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EDEXCEL A LEVEL CHEMISTRY: QUESTIONS BY TOPIC

Energetics I (8)

A Level Chemistry Topic 8

13 questions · 141 marks · Mark schemes included

Pearson Edexcel A Level Chemistry (9CH0), June 2017 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any sub-topic heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

13 questions · 141 marks · grouped by sub-topic



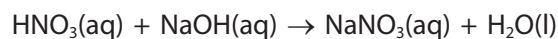
SUB-TOPIC 8(a)

ENTHALPY CHANGES AND CALORIMETRY

9 questions in this sub-topic · 97 marks · lowest tariff first



- 3 Nitric acid reacts with sodium hydroxide solution in a neutralisation reaction.



In an experiment to determine the enthalpy change of neutralisation, the following results were obtained.

Volume of $1.00 \text{ mol dm}^{-3} \text{ HNO}_3 = 25.0 \text{ cm}^3$

Volume of $1.05 \text{ mol dm}^{-3} \text{ NaOH} = 25.0 \text{ cm}^3$

Temperature rise = 6.8°C

- (a) Give a reason why excess sodium hydroxide was used.

(1)

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- (b) Calculate the enthalpy change of neutralisation for the reaction between nitric acid and sodium hydroxide solution, using the results of the experiment.

Give your answer to an appropriate number of significant figures.

[Assume: density of the reaction mixture = 1.0 g cm^{-3}
specific heat capacity of the reaction mixture = $4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$]

(4)

(Total for Question 3 = 5 marks)



(Total for Question 10 = 6 marks)



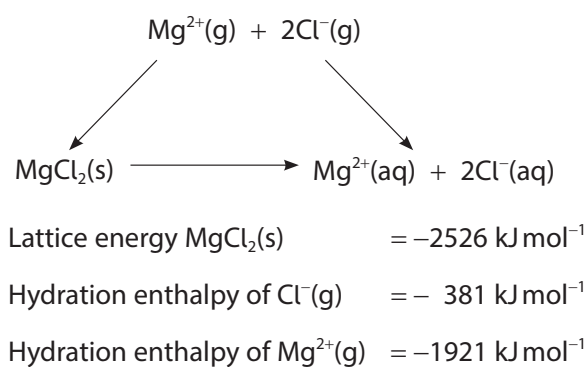
4 This question is about dissolving different compounds.

(a) Which of these compounds is the most soluble in water?

(1)

- ☐ A barium sulfate
- ☐ B calcium sulfate
- ☐ C magnesium sulfate
- ☐ D strontium sulfate

(b) What is the value, in kJ mol^{-1} , for the standard enthalpy change of solution of magnesium chloride?



(1)

- ☐ A +157
- ☐ B -157
- ☐ C +224
- ☐ D -224

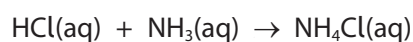


(Total for Question 4 = 8 marks)



7 In acid-base neutralisation reactions, there is a temperature change.

(a) The enthalpy change when hydrochloric acid reacts with aqueous ammonia is $-53.4 \text{ kJ mol}^{-1}$.



Calculate the temperature change you would expect when 25.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid is mixed with 25.0 cm^3 of 1.00 mol dm^{-3} aqueous ammonia.

Give your answer to an appropriate number of significant figures.

[Assume: the density of the solution is 1.00 g cm^{-3}
the specific heat capacity of the solution is $4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$]

(3)



5 This question is about enthalpy changes and energy changes.

(a) Magnesium carbonate reacts with dilute hydrochloric acid at room temperature.



When the reaction is carried out in a sealed container with a constant volume, the heat energy change is not the same as the enthalpy change for this reaction.

Give a reason why this is so.

(1)

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(b) State what is meant by the standard enthalpy change of formation of aluminium oxide, $\text{Al}_2\text{O}_3(\text{s})$. Include standard conditions.

(3)

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(c) Use the data in the table to answer the questions.

Enthalpy change	Value / kJ mol^{-1}
Enthalpy change of hydration of K^+	-322
Enthalpy change of hydration of Ca^{2+}	-1650
Enthalpy change of solution of KCl	+17.2
Lattice energy of KCl	-711

- (i) Name the two properties of ions that affect the value of their enthalpy change of hydration.

(2)

- (ii) Calculate the enthalpy change of hydration for chloride ions by completing the energy cycle, including labels, and using the data in the table.

(3)



enthalpy change of hydration for Cl⁻ ions kJ mol^{-1}

(Total for Question 5 = 9 marks)



- 4 Hess's law can be used to determine enthalpy changes for reactions which cannot be obtained directly.

An example is the reaction of anhydrous copper(II) sulfate with water to form hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

The following outline procedure was carried out.

- Step 1 42.75 g of deionised water was weighed out in a polystyrene cup and the temperature measured.
- Step 2 0.0250 mol of hydrated copper(II) sulfate was added to the water in the polystyrene cup with stirring, making a total of 45.00 g of water.
- Step 3 The temperature change was recorded.
- Step 4 Steps 1 to 3 were repeated using 45.00 g of deionised water and 0.0250 mol of anhydrous copper(II) sulfate.

- (a) Calculate the mass of 0.0250 mol of hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

(2)

- (b) The reaction of hydrated copper(II) sulfate with water is shown.



Calculate the temperature change that would have given this enthalpy change for the stated experimental procedure.

Give your answer to a measurable number of significant figures and state whether the temperature increases or decreases.

[Specific heat capacity of the solution = $4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$]

(3)

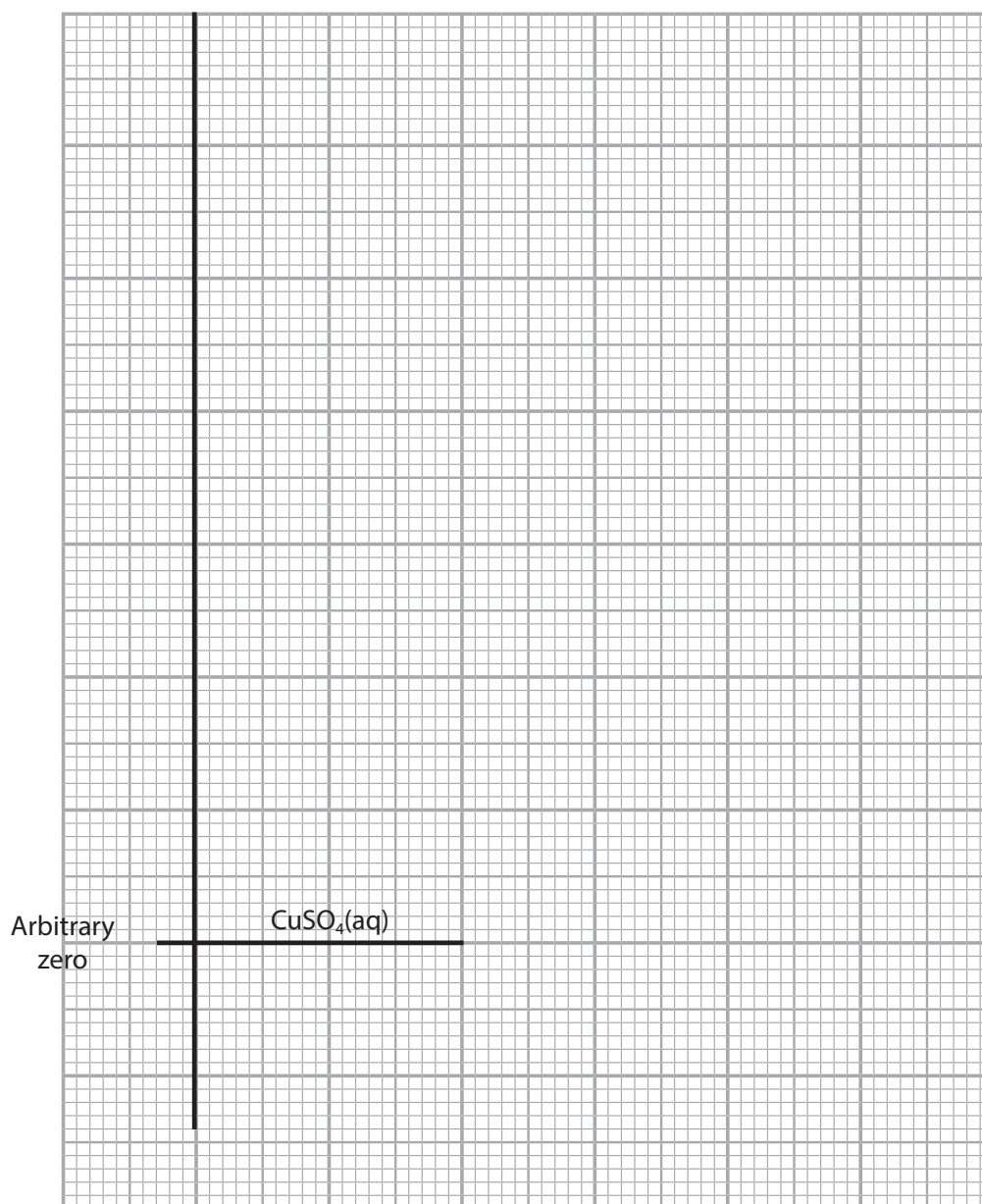


(c) The reaction of anhydrous copper(II) sulfate with water is shown.

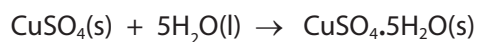


- (i) Draw to scale, on the graph paper, a labelled enthalpy level diagram which shows the enthalpy changes for the reactions of water with hydrated copper(II) sulfate (ΔH_1) and anhydrous copper(II) sulfate (ΔH_2).

(3)



- (ii) Use your enthalpy level diagram in (c)(i) to determine the enthalpy change, $\Delta_r H$, for the reaction



You **must** show your working on the diagram.

(1)

$\Delta_r H$

- (d) State why the enthalpy change for the reaction of one mole of anhydrous copper(II) sulfate with five moles of water to form hydrated copper(II) sulfate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, cannot be measured directly.

(1)

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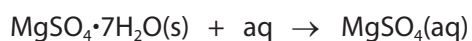
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(Total for Question 4 = 10 marks)



4 This question is about hydrated magnesium sulfate, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$.

*(a) Devise an experimental procedure to determine the enthalpy change of solution for hydrated magnesium sulfate.



Details of the method of calculation are not required.

(6)

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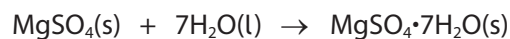


- (b) The enthalpy changes of solution for anhydrous and hydrated magnesium sulfate were found by experiment to be



Calculate, using Hess's law, the enthalpy change for the hydration of anhydrous magnesium sulfate.

Include a sign and units in your answer.



(2)

- (c) Explain how the enthalpy change of hydration of magnesium ions in magnesium sulfate is different from the enthalpy change of hydration of calcium ions in calcium sulfate.

(2)

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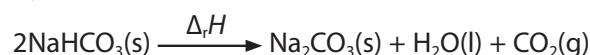
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(Total for Question 4 = 10 marks)



- 7 The enthalpy change for the decomposition of sodium hydrogencarbonate can be determined indirectly using Hess's Law.



A student carried out two experiments.

- (a) **Experiment 1** involved the reaction between sodium hydrogencarbonate and hydrochloric acid.

The student used the following procedure:

- use a measuring cylinder to measure 50 cm^3 of 2.00 mol dm^{-3} hydrochloric acid and pour it into a polystyrene cup
- measure the initial temperature of the acid
- weigh the test tube containing sodium hydrogencarbonate
- tip the sodium hydrogencarbonate into the hydrochloric acid in the polystyrene cup, stir the mixture and record the lowest temperature reached
- weigh the empty test tube.

Results

Measurement	Value
Mass of test tube + NaHCO_3 / g	21.23
Mass of empty test tube / g	15.61
Mass of NaHCO_3 used / g	
Initial temperature / $^{\circ}\text{C}$	21.0
Final temperature / $^{\circ}\text{C}$	14.4
Temperature fall / $^{\circ}\text{C}$	

- (i) Complete the table.

(1)

- (ii) Show, by calculation, that the hydrochloric acid is in excess.
You must show your working.



(2)



(iii) Calculate the enthalpy change for the reaction between sodium hydrogencarbonate and hydrochloric acid, using the results of the experiment.

Include a sign and units in your answer.

Assume: mass of reaction mixture = 50.0 g
specific heat capacity of the reaction mixture = $4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$

(3)



- (b) **Experiment 2** involved the reaction between sodium carbonate and hydrochloric acid.

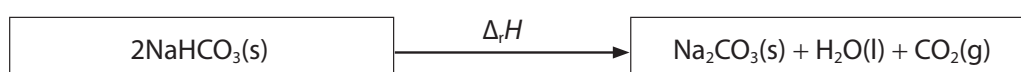
The student repeated the procedure for **Experiment 1** but used sodium carbonate instead of sodium hydrogencarbonate and measured the maximum temperature rise.



The student calculated the enthalpy change for this reaction as $-29.4 \text{ kJ mol}^{-1}$.

- (i) Complete the Hess cycle with appropriate formulae and labelled arrows.

(2)



- (ii) Calculate the enthalpy change for the decomposition of sodium hydrogencarbonate.

Include a sign and units in your answer.



(3)

- (c) Another student carried out the same two experiments and obtained a value for the enthalpy change of decomposition of sodium hydrogencarbonate of $+74 \text{ kJ mol}^{-1}$.

The data book value for this enthalpy change is $+90 \text{ kJ mol}^{-1}$.

- (i) Calculate the percentage error in this student's value.

(1)

- (ii) Calculate the percentage uncertainties in measuring 50 cm^3 of hydrochloric acid using a burette and using a measuring cylinder.

(1)

Apparatus	Uncertainty	Percentage uncertainty
Measuring cylinder	$\pm 0.5 \text{ cm}^3$ for each volume measured	
Burette	$\pm 0.05 \text{ cm}^3$ for each reading	

- (iii) Give a reason why using a burette rather than a measuring cylinder will not improve the accuracy of the experiment.

(1)

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- (iv) Describe changes to the method and how the data is used that would improve the accuracy of the determination of the temperature change in **Experiment 2**. Your description should involve the use of a clock and plotting a graph.

(5)

(Total for Question 7 = 19 marks)



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

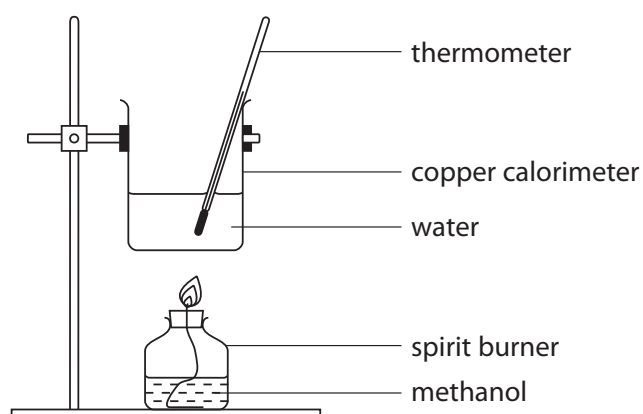
A teacher asked two students to carry out a practical task to determine the enthalpy change of combustion of methanol.

Both students were provided with the same apparatus and chemicals.

The following procedure was provided for the students.

Procedure

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



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

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

Table 1

- (a) Complete **Table 1**, giving the values to an appropriate number of decimal places. (2)
- (b) Write the equation that represents the reaction that occurs when the standard enthalpy change of combustion of methanol, $\text{CH}_3\text{OH}(\text{l})$, is measured. Include state symbols. (2)



- (c) Use Student 1's result to calculate the enthalpy change of combustion of methanol in kJ mol^{-1} .

Give your answer to an appropriate number of significant figures.

Specific heat capacity of water = $4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$

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

(4)



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

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

- (i) Student 1 used a 250 cm^3 measuring cylinder to measure the volume of 150 cm^3 distilled water. The uncertainty in this volume measurement is $\pm 1\text{ cm}^3$.

Calculate the percentage uncertainty in the volume of distilled water that Student 1 measured in the experiment.

(1)

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

(3)

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

Other than human error, give **three** reasons for the difference in the values.

(3)

- (e) Student 1 decided to repeat the experiment.

Student 1 used the copper calorimeter and water from the first experiment and recorded the initial temperature as 60.0°C.

Student 1 burned **exactly** the same mass of methanol as in the first experiment.

Explain, with a reason, how the value for the enthalpy change of combustion of methanol from this experiment would differ, if at all, from the value obtained in the first experiment.

(2)



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

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

(2)

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

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

(2)

(Total for Question 4 = 21 marks)



SUB-TOPIC 8(b)

BOND ENTHALPY

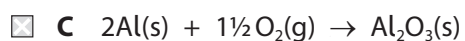
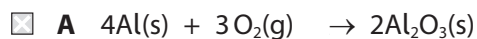
4 questions in this sub-topic · 44 marks · lowest tariff first



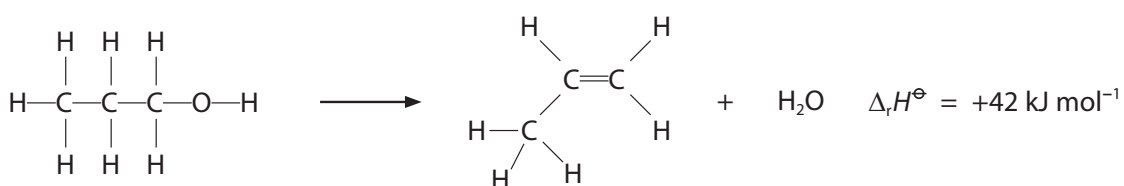
5 This question is about enthalpy changes and entropy changes.

(a) Which is the equation for the standard enthalpy change of formation, $\Delta_f H^\ominus$, of aluminium oxide?

(1)



(b) Propan-1-ol is dehydrated to form propene.



The relevant mean bond enthalpies are given in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C=C	612
C—H	413
O—H	464

Calculate the C—O mean bond enthalpy, using the mean bond enthalpies given in the table and the enthalpy change of reaction.

(3)



(c) Which reaction has a negative value for ΔS_{system} ?

(1)

- ☐ **A** $2\text{Cu(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{CuO(s)}$
- ☐ **B** $2\text{H}_2\text{O}_2\text{(l)} \rightarrow 2\text{H}_2\text{O(l)} + \text{O}_2\text{(g)}$
- ☐ **C** $\text{MgCO}_3\text{(s)} + \text{H}_2\text{SO}_4\text{(aq)} \rightarrow \text{MgSO}_4\text{(aq)} + \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)}$
- ☐ **D** $\text{Zn(s)} + 2\text{HCl(aq)} \rightarrow \text{ZnCl}_2\text{(aq)} + \text{H}_2\text{(g)}$

(d) What is the expression for ΔS_{total} ?

(1)

- ☐ **A** $\Delta S_{\text{surroundings}} + \frac{\Delta H}{T}$
- ☐ **B** $\Delta S_{\text{surroundings}} - \frac{\Delta H}{T}$
- ☐ **C** $\Delta S_{\text{system}} + \frac{\Delta H}{T}$
- ☐ **D** $\Delta S_{\text{system}} - \frac{\Delta H}{T}$



(e) Calcium carbonate decomposes on heating.



$$\Delta_r H = +178 \text{ kJ mol}^{-1}$$

$$\Delta S_{\text{system}} = +165 \text{ J mol}^{-1} \text{ K}^{-1}$$

Show, by calculating the value for the free energy change, ΔG , that this decomposition is not feasible at 298 K, and then calculate the minimum temperature to which calcium carbonate must be heated to make it decompose.

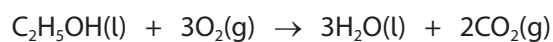
(3)

(Total for Question 5 = 9 marks)



- 5 This question is about 'Direct Ethanol Fuel Cells' which are being developed to power small electronic devices.

The overall reaction in these fuel cells is shown.



- (a) Calculate the enthalpy change for the reaction using the mean bond enthalpy data.

(3)

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C—H	413
C—O	358
O—H	464
O=O	498
C=O	805

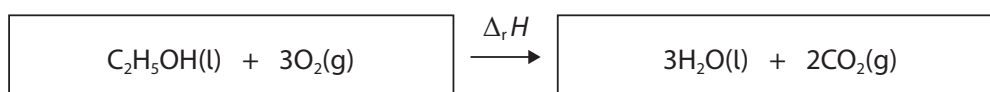
Enthalpy change = ... kJ mol^{-1}



- (b) (i) Complete the enthalpy cycle for the overall reaction in the Direct Ethanol Fuel Cell. Include labels.

(2)

Substance	$\Delta_f H^\ominus / \text{kJ mol}^{-1}$
$\text{C}_2\text{H}_5\text{OH}(\text{l})$	-277
$\text{CO}_2(\text{g})$	-394
$\text{H}_2\text{O}(\text{l})$	-286



- (ii) Calculate a value for the enthalpy change of the Direct Ethanol Fuel Cell reaction, using your cycle.

(1)

Enthalpy change = ... kJ mol^{-1}



(c) Give **two** reasons for the difference between your calculated values in (a) and (b).

(2)

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(d) In the Direct Ethanol Fuel Cell under acidic conditions, at one electrode the ethanol is oxidised in the presence of water to produce carbon dioxide, hydrogen ions and electrons.

At the other electrode, the hydrogen ions and electrons combine with oxygen to form water.

Write the two ionic half-equations for this process.
State symbols are not required.

(2)

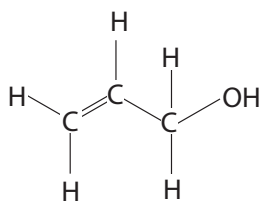
Oxidation half-equation

Reduction half-equation

(Total for Question 5 = 10 marks)



6 Prop-2-en-1-ol is an unsaturated alcohol with the structure shown.



- (a) A student planned to use bond enthalpy data to calculate a value for the enthalpy change of combustion of prop-2-en-1-ol.
- (i) When researching the bond enthalpy data, the student claimed that it was not necessary to find the value for the C=C bond as they could use the value for a C–C bond and multiply it by two.
Explain why the student is **incorrect**.

(2)

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- (ii) Calculate a value for the enthalpy of combustion of prop-2-en-1-ol using the data shown.



Bond	C–C	C=C	C–O	C=O	O–H	C–H	O=O
Bond enthalpy / kJ mol^{-1}	347	612	358	805	464	413	498

(3)

(iii) Explain, in terms of entropy, why the combustion of prop-2-en-1-ol is always feasible in the gaseous state.

(2)

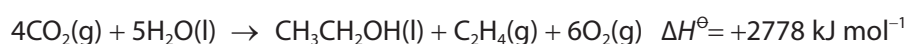
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(b) Chemists are researching a process to make ethanol and ethene directly from carbon dioxide and water.



	CO ₂ (g)	H ₂ O(l)	CH ₃ CH ₂ OH(l)	C ₂ H ₄ (g)	O ₂ (g)
$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$	213.6	69.9	160.7	219.5	205.0

Calculate $\Delta S^\ominus_{\text{total}}$ for the reaction and hence determine whether the reaction is feasible under standard conditions.

(5)

(Total for Question 6 = 12 marks)

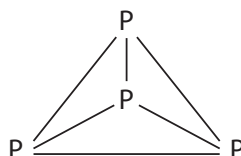


5 The halogens are elements in Group 7 of the Periodic Table.

(a) Chlorine compounds have many uses, including water treatment.

(i) Chlorine and phosphorus (P_4) can react to form phosphorus(V) chloride.

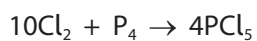
The structure of a molecule of phosphorus is



Some mean bond enthalpy values are shown in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
P—P	+198
Cl—Cl	+243
P—Cl	+326

Calculate the enthalpy change for the reaction between chlorine and phosphorus to form phosphorus(V) chloride.



(3)



(ii) Give a reason why bond enthalpy values are always positive.

(1)

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(b) Sodium chlorate(I) is a bleaching agent.

(i) Sodium chlorate(I) can be made by the reaction of chlorine with sodium hydroxide.

Show, by using oxidation numbers, that this reaction is disproportionation.



(2)

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.....

(ii) A different bleaching agent can be made by the reaction of chlorine with sodium hydroxide under different conditions.

Balance this equation.



(1)

(iii) What conditions are required for the reaction in (b)(ii)?

(1)

- ☐ **A** cold and dilute alkali
- ☐ **B** cold and concentrated alkali
- ☐ **C** hot alkali
- ☐ **D** excess chlorine

- (c) The halogens can be identified by their colour in an organic solvent such as hexane or cyclohexane.

Which sequence of colours is correct for chlorine, bromine and iodine dissolved in an organic solvent?

(1)

	Chlorine	Bromine	Iodine
☒ A	orange	red-brown	black
☒ B	pale green	orange	black
☒ C	orange	red-brown	purple
☒ D	pale green	orange	purple

- (d) Halide ions can be identified by their reaction with silver nitrate.

- (i) Write the **ionic** equation for the reaction between aqueous solutions of sodium iodide and silver nitrate.
Include state symbols.

(2)

- (ii) A solution containing 0.010 mol of a halide ion was reacted with excess silver nitrate and produced 1.88 g of precipitate.

Identify the halide ion.
Justify your answer.

(2)

(Total for Question 5 = 13 marks)



MARK SCHEMES

official Pearson Edexcel mark schemes



Question Number	Acceptable Answer	Additional Guidance	Mark
3(a)	An answer that makes reference to the following point: to make sure that (all) the (nitric) acid / HNO_3 / H^+ has reacted / been neutralised / is used up	Allow (nitric acid) / HNO_3 is the limiting reagent Allow so that 0.025 mol of water / H_2O forms Ignore to make sure that 1 mol of water / H_2O forms Ignore just 'to ensure that reaction is complete'	(1)



Question Number	Acceptable Answer	Additional Guidance	Mark
3(b)	- calculation of heat produced (1) - calculation of amount (mol) of HNO_3 (1) - calculation of enthalpy change (1) - negative sign and units and answer to 2 / 1 SF (1)	<u>Example of calculation</u> heat produced = $50.0 \times 4.18 \times 6.8 = 1421.2 \text{ (J) / } 1.4212 \text{ (kJ)}$ amount HNO_3 used = $25.0 \times 1.00/1000$ = $0.025 / 2.5 \times 10^{-2} \text{ (mol)}$ Ignore moles NaOH and total moles calculated enthalpy change = $\frac{1421.2}{0.025} = 56848 \text{ (J mol}^{-1}\text{)}$ or = $\frac{1.4212}{0.025} = 56.848 \text{ (kJ mol}^{-1}\text{)}$ TE on heat produced and amount HNO_3 final answer $-57 / -60 \text{ kJ mol}^{-1}$ or $-57\,000 / -60\,000 \text{ J mol}^{-1}$ TE on enthalpy change Do not award 3 SF Correct final answer with sign, units and 2 or 1 SF but no working scores (4) Ignore units and sign of enthalpy change in M1 and M3	(4)

(Total for Question 3 = 5 marks)



Question Number	Answer	Additional Guidance	Mark																				
*10	This question assesses the 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 of answer and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	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, a response with four 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 were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages). Accept any six indicative content points	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5-4	3																						
3-2	2																						
1	1																						
0	0																						
	Number of marks awarded for structure of answer and sustained lines of reasoning																						
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2																						
Answer is partially structured with some linkages and lines of reasoning	1																						
Answer has no linkages between points and is unstructured	0																						



Question Number	Answer	Mark
4(a)	The only correct answer is C (magnesium sulfate) <i>A is incorrect because Group 2 sulfates decrease in solubility down Group 2</i> <i>B is incorrect because Group 2 sulfates decrease in solubility down Group 2</i> <i>D is incorrect because Group 2 sulfates decrease in solubility down Group 2</i>	(1)

Question Number	Answer	Mark
4(b)	The only correct answer is B (–157) <i>A is incorrect because this is the value if the cycle is used in the opposite direction</i> <i>C is incorrect because this is the value if the hydration enthalpy for the chloride ion is not multiplied by 2</i> <i>D is incorrect because this is the value if the cycle is used in the opposite direction and the hydration enthalpy for the chloride ion is not multiplied by 2</i>	(1)



Question Number	Answer	Additional Guidance	Mark																				
*4(c)	This question assesses the 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 of answer and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	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, a response with four 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 were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages). In general, an answer with 5 or 6 IPs would score 2 reasoning marks, 3 or 4 IPs would score 1 reasoning mark, 0, 1 or 2 IPs would score 0 reasoning marks. Reasoning marks may be reduced for extra incorrect chemistry.	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5-4	3																						
3-2	2																						
1	1																						
0	0																						
	Number of marks awarded for structure of answer and sustained lines of reasoning																						
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2																						
Answer is partially structured with some linkages and lines of reasoning	1																						
Answer has no linkages between points and is unstructured	0																						



	Indicative content 2-methylpentane is insoluble in water as it cannot hydrogen bond to water (as none of the hydrogen atoms are electropositive) 2-methylpentane is soluble in hexane as London forces in both compounds (are similar in strength / size) - so (resultant) forces in mixture are similar in magnitude to those in each liquid - potassium bromide is soluble in water as its ions are hydrated when dissolved - the enthalpy change of hydration is greater than / close to / compensates for the energy needed to break apart the lattice - potassium bromide is insoluble in hexane as any (London) forces that form between it and hexane would be smaller in magnitude than the forces between the ions	If there is no specific reference to types of intermolecular forces / interaction in IPs 1 and 2 then allow 1 IP for idea of 'like dissolves like' e.g. 2-methylpentane dissolves in hexane as they are both non-polar / does not dissolve in water as water is polar scores 1IP if both IP1 and IP2 not awarded Allow van der Waals / dispersion forces / instantaneous dipole-induced dipole Allow both form only London forces Ignore references to entropy Do not award if water is shown as split into ions	
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(Total Question 4 = 8 marks)



Question Number	Answer	Additional Guidance	Mark
7(a)	- calculation of moles used (1) - calculation of energy for that number of moles (1) - calculation of temperature change and gives answer to 2 SF (because a school thermometer cannot measure to 3 SF) (1)	<u>Example of calculation</u> moles used = $25.0 \times 1.00/1000 = 0.0250$ energy released = $0.025 \times 53.4 = 1.335$ (kJ) / 1335 (J) TE on moles used Ignore sign temperature change = $1335/(50.0 \times 4.18)$ = 6.3876 = 6.4 (°C / K) TE on moles and energy Allow final answer to 3 SF 6.39 (°C / K) Ignore units Correct answer with no working scores (3)	(3)



Question Number	Answer	Additional Guidance	Mark												
7(b)*	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>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5–4	3	3–2	2	1	1	0	0	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).	
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5–4	3														
3–2	2														
1	1														
0	0														

(6)



The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

Comment: Look for the indicative marking points first, then consider the mark for the structure of answer and sustained line of reasoning.

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks. 3 and 4 indicative points would get 1 mark for reasoning and 0, 1 or 2 indicative points would score zero marks for reasoning.



	Indicative content Hydrochloric acid and nitric acid (same value for) hydrochloric acid and nitric acid as they are strong / completely dissociated into ions (in solution) - reaction taking place is $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ / $\text{H}_3\text{O}^+ + \text{OH}^- \rightarrow 2\text{H}_2\text{O}$ Sulfuric acid - sulfuric acid is diprotic / dibasic or (1 mol of) sulfuric acid provides 2 mol H^+ / produces 2 mol H_2O - so value is (almost) twice that of hydrochloric acid / nitric acid or reverse argument Ethanoic acid - ethanoic acid is weak /partially dissociated into ions (in solution) / $\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+$ / $\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_3\text{O}^+$ - some energy is needed to break (O-H) bond(s) to release H^+ ions (so enthalpy change of neutralisation is less than for a strong acid) or enthalpy change of neutralisation includes the enthalpy of dissociation of ethanoic acid so it is less exothermic	Allow correct formulae for names throughout the answer Ignore sulfuric acid as strong(est) acid Allow $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$ and $\text{HNO}_3 + \text{NaOH} \rightarrow \text{NaNO}_3 + \text{H}_2\text{O}$ Allow hydrochloric acid and nitric acid are both monoprotic / monobasic / provide 1 mol H^+ / produce 1 mol H_2O Allow $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$ Allow ethanoic acid is the weakest acid Allow some energy is needed to ionise ethanoic acid	
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(Total for Question 7 = 9 marks)



Question Number	Answer	Additional Guidance	Mark
5(a)	An answer that makes reference to the following point: (the system / it) is not at constant pressure or enthalpy change is the heat change at a constant pressure	Allow a gas / carbon dioxide is produced and this increases the pressure Allow the pressure is increased / increases Ignore reference to temperature	(1)

Question Number	Answer	Additional Guidance	Mark
5(b)	An answer that makes reference to the following points: (the enthalpy/energy change when) 1 mol of aluminium oxide (1) - is formed from its elements in their standard states (1) - at 100 kPa and a 'specified' / 'stated' temperature (1)	Allow $2\text{Al(s)} + 1\frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{Al}_2\text{O}_3\text{(s)}$ for M1 and M2 If state symbols are missing or incorrect only M1 can be awarded Allow M2 for multiples in equation provided state symbols for the elements are correct Allow 1 atm / 1×10^5 Pa / 101 kPa / 1.01×10^5 Pa for pressure Allow a value for the temperature of 298K / 25°C Ignore 273K Ignore other standard conditions e.g. 1 mol dm^{-3} Do not allow °K	(3)



Question Number	Answer	Additional Guidance	Mark
5(c)(i)	An answer that makes reference to the following points: (ionic) radius (ionic) charge	(1) Allow size (of ions) Do not award atomic radius/size of atoms (1) Do not award atomic charge/charge of atoms Allow charge density for 1 mark if no other mark awarded	(2)



Question Number	Answer	Additional Guidance	Mark
5(c)(ii)	- correct species with state symbols in bottom box (1) - arrows in correct directions and labelled (1) - calculation of enthalpy change of hydration of Cl^- ions (1)	Example of cycle Ignore missing aq Allow any clear labels for arrows, including values for lattice energy and $\Delta_{\text{hyd}}H \text{ K}^+$, e.g, LE, HE Allow arrow on left reversed if labelled – lattice energy/+711 Allow two separate arrows on the RHS Standalone mark $\Delta_{\text{hyd}}H \text{ Cl}^- = -711 + 17.2 - (-322)$ $= -371.8 \text{ (kJ mol}^{-1}\text{)}$ No TE on incorrect arrows Ignore SF apart from 1SF	(3)

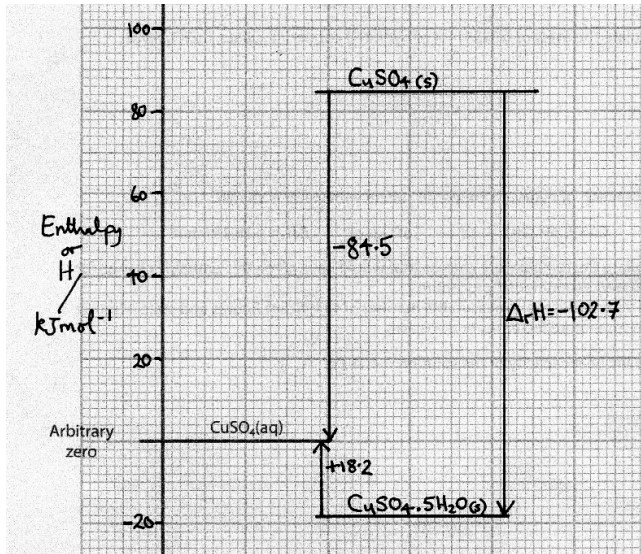
(Total for Question 5 = 9 marks)



Question Number	Answer	Additional Guidance	Mark
4(a)	- molar mass of hydrated copper(II) sulfate (1) - mass of 0.0250 mol hydrated copper(II) sulfate (1)	<u>Example of calculation</u> $M_r(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = 249.6 \text{ (g mol}^{-1}\text{)}$ $m(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = 6.24 \text{ (g)}$ Answer to 2 / 3SF Correct answer with no working scores (2) TE from incorrect M_r	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)	- evaluation of Q (1) - rearrangement to give ΔT (1) - Answer to 1 or 2SF and temperature change (1)	<u>Example of calculation</u> $Q = (\Delta H \times n) = 18.2 \times 0.025 = 0.455 \text{ (kJ) or } 455 \text{ J}$ $\Delta T = Q \div (m \times c)$ $= 455 \div (45.00 \times 4.18)$ $= 2.4189... (^{\circ}\text{C})$ $\Delta T = 2 / 2.4 ^{\circ}\text{C} / \text{K}$ and decrease Allow $-2 / 2.4 ^{\circ}\text{C} / \text{K}$ Correct final answer without working scores (3) TE throughout	(3)



Question Number	Answer	Additional Guidance	Mark
4(c)(i)	- labelled y axis, including units, with appropriate scale (1) - direction and placement of enthalpy changes, +18.2 and -84.5 (1) - Entities with state symbols (1)	Allow energy for 'enthalpy' Ignore horizontal axis Do not award enthalpy change/ΔH for y axis Allow ΔH_1 and ΔH_2 for respective values Arrows must be shown and in the correct direction Ignore activation energy 'curves' Do not award double-headed arrows Ignore inclusion of '+ aq' <u>Example of diagram</u> 	(3)

Question Number	Answer	Additional Guidance	Mark
4(c)(ii)	Use of Hess's law to calculate $\Delta_r H$ shown on the diagram	Value from diagram = $-102.7 \text{ (kJ mol}^{-1}\text{)}$ Allow $\Delta_r H = \Delta H_2 - \Delta H_1 = -84.5 - (+18.2) = -102.7 \text{ (kJ mol}^{-1}\text{)}$ Allow $-103 \text{ (kJ mol}^{-1}\text{)}$ Do not award if no working shown on the diagram	(1)

Question Number	Answer	Additional Guidance	Mark
4(d)	An answer that makes reference to Cannot react exactly 5 mol of water with 1 mol of anhydrous copper(II) sulfate	Cannot measure the temperature (change) for a solid Description that states more (than 5) water molecules will attach to some CuSO_4 while less (than 5) water molecules will attach to other CuSO_4 ACCEPT reasonable ideas such as some water may evaporate (due to exothermic reaction) Ignore heat loss to surroundings if given as an alternative reason Do not award heat is needed to start the reaction	(1)

(Total Question 4 = 10 marks)



Question Number	Answer	Additional Guidance	Mark																				
*4 (a)	This question assesses the 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 of answer and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	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, a response with four 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 were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages). More than one indicative marking point may be made within the same comment or explanation	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5-4	3																						
3-2	2																						
1	1																						
0	0																						
	Number of marks awarded for structure of answer and sustained lines of reasoning																						
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2																						
Answer is partially structured with some linkages and lines of reasoning	1																						
Answer has no linkages between points and is unstructured	0																						



	Indicative content • IP1 – (accurately) weigh/ use a known mass of (hydrated) magnesium sulfate • IP2 – (accurately weigh) known mass of (distilled / deionised) water • IP3 – use of polystyrene cup (and lid) • IP4 – record initial temperature of the water (before adding solid) • IP5 – add magnesium sulfate (to the water in the cup) and stir • IP6 - record temperature (at suitable time intervals) / record final temperature	Allow amount for mass Allow any reasonable stated mass between 1–10g Allow any reasonable volume between 20–250cm³ Allow insulated beaker/calorimeter/styro-foam cup Do not allow if heating is described Do not award recording initial temperature of solid Addition of water to the solid loses IP4 only Allow mix/stir the water and the solid Allow record the lowest or highest temperature reached Allow use of graphical extrapolation Do not award if the solution is being heated	
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Question Number	Answer	Additional Guidance	Mark
4(b)	- rearrangement using Hess's law (1) - evaluation of answer with sign (and units) (1)	<u>Example of calculation and Hess cycle</u> $\Delta H_1 = \Delta H_2 - \Delta H_3 = -63.2 - +15.7 = -78.9 \text{ (kJ mol}^{-1}\text{)}$ $\Delta_r H = (-63.2 - +15.7)$ $\Delta_r H = -78.9 \text{ (kJ mol}^{-1}\text{)}$ Correct answer with no working scores (2) If value converted to J mol^{-1} then both marks can be awarded for $-78\,900 \text{ J mol}^{-1}$ but just $-78\,900$ scores M1 only Allow (1) for $(+78.9 \text{ (kJ mol}^{-1}\text{)})$ Allow (1) for $-47.5 \text{ (kJ mol}^{-1}\text{)}$	(2)



Question Number	Answer	Additional Guidance	Mark
4(c)	- the enthalpy change of hydration of magnesium/Mg (ion) will be more exothermic/more negative (1) - because the magnesium (ion) is smaller than the calcium (ion) but has the same charge (so the attraction between the water molecules and the gaseous ion is stronger) (1)	Do not award just 'enthalpy change is greater' Do not allow calcium (ion) enthalpy change of hydration is more positive/ endothermic Accept reverse argument Allow magnesium (ion) has a greater charge density Allow Mg^{2+} is smaller than Ca^{2+} Do not award atomic radius	(2)

(Total Question 4 = 10 marks)



Question Number	Answer	Additional Guidance		Mark
7(a)(i)	mass and temperature fall correct			(1)
		Mass of NaHCO ₃ used / g	5.62	
		Temperature fall / °C	(-)6.6	

Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	calculation of amount of NaHCO₃ and calculation of amount of hydrochloric acid	<u>Example of calculation</u> amount NaHCO₃ = $\frac{5.62}{23 + 1 + 12 + (3 \times 16)}$ = 0.0669 (mol) TE on mass of NaHCO₃ in (a)(i) and amount HCl = $\frac{50 \times 2.00}{1000}$ = 0.10 (mol) Ignore SF including 1SF	(2)
	0.0669 mol NaHCO₃ needs 0.0699 mol HCl for reaction so HCl is in excess	Allow mol ratio = 1 : 1 so HCl is in excess Allow just more moles of HCl used Allow 0.10 > 0.0669 (mol) Allow HCl is in excess by 0.033 (mol)	



Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	- calculation of heat absorbed (1) - calculation of enthalpy change (1) - positive sign and units (1)	<u>Example of calculation</u> heat absorbed = $50.0 \times 4.18 \times 6.6$ $= 1379.4 \text{ (J)} / 1.3794 \text{ (kJ)}$ Ignore sign enthalpy change = $\frac{1379.4}{0.0669}$ $= 20619 \text{ (J mol}^{-1}\text{)}$ or $= \frac{1.3794}{0.0669}$ $= 20.619 \text{ (kJ mol}^{-1}\text{)}$ TE on heat absorbed and amount NaHCO_3 in (a)(ii) Final answer $+20.6(19) \text{ kJ mol}^{-1}$ or $+20619 \text{ J mol}^{-1}$ TE on enthalpy change Allow $+19.7(06) \text{ kJ mol}^{-1}$ from 0.07 mol in (a)(ii) Allow $\text{kJ mol}^{-1} / \text{J mol}^{-1}$ Ignore SF except 1 SF Ignore incorrect / missing units in M1 and M2 Correct answer with sign and units scores (3)	(3)



Question Number	Answer	Additional Guidance	Mark
7(b)(i)	- correct species and balancing numbers in lower box - both arrows pointing in correct directions	<u>Example of Hess cycle</u> (1) Ignore missing state symbols (1) Stand alone mark Ignore labels on arrows and inclusion of HCl	(2)

Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	- expression for $\Delta_r H$ (1) - substitution of values into expression with both values in same units (1) - calculation of $\Delta_r H$ and sign and units (1)	<u>Example of calculation</u> $\Delta_r H = 2 \times \Delta H_1 - \Delta H_2$ $\Delta_r H = 2 \times 20.619 - (-29.4)$ or $\Delta_r H = 2 \times 20619 - (-29\,400)$ M1 can be scored from values substituted into correct expression in M2 TE on ΔH_1 in (a)(iii) and expression in M1 No TE on incorrect arrows in cycle $\Delta_r H = +70.638 \text{ kJ mol}^{-1}$ or $\Delta_r H = +70638 \text{ J mol}^{-1}$ TE on ΔH_1 in (a)(iii) and expression in M1 provided it is a +ve answer Ignore SF except 1 SF Correct answer with sign and units scores (3)	(3)



Question Number	Answer	Additional Guidance	Mark
7(c)(i)	calculation of percentage error	<u>Example of calculation</u> percentage error $= \frac{(90 - 74)}{90} \times 100 = 17.778 / 17.8 / 18(\%)$ Allow 17.7 recurring Ignore SF except 1SF Do not award 17.7	(1)

Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	calculation of percentage uncertainty using measuring cylinder and burette	<u>Example of calculation</u> percentage uncertainty using measuring cylinder $= \frac{0.5 \times 100}{50} = 1(\%)$ and percentage uncertainty using burette $= \frac{2 \times 0.05}{50} \times 100 = 0.2(\%)$ Ignore SF / ±	(1)

Question Number	Answer	Additional Guidance	Mark
7(c)(iii)	An answer that makes reference to the following point the difference in the uncertainty in using the burette compared with the measuring cylinder is very much smaller than the % error in the value obtained (so other factors are more significant)	Allow the uncertainty using the burette is not significantly less than using the measuring cylinder Allow uncertainty represents a spread of values whereas the error is the difference of the true value and value obtained Allow just 'hydrochloric acid / HCl is in excess' Ignore heat loss	(1)

Question Number	Answer	Additional Guidance	Mark
7(c)(iv)	A description that makes reference to the following points: - measure the temperature of the (hydrochloric) acid every 30 s for 2½ minutes (1) - add the sodium carbonate / solid (at exactly 3 minutes) (1) (stir and) measure the temperature (of the mixture) every 30 s for another 5 minutes (1) - plot a graph of temperature against time (1) (join the two sets of points with 2 best fit straight lines and) extrapolate the lines to the time of mixing and determine the maximum temperature change / rise at that time (1)	Allow different times in M1, M2 and M3 or measure the temperature at regular time intervals Allow use of a lid / additional insulation M4 & M5 can be awarded from a suitably labelled sketch graph	(5)

(Total for Question 7 = 19 marks)



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

Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)	$\text{CH}_3\text{OH(l)} + 1.5\text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)} + 2\text{H}_2\text{O(l)}$		(2)
	Balanced equation	Do not award multiples (enthalpy change is for the complete combustion of one mole) for MP1	
	State symbols all correct	MP2 depends on the award of MP1 or correct species	

Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)	- Calculation of energy change (1) - Calculation of moles of CH₃OH (1) - Calculation of energy ÷ moles CH₃OH (1) ΔH final answer in kJ mol⁻¹ and negative sign included and ΔH final answer to 2 or 3 S.F. (1)	Example of calculation (= $mc\Delta T = 150 \times 4.18 \times 42.5 =$) 26647.5 (J) Moles CH₃OH = $1.60/32 (= 0.05(00))$ $\frac{26647.5}{0.05(00)} = 532950 \text{ (J mol}^{-1}\text{)}$ Ignore any signs at this stage –533 (kJ mol⁻¹) Or –530 (kJ mol⁻¹) Correct answer with no working gains full marks Penalise incorrect units for MP4 only Allow TE at each stage Allow correct rounding to 2SF or more at each stage	(4)
Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)(i)	(±)0.7 (%)	Allow from 1 SF up to calculator value correctly rounded where (% uncertainty =) $(\pm) \frac{1}{150} \times 100 = 0.66666...7 \text{ (%)}$ Allow 0.6 or $\frac{2}{3}$ Do not award 0.66/0.6	(1)



Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)(ii)	An answer that makes reference to the following points: - Calculation of the % uncertainty using the 25 cm³ measuring cylinder (1) Then any two from: % uncertainty with use of 25 cm³ measuring cylinder is greater (1) - Repeated use of the small measuring cylinder will lead to greater transfer losses (1) - Repeated use will take more time (1)	Needs to show combined error in using the 25 cm³ six times is greater than using 250 cm³ measuring cylinder once only Award MP1 EITHER if multiplies errors: $100 \times (0.2 / 25) \times 6 = 4.8\%$ OR If adds errors $100 \times (1.2 / 150) = 0.8\%$ Do not award $(0.2 / 25) \times 100 = 0.8 \%$ Do not award 'easier' to use larger measuring cylinder	(3)



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

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



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

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

(Total for Question 4 = 21 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark
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Question Number	Answer	Mark
5(a)	The only correct answer is C <i>A is not correct because standard enthalpy of formation is for making 1 moles of a compound</i> <i>B is not correct because standard enthalpy of formation is for making 1 moles of a compound</i> <i>D is not correct because oxygen must be O₂</i>	(1)

Question Number	Answer	Additional Guidance	Mark
5(b)	- calculation of energy needed to break bonds (1) - calculation of energy released when bonds are made (1) - calculation of mean bond enthalpy of C—O (1)	<u>Example of calculation</u> Energy to break bonds: (C—C) + (C—H) + (C—O) = 347 + 413 + (C—O) = (C—O) + 760 (kJ) Energy released in forming bonds: (C=C) + (O—H) = 612 + 464 = (-)1076 (kJ) (C—O) + 760 - 1076 = 42 (C—O) = (+)358 (kJ mol⁻¹) TE on M1 and M2 If all bonds broken: Energy to break bonds = (C—O) + 4049 (kJ) Energy released in forming bonds = (-)4365 (kJ) Ignore units Correct answer with no working scores (3) Allow correct working in M1 and M2 if answers not evaluated	(3)



Question Number	Answer	Mark
5(c)	The only correct answer is A <i>B is not correct because all increase in entropy as disorder increases when gases are formed</i> <i>C is not correct because all increase in entropy as disorder increases when gases are formed</i> <i>D is not correct because all increase in entropy as disorder increases when gases are formed</i>	(1)

Question Number	Answer	Mark
5(d)	The only correct answer is D <i>A is not correct because $\Delta S_{\text{surroundings}}$ is incorrect</i> <i>B is not correct because $\Delta S_{\text{surroundings}}$ is incorrect</i> <i>C is not correct because sign of $\Delta H/T$ is incorrect</i>	(1)



Question Number	Answer	Additional Guidance	Mark
5(e)		Penalise incorrect units in M1 or M3 once only Working is not required for the calculations <u>Example of calculation</u> $\Delta G = 178 - \frac{(298 \times 165)}{1000}$ $= (+)128.83 / 129 \text{ (kJ mol}^{-1}\text{)}$ or $\Delta G = 178000 - (298 \times 165)$ $= (+)128830 / 129000 \text{ (J mol}^{-1}\text{)}$ ΔG is positive / >0 so reaction is not feasible Stand alone mark Allow ΔG must be negative for a reaction to be feasible Ignore 'so reaction is not feasible' without a reason No TE on a calculated negative value <u>Example of calculation</u> $\Delta G = 0$, so $\Delta H = T\Delta S_{(\text{sys})}$ or $T = \Delta H/\Delta S_{(\text{sys})}$ or $\Delta S_{\text{total}} = \Delta S_{\text{sys}} - \Delta H/T = 0$, so $T = \Delta H/\Delta S_{(\text{sys})}$ $T = 178/0.165 = 1078.8 / 1079 / 1080 \text{ (K)}$ or $T = 178000/165 = 1078.8 / 1079 / 1080 \text{ (K)}$ or $T = 806 \text{ (}^{\circ}\text{C)}$ Ignore SF except 1 SF	(3)

(Total for Question 5 = 9 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
5(a)	- calculation of enthalpy change for bonds breaking - calculation of enthalpy change for bonds forming - total enthalpy change with negative sign	<u>Example of calculation</u> (1) $= (5 \times 413) + 347 + 358 + 464 + (3 \times 498)$ $= (+) 4728 \text{ (kJ mol}^{-1}\text{)}$ (1) $= (6 \times 464) + (4 \times 805)$ $= (-) 6004 \text{ (kJ mol}^{-1}\text{)}$ (1) $= (-6004 + 4728)$ $= -1276 \text{ (kJ mol}^{-1}\text{)}$ Correct answer with no working scores 3. Allow TE for M3 Allow SF apart from 1SF. (+)1276 scores 2	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
5(b)(i)	An answer that makes reference to the following points: - correct species, balanced, with state symbols in the bottom box (1) - arrows in correct direction and labelled (1)	Allow any suitable labels – e.g just $\Delta_r H^\circ$ / correct numbers left hand -277 and right hand -1646 or 3×-286 and 2×-394 Allow omission of state symbols on the arrows. Allow C(graphite) for C(s)	(2)
5(b)(ii)	calculation of standard enthalpy of combustion of ethanol, $\Delta_c H^\circ$ [C₂H₅OH]	<u>Example of calculation</u> $(\Delta_r H^\circ [\text{C}_2\text{H}_5\text{OH}(\text{l})] = (-286 \times 3) - (2 \times 394) + 277$ $= -1369 \text{ (kJ mol}^{-1}\text{)}$ Allow final answer rounded to -1370 as long as -1369 is seen and the sign on the final answer is correct. Correct answer scores 1 No TE on incorrect cycle	(1)



Question Number	Acceptable Answer	Additional Guidance	Mark
5(c)	An answer that makes reference to the following point: (values are different because) mean bond enthalpies have been used (in the first calculation) (which are different from the actual values) (1) (values are different) because the bond enthalpy values are given for substances in the gas state (and water and ethanol are liquids) (1)	Ignore references to standard conditions	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
5(d)	An answer that makes reference to the following points: - oxidation half–equation (1) - reduction half–equation (1)	$\text{C}_2\text{H}_5\text{OH} + 3\text{H}_2\text{O} \rightarrow 2\text{CO}_2 + 12\text{e}^{(-)} + 12\text{H}^+$ $4\text{H}^+ + 4\text{e}^{(-)} + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ Allow multiples Allow reversible arrows but equations must be written forwards Comment: Allow 1 mark if both equations correct but oxidation and reduction swapped Ignore state symbols even if incorrect	(2)

(Total for Question 5 = 10 marks)



Question Number	Answer	Additional guidance	Mark
6(a)(i)	An explanation that makes reference to the following points - C=C bond is weaker than 2 x C-C bond (1) - as it consists of a pi and a sigma bond (rather than 2 sigma bonds)(1)	Ignore pi bond formed by sideways / less effective orbital overlap	(2)

Question number	Answer	Additional guidance	Mark
6(a)(ii)	- calculation of energy required to break reactant bonds (1) - calculation of energy release when product bonds form (1) - calculation of enthalpy change (1)	<u>Example of calculation:</u> $5(\text{C-H}) + (\text{C}=\text{C}) + (\text{C}-\text{C}) + (\text{C}-\text{O}) + (\text{O}-\text{H}) + 4(\text{O}=\text{O})$ $5(413) + (612) + (347) + (358) + (464) + (4 \times 498)$ $= 5838 \text{ (kJ mol}^{-1}\text{)}$ $6(\text{C}=\text{O}) + 6(\text{O}-\text{H})$ $(6 \times 805) + (6 \times 464)$ $= 7614 \text{ (kJ mol}^{-1}\text{)}$ $5838 - 7614 = -1776 \text{ (kJ mol}^{-1}\text{)}$ Ignore SF except 1 SF Allow TE from M1 and M2 Correct answer no working scores 3	(3)



Question Number	Answer	Additional Guidance	Mark
6(a)(iii)	An explanation that makes reference to one of the following points EITHER ΔS_{total} is always positive (1) - As both $\Delta S_{\text{surroundings}}$ and ΔS_{system} are positive - OR ΔG is always negative - as ΔH is negative and $\Delta S_{\text{(system)}}$ is positive	If no marking points awarded allow 1 mark for idea that ΔS_{system} / $\Delta S_{\text{surroundings}}$ / entropy increases with correct explanation	(2)

Question Number	Answer	Additional Guidance	Mark
6(b)	- expression for ΔS_{system} (1) - calculation of ΔS_{system} (1) - expression for $\Delta S_{\text{surroundings}}$ (1) - calculation of $\Delta S_{\text{surroundings}}$ (1) - calculation of ΔS_{total}, correct units and comment on feasibility (1)	<u>Example of calculation</u> $\Delta S_{\text{system}} = [(6 \times 205) + (219.5) + (160.7)] - [(4 \times 213.6) + (5 \times 69.9)]$ $= 1610.2 - 1203.9 = (+) 406.3 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ $\Delta S_{\text{surroundings}} = -\Delta H/T = -2778 \times 10^3 / 298$ $= -9322.14765 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ $\Delta S_{\text{total}} = 406.3 - 9322.14765$ $= -8915.85 \text{ J K}^{-1} \text{ mol}^{-1}, \text{ (negative) so not feasible}$ Ignore SF except 1 SF. Allow TE and KJ throughout	(5)

(Total for Question 6 = 12 marks)



Question Number	Answer	Additional Guidance	Mark
5(a)(i)	- sum of bonds broken (1) - and sum of bonds made (1) - answer and with negative sign (1)	<u>Example of calculation</u> bonds broken = $(6 \times 198) + (10 \times 243)$ $= 3618 \text{ (kJ mol}^{-1}\text{)}$ bonds made = $(20 \times 326) = (-)6520 \text{ (kJ mol}^{-1}\text{)}$ enthalpy change $= \text{Bonds broken} - \text{bonds made}$ $= (3618 - 6520)$ $= -2902 \text{ (kJ mol}^{-1}\text{)}$ Correct answer with no working scores (3) TE on bonds broken and made	(3)

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	bond breaking requires energy or by convention bond enthalpies refer to dissociation and so are endothermic	ALLOW bond breaking is endothermic ALLOW bond making is exothermic Ignore just 'bonds are broken' / 'it is endothermic'	(1)



Question Number	Answer	Additional Guidance	Mark
5(b)(i)	- chlorine is oxidised and from 0 to +1 (in NaClO) (1) - chlorine is reduced and from 0 to -1 (in NaCl) (1)	Check the equation Allow (1) for three correct oxidation numbers if no other mark is awarded. Allow (1) max for general definition of disproportionation	(2)

Question Number	Answer	Additional Guidance	Mark
5(b)(ii)	equation	$6 \text{ NaOH} + 3 \text{ Cl}_2 \rightarrow \text{NaClO}_3 + 5 \text{ NaCl} + 3 \text{ H}_2\text{O}$ Allow multiples	(1)

Question Number	Answer	Mark
5(b)(iii)	The only correct answer is C (hot alkali) <i>A is not correct because high temperature is required</i> <i>B is not correct because high temperature is required</i> <i>D is not correct because high temperature and not excess chlorine is required</i>	(1)



Question Number	Answer	Mark
5(c)	The only correct answer is D (pale green – orange - purple) <i>A is not correct because chlorine is not orange and the colour stated for bromine is for the pure liquid state and solid iodine can appear black but not in an organic solvent</i> <i>B is not correct because solid iodine can appear black but not in an organic solvent</i> <i>C is not correct because chlorine is not orange and the colour stated for bromine is in the pure liquid state</i>	(1)

Question Number	Answer	Additional Guidance	Mark
5(d)(i)	ionic equation	Example of equation $\text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq}) \rightarrow \text{AgI}(\text{s})$ Allow multiples	(2)
	state symbols	M2 dependent on M1 or near miss	

Question Number	Answer	Additional Guidance	Mark
5(d)(ii)	An answer that includes - halide ion with some justification attempt - calculation of expected mass of silver halides	Incorrect halide scores (0) Bromide (ion)/Br⁻ Do not award 'bromine (ion)' 0.01 mol of AgCl = 1.43 (g) AgBr = 1.88 (g) AgI = 2.35 (g) OR Mass of 1.0 mol is 188 g so subtraction of 107.9 for Ag means X = 80.1 so closest is Br TE on incorrect formula silver halide in d(i)	(2)

(Total Question 5 = 13 marks)

