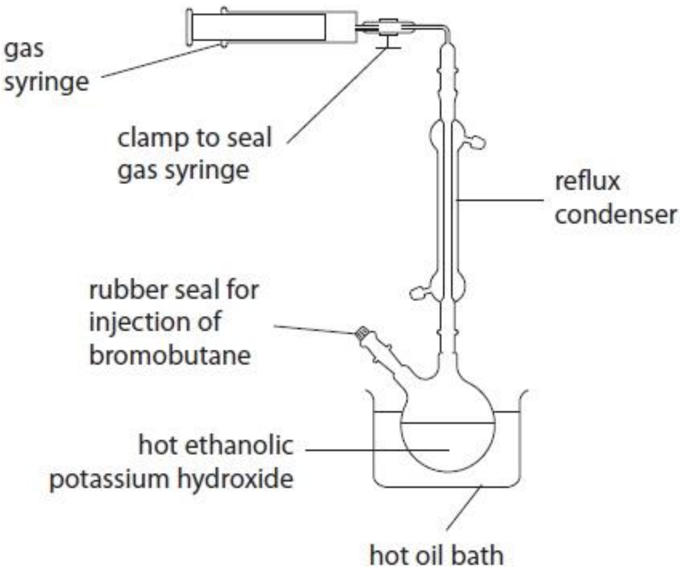
(Total for question = 12 marks)

Q8.

Bromobutanes react with hot ethanolic potassium hydroxide solution to produce gaseous butenes.

$$C_4H_9Br + OH^- \rightarrow C_4H_8 + Br^- + H_2O$$

Apparatus



Procedure

- 0.0080 mol of liquid 1-bromobutane was injected into a round bottom flask containing hot ethanolic potassium hydroxide.
- After the reaction, the syringe was sealed using a clamp.
- The syringe was then removed from the apparatus and allowed to cool to room temperature (298 K).

Result

The final volume of but-1-ene collected was 22.0 cm^3.

Before cooling, the volume of but-1-ene in the gas syringe was 24.0 cm^3.

Calculate the temperature of the gas in the syringe before it cooled.

[Assume no loss from the gas syringe during cooling, and a constant pressure]

(2)

(Total for question = 2 marks)

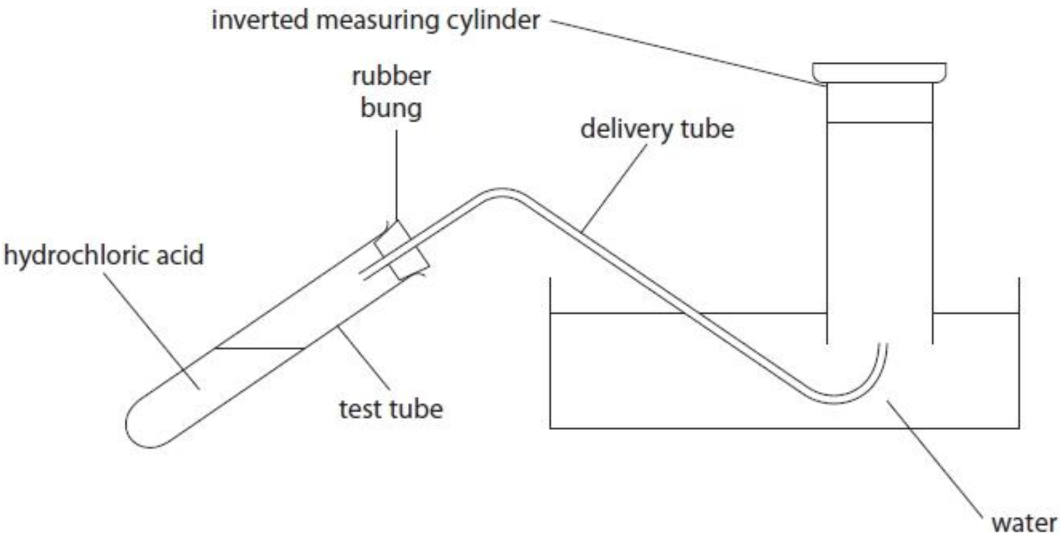
Q9.

(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)

Q10.

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)

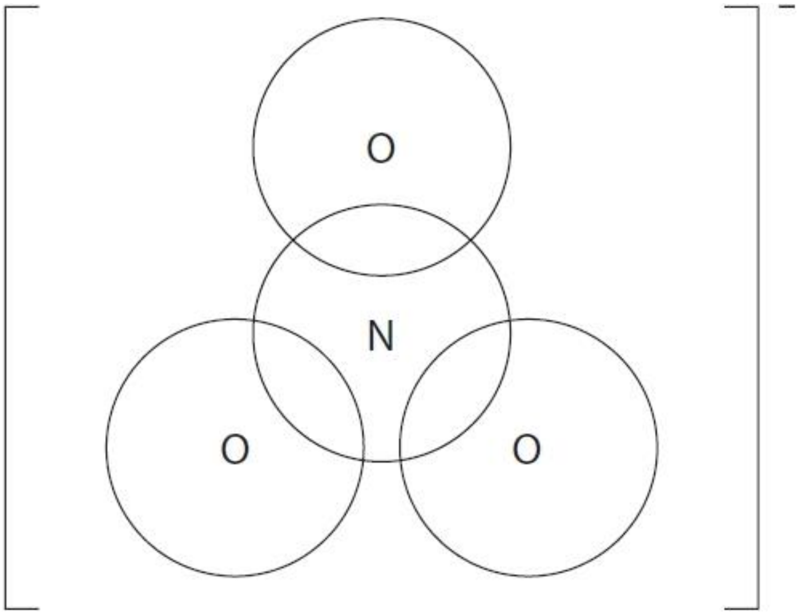
Q11.

This question is about s-block elements and some of their compounds.

The s-block nitrates undergo thermal decomposition.

(i) Draw a dot-and-cross diagram for the nitrate(V) ion, NO_3^-, showing outer electrons only.

(1)



(ii) Write an equation for the thermal decomposition of lithium nitrate.

State symbols are **not** required.

(1)

(iii) The equation for the thermal decomposition of sodium nitrate is different from that for lithium nitrate.

$$NaNO_3(s) \rightarrow NaNO_2(s) + \frac{1}{2}O_2(g)$$

The gas produced is collected in a gas syringe.
Calculate the theoretical volume of gas, in **cm³**, that could be collected at 298 K and 101 kPa by the decomposition of 0.500 g of pure sodium nitrate. Give your answer to 2 significant figures.
[$pV = nRT$, $R = 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$]

(4)

(iv) State one reason why the experimental gas volume may differ from the calculated theoretical volume.

Assume that no gas escapes and measurements have been made accurately.

(1)

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(Total for question = 7 marks)

Q12.

This question is about acids and bases.

Write the ionic equation for the reaction between magnesium oxide and an acid.
State symbols **are** required.

(2)

(Total for question = 2 marks)

Q13.

Ammonium cobalt(II) sulfate is made by mixing aqueous solutions of ammonium sulfate and excess cobalt(II) sulfate.

Dry crystals of ammonium cobalt(II) sulfate, $(NH_4)2SO_4{\cdot}CoSO_4{\cdot}6H_2O$, are obtained by the procedure shown.

Step **1** The reaction mixture is transferred to an evaporating basin, heated gently and then left to crystallise.

Step **2** The crystals are separated by gravity filtration.

Step **3** The crystals are then **rinsed** with a small amount of **ice-cold** water.

Step **4** The rinsed crystals are placed in a **warm oven** for 30 minutes.

The percentage yield of this reaction is 70.0%.

Give **two** possible reasons, other than an incomplete reaction, why the yield is less than 100%.

(2)

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(Total for question = 2 marks)

Q14.

The preparation of 2-chloro-2-methylpropane, $(CH_3)_3CCl$, involves the reaction of concentrated hydrochloric acid with 2-methylpropan-2-ol, $(CH_3)_3COH$, a tertiary alcohol.

$$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$$

In an experiment, 12.0 g of 2-methylpropan-2-ol was shaken with excess concentrated hydrochloric acid in a separating funnel.

After about 15 minutes, the product formed as a separate layer.

Data:

Substance	Boiling temperature / °C	Density / $g\,cm^{-3}$
2-methylpropan-2-ol	82	0.79
2-chloro-2-methylpropane	51	0.84
water	100	1.00

The dried 2-chloro-2-methylpropane was transferred to the distillation apparatus.

11.6 cm^3 of 2-chloro-2-methylpropane was collected from 12.0 g of 2-methylpropan-2-ol.

Calculate the percentage yield using the data in the table.

(4)

Substance	Density / $g\,cm^{-3}$	Molar mass / $g\,mol^{-1}$
2-methylpropan-2-ol	0.79	74
2-chloro-2-methylpropane	0.84	92.5

(Total for question = 4 marks)

Q15.

Catalytic converters in cars remove unwanted substances such as nitrogen monoxide, carbon monoxide and unreacted hydrocarbons from the exhaust fumes.

The formula of the nitrogen monoxide free radical can be written as NO•

(i) Which is true for the NO• free radical ?

(1)

- ☐ **A** NO• is formed during thermal decomposition of LiNO3
- ☐ **B** NO• has a total of 15 protons, 15 neutrons and 16 electrons
- ☐ **C** NO• is a species with an unpaired electron
- ☐ **D** NO• is formed by heterolytic fission

(ii) It has been suggested that unreacted hydrocarbons and nitrogen monoxide are removed in a catalytic converter by reacting them together.

The reaction between decane and nitrogen monoxide produces carbon dioxide, water and nitrogen as the only products.
Complete the balanced equation for this reaction.
State symbols are not required.

(2)

.... $C_{10}H_{22}$ + ... NO $\rightarrow$

(iii) Give a possible reason why this reaction might not proceed according to the equation in (ii).

(1)

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(Total for question = 4 marks)

Q16.

This question is about the elements in Group 2 of the Periodic Table.

An experiment was carried out to determine the molar volume of hydrogen at room temperature.

0.035 g of magnesium was added to excess hydrochloric acid and 32 cm^3 of hydrogen was produced.

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

Calculate the molar volume of hydrogen from the results of this experiment. Include units in your answer.

(2)

(Total for question = 2 marks)

Q17.

This question is about some reactions of chlorine and hydrogen chloride.

Chlorine can be produced by reacting concentrated hydrochloric acid with manganese(IV) oxide.

The equation for this reaction is

$$4HCl(aq) + MnO_2(s) \rightarrow MnCl_2(aq) + Cl_2(g) + 2H_2O(l)$$

(i) Deduce the half-equation for the formation of chlorine.

(1)

(ii) A student reacted 5.0 cm^3 of 5.0 mol dm^{-3} hydrochloric acid with an excess of manganese(IV) oxide. 70 cm^3 of chlorine gas was produced.

The teacher said the expected percentage yield of the experiment is 75 %.
Determine whether the student achieved the expected percentage yield.
[Molar volume of a gas at r.t.p. = 24 000 cm^3 mol^{-1}]

(4)

(Total for question = 5 marks)

Q18.

This question is about some reactions of chlorine and hydrogen chloride.

Hydrogen chloride gas dissolves in water to form hydrochloric acid.

(i) Hydrogen chloride gas does not conduct electricity.

Hydrochloric acid is a good conductor of electricity.
Give a reason for this change in conductivity.

(1)

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(ii) When concentrated hydrochloric acid on a glass rod is held above a concentrated ammonia solution, a white smoke is observed.

Write an equation, including state symbols, for the reaction that produces the white smoke.

(2)

(iii) Hydrochloric acid is added to a test tube containing a sample of solid sodium carbonate.

Give **two** observations.

(2)

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(iv) Describe an experiment to enable you to accurately determine the concentration of an approximately 1 mol dm^{-3} solution of hydrochloric acid, using a solution of sodium hydroxide of concentration 1.00 mol dm^{-3}. Details of the calculation are not required.

(5)

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(Total for question = 10 marks)

Q19.

Nitrogen monoxide and chlorine gases react together to form a single product, nitrosyl chloride, NOCl.

Below 100 °C the yield of NOCl is almost 100 %, but as the temperature rises the yield of NOCl decreases as the equilibrium position shifts to the left.

$$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g) \qquad \Delta_r H^\circ = -75.6 \text{ kJ mol}^{-1}$$

A 1 dm^3 reaction vessel, initially containing 2 mol of NO and 1 mol of Cl_2, was allowed to come to equilibrium at 225 °C to produce 1.82 mol of NOCl.

(i) Calculate the number of moles of NO and Cl_2 at equilibrium.

(2)

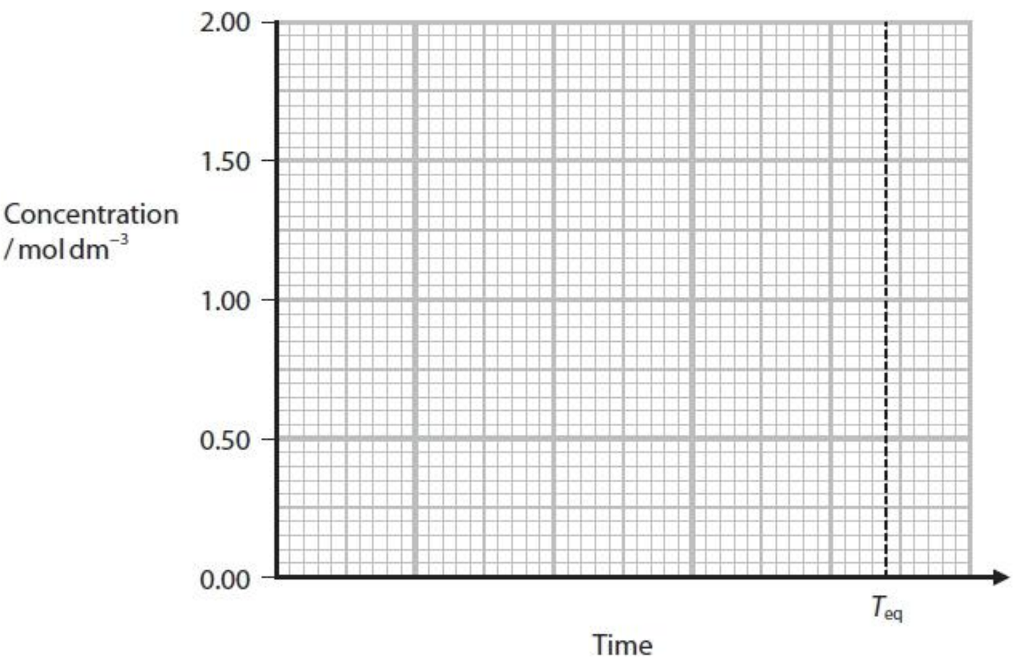
Moles of NO ....

Moles of Cl_2 ....

(ii) Sketch three lines showing the change in concentration over time of the three components of the reaction using the axes given.

You should assume that the reaction reaches equilibrium at time T_{eq}.

(3)



(iii) The expression for the equilibrium constant, K_c , for this reaction is

(1)

☐ **A** $K_c = \dfrac{2[NOCl]}{2[NO][Cl_2]}$

☐ **B** $K_c = \dfrac{[NOCl]^2}{[NO]^2[Cl_2]}$

☐ **C** $K_c = \dfrac{2[NO][Cl_2]}{2[NOCl]}$

☐ **D** $K_c = \dfrac{[NO]^2[Cl_2]}{[NOCl]^2}$

(iv) Give the reason why the equilibrium yield of NOCl decreases when the temperature changes from 25 °C to 225 °C.

The enthalpy change for the reaction at 25 °C is -75.6 kJ mol^{-1}.

(1)

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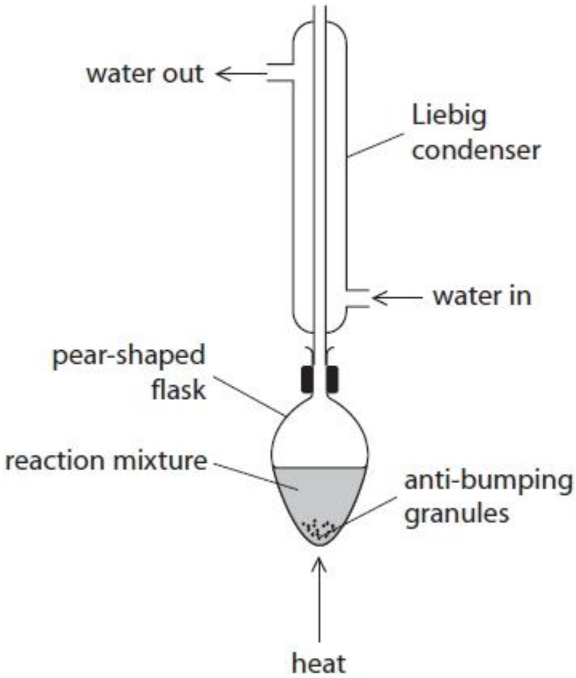
(Total for question = 7 marks)

Q20.

Propanal can be produced from the oxidation of propan-1-ol.

(i) A student assembled the apparatus shown for this oxidation.



Explain why the use of this apparatus would give a very low yield of propanal.

(2)

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(ii) The oxidising agent is acidified $Na_2Cr_2O_7$.

State the oxidation number of chromium in $Na_2Cr_2O_7$.

(1)

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(iii) Complete the ionic half-equation for the oxidation of propan-1-ol.

(1)

$$CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO + \text{...............}H^+ + \text{...............}e^-$$

(iv) State how the use of anti-bumping granules gives smoother boiling.

(1)

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(v) Another student used the correct apparatus for this oxidation. 1.50 g of propan-1-ol produced 0.609 g of propanal.

Calculate the percentage yield of propanal by mass.

(3)

(Total for question = 8 marks)

Q21.

Water gas is a fuel gas consisting of a mixture of carbon monoxide and hydrogen.

Water gas is produced by passing steam over white hot coke.

The equation for the reaction is shown.

$$H_2O(g) + C(s) \rightarrow CO(g) + H_2(g)$$

Calculate the total mass of products when 1000 **kg** of steam reacts completely.

(2)

(Total for question = 2 marks)

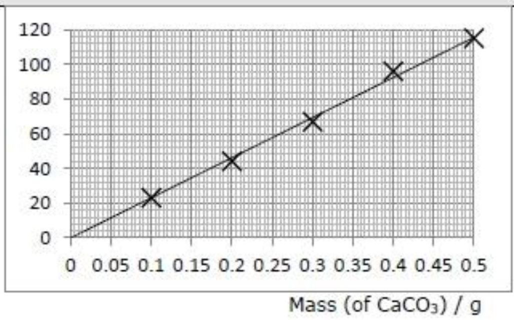
Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$ Balanced equation **(1)** State symbols **(1)**	Accept $CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$ 2nd mark dependent on first or near miss. Reject $H_2CO_3(aq)$ in equation, but allow state symbol mark if otherwise correct.	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(a) (ii)	Finds molar mass of calcium carbonate	Example of calculation Mr of calcium carbonate = 40.1 + 12 + (16 x 3) =100.1 (g mol^{-1}) Allow = 40 + 12 + (16 x 3) = 100 (g mol^{-1}) Accept answer with no working	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(iii)	• calculate moles of calcium carbonate in 0.50 g **(1)** • moles of hydrochloric acid in 20 cm^3 AND Show the hydrochloric acid is in excess with appreciation of 2:1 ratio in equation for reaction **(1)**	Example of calculation moles of calcium carbonate = 0.50/100.1 = 0.004995 = 0.0050 (mol) moles of hydrochloric acid in 20 cm^3 = 20/1000 x 2 = 0.040 (mol) 0.04 (moles of hydrochloric acid) reacts with 0.02 (moles of calcium carbonate) therefore the acid is in (a four times) excess. OR 0.0050 (moles of calcium carbonate) reacts with 0.010 (moles of hydrochloric acid) therefore the acid is in (a four times) excess Ignore calculations using other masses of calcium carbonate	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	Points plotted accurately AND axes labelled **(1)** Points plotted must cover more than half of graph paper AND Reasonable straight line of best fit which may extend to the origin **(1)** Allow ecf on reasonable line on incorrectly plotted points.	Do not award for reversed axes Volume (of CO_2) / cm^3 	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(ii)	Straight line through the origin (therefore volume is directly proportional to mass)	Allow 'There is a positive correlation.'	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	Either • finds gradient from graph **(1)** • molar volume given to 2 s.f. with units **(1)** OR • moles of calcium carbonate **(1)** • molar Volume **(1)**	Example calculation Gradient = $\frac{\text{volume}}{\text{mass}}$ = 231 (cm^3 per gram) Allow correctly calculated values in the range = 210 to 250 (Molar Volume = Gradient x Mr) Molar Volume = 231 x 100.1(or x 100) = 23 (dm^3) (must be 2 s.f) Answer to 2 s.f. (and units) Allow TE from any gradient OR Data may be used from any experiment number eg using data from Experiment 5 Moles of calcium carbonate = 0.50/100.1 = 0.0050 Molar Volume = 115/0.005 = 23 (dm^3) Allow data from a point on the line calculated using route 2	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(d)	To saturate the solution with CO_2 / to stop the CO_2 formed from dissolving		**(1)**

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• calculation of total of moles of gas in product **(1)** • calculation using Avogadro number to find number of molecules **(1)**	<u>Example of calculation</u> Moles of HCl = 40 ÷ 24000 = 1.6667×10^{-3} / 0.0016667 $1.6667 \times 10^{-3} \times 6.02 \times 10^{23}$ = 1.0033×10^{21} For MP2, allow TE on moles of HCl Ignore SF Penalise rounding errors once only	**(2)**

Q3.

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)**	<u>Example of diagram</u>  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: • 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)** • 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 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) Allow only the concordant titres / titres 2 and 4 / 23.20 and 23.20 (cm^3) should be used / are used(in the mean) 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)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	• calculation of percentage uncertainty	<u>Example of calculation</u> $\frac{2 \times 0.05}{23.20} \times 100$ = (±)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)** • calculation of moles $C_2O_4^{2-}$ in 25.0 cm^3 **(1)** • calculation of moles $C_2O_4^{2-}$ in 1.00 dm^3 **(1)** • calculation of **y** to nearest whole number **(1)**	Example of calculation moles MnO_4^- = 23.15 x 0.0203/1000 = 0.00046995 / 4.6995 x 10^{-4} (mol) 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^- 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 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	**(4)**

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 x 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 x 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)

Edexcel Chemistry A-level - Equations and Percentage Yield

Q4.

Question Number	Answer	Additional Guidance	Mark
(i)	• **(M1)** calculation of mole fractions **(1)**	Example of calculation $X_{SO_2} = 0.0160 \div 0.8 = 0.02(0)$ $X_{O_2} = 0.0120 \div 0.8 = 0.015$ $X_{SO_3} = 0.772 \div 0.8 = 0.965$	**(5)**
	• **(M2)** calculation of partial pressures **(1)**	$P_{SO_2} = 0.02(0) \times 2.40 = 0.048$ $P_{O_2} = 0.015 \times 2.40 = 0.036$ $P_{SO_3} = 0.965 \times 2.40 = 2.316$	
	• **(M3)** expression of K_p **(1)**	$K_p = \frac{(P_{SO_3})^2}{(P_{SO_2})^2 \times P_{O_2}}$ Do not award square brackets	
	• **(M4)** calculation of value of K_p **(1)**	$K_p = \frac{2.316^2}{0.048^2 \times 0.036} =$ K_p= 64668.4…./6.46684.. $\times 10^4$ K_p= 65000/6.5 $\times 10^4$/64700/6.47 $\times 10^4$ Ignore SF except 1	
	• **(M5)** units **(1)**	atm^{-1} Correct final answer without working scores	(5)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of the number of molecules	Example of calculation N=(n x L = 0.0160 x 6.02 x 10^{23}) = 9.632 x 10^{21} Ignore SF except 1SF Do not award if any units are given	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: • to ensure that K_p stays the same/ quotient stays the same **or** only temperature changes the value of K_p **(1)** • the number of (sulfur dioxide) molecules decreases **Either** because the equilibrium shifts to the right or because one of the denominators (oxygen) has increased so the other denominator (sulfur dioxide) has to decrease **(1)**	Standalone marks Allow concentration changes have no effect on the value of K_p Allow 'moles' for molecules	**(2)**

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to two of the following: • sulfate / sulfate(VI) / SO_4^{2-} • sulfite / sulfate(IV) / SO_3^{2-} • carbonate / CO_3^{2-}	Penalise lack of charge	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	SO_4^{2-}	Ignore sulfate (ion) Only penalise lack of charge if not penalised in (a)(i)	**(1)**

Question Number	Acceptable Answer	Mark
(iii)	**The only correct answer is C** ***A*** *is not correct because the ratio is one-to-one* ***B*** *is not correct because cations are positive* ***D*** *is not correct because cations are positive*	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	Cation is Mg^{2+} / magnesium (ion)	Do not award use of symbol just "Mg" Award Be^{2+}/ beryllium (ion)	**(1)**

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(c)</td><td>Method 1
Calculates M_r of $MgSO_4$
(1)

Divides percentage by relative formula mass
(1)
Divides ratio by smallest
(1)
x = 7
(1)</td><td>In all cases correct answer with some correct working scores (4)

<u>Example of calculation:</u>
M_r of $MgSO_4$ = 24.3 + 32.1 + (4 x 16) = 120.4
<table>
<tr><th></th><th>$MgSO_4$</th><th>H_2O</th></tr>
<tr><td>%</td><td>48.9</td><td>51.1</td></tr>
<tr><td>Moles (÷ RFM)</td><td>48.9 / 120.4 = 0.406146170…</td><td>51.1 / 18 = 2.838888889…</td></tr>
<tr><td>Ratio (÷ smallest)</td><td>1</td><td>6.98982049</td></tr>
</table></td><td>(4)</td></tr>
<tr><td></td><td>For Alternative
Calculates M_r of $CoCl_2$
(1)

Divides percentage by relative formula mass
(1)

Divides ratio by smallest
(1)</td><td>Allow $MgSO_4.7H_2O$

M_r of $CoCl_2$ = 58.9 + 2 x 35.5 = 129.9
<table>
<tr><th></th><th>$CoCl_2$</th><th>H_2O</th></tr>
<tr><td>%</td><td>54.6</td><td>45.4</td></tr>
<tr><td>Moles (÷ RFM)</td><td>54.6 / 129.9 = 0.42032</td><td>45.4 / 18 = 2.5222</td></tr>
<tr><td>Ratio (÷ smallest)</td><td>1</td><td>6.0007</td></tr>
</table></td><td></td></tr>
</table>

	y = 6 **(1)**	Allow $CoCl_2.6H_2O$	
	Method 2 Calculates M_r of $MgSO_4$ **(1)**	<u>Example of calculation:</u> M_r of $MgSO_4$ = 24.3 + 32.1 + (4 x 16) = 120.4	
	Forms algebraic equation for M_r of $MgSO_4.xH_2O$ **(1)**	M_r of $MgSO_4.xH_2O$ = 120.4 + 18x	
	Finds algebraic expression for ratio of $MgSO_4$ to hydrated $MgSO_4$ **(1)**	$\frac{120.4}{120.4 + 18x} = 48.9\ \%$	
	Solves for x **(1)**	x = 7	

	For Alternative Calculates M_r of $CoCl_2$ **(1)** Forms algebraic equation for M_r of $CoCl_2.xH_2O$ **(1)** Finds algebraic expression for ratio of $CoCl_2$ to hydrated $CoCl_2.xH_2O$ **(1)** Solves for x **(1)**	M_r of $CoCl_2$ = 58.9 + 2 x 35.5 = 129.9 M_r of $CoCl_2.xH_2O$ = 129.9 + 18x $\frac{129.9}{129.9 + 18x} = 54.6\ \%$ x = 6	

	Method 3 Calculates M_r of $MgSO_4$ **(1)** Calculates M_r of $MgSO_4.xH_2O$ **(1)** Calculates mass of water in one mol **(1)** Finds moles of water **(1)** Method 3 for $CoCl_2.yH_2O$ Calculates M_r of for $CoCl_2$. **(1)** Calculates M_r of $CoCl_2.yH_2O$ **(1)** Calculates mass of water in one mol **(1)** Finds moles of water **(1)**	M_r of $MgSO_4$ = 24.3 + 32.1 + (4 x 16.0) = 120.4 M_r of $MgSO_4.xH_2O = \frac{120.4 \times 100}{48.9}$ = 246.2 246.2 – 120.4 = 125.8 $\frac{125.8}{18} = 7$ M_r of $CoCl_2$ = 58.9 + (2 x 35.5) = 129.9 M_r of $CoCl_2.yH_2O = \frac{129.9 \times 100}{54.6}$ = 237.9 237.9 – 129.9 = 108.0 $\frac{108.0}{18} = 6$ Use of Beryllium Calculates M_r of $BeSO_4$ = 105.1 Moles in 48.9% of 100g = 0.46527117 Ratio of $BeSO_4:H_2O$ = 1:6.102 x=6	

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points • recognises/states that disproportionation reactions contain one element that is both reduced and oxidised (1) • identifies the relevant oxidation number changes in chlorine (1)	Allow answers in terms of just Chlorine i.e. Chlorine is both oxidised and reduced Do not award: Chlorine **molecule** both oxidised and reduced Cl changes from 0 in Cl_2 to -1 in NaCl **and** 0 in Cl_2 to +5 in $NaClO_3$ Allow oxidation numbers shown on equation	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points • all molar masses correct (1) • correct use of multiples (1) • calculation of atom economy (1)	<u>Example of calculation</u> $NaClO_3$ = 106.5 NaCl = 58.5 H_2O = 18 Allow calculation of molar masses of left-hand side Cl_2 = 71, NaOH = 40 (5 x 58.5 and 1 x 106.5 and 3 x 18) or (3 x 71 and 6 x 40) M1 and M2 may be combined: total molar mass = 453 = 106.5 x 100 ÷ ((5 x 58.5) + 106.5 + (3 x 18)) = 23.51% Ignore SF except 1 SF TE on molar masses and multiples	(3)

Q7.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	correct equation	Example of equation: $2NaN_3 \rightarrow 2Na + 3N_2$ Allow multiples Ignore state symbols even if incorrect	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• conversion of volume and temperature to correct units **(1)** • rearrangement of ideal gas equation so $n=pV \div RT$ and calculation of $n(N_2)$ in moles **(1)** • evaluation of $n(NaN_3)$ **(1)** • answer converted into mass to 2/3 SF **(1)** Allow TE at each stage	Example of calculation: $67\ dm^3 = 0.067\ m^3$, 300°C = 573 K $n(N_2) = \frac{140\ 000 \times 0.067}{8.31 \times 573} = 1.9699.....(mol)$ $n(NaN_3) = (2/3 \times 1.9699.....=)\ 1.313....$ (mol) m= (1.313 .... x 65 = 85.3629..=) = 85.4 / 85 (g) Correct answer without working scores (4)	(4)

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	An answer that makes reference to the following points: • Nitrogen (is reduced) from +5 to 0 **(1)** • Sodium (is oxidised) from 0 to +1 **(1)** • Balanced equation **(1)**	Look for oxidation numbers annotated on the equation Do not award potassium oxidised Penalise omission of "+" sign, once only Example of balanced equation: $\mathbf{10}Na + \mathbf{2}KNO_3 \rightarrow K_2O + \mathbf{5}Na_2O + N_2$ Allow multiples	(3)

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	An answer that makes reference to the following points: • Neutralisation reaction / acid base reaction **(1)** • Sodium and/or potassium oxides are caustic / corrosive **(1)** • Salts (silicates) formed are inert / unreactive **(1)**	Allow salt formation Allow "metal oxides" Ignore "harmful" / "alkaline" Allow "not harmful"/ "not caustic" Ignore "neutral"	(3)

Question Number	Acceptable Answer	Mark
(d)	The only correct answer is **A** ***B*** *is incorrect because the peak would shift to the left and be higher* ***C*** *is incorrect because the peak would shift to the left not to the right* ***D*** *is incorrect because the peak would be shift to the left not to the right*	(1)

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• calculation of ratio of volumes before and after cooling **(1)** • calculation of temperature of warm syringe **(1)**	Example of calculation $\frac{24}{22}$ = 1.091 / 1.0909... 1.0909 x 298 = 325 **K** / 325.09090909 **K** / 52°C Use of pV = nRT giving 325 K scores 2 Correct answer with no working scores 2 If candidate assumes P = 100000 / 101000 and uses pV = nRT to find T = 315 / 318 K award 1. Ignore SF except 1 SF	**(2)**

Q9.

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 $0.002 \div 2 = 0.001$ or 1×10^{-3} Allow TE from (a) and (b)(ii)	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iv)	• Rearrangement of ideal gas equation **(1)** • conversion of °C to K **(1)** • calculation of volume in m^3 **(1)** • calculation of volume in cm^3 **(1)**	Example of calculation: $pV = nRT$ rearrange $V = \frac{nRT}{p}$ Allow M1 if equation rearrangement not explicitly shown but used correctly in M3 $(273 + 23) = 296$ Allow M2 if $(273 + 23)$ used in equation $V = \frac{1.0 \times 10^{-3} \times 8.31 \times (273 + 23)}{98\,000}$ $= 2.51 \times 10^{-5}$ (m^3) $= 25$ allow 25.1 (cm^3) 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: • gas lost before the bung replaced **(1)** • the magnesium was coated with oxide (so water was formed instead of hydrogen) **(1)**	Ignore 'generic' gas leakages from apparatus Do not award gas may dissolve (in water or acid) Ignore 'generic' references to impurity Ignore references to incomplete reaction	(2)

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)**

Q10.

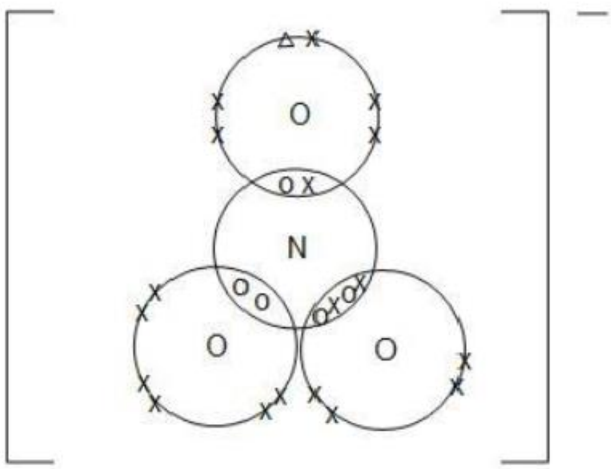
Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• moles of malachite / carbon dioxide **(1)** • convert temperature to kelvin **(1)** • convert pressure to Pa **(1)** • rearrange the expression for V and substitute the candidate's values **(1)** • calculation of V with units and answer 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)**	<u>Example of calculation:</u> 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)**
	OR • moles of copper(II) oxide in 0.571 g **(1)** • moles of copper(II) oxide expected from 0.810 g pure malachite **(1)** • evaluation of answer **(1)** **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)** • calculate total mass of products **(1)** • evaluation of answer **(1)**	97.981(98618) = 98.0(%)/ 98(%) $\frac{0.571}{79.5}$ = 7.18(2389937) x 10^{-3} (mol) 2 x 3.66(5158371) x 10^{-3}= 7.33(0316742) x 10^{-3} (mol) $\frac{7.18(2389937) \times 10^{-3} \times 100}{7.33(0316742) \times 10^{-3}}$ = 97.9(8198618) = 98.0(%) / 98(%) 3.66(5158371) x 10^{-3} x 44 = 0.161(2669683) (g) 3.66(5158371) x 10^{-3} x 18 = 0.0659(7285068) (g) 0.161 + 0.066 + 0.571 = 0.798(239819) (g) $\frac{0.798(239819) \times 100}{0.810}$ = 98.5 (481258) / 99(%) 0.571/ 79.5 = 7.18 x 10^{-3} (mol)	

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

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• dot-and-cross diagram	 Allow diagrams with all dots/all crosses etc Allow lone pairs with electrons separated Ignore covalent bonds (if shown) 'extra' electron may be shown as different shape, colour etc. The double bond can be to any of the three oxygens	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • balanced equation	Example of equation $2LiNO_3 \rightarrow Li_2O + 2NO_2 + ½O_2$ Allow multiples of equation Ignore state symbols even if incorrect	**(1)**

Question Number	Acceptable Answer		Additional Guidance	Mark
(iii)	An answer that makes reference to the following points:		Example of calculation Ignore SF for M1, M2, M3 except 1SF, penalise once only	**(4)**
	• calculation of moles of sodium nitrate	**(1)**	Moles of sodium nitrate = $0.5 \div 85 = 5.8824 \times 10^{-3}$ (mol)	
	• calculation of moles of oxygen	**(1)**	Moles of oxygen gas $O_2 = 5.8824 \times 10^{-3} \div 2$ $= 2.9412 \times 10^{-3}$ (mol)	
	• substitution in $pV = nRT$ and rearrangement	**(1)**	$pV = nRT$ $V = \frac{nRT}{p} =$ $\frac{2.9412 \times 10^{-3} \times 8.31 \times 298}{101000}$	
	• final answer to 2SF only and in cm^3	**(1)**	(= 7.21136×10^{-5} m^3) =72 (cm^3) If M2 not divided by 2 then final answer = 140 cm^3 – scores (3) marks. 144 cm^3 – scores (2) marks. Correct final answer with no working scores (4) Allow TE throughout	

Question Number	Acceptable Answer	Additional Guidance	Mark
(iv)	• incomplete reaction / decomposition	Ignore pressure not 101 kPa or temperature not 298 K Do not award reversible reaction / impure reactant or product / oxygen soluble in water / side reactions	(1)

Q12.

Question Number	Answer	Additional Guidance	Mark
	• balanced equation (1) • state symbols (1)	Example of equation $MgO(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(l)$ Allow multiples Conditional on M1 or near miss e.g. Mg^+ Allow a fully balanced equation with correct state symbols for 1 mark e.g. $MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$ e.g. $MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$ e.g. uncancelled spectator ions from the acid with (aq) Do not award M1 for $Mg^{2+}(s) + O^{2-}(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(l)$ But M2 can be awarded for correct state symbols	(2)

Q13.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to **two** of the following points:	Allow e.g. crystals / salt / solid / product for ammonium cobalt(II) sulfate	**(2)**
	• some ammonium cobalt(II) sulfate solution lost if it 'spits' out of basin when heated (in Step 1) **(1)**	Do not award crystals evaporated for M1 only	
	• some ammonium cobalt(II) sulfate remains in solution (in Step 1) **(1)**	Allow the crystals weren't left to crystallise for long enough Allow just 'solid is lost during filtration'	
	• some ammonium cobalt(II) sulfate is soaked into the filter paper/ some ammonium cobalt(II) sulfate crystals remain on filter paper (in Step 2) **(1)**	Allow any type of specific transfer loss e.g. some product left behind in the beaker / flask / evaporating basin	
	• transfer losses from reaction flask / beaker to evaporating basin / from evaporating basin to filter funnel (in Steps 1 and 2) **(1)**	Allow crystals decompose during drying Allow some ammonium cobalt(II) sulfate dissolves in ice-cold water (in Step 3)	
	• some water of crystallisation is lost during the drying process (in Step 4) **(1)**	Ignore formation of alternative product Ignore reaction is reversible	

Q14.

Question Number	Answer	Additional Guidance	Mark
	Method 1 • calculation of the mass of 2-chloro-2- methylpropane collected **(1)** • calculation of the moles of 2-chloro-2- methylpropane collected **(1)** • calculation of the maximum moles of 2- chloro-2-methylpropane possible **(1)** • calculation of the percentage yield **(1)** Method 2 • calculation of the moles of 2- methylpropan-2-ol **(1)** • calculation of maximum mass of 2-chloro- 2-methylpropane possible **(1)** • calculation of maximum volume of 2- chloro-2-methylpropane **(1)** • calculation of the percentage yield **(1)**	Example of calculation: = 11.6 x 0.84 = 9.744 (g) $= \frac{9.744}{92.5}$ = 0.10534 / 0.105 (mol) $= \frac{12.00}{74}$ = 0.16216 / 0.162 (mol) $= \frac{0.10534}{0.16216}$ x 100 = 64.961 / 65.0 (%) $= \frac{12.00}{74}$ = 0.16216 / 0.162 (mol) = 0.16216 x 92.5 = 14.998 / 15.0 (g) $= \frac{14.998}{0.84}$ = 17.855 (cm^3) $= \frac{11.6}{17.855}$ x 100 = 64.968 / 65.0 (%)	**(4)**

	Method 3 • calculation of the mass of 2-chloro-2- methylpropane collected • calculation of the moles of 2-chloro-2- methylpropane collected • calculation of mass of methylpropan-2-ol if yield were 100% • calculation of percentage yield	$= 11.6 \times 0.84 = 9.744$ (g) $= \frac{9.744}{92.5} = 0.10534 / 0.105$ (mol) $=0.10534 \times 74 = 7.7952$ (g) $= \frac{7.7952}{12.0} \times 100 = 64.960 / 65.0$ (%) Other variations on these methods are possible. Final answer which rounds to 65.0 % with some relevant working scores (4) ALLOW TE throughout but do not award M4 for yields over 100% Ignore SF except 1 SF	

Q15.

Question Number	Answer	Mark
(i)	The only correct answer is **C** (NO• is a species with an unpaired electron) ***A** is not correct because nitrogen dioxide, NO_2, is formed during this reaction* ***B** is not correct because this would be NO^-. NO• has 15 protons, 15 neutrons and 15 electrons* ***D** is not correct because radicals such as this are made by homolytic fission*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• correct substances (1) • correct balancing (1)	Example of equation $2C_{10}H_{22} + 62NO \rightarrow 20CO_2 + 22H_2O + 31N_2$ Ignore a dot on NO ALLOW multiples	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following point: • oxygen is present and so $C_{10}H_{22}$ / intermediate compounds might react with oxygen Or NO might react with CO	Allow there is (enough) oxygen for complete combustion Allow the reaction must occur in a series of steps as there are too many particles reacting in the equation Allow it is unlikely for the reactants to be in the correct ratio Allow it is unlikely there will be enough NO / decane Allow reactants can react in other ways giving formation of other named products (such as CO, C, NO_x) Allow NO may react with other substances / air / oxygen to form NO_x / oxides of nitrogen / other nitrogen containing products	(1)

Q16.

Question Number	Answer	Additional Guidance	Mark
	• calculation of mol of magnesium **(1)** • calculation of molar volume of H_2 **and** units **(1)**	<u>Example of calculation</u> mol Mg = 0.035 ÷ 24.3 = 1.4403×10^{-3} / 0.0014403 (mol) (mol H_2 = mol Mg) molar volume of H_2 = 32 ÷ 1.4403×10^{-3} = 22 217 / 22 220 / 22 200 /22 000 /2.2217×10^4 / 2.220×10^4 / 2.22×10^4 / 2.2×10^4 **and** cm^3 (mol^{-1}/mol^-) Allow value converted to dm^3 e.g. 22.2 **and** dm^3 (mol^{-1}/ mol^-) If they have rounded to 1.4×10^{-3} in step 1 then an example of a correct answer would be 22857 **and** cm^3mol^{-1} **or** 23 **and** dm^3mol^{-1} TE on mol Mg Additional guidance Allow 1.4583×10^{-3} and 2.1942×10^4 if 24 used for Mg Correct answer with no working scores (2) Ignore SF except 1 SF	**(2)**

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• half-equation	<u>Example of half-equation</u> $2Cl^- \rightarrow Cl_2 + 2e^{(-)}$ Allow multiples Allow $2Cl^- - 2e^{(-)} \rightarrow Cl_2$ Ignore state symbols even if incorrect DNA reverse equation	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • calculation of moles of HCl **(1)** • calculation of theoretical moles of Cl_2 produced **(1)** • calculation of theoretical volume of Cl_2 **(1)** • calculation of % yield **and** comparison with expected yield **(1)**	<u>Example of calculation</u> (5.0 x 5.0)÷1000 = 0.025 / 2.5 x 10^{-2} (mol) 0.025÷4 = 0.00625 /6.25 x 10^{-3} (mol) 0.00625 x 24000 = 150 (cm^3) % yield = (70÷150) x 100 = 46.7/47(%) **and** less than expected / did not achieve expected yield / expected yield is 75% of 150 =112.5 cm^3 Allow calculation of actual moles of Cl_2 for MP3, then calculation of yield based on moles for MP4: 70÷24000 = 2.9167 x 10^{-3} (mol) then % yield and comparison for MP4 (2.9167 x10^{-3} ÷ 0.00625) x 100 = 46.7/47(%) Ignore SF except 1 Allow TE at each stage	**(4)**

Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • the covalent bond in hydrogen chloride changes to an ionic bond in aqueous solution	Both types of bond required Accept covalent bond breaks, ions are formed Accept $HCl(g) \rightarrow H^+(aq) + Cl^-(aq)$ or $HCl(g) + H_20(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$	(1)

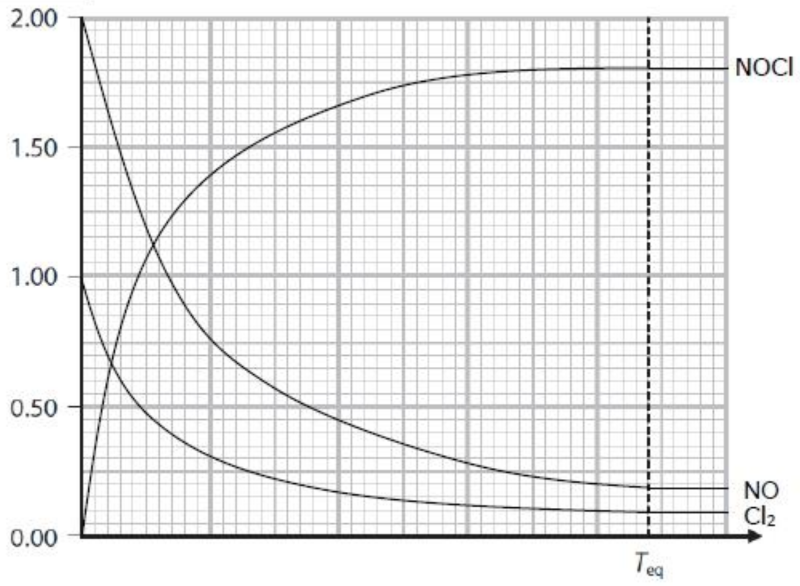
Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• correct species on each side of equation (1) • correct states for all species (1)	Example of equation: $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$ / $NH_4^+Cl^-(s)$ / $NH_4^+(s) + Cl^-(s)$ Allow (aq) or (g) for reactants Do not award (liquid) for either reactant Two products will lose both marks	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: • first observation (1) • second observation (1)	Allow observations in any order Sodium carbonate/Na_2CO_3/(white) solid dissolves/disappears/forms a colourless solution Effervescence/fizzing/bubbles Ignore gas/carbon dioxide given off Do not award if any named gas other than carbon dioxide, eg hydrogen or oxygen	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iv)	A description that makes reference to the following points: • remove a fixed amount of one solution using a pipette into a conical flask and fill up the burette with other solution **(1)** • add a named indicator **and** colour change **(1)** • add solution from burette to flask until indicator changes colour **(1)** • technique mark **(1)** • repeat titrations (until concordant results obtained) **(1)**	Allow use of any suitable flask in place of conical flask. Allow any recognised acid/base indicator: methyl red / orange, phenolphthalein etc. Ignore litmus /UI. Do not award reversed colour change Do not penalise reverse colour change again here. Any one from: Rinsing burette/pipette with appropriate solution, use of white tile, adding slowly, swirling flask etc. Ignore mention of 'rough' or 'trial' runs etc	**(5)**

Q19.

Question Number	Answer	Additional Guidance	Mark
(i)	• calculation of the moles of NO present at equilibrium (1) • calculation of the moles of Cl_2 present at equilibrium (1)	Example of calculation $2 - 1.82 = 0.18$ (mol) $1 - \frac{1.82}{2} = 0.09$ (mol) Allow TE	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• line starting at 2.00 and ending at 0.18 (1) • line starting at 1.00 and ending at 0.09 (1) • line starting at 0.00 and ending at 1.82 (1)	 Ignore lack of labels Allow any reasonable curves, curving in the direction shown, with no maximum or minimum Do not award straight lines If no marks awarded, allow (1) for 3 correct starting points and / or (1) for 3 correct finishing points Ignore lines going past T_{eq} unless they are clearly far from horizontal (allow the line to go up or down by 1 square from value at T_{eq} Allow TE on answers to (i)	(3)

Question Number	Answer	Mark
(iii)	The only correct answer is **B** ($K_c = \frac{[NOCl]^2}{[NO]^2[Cl_2]}$) ***A** is not correct because this is multiplying [NOCl] and [NO] by 2 rather than squaring* ***C** is not correct because this is multiplying by 2 and is upside down* ***D** is not correct because this is upside down*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iv)	An answer that makes reference to the following points: • equilibrium shifts to favour the endothermic direction (which is the backward reaction)	Answer must make reference to either exo- or endothermic or to significance of negative ΔH Allow the backward reaction is endothermic (so yield decreases) Allow the forward reaction is exothermic so reaction shifts to the left Ignore just forward reaction is exothermic Do not award 'the rate of the forward reaction decreases'	**(1)**

Q20.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to • propanal is condensed back (to the pear-shaped flask) **(1)** • so propanal is (further) oxidised (to propanoic acid) or propanal is more readily oxidised than propan-1-ol **(1)**	Allow aldehyde for propanal Allow 'apparatus is reflux' Allow propanal is not being removed /distilled off (from the oxidising agent) Ignore just 'reacts further' Do not award reference to propanal being completely oxidised	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• (+)VI	Allow (+) six / (+)6 / six (+) / 6(+)	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• balanced equation	<u>Example of equation</u> $CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO + 2H^+ + 2e^-$	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iv)	• provides a surface for bubbles to form / enables smaller bubbles to form / provides nucleation sites for bubbles or to prevent large bubbles forming	Allow distribution of heat more evenly / to prevent superheating Ignore mixing / to stop bumping / spitting / explosion / liquid splashing out / vigorous reaction / loss of reactants Do not award reference to large gas molecules	**(1)**

Question Number	Answer	Additional Guidance	Mark
(v)	• (**M1**) evaluation of number of moles of propan-1-ol **(1)** Method one using masses for percentage calculation • (**M2**) evaluation of maximum mass of propanal **(1)** • (**M3**) percentage yield **(1)** or Method two using moles for percentage calculation • (**M2**) evaluation of actual moles of propanal **(1)** • (**M3**) percentage yield **(1)**	<u>Example of calculation</u> n(propan-1-ol) = (1.50 ÷ 60) = 0.025 (mol) n(propan-1-ol) = n(propanal) max m(propanal) = (0.025 x 58) = 1.45 (g) %Yield = ((0.609 ÷ 1.45) x 100) = 42 % n(propanal) = (0.609 ÷ 58) = 0.0105 (mol) %Yield =((0.0105 ÷ 0.025) x 100) = 42 % Allow TE at each stage Ignore SF except 1SF Penalise incorrect M_r values once only Correct answer without working scores (3)	**(3)**

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Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • calculation of mass of carbon required **(1)** • calculation of total mass of reactants **and** mass of reactants = mass of products **(1)** **OR** • mathematical expression of total mass of reactants/products **(1)** • evaluation **(1)**	Example of calculations Moles of water = moles of carbon Moles of carbon =1000000 ÷ 18 = 55556 / 5.5556×10^4 Mass of carbon = 55556 x12 $\div 10^3$ = 672 / 666.67 (kg) Answer depends on no of SF used for moles of carbon. Check. Mass of reactants = mass of products = 1000 + 666.72 = 1666.7 (kg) $\frac{1000(18+12)}{18}$ or $\frac{1000(28+2)}{18}$ 1666.7 (kg) Ignore SF except 1 SF Allow TE throughout Correct answer with no working scores (2)	**(2)**