PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 2: THE ELEMENTS OF GROUPS 1 AND 2

SCORE	PERCENTAGE
/153	%

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Q1.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which property **decreases** as Group 2 of the Periodic Table is descended?

☒ **A** reactivity of the elements

☒ **B** solubility of the hydroxides

☒ **C** solubility of the sulfates

☒ **D** thermal stability of the carbonates

(Total for question = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

Q2.

A colourless solid, Q, was warmed with sodium hydroxide solution. A gas was evolved which turned damp red litmus paper blue. What is solid Q?

(1)

☒ **A** $NaNO_3$

☒ **B** NH_4Cl

☒ **C** NaCl

☒ **D** $Ca(NO_3)_2$

(Total for question = 1 mark)

Q3.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A white solid, **X**, gives a red colour in the flame test and a cream precipitate forms when acidified silver nitrate solution is added to a solution of **X**.

(a) What is the white solid, **X**?

(1)

☒ **A** lithium chloride

☒ **B** calcium chloride

☒ **C** strontium bromide

☒ **D** barium bromide

(b) What causes the flame colour to be red?

(1)

☒ **A** electrons absorb blue and green light as they are promoted

☒ **B** electrons emit red light as they are promoted

☒ **C** blue and green light is absorbed as electrons return to lower energy levels

☒ **D** red light is emitted as electrons return to lower energy levels

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 2 marks)

Q4.

Magnesium oxalate, MgC_2O_4 , decomposes on heating to form magnesium carbonate and carbon monoxide.

$$MgC_2O_4(s) \rightarrow MgCO_3(s) + CO(g)$$

(a) A 6.0 g sample of magnesium oxalate was heated for three minutes but the decomposition was only 70 % complete.

Calculate the total mass of solid that remains.

(4)

(b) In practice, magnesium carbonate also decomposes on stronger heating.

Describe and explain the trend in the thermal decomposition of Group 2 carbonates.

(3)

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(c) Suggest why a pure sample of magnesium carbonate will **not** be produced from the decomposition of magnesium oxalate even if the sample is heated for longer.

(1)

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(Total for question = 8 marks)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

(a) A pellet of sodium hydroxide has a mass of 0.700 g.

Some pellets were dissolved to make 350 cm^3 of 0.25 mol dm^{-3} solution.

[M_r value: NaOH = 40]

How many pellets were dissolved?

(1)

☒ **A** 4

☒ **B** 5

☒ **C** 8

☒ **D** 125

(b) 25.0 cm^3 of the sodium hydroxide solution prepared in (a) was placed in a conical flask and titrated with sulfuric acid.

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

Calculate the number of moles of sulfuric acid that reacted.

(1)

☒ **A** 0.0031

☒ **B** 0.0063

☒ **C** 0.013

☒ **D** 0.044

(c) Phenolphthalein indicator was used for the titration in (b).

What was the colour change at the endpoint?

(1)

☒ **A** colourless → pink

☒ **B** pink → colourless

☒ **C** orange → yellow

☒ **D** yellow → orange

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 3 marks)

Q6.

Which statement is correct?

(1)

☒ **A** barium carbonate is less stable to heat than magnesium carbonate

☒ **B** barium hydroxide is less soluble in water than magnesium hydroxide

☒ **C** barium sulfate is less soluble in water than magnesium sulfate

☒ **D** barium metal is less reactive with water than magnesium metal

(Total for question = 1 mark)

Q7.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Barium chloride solution, $BaCl_2(aq)$, reacts with gallium sulfate solution, $Ga_2(SO_4)_3(aq)$ to form a precipitate of barium sulfate, $BaSO_4(s)$.

What is the minimum volume of 0.100 mol dm^{-3} barium chloride needed to precipitate **all** the sulfate ions in 200 cm^3 of 0.05 mol dm^{-3} gallium sulfate?

☒ **A** 100 cm^3

☒ **B** 200 cm^3

☒ **C** 300 cm^3

☒ **D** 400 cm^3

(Total for question = 1 mark)

Q8.

This question is about calcium carbonate, $CaCO_3$.

(a) Calcium carbonate decomposes on heating.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Explain why calcium carbonate decomposes at a higher temperature than magnesium carbonate, in terms of the charge and size of the cations.

(3)

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(b) Calcium carbonate reacts with dilute hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

A student determines the initial rate of this reaction by collecting the carbon dioxide in a gas syringe and measuring the volume at regular time intervals.

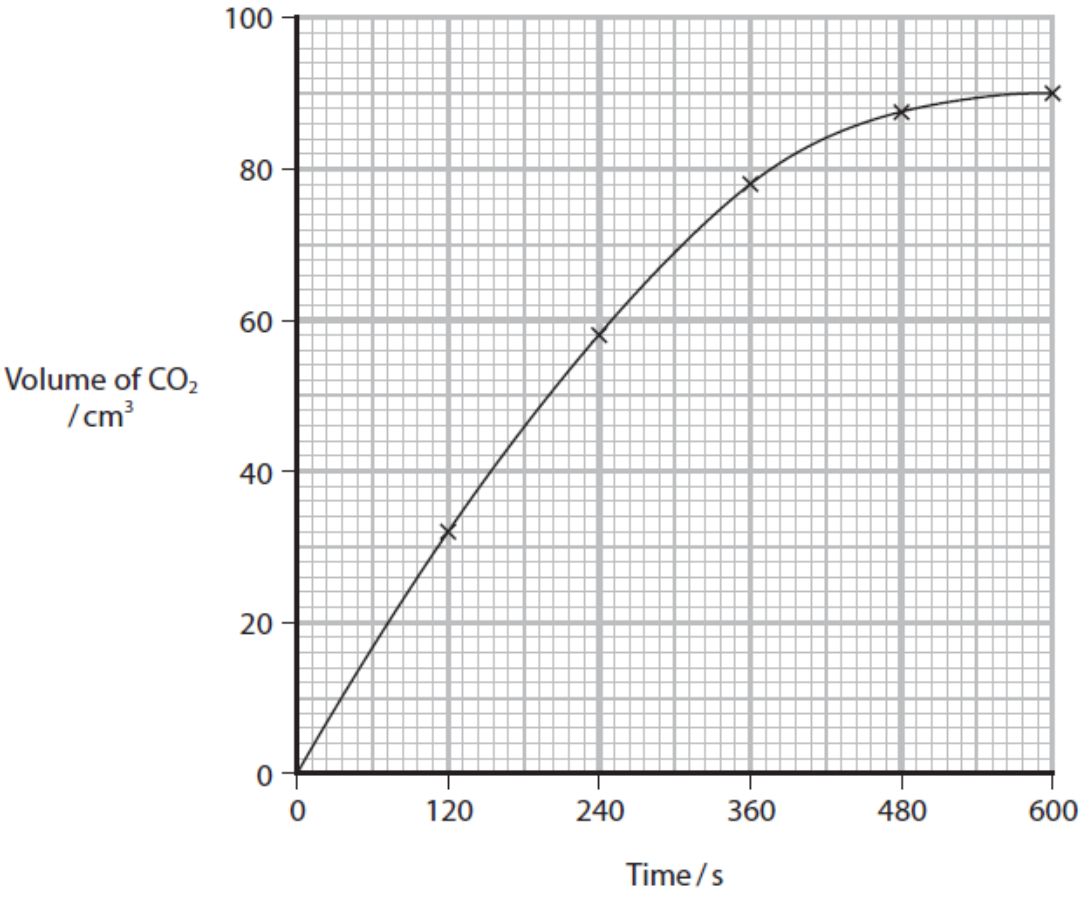
(i) The gas syringe can measure a maximum of 100 cm^3 of gas.

Calculate the **maximum** volume of 0.500 mol dm^{-3} hydrochloric acid that can be added to excess calcium carbonate at room temperature and pressure (r.t.p.) without exceeding the measurable volume of the gas syringe.

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

(3)

(ii) The results of the student's experiment are shown on the graph.



Calculate the initial rate of this reaction.
You **must** show your working on the graph.
Include units in your answer.

(3)

(iii) The student repeats the experiment but uses hydrochloric acid with a concentration of 0.250 mol dm^{-3}. All other variables are kept the same.

State what would happen to the initial rate of reaction and the final volume of carbon dioxide collected.

(1)

Initial rate of reaction

.....

Final volume of carbon dioxide collected

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(Total for question = 10 marks)

Q9.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A student carries out two sets of titrations, one using methyl orange and the other using phenolphthalein as indicators.

The conical flask contains sodium hydroxide solution and the burette contains hydrochloric acid.

What are the colour changes at the end-points?

		Methyl orange	Phenolphthalein
☒	**A**	red to orange	colourless to pink
☒	**B**	yellow to orange	pink to colourless
☒	**C**	red to orange	pink to colourless
☒	**D**	yellow to orange	colourless to pink

(Total for question = 1 mark)

Q10.

This question is about compounds containing Group 2 elements.

(a) Hydrated magnesium nitrate has the formula $Mg(NO_3)_2.xH_2O$.

A student devised an experiment to determine the value of **x** by leaving 5.12 g of hydrated magnesium nitrate for several hours in a warm oven. After this time, the solid remaining had a mass of 2.97 g.

(i) State why the student used a warm oven to remove the water from the

hydrated salt, rather than direct heating with a Bunsen burner.

(1)

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(ii) Use the data obtained by the student to calculate the value of **x**.

You **must** show your working.

(4)

(b) Magnesium carbonate, MgCO3, is a white solid used as an additive in foods.

(i) Explain, in terms of energy changes, why magnesium carbonate is insoluble in water.

(2)

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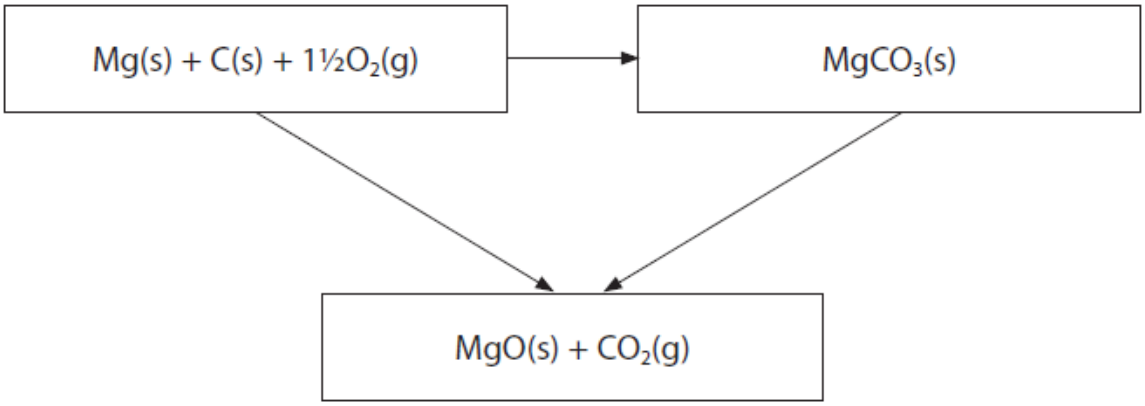
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(ii) The Hess cycle and data to calculate the enthalpy change for the thermal decomposition of MgCO3 are shown.



Compound	$\Delta_f H^{\ominus}$ / kJ mol^{-1}
$CO_2(g)$	−394
MgO(s)	−602
$MgCO_3(s)$	−1096

Calculate the enthalpy change for the thermal decomposition of $MgCO_3$.

(2)

(iii) Explain the trend in thermal stability of Group 2 carbonates.

(4)

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(Total for question = 13 marks)

Q11.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Which of these compounds does **not** produce a colour in a flame test, and produces an alkaline gas when warmed with sodium hydroxide solution?

☐ **A** $Ca(OH)_2$

☐ **B** $Mg(OH)_2$

☐ **C** NH_4Cl

☐ **D** $BeCl_2$

(Total for question = 1 mark)

Q12.

Equations for four reactions of copper or its compounds are shown.

Reaction 1 $2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$

Reaction 2 $Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

Reaction 3 $2Cu^+ \rightarrow Cu + Cu^{2+}$

Reaction 4 $CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$

(a) Which is a disproportionation reaction?

(1)

☒ **A** Reaction 1

☒ **B** Reaction 2

☒ **C** Reaction 3

☒ **D** Reaction 4

(b) Which is an acid-base reaction?

(1)

☒ **A** Reaction 1

☒ **B** Reaction 2

☒ **C** Reaction 3

☒ **D** Reaction 4

(Total for question = 2 marks)

Q13.

Magnesium ethanedioate (MgC_2O_4) decomposes on gentle heating to form magnesium carbonate and carbon monoxide.

$$MgC_2O_4 \rightarrow MgCO_3 + CO$$

(a) (i) State why the thermal decomposition of magnesium ethanedioate should be carried out in a fume cupboard.

(1)

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(ii) After heating a 6.0 g sample of magnesium ethanedioate for three minutes, the decomposition was 70 % complete.

Calculate the total mass of the solid mixture that remains.

(4)

(b) Magnesium carbonate undergoes thermal decomposition at a higher temperature than magnesium ethanedioate.

$$MgCO_3 \rightarrow MgO + CO_2$$

Explain the trend in the thermal decomposition of Group 2 carbonates going down the group.

(3)

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(Total for question = 8 marks)

Q14.

This question is about ethanoic acid and some related salts.

(a) A test to confirm the presence of an aqueous acid is adding a small amount of solid sodium carbonate to the solution.

Describe **two** observations you would **see** in this test.

(2)

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(b) Sodium ethanoate is a component of reusable hand warmers. In use, a supersaturated solution of sodium ethanoate recrystallises to form solid hydrated sodium ethanoate, releasing energy.

$CH_3COONa(aq) + 3H_2O(l) \rightarrow CH_3COONa.3H_2O(s) \quad \Delta_r H = -19.7 \text{ kJ mol}^{-1}$

A hand warmer has a mass of 63.2 g and forms 20.1 g of hydrated sodium ethanoate on recrystallisation.

Calculate the maximum temperature reached by the hand warmer if its initial temperature is 5.0°C.

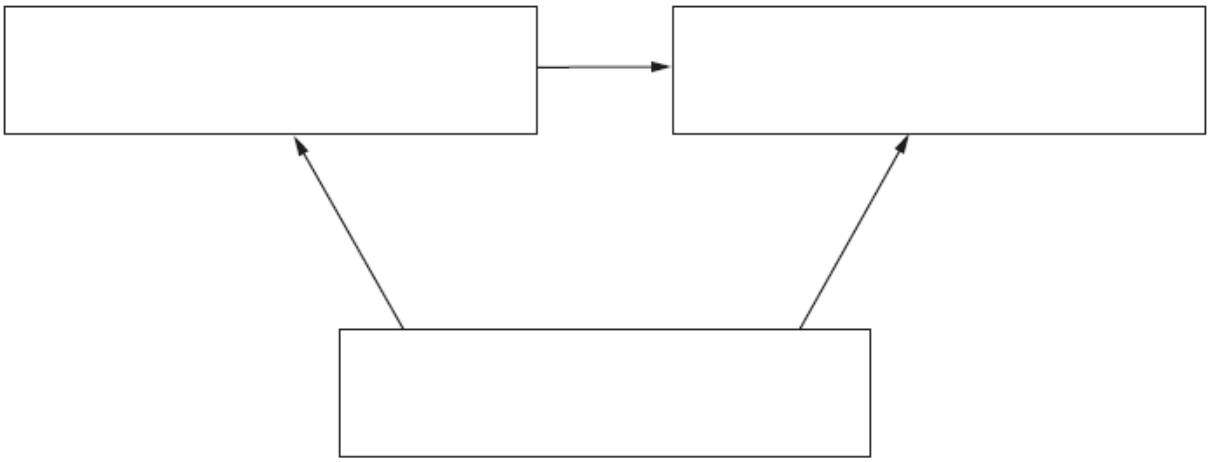
[Specific heat capacity of the hand warmer = 3.0 J $°C^{-1}$ g^{-1}]

(5)

(c) Ammonium ethanoate, $CH_3COONH_4(s)$, is used to control the pH of foods. It can be formed by the reaction of pure ethanoic acid, $CH_3COOH(l)$, with ammonium carbonate, $(NH_4)_2CO_3(s)$.

Calculate the standard enthalpy change for this reaction by completing the Hess cycle and using the data shown.

(5)



Compound	Enthalpy change of formation / kJ mol^{-1}
$CH_3COOH(l)$	−484.5
$(NH_4)_2CO_3(s)$	−939.9
$CH_3COONH_4(s)$	−586.3
$CO_2(g)$	−393.5
$H_2O(l)$	−285.8

(d) Ammonium carbonate, $(NH_4)_2CO_3$, is an ingredient in cleaning solutions for camera lenses.

These are aqueous solutions which contain no more than 1.8 g of ammonium carbonate in 100 cm^3 of solution.

Calculate the maximum concentration, in mol dm^{-3}, of ammonium carbonate in such a solution.

(2)

(Total for question = 14 marks)

Q15.

Ethanedioic acid is a solid diprotic acid. A student used ethanedioic acid in a titration to find the concentration of a potassium hydroxide solution.

The equation for the reaction is:

$$2KOH + (COOH)_2 \rightarrow (COOK)_2 + 2H_2O$$

(a) Calculate the mass of ethanedioic acid that should be used to make 1000 cm^3 of a 0.0500 mol dm^{-3} solution in water.

Give your answer to an appropriate number of significant figures.

[Molar mass of ethanedioic acid = 90.0 g mol^{-1}].

(2)

(b) A student decided to check to see if phenolphthalein was a suitable indicator for this titration. The student measured 400 cm^3 of the 0.0500 mol dm^{-3} ethanedioic acid into a beaker and added a few drops of phenolphthalein indicator.

Calculate the minimum mass of solid potassium hydroxide that should be added to produce a colour change.

(2)

*(c) A student used a 0.0500 mol dm^{-3} solution of ethanedioic acid to find an accurate concentration of a potassium hydroxide solution which was known to have an approximate concentration of 0.1 mol dm^{-3}.

Describe a procedure to obtain reliable titration results using standard laboratory equipment.

(6)

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(Total for question = 10 marks)

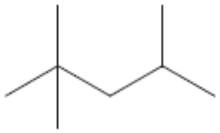
Q16.

Fuels

Fuels burn in oxygen to release a lot of energy.

Many hydrocarbons and alcohols are used as fuels. During complete combustion, they produce carbon dioxide and water.

Petrol contains 2,2,4-trimethylpentane, an isomer of octane, that promotes smooth combustion.



2,2,4-trimethylpentane

Alcohols, such as methanol and ethanol, can be used as fuels either on their own or as additives in petrol.

(a) The standard enthalpy change of combustion, $\Delta_c H^{\ominus}$, of 2,2,4-trimethylpentane is −5461 kJ mol^{-1}.

(i) State the two standard conditions for this enthalpy change.

(1)

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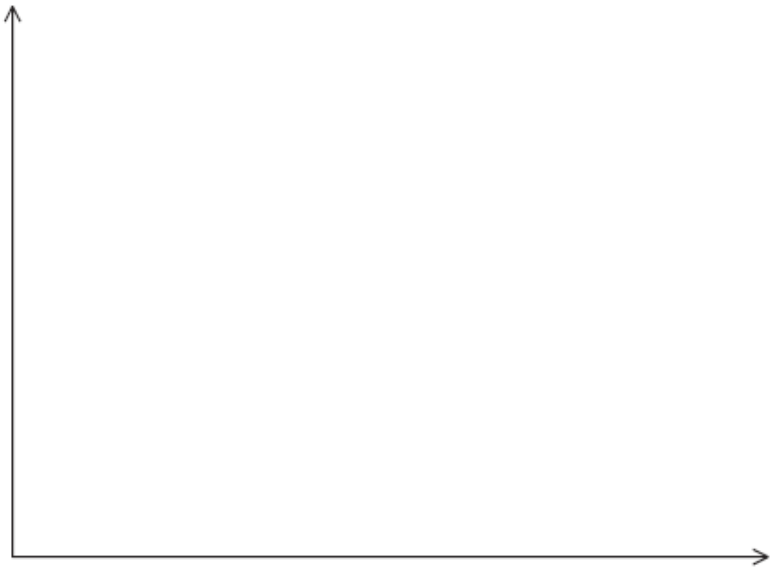
(ii) Write the equation for the complete combustion of 2,2,4-trimethylpentane, using **molecular** formulae.

State symbols are not required.

(2)

(iii) Draw a labelled enthalpy level diagram for the complete combustion of 2,2,4-trimethylpentane.

(2)

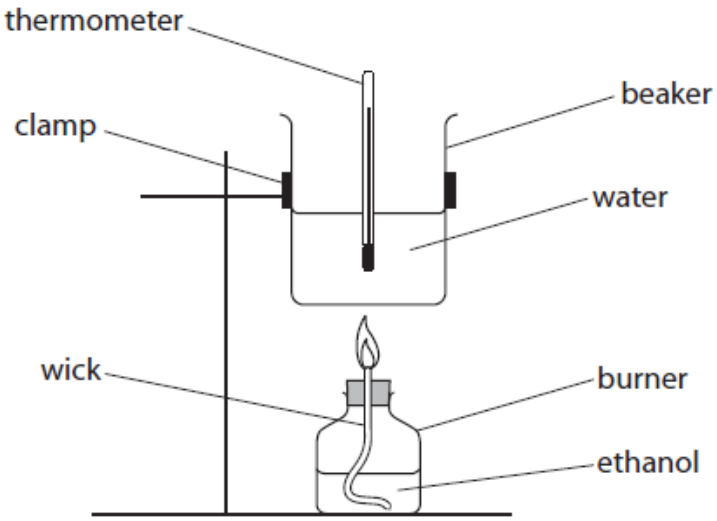


(iv) Calculate the heat energy released during the complete combustion of 1 dm^3 of 2,2,4-trimethylpentane.

[Density of 2,2,4-trimethylpentane = 0.692 g cm^{-3}]

(3)

(b) In an experiment to determine the enthalpy change of combustion of ethanol, C_2H_5OH, a student used the apparatus shown.



Results:

Mass of water = 100.0 g

Mass of ethanol used = 0.305 g

Temperature rise of water = 13.2°C

(i) Calculate the enthalpy change of combustion of ethanol.

Give your answer to an appropriate number of significant figures, and include a sign and units.

[Specific heat capacity of water = 4.18 J $g^{-1}°C^{-1}$]

(4)

(ii) The uncertainty in each thermometer reading is ±0.05 °C.

Calculate the percentage uncertainty in the temperature rise in this experiment.

(1)

(iii) The student looked in a data book and found the actual value for the standard enthalpy change of combustion of ethanol was more exothermic than the experimental value obtained.

Give **two** reasons for the difference between the data book value and the experimental value, other than referring to standard conditions.

(2)

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(c) The enthalpy changes for the conversion of four compounds in the gas phase into their constituent atoms are shown.

$$H_2O(g) \rightarrow 2H(g) + O(g) \qquad \Delta_r H = +928\ kJ\ mol^{-1}$$

$$CH_4(g) \rightarrow C(g) + 4H(g) \qquad \Delta_r H = +1740\ kJ\ mol^{-1}$$

$$CH_3OH(g) \rightarrow C(g) + 4H(g) + O(g) \qquad \Delta_r H = +2105\ kJ\ mol^{-1}$$

$$C_2H_5OH(g) \rightarrow 2C(g) + 6H(g) + O(g) \qquad \Delta_r H = +3322\ kJ\ mol^{-1}$$

Calculate the bond enthalpy of the C—C bond, in kJ mol^{-1}.
You **must** show your working.

(3)

(d) Ethanol can be manufactured by reacting ethene with steam.

$$C_2H_4(g) + H_2O(g) \leftrightarrow C_2H_5OH(g) \qquad \Delta_r H = -45\ kJ\ mol^{-1}$$

This reaction is usually carried out in industry at 300 °C and 70 atm pressure using a catalyst.

Explain the effect on the equilibrium position and the equilibrium yield of ethanol if the reaction is carried out at 300°C and 200 atm pressure.

(2)

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(Total for question = 20 marks)

Q17.

This question is about Group 1 metals.

(a) When potassium is placed into a beaker of cold water, potassium hydroxide and hydrogen are formed.

(i) Write the equation for this reaction. Include state symbols.

(2)

(ii) This is a redox reaction.

State which element is oxidised and which is reduced.
Justify your answer by giving the initial and final oxidation numbers of any element that changes oxidation state.

(2)

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(iii) The reaction of potassium with water is very vigorous and a flame is seen.

State the colour of the flame.

(1)

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(b) The label has come off a bottle known to contain **M**, a Group 1 metal which is stored in oil.

A student carried out an experiment to determine the identity of **M**.

Procedure

Step **1**

A small piece of **M** was wiped with tissue paper to remove the oil.
The piece of **M** was weighed and placed in a beaker of distilled water.

Step **2**

After the reaction had finished, the contents of the beaker and washings were transferred to a 250.0 cm^3 volumetric flask. The solution was made up to the mark with distilled water and mixed thoroughly.

Step **3**

A pipette was used to transfer 25.0 cm^3 portions of this solution to conical flasks. Each portion was then titrated with hydrochloric acid of concentration 0.400 mol dm^{-3}.

Results

Mass of metal, **M**	0.37 g
Mean titre of hydrochloric acid	12.80 cm^3

The reaction taking place is shown.

$$\mathbf{M}OH(aq) + HCl(aq) \rightarrow \mathbf{M}Cl(aq) + H_2O(l)$$

(i) The indicator used was phenolphthalein.

State the colour **change** at the end-point.

(2)

from ..... to .....

(ii) Calculate the relative atomic mass of **M** and use it to identify the Group 1 metal, **M**.

(4)

(c) Another student repeated the experiment, using a different sample of metal **M**, but did not wipe off the oil before weighing it.

State how this would change the calculated value of the relative atomic mass of **M**. Justify your answer.

(2)

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(Total for question = 13 marks)

Q18.

Group 2 hydroxides, $M(OH)_2$, are used to neutralise acids.

(a) Write an equation for the reaction of calcium with cold water.

State symbols are not required.

(1)

(b) Explain why a saturated solution of calcium hydroxide is more alkaline than a saturated solution of magnesium hydroxide.

(2)

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(c) A solution was tested for the presence of carbonate ions.

Dilute hydrochloric acid was added to the solution and the gas given off was bubbled through limewater (aqueous calcium hydroxide). A white precipitate formed.

(i) Write the **ionic** equation for the formation of the gas.

State symbols are not required.

(1)

(ii) Write the equation for the formation of the precipitate.

Include state symbols.

(2)

(d) Magnesium hydroxide can be used to neutralise hydrochloric acid in the stomach to relieve acid indigestion.

$$Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$$

Calculate the minimum mass of magnesium hydroxide needed to neutralise 0.150 mol of hydrochloric acid.

Give your answer to an appropriate number of significant figures.

(3)

(Total for question = 9 marks)

Q19.

Which statement is **not** explained by hydrogen bonding?

(1)

☒ **A** all Group 1 hydroxides are soluble in water

☒ **B** many simple alcohols are soluble in water

☒ **C** the density of ice is less than the density of liquid water at 0 °C

☒ **D** the melting temperature of water is abnormally high

(Total for question = 1 mark)

Q20.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

What volume, in dm^3, of hydrogen gas will be produced when 3.00 g of lithium is reacted with water at room temperature and pressure (r.t.p.)?

$$2Li + 2H_2O \rightarrow 2LiOH + H_2$$

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

☒ **A** 0.217

☒ **B** 0.435

☒ **C** 5.22

☒ **D** 10.4

(Total for question = 1 mark)

Q21.

Compound X gives a red flame test colour and a white precipitate on addition of dilute hydrochloric acid followed by barium chloride solution. Which compound is X?

(1)

☒ **A** calcium chloride

☒ **B** lithium sulfate

☒ **C** potassium sulfate

☒ **D** strontium chloride

(Total for question = 1 mark)

Q22.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

In an oxide of potassium, the oxidation number of oxygen is $-\frac{1}{2}$.

What is the formula of this oxide?

☒ **A** K_2O

☒ **B** K_2O_2

☒ **C** K_2O_3

☒ **D** KO_2

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q23.

A white solid **X** produces a red colour in a flame test.

When aqueous silver nitrate and nitric acid are added to a solution of **X**, a cream precipitate is formed which dissolves in concentrated aqueous ammonia.

What is the formula of **X**?

☒ **A** $SrBr_2$

☒ **B** NaBr

☒ **C** LiCl

☒ **D** BaI_2

(Total for question = 1 mark)

Q24.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer

with a cross ☒.

Compound **Q** gives off nitrogen dioxide when heated, and produces a red colour in a flame test.

(a) Which of these compounds could be **Q**?

(1)

☐ **A** barium nitrate

☐ **B** lithium nitrate

☐ **C** magnesium nitrate

☐ **D** rubidium nitrate

(b) Which colour and test results are correct for nitrogen dioxide gas?

(1)

	Colour of nitrogen dioxide	Colour change of damp litmus paper
☐ **A**	brown	blue to red
☐ **B**	brown	red to blue
☐ **C**	colourless	blue to red
☐ **D**	colourless	red to blue

(Total for question = 2 marks)

Q25.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which is the ionic equation for the reaction of solid barium carbonate with dilute hydrochloric acid?

☐ **A** $BaCO_3(s) + 2H^+(aq) \rightarrow Ba^{2+}(aq) + CO_2(g) + H_2O(l)$

☐ **B** $Ba_2CO_3(s) + 2H^+(aq) \rightarrow 2Ba^+(aq) + CO_2(g) + H_2O(l)$

☐ **C** $CO_3^{2-}(s) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$

☐ **D** $CO_3^{2-}(s) + 2HCl(aq) \rightarrow 2Cl^-(aq) + CO_2(g) + H_2O(l)$

(Total for question = 1 mark)

Q26.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Several factors may affect ionisation energies:

I) the number of protons increases

II) the outer electron is further from the nucleus

III) the amount of shielding increases

IV) the number of unpaired outer electrons increases

Which factors explain the **decrease** in ionisation energy as Group 1 is descended?

☒ **A** I and II

☒ **B** II and III

☒ **C** III and IV

☒ **D** I, II, III and IV

(Total for question = 1 mark)

Q27.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Magnesium nitrate decomposes on heating.

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

What is the total volume of gas formed at room temperature and pressure (r.t.p.) when 0.005 mol of magnesium nitrate decomposes completely?

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

☒ **A** 600 cm^3

☒ **B** 300 cm^3

☒ **C** 240 cm^3

☒ **D** 120 cm^3

(Total for question = 1 mark)

Q28.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which nitrate forms oxygen as the **only** gaseous product on heating?

☒ **A** $LiNO_3$

☒ **B** $NaNO_3$

☒ **C** $Mg(NO_3)_2$

☒ **D** $Ca(NO_3)_2$

(Total for question = 1 mark)

Q29.

Exactly 50.0 cm^3 of 2.00 mol dm^{-3} nitric acid reacts with 50.0 cm^3 of 1.00 mol dm^{-3} barium hydroxide to form a neutral solution of barium nitrate.

(a) What is the concentration, in mol dm^{-3}, of barium nitrate in the solution?

(1)

☒ **A** 0.05

☒ **B** 0.50

☒ **C** 1.00

☒ **D** 2.00

(b) The volume of the nitric acid is measured using a burette.

Each burette reading has an uncertainty of ± 0.05 cm^3.

What is the percentage uncertainty in measuring 50.00 cm^3 of the nitric acid?

(1)

☒ **A** ± 0.40%

☒ **B** ± 0.20%

☒ **C** ± 0.10%

☒ **D** ± 0.05%

(Total for question = 2 marks)

Q30.

Potassium chlorate(V), $KClO_3$, is a crystalline solid used in fireworks.

It is produced by the Liebig Process in two stages.

Stage **1** Chlorine gas is passed through hot calcium hydroxide solution forming calcium chlorate(V), $Ca(ClO_3)_2$.

$$6Ca(OH)_2(aq) + 6Cl_2(g) \rightarrow Ca(ClO_3)_2(aq) + 5CaCl_2(aq) + 6H_2O(l)$$

Stage **2** Potassium chloride solution is then added to form potassium chlorate(V).

$$Ca(ClO_3)_2(aq) + 2KCl(aq) \rightarrow 2KClO_3(aq) + CaCl_2(aq)$$

The solution is heated to reduce its volume and then allowed to crystallise.
The crystals are filtered off.
The remaining filtrate is evaporated further to obtain more crystals.

(a) (i) Write the **overall** equation for the Liebig Process.
State symbols are not required.

(1)

(ii) Calculate the **overall** atom economy by mass for the production of potassium chlorate(V), $KClO_3$, using your equation in (a)(i).

(3)

(b) Explain the type of reaction that takes place in Stage 1 of the Liebig Process, using oxidation numbers.

$$6Ca(OH)_2(aq) + 6Cl_2(g) \rightarrow Ca(ClO_3)_2(aq) + 5CaCl_2(aq) + 6H_2O(l)$$

(3)

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(c) The crystals of potassium chlorate(V) formed also contain some halide ion impurities.

(i) Describe a chemical test on a solution of these crystals to **confirm** that the impurities present are chloride ions rather than bromide ions. Include the expected results.

(3)

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(ii) 1.52 g of impure potassium chlorate(V), formed in the Liebig Process, was heated until the mass of solid remaining was constant at 1.02 g.

The reaction that occurred was

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

The impurities present did not decompose on heating.

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

(5)

(d) In fireworks, potassium chlorate(V) decomposes. This thermal decomposition takes place in two stages with a solid catalyst.

$$4KClO_3 \rightarrow KCl + 3KClO_4$$

$$KClO_4 \rightarrow KCl + 2O_2$$

(i) Give the systematic name of $KClO_4$.

(1)

.....

(ii) A student investigated the role of the catalyst in this reaction.

Procedure

Step **1** Heat a sample of $KClO_3$, in a test tube, with a known mass of insoluble catalyst until the mass remains constant.

Step **2** Mix the contents of the test tube with water.

Step **3** Filter the mixture and rinse with deionised water.

Step **4** Dry the remaining solid.

Step **5** Measure the mass of the dry solid.

Explain how each of the steps in this procedure is needed to show that the catalyst is **not** used up in this reaction.

(4)

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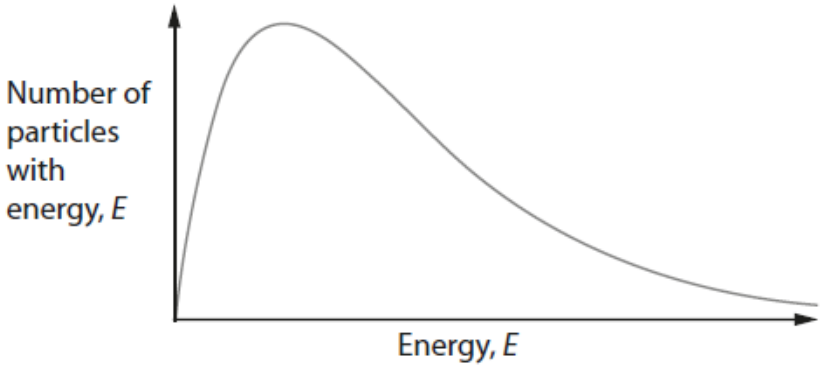
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(e) Explain, using the diagram, how a catalyst speeds up a chemical reaction.

(2)



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(Total for question = 22 marks)

Mark Scheme

Q1.

Question Number	Answer	Mark
	The only correct answer is C (solubility of the sulfates) *A is not correct because the reactivity of the elements increases down the group* *B is not correct because the solubility of the hydroxides increases down the group* *D is not correct because the thermal stability of the carbonates increases down the group*	1

Q2.

Question number	Answer	Mark
	B NH_4Cl	1

Q3.

Question number	Answer	Mark
(a)	**The only correct answer is C** (strontium bromide) *A is not correct because the chloride will give a white precipitate* *B is not correct because the chloride will give a white precipitate* *D is not correct because the barium will give a green flame*	(1)

Question number	Answer	Mark
(b)	**The only correct answer is *D*** (red light is emitted as electrons return to lower energy levels) *A is not correct because the electrons absorb heat as they are promoted* *B is not correct because the electrons emit light when they return to ground state* *C is not correct because light energy is emitted when the electrons return to the ground state*	(1)

Q4.

Q	Answer	Additional Guidance	Mark
(a)		Example of a calculation:	**4**
	• calculation of mass of oxalate remaining **(1)**	6.0 × 0.3 = **1.8** (g) will remain as oxalate	
	• 4.2 g will decompose to carbonate **(1)**	6.0 – 1.8 = **4.2** (g) will decompose	
	• M_r of oxalate and carbonate used to give mass of carbonate **(1)**	(4.2 ÷ 112.3) × 84.3 = **3.15** (g)	
	• final answer **(1)**	3.15 + 1.8 = **4.95** (g)	
	Alternative method 1:		
	• calculate moles of oxalate **(1)**	6.0 ÷ 112.3 = **0.0534** (mol)	
	• calculate 70% **(1)**	0.7 × 0.0534 = **0.0374** (mol)	
	• calculation of M_r of CO and mass lost **(1)**	28 × 0.0373 = **1.047** (g)	
	• subtract from original mass **(1)**	6.0 – 1.047 = **4.95**(3) (g)	
	Alternative method 2:		
	• calculate mass that has decomposed **(1)**	6.0 × 0.7 = **4.2** (g)	
	• calculate moles that have decomposed **(1)**	(4.2 ÷ 112.3) = **0.0374** (mol)	
	• calculate mass of carbonate **(1)**	0.0374 × 84.3 = **3.15** (g)	
	• addition of remaining solid **(1)**	3.15 + (6 – 4.2) = **4.95** (g)	

	Alternative method 3:		
	• M_r of CO and oxalate **(1)**	28 **and** 112.3	
	• calculation of mass of CO **(1)**	6.0 × (28 ÷ 112.3) = **1.496** (g)	
	• 70% of mass of CO **(1)**	1.496 × 0.7 = **1.047** (g)	
	• subtraction of mass of CO **(1)**	6.0 – 1.047 = **4.95**(3) (g)	
		Ignore SF	
		Correct answer scores 4	

Q	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • the temperature of decomposition of carbonates / stability increases down the group **(1)** • (this is because) the size of the cation increases but has the same charge **(1)** • so is less polarising (of the C–O bond) **(1)**	Accept reverse arguments Allow charge density decreases (down the group) The trend down the group must be mentioned for all 3 marks to be awarded	**3**

Q	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points: • the magnesium carbonate may begin to decompose (before the oxalate decomposition is complete).	Allow the sample would be contaminated with magnesium oxide	**1**
		(Total for Question = 8 marks)	

Q5.

Q	Answer	Mark
(a)	**The only correct answer is B** (5) ***A*** *is incorrect because this is the rounded number of grams of NaOH needed* ***C*** *is incorrect because this is the mass of a pellet divided by the moles of NaOH* ***D*** *is incorrect because this is the moles of NaOH multiplied by 1000 and divided by 0.7*	**1**

Q	Answer	Mark
(b)	**The only correct answer is A** (0.0031 mol) ***B*** *is incorrect because this is the moles of sodium hydroxide* ***C*** *is incorrect because the number of moles of NaOH has been doubled instead of halved* ***D*** *is incorrect because this calculation has ignored the sample of 25.0 cm^3*	**1**

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Q	Answer	Mark
(c)	**The only correct answer is B** (pink → colourless) ***A*** *is incorrect because the indicator would start pink in sodium hydroxide* ***C*** *is incorrect because this is the opposite colour change for methyl orange indicator* ***D*** *is incorrect because this is the colour change for methyl orange* indicator	**1**

Q6.

Question Number	Answer	Mark
	The only correct answer is C (barium sulfate is less soluble in water than magnesium sulfate) *A is incorrect because carbonate thermal stability increases down Group 2* *B is incorrect because hydroxide solubility increases down Group 2* *D is incorrect because barium is more reactive than magnesium with water*	**(1)**

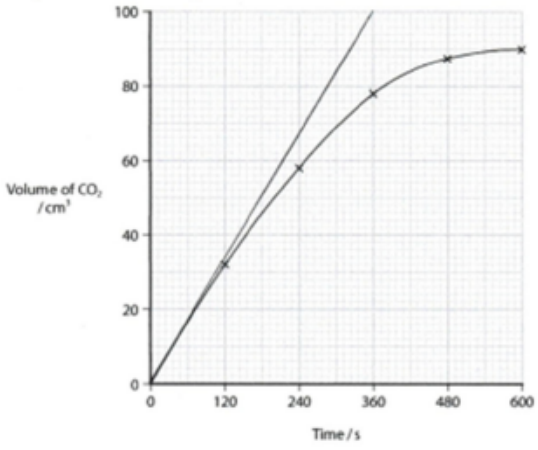
Q7.

Question Number	Correct Answer	Mark
	The only correct answer is C (300 cm^3) ***A*** *is incorrect as the stoichiometry has not been considered* ***B*** *is incorrect as the stoichiometry and the differences in concentration have not been considered* ***D*** *is incorrect as the stoichiometry has not been considered and the ratio of concentrations has been used the wrong way round*	**1**

Q8.

Question Number	Answer	Additional Guidance	Mark
(a)	An explanation that makes reference to the following points: • **Size (and charge)** calcium ion / Ca^{2+} has a larger (ionic) radius than a magnesium ion (but the same charge) **or** magnesium ion / Mg^{2+} has a smaller (ionic) radius / is smaller than a calcium ion (but the same charge) **(1)** • **Polarising power** so calcium ion / Ca^{2+} causes less polarisation / distortion **or** magnesium ion / Mg^{2+} causes more polarisation / distortion **(1)** • **What is polarised** of the carbonate ion / CO_3^{2-} / anion / negative ion / C–O bonds / C=O bonds /CO bonds **(1)**	Penalise omission of 'ion' or just magnesium / Mg / calcium / Ca without charge once only in M1 and M2 Allow reverse argument for magnesium ions in M1 and M2 Allow size for radius or just 'bigger / smaller' Allow ionic radius / size of cation increases down the group / decreases up the group Allow calcium carbonate has a larger **cation** Allow calcium ions have a lower charge density Allow calcium ions have more shells of electrons Ignore effective nuclear charge / mass : charge ratio Ignore atomic radius Ignore omission of same charge Do not award M1 if mention of different / incorrect charges on magnesium and calcium ions Allow polarising power of cation decreases down the group Allow Ca^{2+} causes less weakening of bonds for polarisation Do not award just 'the carbonate ion is less polarisable' for M2, although this can score M3 Allow electron cloud for ion Do not award reference to nitrate / N-O bonds Do not award reference to breaking unspecified bonds / (ionic) bond between cation and anion Do not award references to intermolecular forces	**(3)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• calculation of mol of CO_2 (1) • calculation of mol of HCl (1) • calculation of volume of HCl **and** corresponding volume unit (1)	Example of calculation: mol CO_2 = $\frac{100}{24\,000}$ = 0.0041667 / 4.1667 x 10^{-3} (mol) mol HCl = 2 x 0.0041667 = 0.0083333 / 8.3333 x 10^{-3} (mol) TE on M1 vol HCl = $\frac{0.0083333}{0.500}$ x 1000 = (16.667) = 16.6 cm^3 / 0.0166 dm^3 Do not award incorrect units e.g. cm^{-3} / dm^{-3} Allow 16.67 / 16.7 cm^3 as the theoretical volume of CO_2 is 100.02 / 100.2 cm^3 Do not award 17 cm^3 as the theoretical volume of CO_2 is 102 cm^3 so would exceed the measurable volume of the syringe Allow any number between 16 and 16.7 cm^3 / 0.016 and 0.0167 dm^3 inclusive TE on M2 Ignore SF except 1 SF Correct answer with units and no working scores (3) Accept fractions / correct working not evaluated for M1 and M2 e.g. 1/240, 1/120	(3)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)		Example of working:  	(3)
	• tangent drawn at t = 0	Tangent must touch the curve for at least 24 s (2 small squares horizontally) and extend to at least 20 cm^3	
	• gradient	Gradient = $\frac{100}{360}$ = 0.27778 (expected value 0.25 to 0.33 for tangent at t = 0) TE on tangent drawn at any time value If no tangent drawn, allow a selected point and y/x value e.g. 32/120 = 0.27	
	• units	Stand alone mark $cm^3\ s^{-1}$ or cm^3 / s or $\frac{cm^3}{s}$ Allow $cm^3\ s^-$	

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An answer that makes reference to the following point: • initial rate halves **and** final volume of CO_2 halves / is 45 (cm^3)	Allow initial rate decreases **and** final volume of CO_2 decreases Do not award any specific decrease (e.g. decrease by a factor of 4) except for half	(1)

Q9.

Question Number	Answer	Mark
	The only correct answer is B (yellow to orange and pink to colourless) ***A*** *is not correct because the phenolphthalein colour change is reversed and the methyl orange colour change is for acid to neutral* ***C*** *is not correct because the methyl orange colour change is for acid to neutral* ***D*** *is not correct because the phenolphthalein colour change is reversed*	1

Q10.

Question Number	Answer	Additional guidance	Mark
(a)(i)	• magnesium nitrate decomposes / breaks down (when heated with a Bunsen burner)	Ignore references to evaporation Do not award 'reacts with oxygen' Do not award **just** the idea that magnesium nitrate reacts Ignore products of decomposition even if incorrect Ignore 'spitting' / any references to removing water too quickly	(1)

Question Number	Answer	Additional guidance	Mark
(a)(ii)	• calculate mass of water removed **(1)** calculates moles of water removed **(1)** • calculates moles of anhydrous magnesium nitrate **(1)** • deduces x **(1)** **OR** • calculates moles of anhydrous magnesium nitrate **(1)** • Calculates Mr of hydrated salt **(1)** • Writes expression to find x in terms of mass and *M* **(1)** • deduces **x** **(1)**	Example of calculation 5.12 – 2.97 = 2.15 g 2.15 / 18 = 0.11944 (mol) M1 could be subsumed in M2 2.97/148.3 = 0.0200 (mol) 0.11944:0.0200 = 6:1 so x = 6 (must be integer) 2.97/148.3 = 0.0200 (mol) 5.12/0.0200 = 256 148.3 + 18x = 256 x = 6 (must be integer) Allow TE at each step Correct answer with no working scores M4 only Ignore SF apart from M4, which must be 1SF	**(4)**

Question Number	Answer	Additional guidance	Mark
(b)(i)	An explanation that makes reference to the following points: • large(r) amount of energy required to break **ionic** bonds (in lattice / $MgCO_3$ / solid) **(1)** • small(er) amount of energy released during hydration (of ions) / when ions form bonds to water **(1)** **OR** Lattice energy is **more exothermic** **(1)** than the hydration enthalpies **(1)**	Do not award molecules / atoms / London forces Ignore references to H bonds If no other mark is awarded allow 1 for 'lattice energy is **greater** than hydration enthalpy'	**(2)**

Question Number	Answer	Additional guidance	Mark
(b)(ii)	• application of Hess's Law **(1)** • calculation of $\Delta_f H^\circ$ **(1)**	Example of calculation: +(–394 –602) + 1096 **(+)** 100 (kJ mol^{-1}) Correct answer with no working scores 2 marks – 100 (kJ mol^{-1}) scores 1 mark (+) 702 (kJ mol^{-1}) scores 1 mark (+) 494 (kJ mol^{-1}) scores 1 mark – 2092 (kJ mol^{-1}) scores 1 mark (+) 2092 (kJ mol^{-1}) scores 1 mark Ignore units even if incorrect	**(2)**

Question Number	Answer	Additional guidance	Mark
(b)(iii)	An explanation that makes reference to the following points • Group 2 carbonates increase in (thermal) stability as you go down the group **(1)** • size of the (metal) **ion** increases / charge density (of ion) decreases **(1)** • so metal ion is less polarising or (electron cloud of) anion less distorted **(1)** • so weakens (covalent) bonds in carbonate ion less / more energy needed to break (covalent) bonds in carbonate **(1)**	Accept reverse argument Each marking point is independent Ignore 'atomic radius'' Allow C-O or C=O as alternative for 'bonds in carbonate'	**(4)**

Q11.

Question Number	Correct Answer	Mark
	The only correct answer is C (NH_4Cl) ***A*** *is incorrect as* Ca^{2+} *does not produce an alkaline gas when warmed with sodium hydroxide solution* ***B*** *is incorrect as* Mg^{2+} *does not produce an alkaline gas when warmed with sodium hydroxide solution* ***D*** *is incorrect as* Be^{2+} *does not produce an alkaline gas when warmed with sodium hydroxide solution*	**1**

Q12.

Question Number	Answer	Mark
(a)	**The only correct answer is C** (Reaction 3) *A is incorrect because different species are oxidised and reduced* *B is incorrect because different species are oxidised and reduced* *D is incorrect because there is no change in oxidation state*	**(1)**

Question Number	Answer	Mark
(b)	**The only correct answer is D** (Reaction 4) *A is incorrect because neither reactant is acting as an acid or base* *B is incorrect because this is a redox reaction* *C is incorrect because neither reactant is acting as an acid or base and it is a redox reaction*	**(1)**

Q13.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• **carbon monoxide / CO** is (a) toxic (gas)	Allow explanations of toxicity in terms of reaction with haemoglobin Allow poisonous Ignore "fumes are toxic" Ignore harmful Ignore "it is toxic" Do not award corrosive	**(1)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: • M_r of MgC_2O_4 and $MgCO_3$ **(1)** • mass of MgC_2O_4 that reacts **(1)** • mass of $MgCO_3$ that is formed **(1)** • mass of MgC_2O_4 remaining **and** total solid **(1)**	Example calculation: M_r MgC_2O_4 = 112.3 and M_r $MgCO_3$ = 84.3 6.0 × 0.7 = 4.2 (g) **OR** 6.0 × 0.3 = 1.8 (g) (4.2 ÷ 112.3) × 84.3 = 3.15 (g) (6.0 – 4.2 = 1.8 (g)) 3.15 + 1.8 = 4.95 (g) Alternative method: (moles oxalate calculated) 6 ÷ 112.3 = 0.05343 (moles carbon monoxide calculated) 0.7 × 0.05343 = 0.03740 (mass carbon monoxide calculated) 0.03740 × 28 = 1.0472 (g) mass of solid remaining 6.0 – 1.0472 = 4.95(28) (g) Ignore SF except 1SF Allow use of Magnesium as 24 to get 4.96 (g) Correct answer with some working scores (4)	**(4)**

Question Number	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • the temperature of decomposition of carbonates / thermal stability increases (down the group) **(1)** • the size of the **cation** increases (but has the same charge) **(1)** • (so) polarises the anion / carbonate (ion) less **(1)**	Ignore references to rate Ignore "decomposition decreases down the group" Allow amount of heat energy needed to decompose increases down the group Accept reference to the metal ion size/radius Allow charge density of (cat)ion decreases Ignore "ion size decreases" Do not award atomic radius Allow polarises electron cloud less Allow weakens the carbon oxygen bond	**(3)**

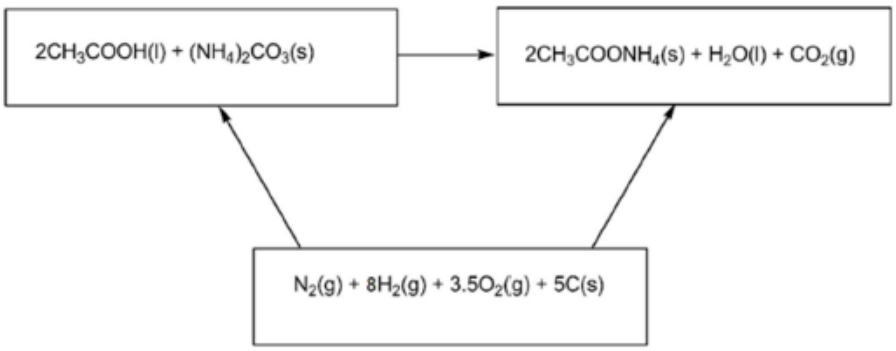
Q14.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • (white) solid / crystals / sodium carbonate dissolves **(1)** • (colourless) bubbles(of gas) / effervescence / fizzing **(1)**	Allow colourless solution forms Allow solid / sodium carbonate disappears Do not award just solid / sodium carbonate becomes smaller Do not award sodium dissolves / disappears Ignore incorrect formula for sodium carbonate Ignore just 'gas / carbon dioxide / CO_2 produced' Ignore limewater test on gas produced Do not award bubbles of an incorrect gas e.g. bubbles of oxygen Ignore 'heat is given off' Do not award 'solid melts' Do not award precipitate forms Do not award 'coloured solution forms' Apply list principle if more than 2 observations given	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	• calculation of molar mass of hydrated sodium ethanoate **(1)** • calculation of moles of hydrated sodium ethanoate **(1)** • calculation of energy released **(1)** • calculation of ΔT **(1)** • calculation of final T **(1)**	<u>Example of calculation</u> 136 (g mol^{-1}) 20.1 ÷ 136 = 0.14779 (mol) 0. 14779 × 19700 = 2911.5 / 2.911 x 10^3 (J) / 2.911 (kJ) 2911.54 ÷ (63.2 × 3.0) = 15.3562 (°C) 15.3562 + 5.0 = 20 / 20.4 (°C) Allow TE throughout but TE for M5 must give temperature of 50°C or less Ignore SF	**5**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	• top 2 boxes of Hess Cycle complete (reaction) **(1)** • bottom box of Hess Cycle complete (elements) **(1)** • inclusion of multiples of 2 for $\Delta_f H^\ominus$[$CH_3COOH(l)$] and $\Delta_f H^\ominus$[$CH_3COONH_4(s)$] **(1)** • evidence of correct manipulation of Hess Cycle to find $\Delta_r H^\ominus$ (products – reactants) **(1)** • calculation of final answer **(1)**	Example of calculation See below for example of cycle Penalise incorrect / omission of state symbols once only in M1 and M2 Allow $H_2CO_3(aq)$ in top right box (2 × −586.3) **and** (2 × −484.5) [(2 × −586.3) + (−285.8) + (−393.5)] – [(2 × −484.5) + (−939.9)] = (+) 57 kJ mol^{-1} Allow TE from M3 to M4 and M5 No TE from an incorrect Hess Cycle Correct answer with no working scores M3, M4 and M5 Lack of multiples in M3 gives (+) 158.8, which scores M4 and M5	**5**

Example of completed diagram



Question Number	Acceptable Answers	Additional Guidance	Mark
(d)	• calculation of mass of ammonium carbonate in 1 dm^3 of solution **(1)** • calculation of concentration of solution **(1)** OR • Calculation of number of moles of ammonium carbonate **(1)** • calculation of concentration of solution **(1)**	Example of calculation 1.8 x 10 = 18 (g dm^{-3}) 18 ÷ 96 = 0.1875 (mol dm^{-3}) 1.8 ÷ 96 = 0.01875 (mol) 0.01875 ÷ 0.1 = 0.1875 (mol dm^{-3}) Correct answer no working scores 2 Ignore SF except 1 SF in final answer	**2**

Q15.

Question number	Answer	Additional guidance	Mark
(a)	• calculation of number of moles (1) • evaluation to 2/3 SF (1)	Example of calculation: 0.0500 cm^3 (× 1000 ÷ 1000) = 0.0500 (mol) (0.0500 × 90.0) = 4.50 (g)	**2**

Question number	Answer	Additional guidance	Mark
(b)	An answer that make reference to the following points: • moles of ethanedioic acid (1) • moles of potassium hydroxide and mass of potassium hydroxide. (1)	Example of calculation: Moles acid = 400 × 0.0500 ÷ 1000 = 2.00×10^{-2} Moles KOH = $2.00 \times 10^{-2} \times 2$ = 4.00×10^{-2} mol $4.00 \times 10^{-2} \times 56.1 = 2.24(4)$ g Correct answer with no working scores 2 Ignore SF except 1 SF	**2**

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>(c)</td>
<td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><th></th><th>Number of marks awarded for structure and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr>
</table>
</td>
<td>Guidance on how the mark scheme should be applied.

The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

In general, it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.</td>
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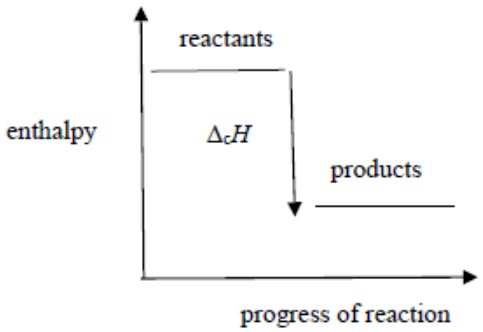
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	Answer is partially structured with some linkages and lines of reasoning.	1	If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded, do not deduct mark(s). Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.	
	Answer has no linkages between points and is unstructured.	0		
	Indicative points: • rinse glassware with appropriate solutions • fill the burette with potassium hydroxide solution, ensuring there are no air bubbles • use a pipette **and** pipette filler to transfer 25.0 cm^3 / 10 cm^3 of acid to a conical flask • (add indicator to the acid in the conical flask and) carry out a range finder/rough titration • add potassium hydroxide drop by drop near the end point • repeat titrations **until** concordant/within ± 0.2 cm^3 .		Do not award just 'rinse with distilled water'. Alternative IP 2 to 5 if acid (solution) used in burette: • fill the burette with (ethanedioic) acid solution, ensuring there are no air bubbles • use a pipette **and** pipette filler to transfer 25.0 cm^3 of potassium hydroxide solution to a conical flask • (add indicator to the potassium hydroxide in the conical flask and) carry out a range finder/rough titration • add (ethanedioic) acid drop by drop near the end point.	

Q16.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• (temperature) 298 K / 25°C **and** (pressure) 1 atm / 100 kPa / 101 kPa / 1 x 10^5 Pa / 1.01 x 10^5 Pa	Allow 'a specified / stated temperature' Ignore just 'room temperature' Do not award 298°K Do not award incorrect pressure units e.g. 101 Pa	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	• molecular formula for 2,2,4-trimethylpentane (1) • rest of equation correct **conditional** on use of C_8H_{18} **or** use of structural / displayed / skeletal formula for 2,2,4-trimethylpentane (1)	Example of equation: $C_8H_{18} + 12½O_2 \rightarrow 8CO_2 + 9H_2O$ Accept 25/2 for 12½ Allow multiples e.g. $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ Ignore state symbols even if incorrect	(2)

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	• y axis labelled enthalpy **and** products line drawn at a lower level than reactants line (1) • downwards arrow labelled with Δ_cH (1)	Example of diagram;  Allow energy / H / enthalpy level as label for y axis Do not award ΔH / enthalpy change / energy change as label for y axis Allow names / formulae of reactants and products but both must be there e.g. $C_8H_{18} + O_2$ for reactants and $CO_2 + H_2O$ for products Ignore missing / incorrect balancing numbers if formulae given Ignore label / missing label on x axis Ignore activation energy hump(s) M2 Conditional on reactants higher than products Allow label as ΔH / −5461 / other label that indicates enthalpy change of combustion / reaction Do not award double headed arrow / or just a line with no arrow / arrow labelled $-\Delta H$	(2)

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Question Number	Answer	Additional Guidance	Mark
(a)(iv)	• calculation of energy given out by 1 g **(1)** • calculation of energy given out by 1 cm^3 **(1)** • calculation of energy given out by 1 dm^3 **(1)**	Example of calculation: **Method 1** enthalpy change / g = $\frac{5461}{114}$ = 47.904 (kJ) enthalpy change / cm^3 = 47.904 x 0.692 = 33.149 (kJ) TE on M1 enthalpy change / dm^3 = 33.149 x 1000 = 33 149 / 33.149 x 10^3 (kJ) TE on M2 **Method 2** mass of 2,2,4-trimethylpentane in 1 dm^3 = 0.692 x 1000 = 692 (g) (1) mol in 1 dm^3 = $\frac{692}{114}$ = 6.0702 (mol) (1) TE on M1 enthalpy change / dm^3 = 6.0702 x 5461 = 33 149 / 33.149 x 10^3 (kJ) (1) TE on M2 Allow alternative methods Correct answer with some working scores (3) Ignore SF except 1 SF Ignore minus sign Ignore units, even if incorrect	**(3)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• calculation of heat evolved (1) • calculation of moles of ethanol used (1) • working for heat evolved per mole (1) • value of $\Delta_c H$ to 2 / 3 SF **and** negative sign **and** units (1)	Example of calculation: heat evolved = 100.0 x 4.18 x 13.2 = 5517.6 (J) / 5.5176 kJ Do not award 100.305 x 4.18 x 13.2 = 5534.4 (J) amount of ethanol = $\frac{0.305}{46}$ = 0.0066304 / 6.6304×10^{-3} (mol) heat evolved per mole = $\frac{5.5176}{6.6304 \times 10^{-3}}$ (= 832.17) TE on M1 and M2 $\Delta_c H$ = − 830 / − 832 kJ mol^{-1} Allow units kJ/mol or $\frac{kJ}{mol}$ or kJ mol^{-} Ignore letter case in units e.g. k or K, J or j Accept − 830 000 / − 832 000 J mol^{-1} TE on M3 Ignore SF except 1 SF in M1, M2 and M3 Correct answer with some working to 2/3 SF with sign and units scores (4)	(4)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• calculation of percentage error	Example of calculation: $\frac{2 \times 0.05}{13.2} \times 100) = 0.75758$ (%) Allow 0.7576 / 0.758 / 0.76 / 0.8 Correct answer with no working scores (1) Ignore signs Do not award 0.75 / 0.757 / 0.80	(1)

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An answer that makes reference to any **two** of the following points: • heat loss (to the surroundings) (1) • incomplete combustion (of ethanol) (1) • some ethanol evaporates (1) • calculation does not take into account the heat capacity of the beaker (1)	Allow insufficient oxygen for combustion Ignore not all of the ethanol was burned Ignore product(s) / water evaporates Allow some heat is used to heat up the beaker Ignore thermometer Ignore ethanol was impure Ignore water was not stirred Ignore no lid on beaker	(2)

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Question Number	Answer	Additional Guidance	Mark
(c)	• calculation of bond energies of O–H **and** C–H (1) • calculation of bond energy of C–O (1) • calculation of bond energy of C–C (1)	Example of calculation: **Method 1** bond energy O–H = 928/2 = (+)464 (kJ mol^{-1}) **and** bond energy C–H = 1740/4 = (+)435 (kJ mol^{-1}) bond energy C–O = 2105 – (3 x 435) – 464 = (+)336 (kJ mol^{-1}) TE on M1 bond energy C–C = 3322 – (5 x 435) – 464 –336 = (+)347 (kJ mol^{-1}) **Method 2** 3322 – 2105 = 1217 = C–C + 2 x C–H (1) bond energy 2 x C–H = 1740/2 = (+)870 (kJ mol^{-1}) (1) C–C = 1217 – 870 = (+)347 (kJ mol^{-1}) (1) M3 TE on M1 and M2 in both methods Correct answer with some working scores (3)	(3)

Question Number	Answer	Additional Guidance	Mark
(d)	An answer that makes reference to the following points: • there are fewer (gas) molecules on the right hand side / more (gas) molecules on the left hand side (1) • so the equilibrium position will shift to the right / product side **and** the equilibrium yield of ethanol will increase (1)	Ignore effect of temperature Ignore effect on rate of reaction Allow moles for molecules Allow 2 (gas) molecules on the left and 1 (gas) molecule on the right Allow higher pressure favours the side with fewer (gas) molecules Allow forward reaction is favoured **and** the equilibrium yield of ethanol will increase	(2)

Q17.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• correct equation (1) • correct state symbols (1)	Examples of equations $2K(s) + 2H_2O(l) \longrightarrow 2KOH(aq) + H_2(g)$ OR $K(s) + H_2O(l) \longrightarrow KOH(aq) + ½H_2(g)$ Allow multiples M2 dependent on M1 or correct species and an unbalanced equation	(2)

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: • K / potassium from 0 to +1 **and** oxidation (1) • H / hydrogen from +1 to 0 **and** reduction (1)	If oxidation numbers are wrong or omitted one mark is scored for K oxidised **and** H reduced. or one mark is scored for K changes from 0 to +1 **and** H changes from +1 to 0.	(2)

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	• lilac	Allow purple or lilac-purple Do not award any other colour	(1)

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• from (pale) pink (1) • to colourless (1)	Do not award red/purple Award (1) mark for correct colours in reverse order	(2)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• moles of HCl in titre (1) • moles of MOH in the flask (= mol M) (1) • molar mass of M (1) • identification of M (1)	<u>Example of calculation</u> $12.8 \times 0.400 \div 1000 = 5.12 \times 10^{-3} / 0.00512$ (mol) $5.12 \times 10^{-3} / 0.00512 \times 10 = 5.12 \times 10^{-2} / 0.0512$ $0.37 \div 5.12 \times 10^{-2} = 7.23$ (g mol^{-1}) Ignore SF Li TE for each stage but for M4, **M** must be a Group 1 metal and is dependent on a calculation of a molar mass.	(4)

Question Number	Answer	Additional Guidance	Mark
(c)	A description that makes reference to the following points: • (some) oil weighed with M/ the mass of M is lower than the mass of material weighed/ (1) • relative atomic mass of M will be greater (1)	Ignore mass increased/decreased/mass different Allow fewer moles of HCl (required in the titration)/lower titration value	(2)

Q18.

Question Number	Answer	Additional Guidance	Mark
(a)	• correct balanced equation	Example of equation: $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$ or multiples Allow $Ca + H_2O \rightarrow CaO + H_2$ Ignore state symbols even if incorrect	(1)

Question Number	Answer	Additional Guidance	Mark
(b)	An explanation that makes reference to the following points: • concentration of hydroxide ions is greater (1) • calcium hydroxide is more soluble than magnesium hydroxide (1)	Allow more hydroxide ions are in solution Allow the solubility of the hydroxides increases going down Group 2 reverse argument	(2)

Question Number	Answer	Additional Guidance	Mark
(c)(i)	• correct ionic equation	Example of equation: $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ Ignore state symbols even if incorrect Do not award H_2CO_3 / $H^+ + HCO_3^-$ as final products	(1)

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	• correct balanced equation (1) • state symbols (1)	Example of equation: $CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$ M2 depends on M1 Allow equation near miss e.g. $Ca(OH)_2 + CO_2 \rightarrow CaCO_2 + H_2O$ or all correct species being present	(2)

Question Number	Answer	Additional Guidance	Mark
(d)	• calculation of the amount of $Mg(OH)_2$ (1) • calculation of M_r $Mg(OH)_2$ (1) • calculation of mass $Mg(OH)_2$ **and** answer given to 2 or 3 SF (1)	Example of calculation: Amount of $Mg(OH)_2$ = 0.150 ÷ 2 = 0.075 (mol) M_r $Mg(OH)_2$ = 58.3 Mass of $Mg(OH)_2$ = 0.075 x 58.3 = 4.3725 (g) = 4.4 / 4.37 (g) Allow if Mg = 24 then M_r = 58 and mass = 4.4 / 4.35 Correct answer to 2 or 3 SF with no working scores (3)	(3)

Q19.

Question number	Answer	Mark
	A all Group 1 hydroxides are soluble in water	1

Q20.

Q	Answer	Mark
	The only correct answer is C (5.22 dm^3) ***A*** *is incorrect because this is the number of moles of hydrogen* ***B*** *is incorrect because this is the number of moles of lithium* ***D*** *is incorrect because this is the number of moles of lithium multiplied by the molar volume*	**1**

Q21.

Question number	Answer	Mark
	B lithium sulfate	1

Q22.

Question Number	Answer	Mark
	The only correct answer is D (KO_2) ***A*** *is incorrect because in this oxide potassium would have an oxidation number of +1/4* ***B*** *is incorrect because in this oxide potassium would have an oxidation number of +1/2* ***C*** *is incorrect because in this oxide potassium would have an oxidation number of +3/4*	**(1)**

Q23.

Question Number	Answer	Mark
	The only correct answer is A ($SrBr_2$) *B is incorrect because sodium produces a yellow flame test* *C is incorrect because although the flame test would be red the silver halide ppt would be white* *D is incorrect because the flame test would be green and the silver halide ppt would be yellow and insoluble in concentrated ammonia*	**(1)**

Q24.

Question Number	Answer	Mark
(a)	**The only correct answer is B** (lithium nitrate) ***A*** *is incorrect because barium has a green colour in the flame test* ***C*** *is incorrect because magnesium does not have a red colour in the flame test* ***D*** *is incorrect because rubidium nitrate does not produce nitrogen dioxide when heated*	**(1)**

Question Number	Answer	Mark
(b)	**The only correct answer is A** (brown and blue to red) ***B*** *is incorrect because nitrogen dioxide would have no effect on damp red litmus paper* ***C*** *is incorrect because nitrogen dioxide is brown* ***D*** *is incorrect because nitrogen dioxide is brown and would have no effect on damp red litmus paper*	**(1)**

Q25.

Question number	Answer	Mark
	The only correct answer is A ($BaCO_3(s) + 2H^+(aq) \rightarrow Ba^{2+}(aq) + CO_2(g) + H_2O(l)$) ***B*** *is incorrect because* Ba_2CO_3 *is not the formula for barium carbonate* ***C*** *is incorrect because solid barium carbonate should not be split up into ions* ***D*** *is incorrect because hydrochloric acid is in solution and should be split up into ions and* Cl^- *are spectator ions*	**(1)**

Q26.

Q	Answer	Mark
	The only correct answer is B (II and III) ***A*** *is incorrect because number of protons increasing is not a reason for decreasing ionisation energy down the group* ***C*** *is incorrect because electrons being unpaired is not a reason for decreasing ionisation energy down the group* ***D*** *is incorrect because statements I and IV are not reasons for decreasing ionisation energy down the group*	**1**

Q27.

Question Number	Correct Answer	Mark
	The only correct answer is B (300 cm^3) ***A*** *is incorrect as it assumes the ratio of magnesium nitrate to gaseous products is 1:5* ***C*** *is incorrect as it assumes the only gaseous product is* NO_2 ***D*** *is incorrect as it assumes the ratio of magnesium nitrate to gaseous products is 1:1*	**1**

Q28.

Question Number	Answer	Mark
	The only correct answer is B ($NaNO_3$) ***A*** *is not correct because both oxygen and nitrogen dioxide would be produced* ***C*** *is not correct because both oxygen and nitrogen dioxide would be produced* ***D*** *is not correct because both oxygen and nitrogen dioxide would be produced*	**1**

Q29.

Question Number	Answer	Mark
(a)	**The only correct answer is B** (0.50) *A is incorrect because 0.050 is the number of moles produced* *C is incorrect because the solution concentration is assumed to be the same as the alkali* *D is incorrect because the solution concentration is assumed to be equal to that of the acid*	**(1)**

Question Number	Answer	Mark
(b)	**The only correct answer is B** (± 0.20%) *A is incorrect because both solutions have been considered* *C is incorrect because the uncertainty has not been doubled* *D is incorrect because the volume measured has been ignored*	**(1)**

Q30.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	$3Ca(OH)_2 + 3Cl_2 + KCl \rightarrow KClO_3 + 3CaCl_2 + 3H_2O$ OR $6Ca(OH)_2 + 6Cl_2 + 2KCl \rightarrow 2KClO_3 + 6CaCl_2 + 6H_2O$	Allow multiples If multiple used allow '$CaCl_2$ +5$CaCl_2$' Ignore state symbols	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	• calculation of M_r of $KClO_3$ **(1)** • calculation of M_r of all products / reactants **(1)** • calculation of overall atom economy **(1)**	<u>Example of calculation</u> 39.1 + 35.5 + 48 (= 122.6) 122.6 + (3 ×18) + ((71+40.1) × 3) = 509.9 Value for M2 should be consistent with numerator of atom economy expression (122.6 ÷509.9) ×100 = 24.044 = 24.0 % Ignore SF except 1 SF Use of 39 for K or 40 for Ca is acceptable Allow TE from (a)(i) using either M_r of all products or reactants Allow TE throughout calculation But TE for M3 must give a value of less than 100 %	**3**

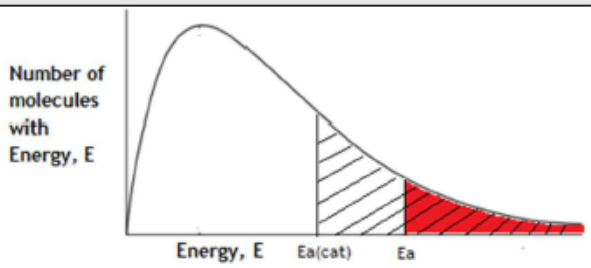
Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	An explanation that makes reference to the following points: • disproportionation reaction **(1)** • as chlorine (atoms) are oxidised from 0 (in chlorine) to (+) 5 (in calcium chlorate) **(1)** • and reduced (from 0) to −1 (in calcium chloride) **(1)**	Allow incorrect spellings of disproportionation if the word is recognisable and could not be confused with another chemical term Ignore redox Mark independently of M2 and M3 If initial oxidation state of 0 is not referenced at least once in either M2 or M3, then allow 1 for Cl is oxidised to +5 and reduced to -1 Changes in oxidation number can be shown above equation If no reference to oxidation and reduction then allow 1 mark for correct changes in oxidation number	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	An answer that makes reference to the following points: • add (dilute) nitric acid and silver nitrate (solution) **(1)** • white precipitate forms / precipitate forms whose colour is difficult to distinguish (between white and cream) **(1)** • which dissolves in dilute ammonia / dilute NH_3 / $NH_3(aq)$**(1)**	Throughout the question if formulae are given they must be correct Allow acidified silver nitrate / $AgNO_3$ and H^+ Allow $AgNO_3$ Allow HNO_3 Do not award hydrochloric acid / sulfuric acid Allow white solid / white crystals / white ppt Allow aqueous ammonia Allow 'disappears' for dissolves Do not award **just** 'dissolves in concentrated NH_3' M2 and M3 dependent on reference to silver nitrate / $AgNO_3$	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	• calculation of mass of oxygen **(1)** • calculation of moles of oxygen **(1)** • deduction of moles of potassium chlorate /calculation of mass of KCl **(1)** • calculation of mass of potassium chlorate in impure sample **(1)** • calculation of % purity of sample to 2 or 3 SF **(1)**	<u>Example of calculation</u> 1.52 − 1.02 = 0.50 (g) 0.50 ÷ 32 = 0.015625 (mol) 0.015625 × (2÷3) = 0.010417 (mol) / 0.015625 x (2/3) x 74.6 = 0.777 (g) 0.010417 × (39.1 + 35.5 + 48) = 1.2771 (g) / 0.777 + 0.5 = 1.277 (g) = (1.2771 ÷ 1.52) × 100 = 84.019 = 84 / 84.0 (%) Penalise incorrect rounding once only in M1-M4 Allow TE at each step, but TE for M5 must give a value less than 100% and based on 1.52 Allow alternative methods based on finding x where x = mass of impurity	**5**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	potassium chlorate(VII) OR chlorate(VII) potassium	Allow pottassium chlorate(VII) Do not award just potassium chlorate	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An explanation that makes reference to any four of the following points: • heat to constant mass so all of the potassium chlorate(V) decomposes **(1)** • the solid product or potassium chloride dissolves (when the water is added) **(1)** • the rinsing removes potassium chloride (solution, which would otherwise add to the mass of the solid when it dries **(1)** • drying ensures the final mass recorded is only that of that catalyst **(1)** • the mass (of solid) recorded (at the end of the procedure) should be the same of that of the catalyst at the start **(1)**	Allow so all $KClO_3$ reacts / so reaction goes to completion Allow the catalyst does not dissolve (when the water is added) Ignore KCl reacts with the water / catalyst does not react with the water Allow to remove soluble impurities (from catalyst) Allow 'to remove water from the catalyst' / 'ensure the catalyst is dry' Allow 'to compare to the mass of catalyst' Allow 'to check the mass (of catalyst) hasn't changed'	4

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to the following points: • activation energies shown and labelled for both catalysed and uncatalysed reaction **(1)** • number of molecules with $E > E_a$ shown on diagram **(1)**	 M2 can be awarded by written description	2