PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 2: ENERGETICS

SCORE	PERCENTAGE
/193	%

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Q1.

Magnesium reacts with sulfuric acid in an exothermic reaction.

(a) Write an equation for the reaction.
Include state symbols in your answer.

(2)

(b) A student carried out an experiment to determine the enthalpy change of the reaction.

A sample of 0.50 g of magnesium powder was added to 25 cm^3 of 0.20 mol dm^{-3} sulfuric acid.

Calculate the number of moles of magnesium and of sulfuric acid that **reacted**.
Justify your answer.

(3)

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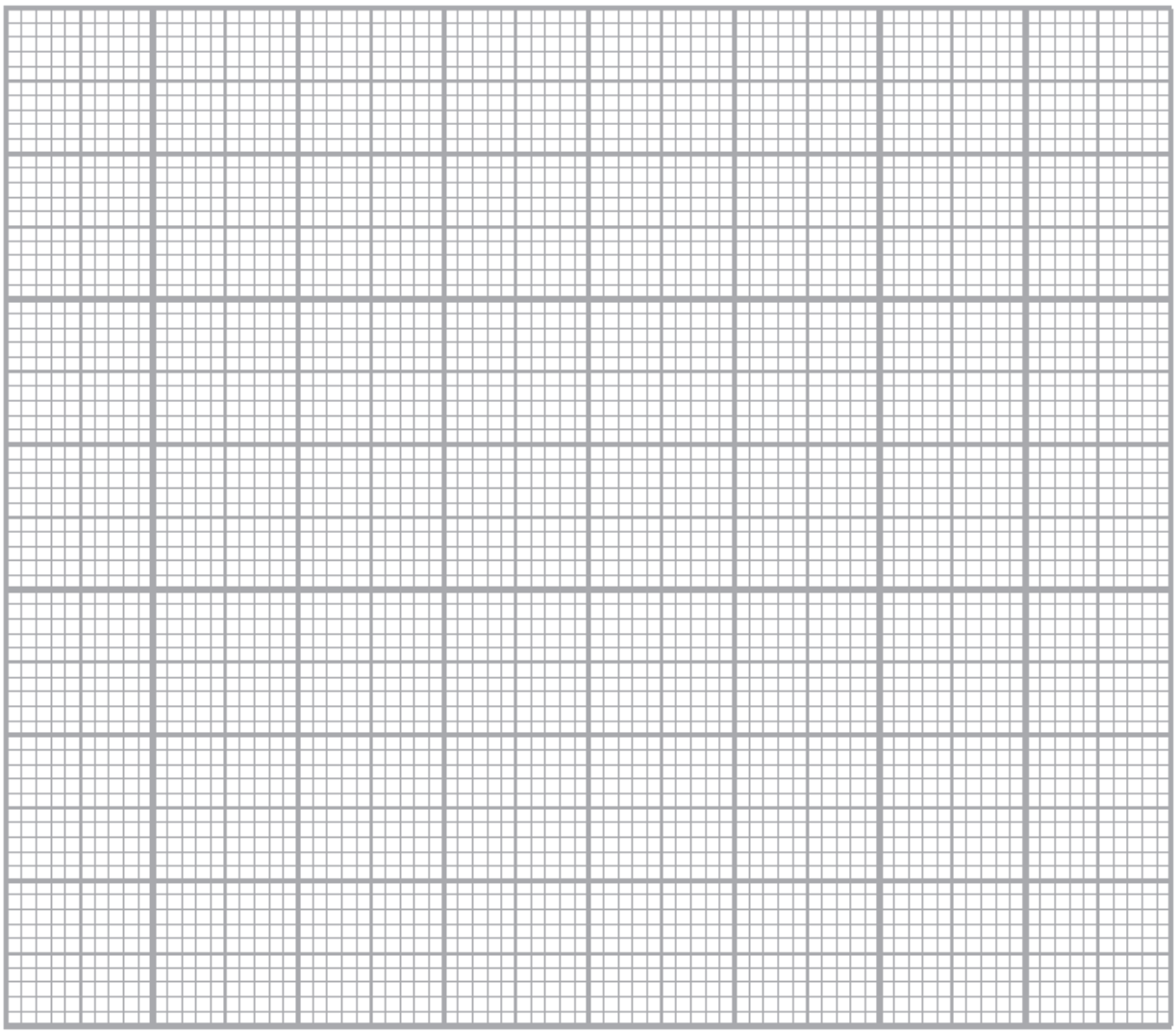
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(c) (i) The results obtained are given in the table.

Plot the results on the grid.

(2)

Time / minutes	Temperature / °C	
0	22.2	
1	22.0	
2	22.0	← Mg added
3	39.6	
4	41.8	
5	40.8	
6	40.2	
7	39.4	
8	38.6	



(ii) Use your graph to determine the maximum change in temperature.

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

(2)

ΔT = ...

(d) Calculate the standard molar enthalpy change for the reaction, using your answers to (b) and (c)(ii).

Include a sign and units in your answer.

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

(4)

(Total for question = 13 marks)

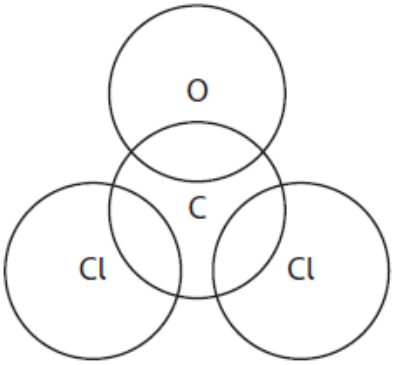
Q2.

Phosgene ($COCl_2$) is a colourless gas used in the pharmaceutical industry.

Phosgene has a boiling temperature of 8 °C and is extremely toxic.

(a) Complete the dot-and-cross diagram to show the bonding in phosgene.

(2)



(b) Phosgene can be formed from carbon monoxide and chlorine, using a catalyst of activated carbon.

$$CO(g) + Cl_2(g) \leftrightarrow COCl_2(g) \qquad \Delta_r H = -107.6 \text{ kJ mol}^{-1}$$

(i) State and explain how the reaction conditions could be changed to maximise the **equilibrium** yield of phosgene in this reaction.

(4)

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(ii) The standard enthalpy change of formation for phosgene is $\Delta_f H = -220.1$ kJ mol^{-1}.

Complete the Hess cycle and determine the standard enthalpy change of formation for carbon

monoxide. Use the data from (b)(i).

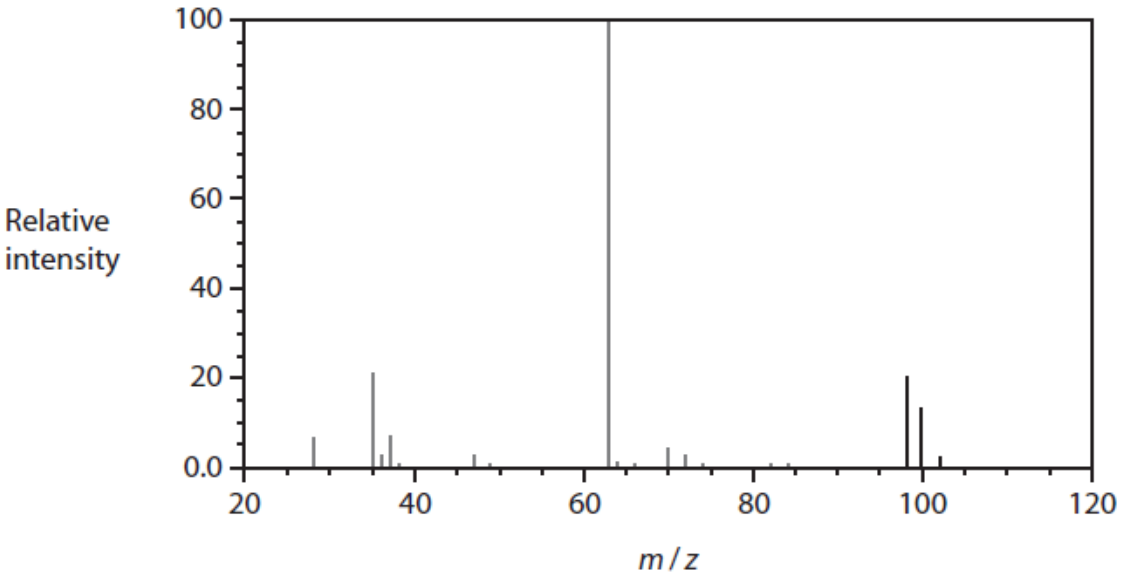
Include state symbols in your cycle.

(4)

$CO(g) \quad + \quad Cl_2(g) \quad \rightarrow \quad COCl_2(g)$

(c) The mass spectrum of a sample of phosgene is shown.

The peak at $m / z = 65$ has been omitted.



(i) Give the reason for the **ratio** of peak heights at m / z values of 102, 100 and 98.

(2)

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(ii) Suggest an identity for the peak at $m / z = 63$.

(1)

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(iii) The peak at $m / z = 65$ has been omitted.

Draw **on the mass spectrum** the peak at $m / z = 65$, showing its relative intensity.

(1)

(d) Use your Data Booklet to suggest the wavenumber of a strong absorbance you would expect to see in the infrared spectrum for phosgene. Justify your answer.

(2)

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(e) In UV light, trichloromethane ($CHCl_3$, boiling temperature 61°C) reacts with oxygen to form phosgene and hydrogen chloride.

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

(1)

(ii) In a closed bottle, the rate of this reaction decreases with time.

Give a reason for this.

(1)

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(iii) Suggest a precaution that should be taken when opening a bottle of trichloromethane.

(1)

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(iv) Trichloromethane can be used as an anaesthetic.

Suggest whether an old bottle of trichloromethane can still be used for medical treatment, giving a reason for your answer.

(1)

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(Total for question = 20 marks)

Q3.

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 equation represents the standard enthalpy change of atomisation of bromine?

☐ **A** $Br_2(g) \rightarrow 2Br(g)$

☐ **B** $Br_2(l) \rightarrow 2Br(g)$

☐ **C** $\frac{1}{2}Br_2(l) \rightarrow Br(g)$

☐ **D** $\frac{1}{2}Br_2(g) \rightarrow Br(g)$

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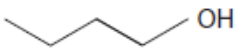
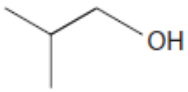
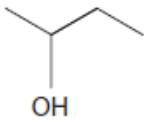
(Total for question = 1 mark)

Q4.

Biobutanol is a possible alternative to bioethanol as an additive to petrol.

(a) (i) Complete the table for the four isomers of C_4H_9OH which are alcohols.

(3)

Skeletal formula	Name	Classification	Boiling temperature / °C
	butan-1-ol	primary	117
			108
			99
	2-methylpropan-2-ol		82

(ii) Explain the difference in boiling temperature between butan-1-ol and 2-methylpropan-2-ol.

(2)

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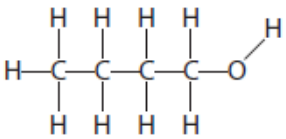
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(iii) The displayed formula of butan-1-ol is shown.

Complete the diagram to show the strongest intermolecular force between **two** molecules of butan-1-ol. Include the intermolecular bond angle.

(2)



(b) (i) Complete the equation for the combustion of butan-1-ol.

State symbols are not required.

(1)



(ii) Calculate a value for the enthalpy change of combustion of butan-1-ol using the equation in (b)(i) and the mean bond enthalpies in the table.

(3)

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

(iii) A data book value of the molar enthalpy change of combustion of butan-1-ol is −2670 kJ mol^{-1}

Give **two** reasons for the difference between this value and the value calculated in (b)(ii).

(2)

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(c) Biobutanol has some advantages over bioethanol.

(i) The combustion of bioethanol releases 23 MJ dm^{-3} compared to petrol which releases 32 MJ dm^{-3}.

Calculate the energy released in MJ dm^{-3} for the combustion of biobutanol.

Biofuel	Formula	$\Delta_c H$/kJ mol^{-1}	Density/g cm^{-3}
biobutanol	C_4H_9OH	−2670	0.810

(2)

(ii) Biobutanol can be mixed with petrol in any proportion whereas bioethanol cannot.

Petrol is a mixture of liquid alkanes.

Explain why petrol is more miscible with biobutanol than with bioethanol.

(2)

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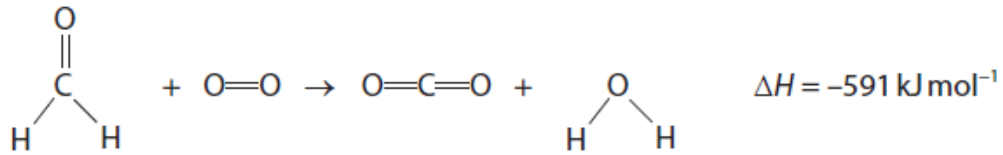
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(Total for question = 17 marks)

Q5.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The equation for the complete combustion of methanal is shown.



Some bond enthalpy data are shown.

Bond	Bond enthalpy / kJ mol^{-1}
C—H	413
O=O	498
C=O in CO_2	805
O—H	464

What is the C=O bond enthalpy in methanal?

☒ **A** 623 kJ mol^{-1}

☒ **B** 678 kJ mol^{-1}

☒ **C** 805 kJ mol^{-1}

☒ **D** 1036 kJ mol^{-1}

(Total for question = 1 mark)

Q6.

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 ☒.

Hydrogen reacts with oxygen to form steam.

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H2O(g) \qquad \Delta H = -242 \text{ kJ mol}^{-1}$$

Bond	Bond enthalpy / kJ mol^{-1}
H—H	436
O═O	498

What is the bond enthalpy of the O—H bond, in kJ mol^{-1}?

☒ **A** 221.5

☒ **B** 463.5

☒ **C** 588

☒ **D** 927

(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 ☒.

Chlorine reacts with ethane to form chloroethane and hydrogen chloride.

$$Cl_2 + C_2H_6 \rightarrow C_2H_5Cl + HCl$$

Bond	Bond enthalpy / kJ mol^{-1}
C—Cl	346
C—H	413
Cl—Cl	243
H—Cl	432
C—C	347

What is the enthalpy change for the reaction, in kJ mol^{-1}?

☒ **A** −1434

☒ **B** −122

☒ **C** +122

☒ **D** +1434

(Total for question = 1 mark)

Q8.

This question is about enthalpy changes.

(a) An experiment was carried out to determine the enthalpy change of combustion for ethanol.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

1.19 g of ethanol was burned in a spirit burner. The heat energy from this combustion raised the temperature of 100 g of water from 21.6 °C to 63.9 °C.

(i) Calculate the number of moles of ethanol in 1.19 g.

[Molar mass of ethanol = 46.0 g mol^{-1}]

(1)

(ii) Calculate the heat energy required to raise the temperature of 100 g of water from 21.6 °C to 63.9 °C.

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

(2)

(iii) Use your answers to (a)(i) and (ii) to calculate a value for the enthalpy change of combustion of ethanol.

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

(3)

(iv) The value of the enthalpy change of combustion from this experiment was very inaccurate.

Give two reasons why this value was so inaccurate, apart from heat loss.

(2)

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(b) Mean bond enthalpies can be used to calculate a value for the enthalpy change of combustion of a compound.

(i) Give the meaning of the term 'mean bond enthalpy'.

(2)

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(ii) Calculate a value for the enthalpy change of combustion of methanol, using the information in the table and the equation shown.

(3)

$$CH_3OH + 1\tfrac{1}{2}O_2 \rightarrow CO_2 + 2H_2O$$

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

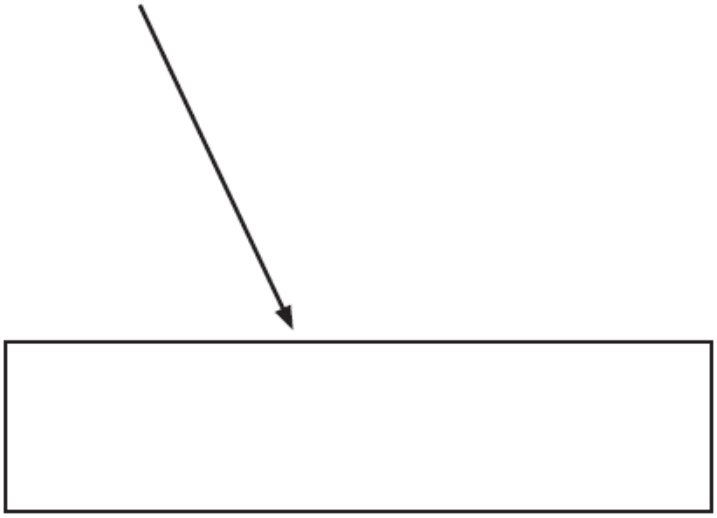
(c) Enthalpy changes of combustion can be used to calculate the enthalpy change of formation of a compound.

Substance	Standard enthalpy change of combustion, $\Delta_c H^{\ominus}$ / kJ mol^{-1}
C(s,graphite)	–394
$H_2(g)$	–286
$CH_3CHO(g)$	–1167

Complete the Hess cycle and use it to calculate the standard enthalpy change of formation for ethanal, CH_3CHO.

(3)

$$2C(s, \text{graphite}) + 2H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow CH_3CHO(g)$$



(Total for question = 16 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 ☒.

Use the data shown.

$$CH_4(g) + 2F_2(g) \rightarrow CF_4(g) + 2H_2(g) \qquad \Delta H^{\ominus} = -858\,\text{kJ mol}^{-1}$$

$$C(s) + 2F_2(g) \rightarrow CF_4(g) \qquad \Delta H^{\ominus} = -933\,\text{kJ mol}^{-1}$$

What is the standard enthalpy change of formation of methane (CH_4) in kJ mol^{-1}?

☒

A −1791

☒ **B** −75

☒ **C** +75

☒ **D** +1791

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

(Total for question = 1 mark)

Q10.

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 experiment, 50.0 cm^3 of 1.0 mol dm^{-3} HCl(aq) reacts with 50.0 cm^3 of 1.0 mol dm^{-3} NaOH(aq).

The energy released = 2500 J.

The specific heat capacity of the mixture is 4.18 J g^{-1} $°C^{-1}$

What temperature change occurs in the reaction?

☒ **A** an increase of 6.0°C

☒ **B** a decrease of 6.0°C

☒ **C** an increase of 12.0°C

☒ **D** a decrease of 12.0°C

(Total for question = 1 mark)

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 ☒.

What is the mass of carbon formed when 1.80 g of propan-1-ol, C_3H_7OH, undergoes incomplete combustion according to the equation shown?

$$C_3H_7OH(l) + 2O_2(g) \rightarrow 2C(s) + CO(g) + 4H_2O(l)$$

☒ **A** 0.18 g

☒ **B** 0.36 g

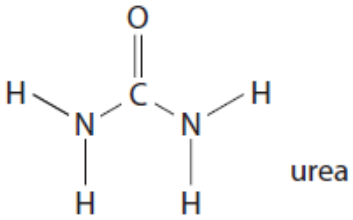
☒ **C** 0.72 g

☒ **D** 1.08 g

(Total for question = 1 mark)

Q12.

Some diesel cars contain an extra catalytic converter for the reduction of nitrogen oxides (NO_x) in exhaust gases.
A solution of urea is used for this process.



urea

(a) Urea has a melting temperature of 133 °C.

Explain why this value is higher than expected for a relatively small molecule.

(3)

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(b) A saturated solution of urea has a concentration of 9.07 mol dm^{-3} at 25°C.

Calculate the mass of urea in 150 cm^3 of a saturated solution.

(2)

(c) State why NO_x emissions are harmful to the environment.

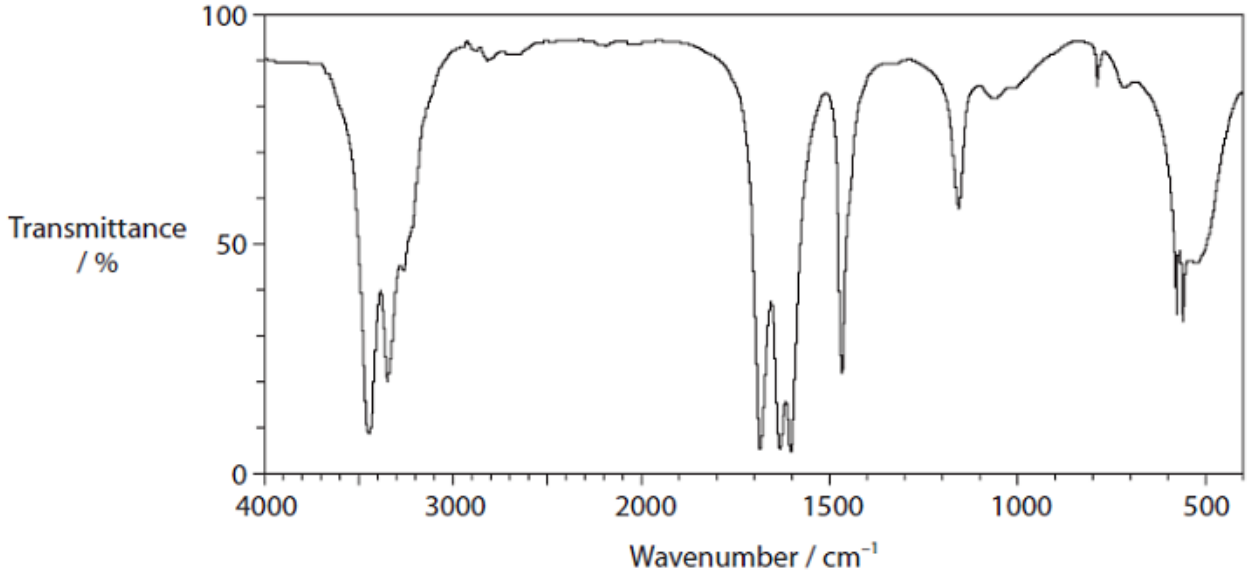
(1)

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(d) An infrared spectrum of urea is shown.

Refer to your Data Booklet.



(i) Draw a circle around an absorption in the spectrum that could be due to the stretching of the N—H bond.

(1)

(ii) Identify the bond responsible for the absorption at 1683 cm^{-1}.

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(1)

(e) In a diesel car exhaust system, the urea reacts with water to form ammonia and carbon dioxide. The enthalpy change for this reaction is +133 kJ mol^{-1}.

(i) Complete the equation for this **reversible** reaction.

State symbols are not required.

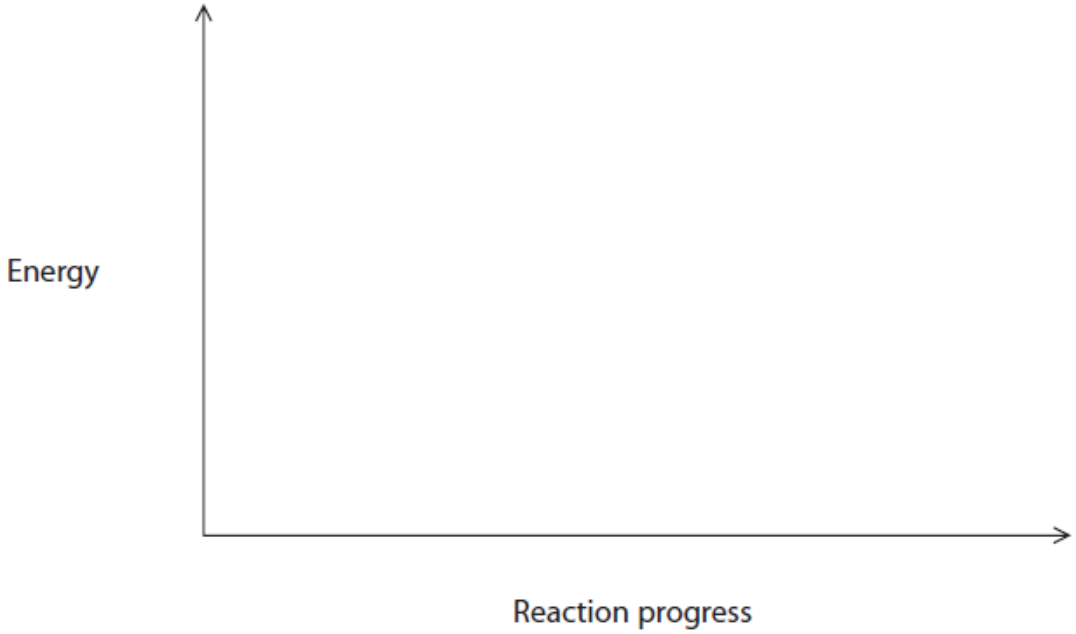
(1)

$(NH_2)_2CO + H_2O$

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(ii) Sketch the reaction profile for the forward reaction on the axes provided.

Include labels for ΔH and the activation energy (E_a).



(3)

(f) The catalytic converter contains metal oxides. When the exhaust gases pass through the catalytic converter, ammonia reacts with NO_x gases to form nitrogen and water.

(i) Explain why it is **not** correct to state that urea is acting as a catalyst in the reaction.

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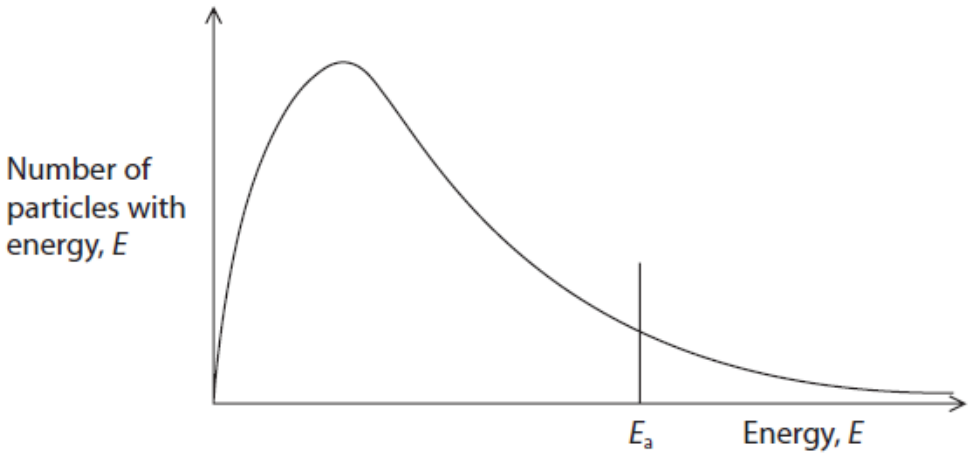
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(1)

(ii) Explain how a catalyst increases the rate of a chemical reaction.

Use the Maxwell-Boltzmann distribution shown and refer to the collision theory.

(3)



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(g) The catalytic converter works best at a temperature of around 350 °C.

(i) Suggest how the catalytic converter reaches this temperature.

(1)

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(ii) The chemical reactions in the exhaust system of a diesel car, using a catalytic converter, form 89.3 m^3 of nitrogen per hour.

Calculate the number of molecules of nitrogen formed per hour.

[Molar volume at 350 °C = 51.1 $dm^3\ mol^{-1}$

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

(3)

(Total for question = 20 marks)

Q13.

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, $MgCO_3$, 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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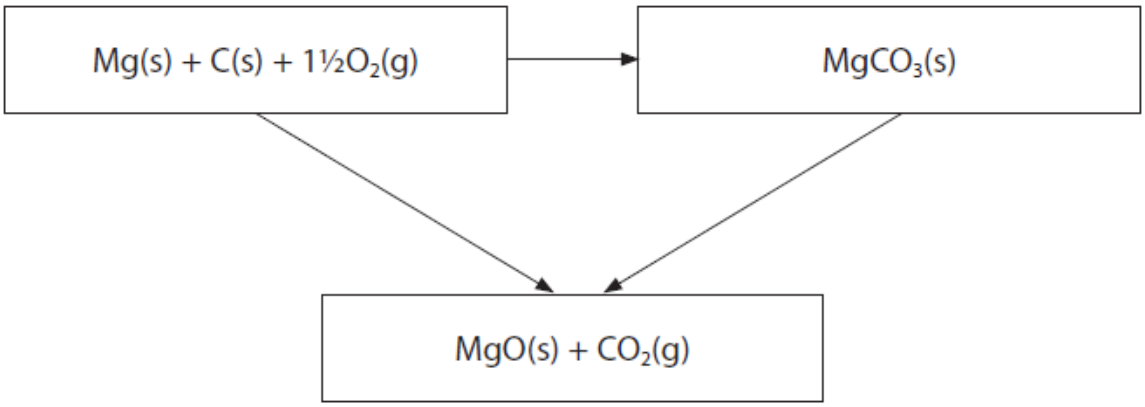
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(ii) The Hess cycle and data to calculate the enthalpy change for the thermal decomposition of $MgCO_3$ are shown.



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)

Q14.

Sodium hydrogencarbonate can be decomposed to sodium carbonate by heating to about 300 °C.

The equation for the reaction is:

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(l)$$

(a) Give a reason why it is **not** possible to measure the enthalpy change for this reaction directly.

(1)

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(b) (i) State what is meant by the standard enthalpy change of formation.

(2)

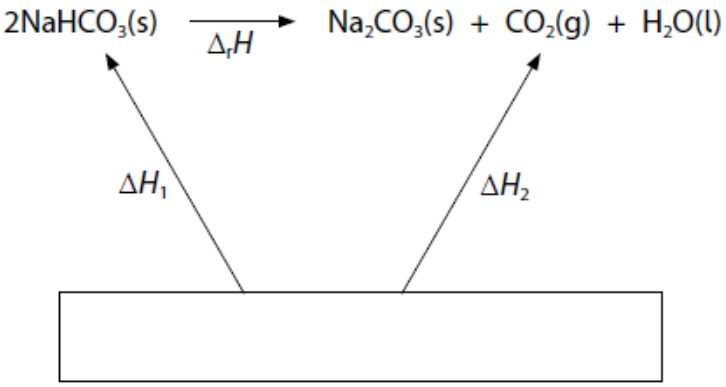
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(ii) Complete the Hess cycle that you would use to determine the enthalpy change for this reaction from the standard enthalpy changes of formation.

(2)



(iii) Calculate the standard enthalpy change for the thermal decomposition of sodium hydrogencarbonate, using the information in the table and your completed cycle. Include a sign and units in your answer.

(4)

Compound	Standard enthalpy change of formation, $\Delta_f H^{\ominus}$ / kJ mol^{-1}
$NaHCO_3(s)$	–950.8
$Na_2CO_3(s)$	–1130.7
$CO_2(g)$	–393.5
$H_2O(l)$	–285.8

(iv) Use your answer to (b)(iii) to draw an enthalpy level diagram for this reaction, labelling the axes provided.

(2)



(Total for question = 11 marks)

Q15.

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 ☒.

The bond enthalpy for the Cl—Cl bond is +243.0 kJ mol^{-1}.

What is the enthalpy change of atomisation of chlorine in kJ mol^{-1}?

☒ **A** +243.0

☒ **B** –243.0

☒ **C** +121.5

☒ **D** –121.5

(Total for question = 1 mark)

Q16.

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 ☒.

The equation for a reaction is

$$2C(s) + O_2(g) \rightarrow 2CO(g)$$

Which is the correct symbol for the enthalpy change for this reaction?

☒ **A** $\Delta_{at}H$

☒ **B** $\Delta_c H$

☒ **C** $\Delta_f H$

☒ **D** $\Delta_r H$

(Total for question = 1 mark)

Q17.

A student carries out two experiments and uses the results to determine the enthalpy change when anhydrous copper(II) sulfate forms hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$.

$$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4 \cdot 5H_2O(s)$$

(a) In the first experiment, the student determines the enthalpy change when hydrated copper(II) sulfate dissolves in water.

$$CuSO_4 \cdot 5H_2O(s) + aq \rightarrow CuSO_4(aq)$$

10.68 g of hydrated copper(II) sulfate is added to distilled water in a polystyrene cup to give 55.0 g of solution.
The mixture is stirred and the temperature change determined.

Results

Initial temperature = 21.0 °C

Minimum temperature = 18.5 °C

Calculate the enthalpy change for this reaction.
Give your answer to an appropriate number of significant figures.
Include a sign and units.

Data: Specific heat capacity of the solution = 3.70 J g^{-1} $°C^{-1}$
Molar mass $CuSO_4 \cdot 5H_2O$ = 249.6 g mol^{-1}

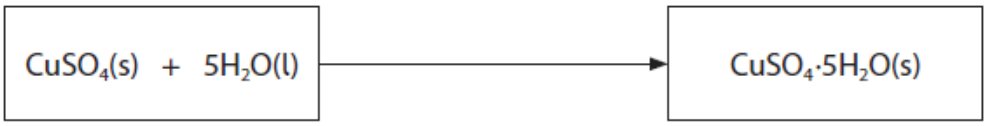
(4)

(b) In the second experiment, the student determined the enthalpy change of the reaction when anhydrous copper(II) sulfate dissolves in water.

$$CuSO_4(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H = -67.4 \text{ kJ mol}^{-1}$$

(i) Complete the Hess cycle.

(2)



(ii) Calculate the enthalpy change when anhydrous copper(II) sulfate forms hydrated copper(II) sulfate. Include a sign and units.

(2)

(Total for question = 8 marks)

Q18.

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 equation represents the standard enthalpy change of formation, $\Delta_f H^{\ominus}$, for aluminium oxide?

☒ **A** $2Al(s) + 1\frac{1}{2}O_2(g) \rightarrow Al_2O_3(s)$

☒ **B** $2Al(s) + 3O(g) \rightarrow Al_2O_3(s)$

☒ **C** $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

☒ **D** $4Al(s) + 6O(g) \rightarrow 2Al_2O_3(s)$

(Total for question = 1 mark)

Q19.

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 ☒.

Some enthalpy changes of combustion are shown.

Substance	Enthalpy change of combustion / kJ mol^{-1}
$CH_3CHO(l)$	−1167
C(s)	−394
$H_2(g)$	−286

What is the enthalpy change of formation of ethanal, CH_3CHO, in kJ mol^{-1}?

☒ **A** +765

☒ **B** −765

☒ **C** +193

☒ **D** −193

(Total for question = 1 mark)

Q20.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

5.20 g of sodium hydrogencarbonate is added to an excess of acid.

The temperature increases and the energy change is calculated to be 1030 J.

What is the enthalpy change per mole of sodium hydrogencarbonate?

[M_r $NaHCO_3$ = 84.0]

☒ **A** –12.3 kJ mol^{-1}

☒ **B** –16.6 kJ mol^{-1}

☒ **C** –63.8 kJ mol^{-1}

☒ **D** –16 600 kJ mol^{-1}

(Total for question = 1 mark)

Q21.

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 ☒ .

The enthalpy changes for two reactions are shown.

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ $\Delta_r H = -57.2\ kJ\ mol^{-1}$

$CH_3COOH(aq) + OH^-(aq) \rightarrow CH_3COO^-(aq) + H_2O(l)$ $\Delta_r H = -56.0\ kJ\ mol^{-1}$

What is the enthalpy change for the dissociation of $CH_3COOH(aq)$ into $CH_3COO^-(aq)$ and $H^+(aq)$ ions, in kJ mol^{-1}?

☒ **A** +113.2

☒ **B** +1.2

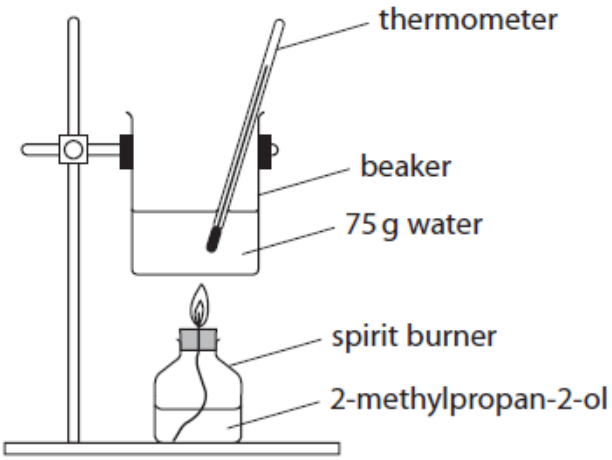
☒ **C** −1.2

☒ **D** −113.2

(Total for question = 1 mark)

Q22.

Enthalpy changes of combustion can be determined using calorimetry or calculated using Hess cycles. Apparatus for a calorimetry experiment is shown.



A sample of 2-methylpropan-2-ol was burned in a spirit burner and used to heat 75 g of water. The results are shown.

	At the start	At the end	Change
Mass of spirit burner / g	267.35	266.78	
Temperature of water / °C	19.5	65.3	

(a) (i) Complete the table.

(1)

(ii) Calculate the enthalpy change of combustion, $\Delta_c H$, of 2-methylpropan-2-ol.

Give a sign and units in your answer.
[Specific heat capacity of water = 4.18 J g^{-1} $°C^{-1}$]

(4)

(b) The standard enthalpy change of combustion, $\Delta_c H^{\ominus}$, can be calculated using standard enthalpy changes of formation.

Compound	$\Delta_f H^{\ominus}$ / kJ mol^{-1}
2-methylpropan-2-ol	–359
carbon dioxide	–394
water	–286

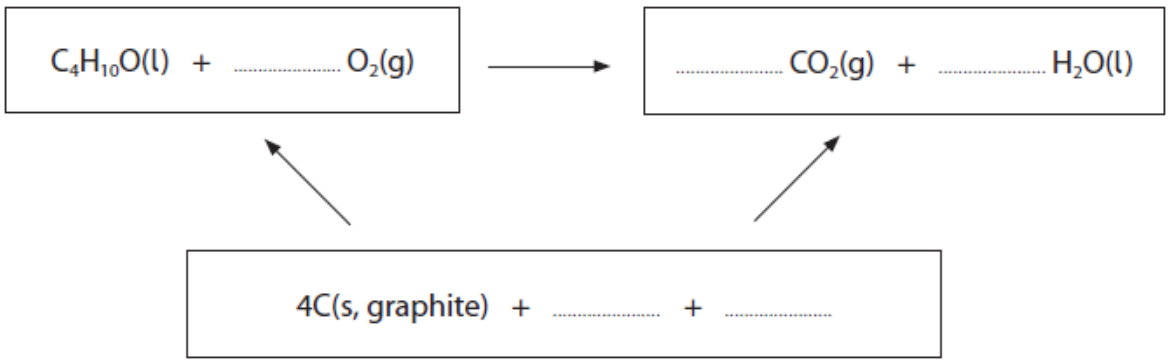
(i) State why no $\Delta_f H^{\ominus}$ value has been given for oxygen.

(1)

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(ii) Complete the Hess cycle.



(2)

(iii) Calculate the standard enthalpy change of combustion of 2-methylpropan-2-ol using the data in the table and the completed Hess cycle.

(2)

(c) The value for $\Delta_c H$ obtained in part (a)(ii) is much less exothermic than $\Delta_c H^{\ominus}$

Suggest **two** reasons for this other than non-standard conditions.

(2)

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(Total for question = 12 marks)

Q23.

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.

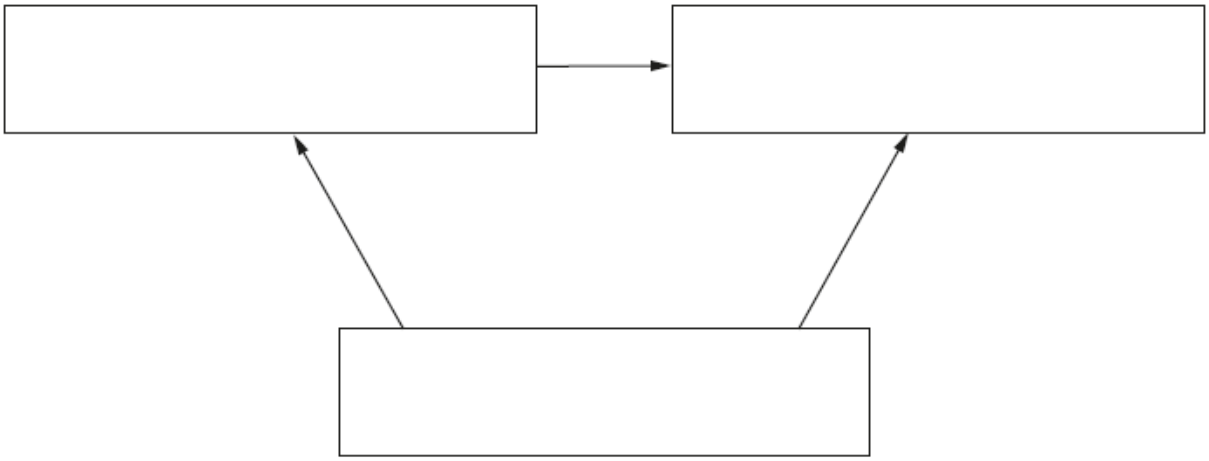
[Specific heat capacity of the hand warmer = 3.0 J $°C^{-1}$ g^{-1}]

(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)

Q24.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which are correct for the reaction shown?

$$CH_3COOH + KOH \rightarrow CH_3COO^-K^+ + H_2O \quad \Delta H = -55.8 \text{ kJ mol}^{-1}$$

		Type of reaction	Type of enthalpy change
☒	**A**	endothermic	formation
☒	**B**	endothermic	neutralisation
☒	**C**	exothermic	formation
☒	**D**	exothermic	neutralisation

(Total for question = 1 mark)

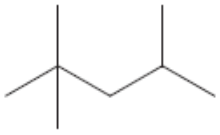
Q25.

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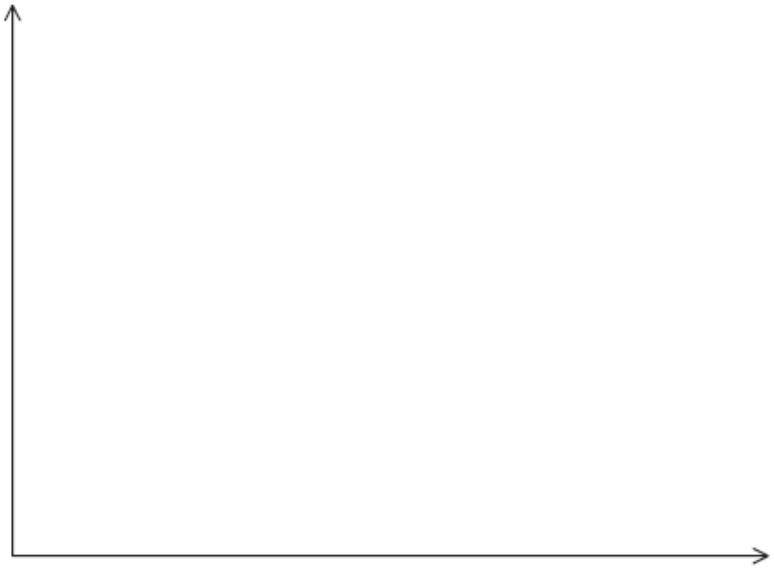
(ii) Write the equation for the complete combustion of 2,2,4-trimethylpentane, using **molecular** formulae.

State symbols are not required.

(2)

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

(2)

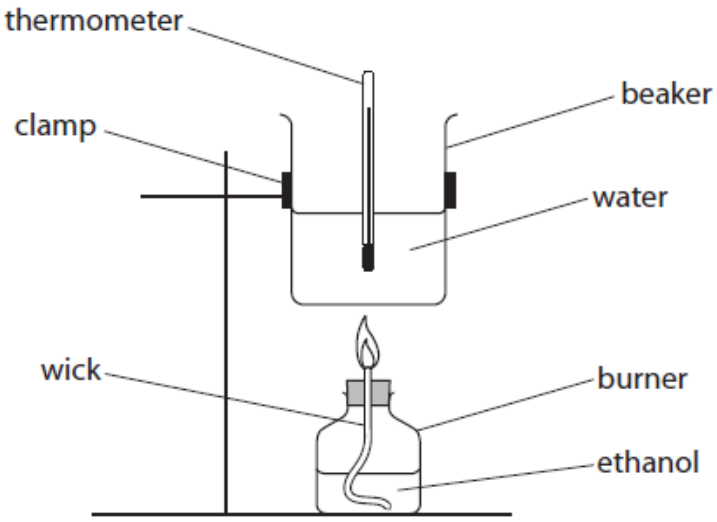


(iv) Calculate the heat energy released during the complete combustion of 1 dm^3 of 2,2,4-trimethylpentane.

[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)

Q26.

Under certain conditions, graphite burns to form carbon monoxide.

$$2C(s) + O_2(g) \rightarrow 2CO(g) \qquad \Delta H = -221 \text{ kJ mol}^{-1}$$

Which of these is correct?

(1)

☒ **A** $\Delta_c H$ (carbon) $= -221 \text{ kJ mol}^{-1}$

☒ **B** $\Delta_f H$ (carbon monoxide) $= -221 \text{ kJ mol}^{-1}$

☒ **C** $\Delta_c H$ (carbon) $= -110.5 \text{ kJ mol}^{-1}$

☒ **D** $\Delta_f H$ (carbon monoxide) $= -110.5 \text{ kJ mol}^{-1}$

(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 ☒.

The standard enthalpy change of neutralisation for the reaction between sodium hydroxide solution and hydrochloric acid
is –56 kJ mol^{-1}.

Which row in the table is correct for this neutralisation?

	Reaction type	Temperature
☒ **A**	exothermic	increases
☒ **B**	exothermic	decreases
☒ **C**	endothermic	increases
☒ **D**	endothermic	decreases

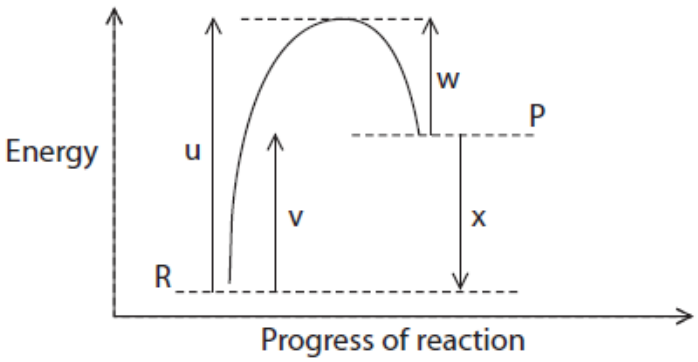
(Total for question = 1 mark)

Q28.

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 ☒.

The diagram shows a reaction profile for a reversible reaction.

$R \rightleftharpoons P$



(a) Which symbol represents the enthalpy change for the reaction R → P?

(1)

☒ **A** u

☒ **B** v

☒ **C** w

☒ **D** x

(b) Which symbol represents the activation energy of the reaction P → R?

(1)

☒ **B** u

☒ **B** v

☒ **C** w

☒ **D** x

(c) Hess's Law can be applied to this system.

Which expression is correct?

(1)

☒ **A** v + x = u + w

☒ **B** w + x = u

☒ **C** u – w = v

☒ **D** u – v = x

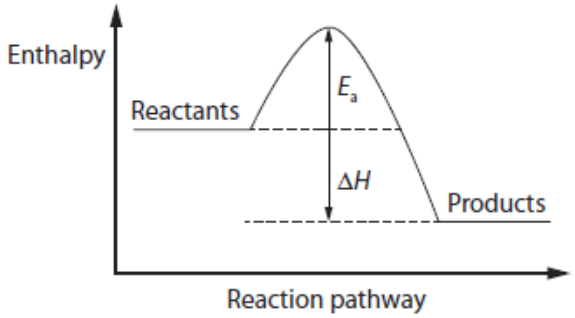
(Total for question = 3 marks)

Q29.

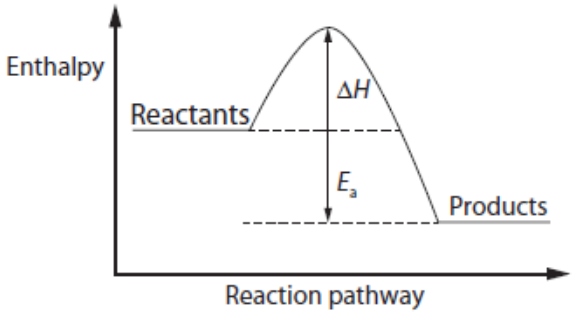
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which is the correctly labelled reaction profile for an exothermic reaction?

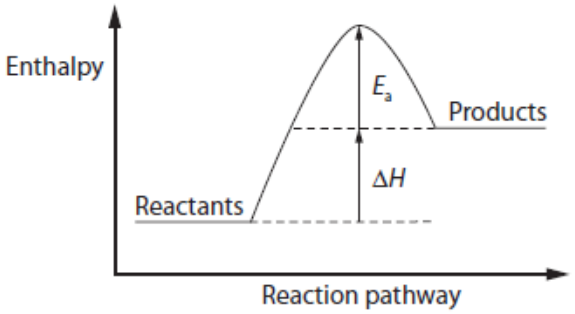
☒ **A**



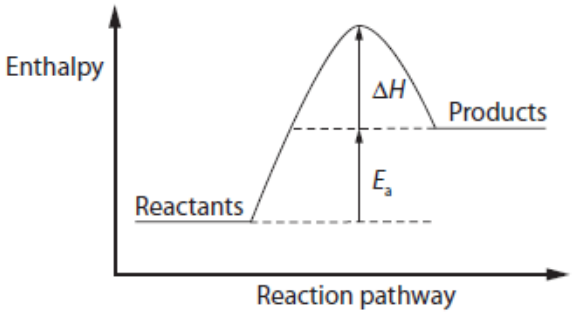
☒ **B**



☒ **C**



☒ **D**



(Total for question = 1 mark)

Q30.

(a) Silver ions have anti-microbial properties and are used in some wound dressings. Silver nitrate can be made
by warming a mixture of silver metal and concentrated nitric acid.

$$Ag(s) + 2HNO_3(aq) \rightarrow AgNO_3(aq) + NO_2(g) + H_2O(l)$$

Show, by reference to oxidation numbers, that this is a redox reaction.

(2)

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(b) Two students used different methods to determine the concentration of a silver nitrate solution.

(i) Student A used a calorimetric method, reacting a 50.0 cm^3 sample of the solution with excess powdered zinc.

$$AgNO_3(aq) + \tfrac{1}{2}Zn(s) \rightarrow \tfrac{1}{2}Zn(NO_3)_2(aq) + Ag(s) \quad \Delta_r H = -36.1\ kJ\,mol^{-1}$$

The student recorded a maximum rise in temperature of 5.2 °C.

Calculate the concentration of the silver nitrate solution in mol dm^{-3}.

[Assume the specific heat capacity of the solution is 4.18 J g^{-1} $°C^{-1}$ and the density of the solution is 1.00 g cm^{-3}.]

(3)

(ii) Student B used a gravimetric method, which involved weighing a product of a reaction.

A 50.0 cm^3 sample of the same silver nitrate solution was mixed with excess potassium bromide solution.
The precipitate was filtered and weighed.

$$AgNO_3(aq) + KBr(aq) \rightarrow AgBr(s) + KNO_3(aq)$$

The mass of the precipitate was found to be 5.96 g.

Calculate the concentration of the silver nitrate solution, in mol dm^{-3}, from this gravimetric method.

(2)

(iii) The students' values were different from the data book value.

Student A's value was lower and student B's value was higher.
Give a possible reason for each difference.

(2)

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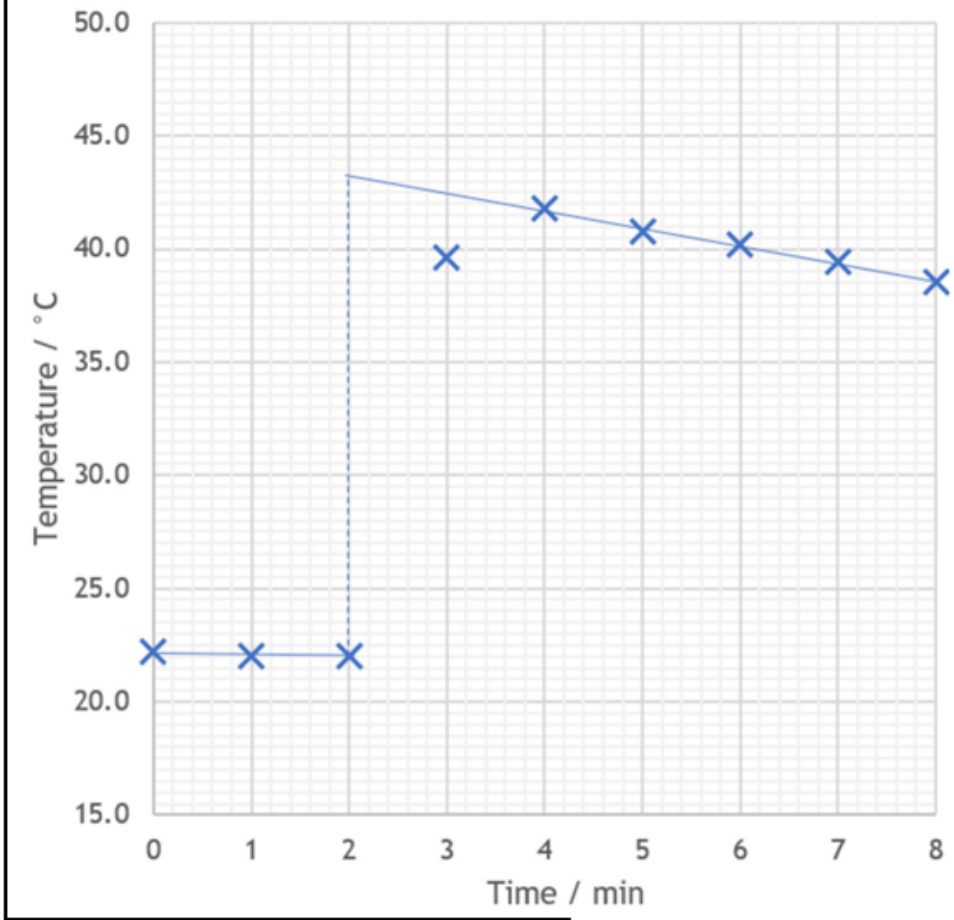
(Total for question = 9 marks)

Mark Scheme

Q1.

Q	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • correct balanced equation **(1)** • correct state symbols **(1)**	Example of equation: $Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$ OR $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ M2 dependent on M1 or near miss (e.g. missing 2 on $2H^+$)	**2**

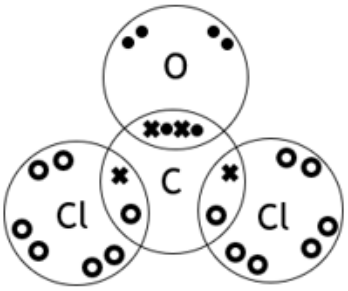
Q	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • moles calculated correctly for magnesium **(1)** • moles calculated correctly for acid **(1)** • justification of both the reacted moles being the smaller value as a 1:1 stoichiometry (and Mg being in excess) **(1)**	Example answer: 0.5 ÷ 24.3 = 0.020576 moles of Mg Allow use of 24 for 24.3 gives 0.020833 Allow 0.020 Do not award 0.02 0.2 × (25 ÷ 1000) = 0.005 moles of acid 0.005 moles of each react as it is a 1:1 relationship (This can be shown in working/text, but must not be contradicted in final answer) Ignore any further workings e.g. 0.005 + 0.005 = 0.01 TE from equation for stoichiometry	**3**

Q	Answer	Additional Guidance	Mark
(c)(i)	An answer that makes reference to the following points: Example of graph:  • suitable choice of scale so that the points cover at least 50% of the grid in both directions and allow for extrapolation AND correct choice of axes suitably labelled including units **(1)** • all points plotted correctly **(1)**	Allow units in brackets e.g. (min) instead of "/ min" NB Lines do not have to be present for (c)(i) Ignore scale breaks between 0 and 20/22 on the y-axis that allow for M1 and M2 to be scored	**2**

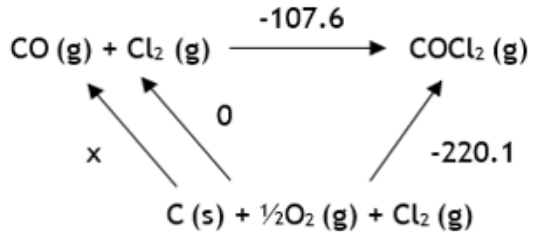
Q	Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following points: • two straight lines of best fit **(1)** with the cooling curve extrapolated back to 2 minutes • calculation of temperature change from the graph at 2 minutes **(1)**	<u>Example of calculation</u>: Ignore points 2, 3 and 4 being joined by a line 43.5 – 22.0 = 21.5(°C) TE from the graph in 19(c)(i)	**2**

Q	Answer	Additional Guidance	Mark
(d)	An answer that makes reference to the following points: • recall of equation **(1)** • substitution of correct values **(1)** • conversion to molar quantity **(1)** • correct sign **and** units **(1)**	Example calculation: $\Delta H = (-)mc\Delta T$ $\Delta H = 25 \times 4.18 \times 21.5 = 2246.75$(J) $\Delta H \div 0.005 = (-)449\,350$ (J mol^{-1}) / (–)449 (kJ mol^{-1}) – 449 350 J mol^{-1} / – 449 kJ mol^{-1} TE throughout and from 19(c)(ii) and 19(a) [– 413.8kJ mol^{-1} scores 4 if 19.8 used as ΔT] If mass of 25.5g is used, then the answer will be – 458 337 J mol^{-1} / – 458 kJ mol^{-1} for 3 marks Ignore SF except 1SF Ignore rounding Correct answer with sign and units scores (4)	**4**
		(Total for Question = 13 marks)	

Q2.

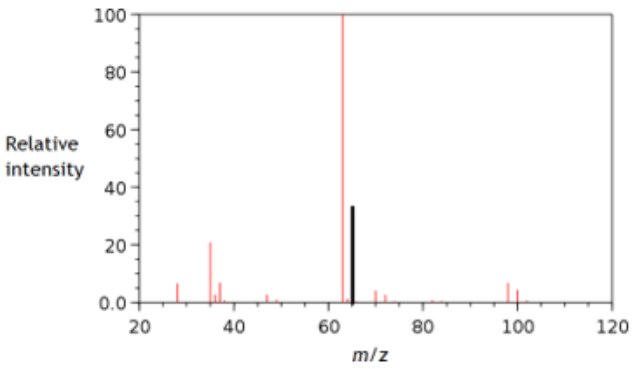
Q	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: A diagram that includes: • carbon singly covalently bonded to two chlorine atoms and three lone pairs on each chlorine **(1)** • carbon doubly bonded to an oxygen atom and two lone pairs on the oxygen **(1)**	 Penalise lack of lone pairs once only Allow any representation of electrons Allow individual electrons spread out, rather than in pairs Allow horizontal shared pairs of electrons Ignore lines representing covalent bonds	**2**

Q	Answer	Additional Guidance	Mark
(b)(i)	An explanation that makes reference to the following points: Any two pairs from the three: • decrease the temperature **(1)** • as the (forward) reaction is exothermic **(1)** • increase the pressure **(1)** • as there a fewer moles of (gas) on the product side **(1)** **EITHER** • remove the phosgene (as it is formed) **(1)** • to reduce the concentration of product (so equilibrium moves to the right) **(1)** **OR** • add more CO / Cl_2 **(1)** • to increase the concentration of the reactants (so equilibrium moves to the right) **(1)**	Ignore references to rate of reaction Allow T↓ Allow "favours the exothermic reaction" Allow P↑ if numbers are quoted, they must be 2:1 Allow "favours the side with fewer moles"	**4**

Q	Answer	Additional Guidance	Mark
(b)(ii)	An answer that makes reference to the following points: • correct species **(1)** • correct state symbols **(1)** • correct arrows **(1)** • calculation of value **(1)**	Example of an answer:  ΔH_f CO = −220.1 – (−107.6) = −112.5 (kJ mol^{-1}) Accept state symbol for C(s, graphite) Ignore absence of arrow and value to chlorine Numbers are not required on the cycle	**4**

Q	Answer	Additional Guidance	Mark
(c)(i)	An explanation that makes reference to the following points: • chlorine isotopes (35 and 37) are in the ratio of 3:1 **(1)** • (as there are) two chlorine atoms give the ratio of 9:6:1 **(1)**	Accept ^{37}Cl 75% : ^{35}Cl 25% Allow this shown in workings e.g. $CO^{37}Cl^{37}Cl^{(+)}$ = 102, $CO^{35}Cl^{37}Cl^{(+)}$ = 100, $CO^{35}Cl^{35}Cl^{(+)}$ = 98 Do not award ^{36}Cl Mark independently Reference to isotopes of carbon should be penalised once	**2**

Q	Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following point • $CO^{35}Cl^{+}$	Allow the + on any of the atoms Ignore brackets	**1**

Q	Answer	Additional Guidance	Mark
(c)(iii)	An answer that makes reference to the following point • peak drawn at 65 with relative intensity of 33.3	Example of completed graph:  Allow a peak height between 30-35	**1**

Q	Answer	Additional Guidance	Mark
(d)	An answer that makes reference to the following points: • 1795 (cm^{-1}) **(1)** • (from the) C=O (stretching vibrations) **(1)**	Allow a number or range within 1630-1850 (cm^{-1}) M2 is dependent on M1 Allow a number or range within 550-850 (cm^{-1}) **and** C-Cl (stretching vibrations) for 2 marks Ignore acyl chloride Do not award M2 for aldehydes/ketones	**1**

Q	Answer	Additional Guidance	Mark
(e)(i)	An answer that makes reference to the following point: • balanced equation	$2CHCl_3 + O_2 \rightarrow 2COCl_2 + 2HCl$ Accept multiples of the equation Ignore state symbols even if incorrect	**1**

Q	Answer	Additional Guidance	Mark
(e)(ii)	An answer that makes reference to the following point: • oxygen concentration will decrease	Allow oxygen used up Allow [O_2] decreases Allow volume of oxygen decreases Do not award "air is used up" "Reactants are used up" is insufficient as doesn't apply information from the question Comments about trichloromethane decreasing negate the oxygen mark	**1**

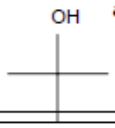
Q	Answer	Additional Guidance	Mark
(e)(iii)	An answer that makes reference to the following point • use a fume cupboard (due to toxic and irritant gases)	Allow open in a well-ventilated laboratory / open outside / wear a **gas** mask Ignore eye protection / laboratory coats / gloves Ignore just "mask" and "do not inhale" Do not award face shield	**1**

Q	Answer	Additional Guidance	Mark
(e)(iv)	An answer that makes reference to the following points: • no, because some of the HCl/$COCl_2$ may have dissolved into the chloroform / be trapped as bubbles in the liquid	Allow may have reacted (with oxygen) to give (toxic) phosgene / $COCl_2$	**1**
		(Total for Question = 20 marks)	

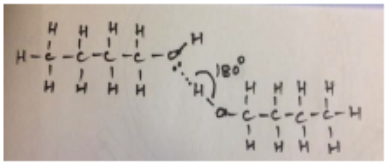
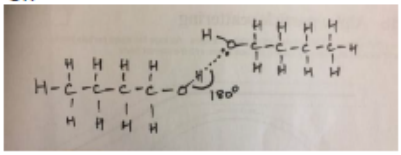
Q3.

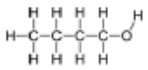
Question number	Answer	Mark
	The only correct answer is C ($\frac{1}{2}Br_2(l) \rightarrow Br(g)$) ***A** is not correct because 2 moles of Br atoms form and Br_2 is in gaseous state* ***B** is not correct because 2 moles of Br atoms form* ***D** is not correct because Br_2 is in gaseous state*	**(1)**

Q4.

Question Number	Answer		Additional Guidance	Mark
(a)(i)	• (2)-methylpropan-1-ol and primary • butan-2-ol and secondary •  and tertiary	(1) (1) (1)	All 6 correct scores 3 4 or 5 correct scores 2 2 or 3 correct scores 1 Ignore bond lengths and bond angles Do not award displayed formula	(3)

Question Number	Answer		Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to the following points:		Accept reverse argument (butan-1-ol has a higher boiling temperature than 2-methylpropan-2-ol because)	(2)
	• Identification of (at least) one of the intermolecular forces and a comparison of its strength in the two molecules	(1)	the instantaneous dipoles-induced dipoles / London forces / dispersion forces / van der Waals forces are stronger between straight chains Allow There are more London forces OR the hydrogen bonding is stronger between straight chain molecules	
	• an explanation for this difference	(1)	the straight chain molecule/ butan-1-ol has greater surface area / more points of contact OR as the -OH group is more exposed / less hindered (so less energy is needed to break the intermolecular forces) If the explanation is in terms of London forces, ignore 'hydrogen bonding is similar / same' Ignore 'references to"longer carbon chain" Do not award Any reference to longer carbon bonds/breaking covalent bonds	

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	• O---H—O (1) • bond O-H-O must be shown as (approximately) linear (1) **and** angle labelled as 180°	Example of diagrams:  OR  Do not penalise omission of lone pair on the oxygen or errors in the carbon chain e.g. missing Hs Do not award hydrogen bond shown as a solid line (M1) H—O---H bond shown as 180° (M2) Incorrect -OH attachment to chain (M2) ignore bond lengths	(2)

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• balanced equation	 + 6 O=O ⟶ 4 O=C=O + 5 H−O−H	(1)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• calculation or working of energy needed to break bonds (1) • calculation or working of energy released when bonds are made (1) • calculation of energy change and give a sign (1)	Here, and throughout the paper do not penalise mol⁻ for mol^{-1} Energy to break all bonds: (3x347) + (9x413) + 358 + 464 + (6x498) = 8568 (kJ mol^{-1}) Energy released when all bonds made: (10x464) + (8x805) = 11080(kJ mol^{-1}) −11080 + 8568 = −2512 (kJ mol^{-1}) Do not award incorrect units TE on incorrect balancing of equation and TE at each stage of calculation Ignore SF except 1SF Correct answer no working scores (3) Comment Common error is the use of 6.5 x 498 (forgets about the alcohol oxygen). This gives −2263 kJ mol^{-1} scores 2.	(3)

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An answer that makes reference to the following points: • mean bond enthalpies do not refer to specific compounds such as butan-1-ol/ mean bond enthalpies are averages/mean for different molecules/bonds in different environments/compounds **(1)** • butan-1-ol is a liquid and bond enthalpies refer to gases OR mean bond enthalpy calculations do not include changes of state **(1)**	Ignore just "mean bond enthalpies are an average" Ignore references to standard conditions Just 'different states'	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)(i)	• calculation of energy produced per gram **(1)** • calculation of energy produced per cm^3 **(1)** OR • calculation of moles in 1 cm^3 **(1)** • calculation of energy produced per cm^3 **(1)**	Example of calculations: (–)2670 ÷ 74 = (–)36.081/36.1 / 36 ($kJ\ g^{-1}$) 36.1 x 0.81= 29.226/29.2 / 29 ($MJ\ dm^{-3}$) 0.81 / 74 = 0.010946 (moles) 0.010946 x (–)2670 = 29.226/29.2 / 29 ($MJ\ dm^{-3}$) Units, if given, must be correct in $MJ\ dm^{-3}$ Correct answer with no working scores (2) Ignore sign and SF except 1SF	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following points: • biobutanol has a longer hydrocarbon / alkane chain/ more electrons than bioethanol **(1)** • so more/stronger London forces / dispersion forces / Van der Waals forces between biobutanol and petrol (than bioethanol and petrol) **(1)**	Ignore references to polarity, non-polar parts Allow London forces in biobutanol and petrol are similar Do not award just "biobutanol has stronger London forces than bioethanol"	**(2)**

Q5.

Question Number	Answer	Mark
	The only correct answer is A (623 $kJ\ mol^{-1}$) ***B*** *is incorrect because this is the C=O bond in CO_2 added to an O–H bond minus 591* ***C*** *is incorrect because this is the value for C=O in CO_2* ***D*** *is incorrect because this is the value when only one of the two C-H bonds is taken into account*	**(1)**

Q6.

Question Number	Answer	Mark
	The only correct answer is B (463.5) ***A*** *is not correct because 242 has been subtracted not added* ***C*** *is not correct because 498 has not been divided by 2* ***D*** *is not correct because the final answer has not been divided by 2*	**1**

Q7.

Question number	Answer	Mark
	The only correct answer is B (–122) ***A*** *is not correct because it is the sum of formation of all product and reactant bonds* ***C*** *is not correct because the energy to break the bonds is less than the energy released when the new bonds form* ***D*** *is not correct because it is the sum of breaking all product and reactant bonds*	**(1)**

Q8.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• calculation of moles of ethanol	Example of calculation: 1.19/46 = 0.025870/ 2.5870 x 10^{-2} (mol) Ignore SF except 1 SF	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	• calculation of temperature change (1) • calculation of energy required (1)	Example of calculation: (63.9-21.6) = 42.3(°C) 42.3 x 4.18 x 100= 17681.4 (J) / 17.6814 (kJ) Units are not required in (a)(ii) but if given they must be correct. If values converted to kJ units must be given. Ignore signs Ignore SF except 1 SF Correct answer with no working scores 2	(2)

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	• calculation of the energy per mole (1) • (calculation of the enthalpy change per mole) **and** sign **and** units (1) • answer to 2 or 3 SF (1)	Example of calculation: 17681 ÷ 0.025870 = 683480 (J mol^{-1}) / 683.48 (kJ mol^{-1}) – 683480 J mol^{-1} / –683.48 kJ mol^{-1} 680000 / 683000 / 680 / 683 TE from 19(a)(i) and 19(a)(ii)	(3)

Question Number	Answer	Additional Guidance	Mark
(a)(iv)	An explanation that makes reference to the following points: • incomplete combustion (1) • evaporation of the ethanol/alcohol/fuel (1)	Allow formation of soot / carbon / carbon monoxide Allow insufficient oxygen Ignore incomplete reaction/experiment Ignore not all the ethanol burned/reacted Ignore evaporation of the water/product Ignore non-standard conditions / heat loss / specific heat capacity of water / hotspots / systematic errors	(2)

Question Number	Answer	Additional Guidance	Mark
(b)(i)	An answer that makes reference to the following points: (1) • energy required to break **one mole** of a (specific) bond • in the **gaseous** phase/state **and** (1) averaged over a number of compounds/ different molecules/different compounds/different molecules	Allow enthalpy/enthalpy change/ Energy/ energy change Ignore just mean Ignore any equations even if incorrect Ignore any mention of conditions Do not award if there is any indication that it is averaged over a number of different types of bonds. If neither M1 or M2 is scored 'The energy required to break a particular bond averaged out over a number of compounds' (1)	(2)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• **M1** Calculation of the energy change to break the bonds (1) • **M2** Calculation of the energy change to make the bonds (1) (1) • **M3** Calculation of the enthalpy change of the reaction	<u>Example of calculation</u> Breaking 3 × C-H, 1 × C-O, 1× O-H, 1½ × O=O, (3 × 413) + (1× 358) +(1 × 464) +(1½ × 498) = (+) 2808(kJ mol^{-1}) Making 2 x C=O, 4 x O-H (2 x 805) + (4 x 464) = (–) 3466(kJ mol^{-1}) = 2808(kJ mol^{-1}) –3466(kJ mol^{-1}) –658 (kJ mol^{-1}) Ignore SF except 1SF Ignore units even if wrong M3 TE on M1 and M2 +658 (kJ mol^{-1}) scores (**2**) If the TE answer is + we do not need to see the sign. Correct answer with or without working scores (**3**)	(3)

Question Number	Answer	Additional Guidance	Mark
(c)	• correct Hess cycle with arrow on the RHS going down and correct balanced products in the box. (1) (1) • calculation of left-hand side (1) • Correct **Answer** and **sign**	Example of calculation $2C\ (s,graphite) + 2H_2(g) + \frac{1}{2}O_2(g) \rightarrow CH_3CHO(g)$ $(+2\ \frac{1}{2}O_2)$ $(+2\ \frac{1}{2}O_2)$ $2CO_2(g) + 2H_2O\ (l)$ Ignore state symbols even if incorrect No TE on incorrect cycle $(2 \times -286) + (2 \times -394) = -1360$ (kJ mol^{-1}) An expression giving -1360 (kJ mol^{-1}) is sufficient (-1360 (kJ mol^{-1}) + 1167 (kJ mol^{-1})) $= -193$ (kJ mol^{-1}) If units are given they must be correct Allow kJ mol^{-} for kJ mol^{-1} Correct answer with or without working scores M2 and M3 +193 (kJ mol^{-1}) scores M2 TE on LHS	(3)

Q9.

Question number	Answer	Mark
	The only correct answer is B (-75 kJ mol^{-1}) *A is not correct because the 2 equations have been added together* *C is not correct because the second equation has been subtracted from the first equation* *D is not correct because both equations have been reversed and added together*	**(1)**

Q10.

Question number	Answer	Mark
	The only correct answer is A (*an increase of 6.0°C*) ***B*** *is not correct because neutralisation reactions are exothermic, so temperature will rise not fall* ***C*** *is not correct because the total volume of solution is 100 cm³, not 50 cm³* ***D*** *is not correct because neutralisation reactions are exothermic, so temperature will rise not fall and because the total volume of solution is 100 cm³, not 50 cm³*	**(1)**

Q11.

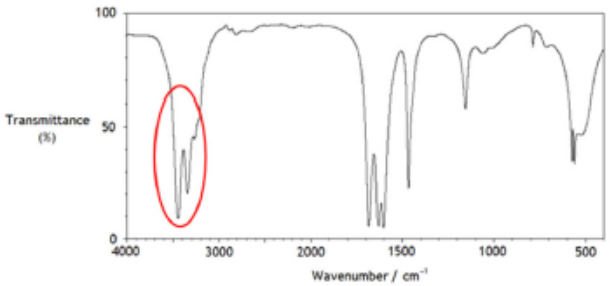
Question Number	Answer	Mark
	The only correct answer is C (0.72 g) ***A*** *is not correct because a 2:1 ratio has been used, not 1:2* ***B*** *is not correct because a 1:1 ratio has been used, not 1:2* ***D*** *is not correct because a 1:3 ratio has been used, not 1:2*	1

Q12.

Question Number	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • urea forms hydrogen bonds **(1)** • urea forms (permanent) dipole-dipole forces **(1)** • these forces are stronger than London forces **(1)**	Ignore references to number of hydrogen bonds Allow a correct diagram Allow hydrogen bonds are the strong**est** intermolecular forces Allow dispersion forces/van der Waals for London forces Do not award M3 if breaking covalent bonds is referenced	**(3)**

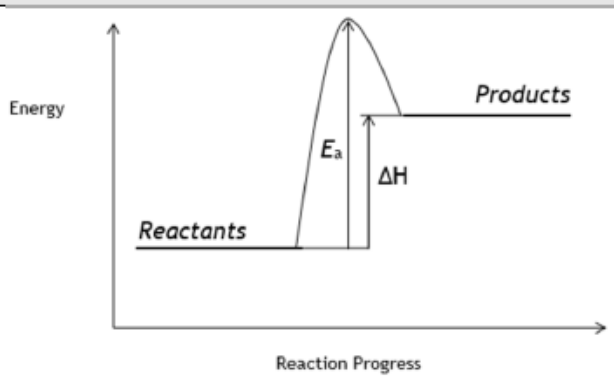
Question Number	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • M_r of urea **(1)** OR moles of urea • mass of urea required **(1)**	M_r = 60 (9.07 ÷ 1000) × 150 = 1.36(05) (9.07 ÷ 1000) × 150 × 60 = 81.63 (g) / 81.6 (g) Ignore SF except 1 SF Correct answer scores (2) No M2 if units other than grams are used	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following point: • (oxides of nitrogen lead to the formation of) acid rain	Allow formation of photochemical smog Allow "NO can react with ozone" Allow descriptions of acid rain formation e.g. forms HNO_3 Do not award greenhouse effect / global warming Do not award depletes the ozone layer without reference to nitrogen(II) oxide/NO	**(1)**

Question Number	Answer	Additional Guidance	Mark
(d)(i)	An answer that makes reference to the following point • correct peak circled	Example of completed spectra:  Allow any number of the three peaks in the region to be circled individually Extra circles negate the mark	**(1)**

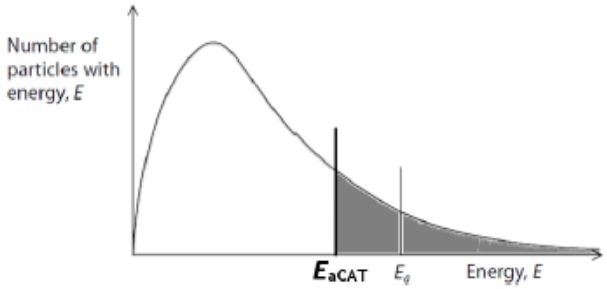
Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to the following point • C=O		**(1)**

Question Number	Answer	Additional Guidance	Mark
(e)(i)	An answer that makes reference to the following points • products **and** reversible arrow	Example of balanced equation: $\rightleftharpoons 2NH_3 + CO_2$ Accept products in any order Allow multiples if equation is balanced Allow 2 full headed arrows, one in either direction	**(1)**

Question Number	Answer	Additional Guidance	Mark
(e)(ii)	An answer that makes reference to the following points: • line labelled products higher than line labelled reactants and to the right **(1)** • ΔH labelled correctly **(1)** • E_a labelled correctly **(1)**	 Accept actual reactants and products labelled on diagram (even if slightly incorrect names or formulae are used) Ignore state symbols even if incorrect Allow ΔH given as +133 Double-headed arrows penalised once only Arrows in wrong direction or missing heads penalised each time M2 and M3 can be given as a TE on exothermic reaction if arrows are consistent	**(3)**

Question Number	Answer	Additional Guidance	Mark
(f)(i)	An explanation that makes reference to the following points: • the urea is a reactant and forms a new product (that leaves the catalytic converter)	Allow "catalysts are not used up in the reaction" Allow "urea is used up in the reaction" Allow "the amount/mass of urea changed" Allow "urea is not reformed" Allow "the catalyst is a metal oxide" Ignore references to activation energy / rate / reusable Do not award "catalysts do not react"	**(1)**

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Question Number	Answer	Additional Guidance	Mark
(f)(ii)	An explanation that makes reference to the following points: • catalyst decreases the activation energy required **(1)** • more particles have the energy required for the reaction to take place **(1)** • increases the number of successful collisions per unit time / frequency of successful collisions **(1)**	Example of a completed diagram  Accept M1 shown on the diagram Allow "Ea moves to the left" Allow area under the curve above Ea increases for M2 NOTE: Shading is not required, but incorrect shading would negate M2	**(3)**

Question Number	Answer	Additional Guidance	Mark
(g)(i)	• hot gases from the engine warm up the catalytic converter	Allow uses the (heat) energy from the engine Allow energy from combustion of fuel Allow the reactions that occur in the catalytic converter are exothermic	**(1)**

Question Number	Answer	Additional Guidance	Mark
(g)(ii)	• conversion of m^3 to dm^3 **(1)** • moles of nitrogen **(1)** • number of molecules of nitrogen **(1)**	<u>An example of a calculation:</u> $89.3 \times 1000 = 89300\ dm^3$ $89300 \div 51.1 = 1747.6 / 1748$ mol $1748 \times 6.02 \times 10^{23} = 1.052 \times 10^{27} / 1.05 \times 10^{27} / 1.1 \times 10^{27}$ Allow TE throughout Ignore SF except 1SF Ignore units even if incorrect $1.052 \times 10^{24} / 1.05 \times 10^{24} / 1.1 \times 10^{24}$ scores 2 $1.052 \times 10^{21} / 1.05 \times 10^{21} / 1.1 \times 10^{21}$ scores 2 $2.747 \times 10^{30} / 2.75 \times 10^{30} / 2.8 \times 10^{30}$ scores 2 Correct answer with some working scores (3)	**(3)**

Q13.

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)**

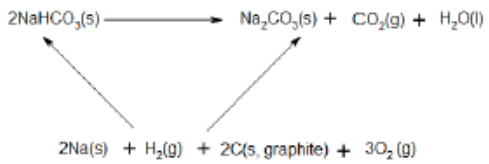
Question Number	Answer	Additional guidance	Mark
(b)(ii)	• application of Hess's Law **(1)** • calculation of $\Delta_f H^\circ$ **(1)**	Example of calculation: +(−394 –602) + 1096 **(+)** 100 (kJ mol^{-1}) Correct answer with no working scores 2 marks – 100 (kJ mol^{-1}) scores 1 mark (+) 702 (kJ mol^{-1})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

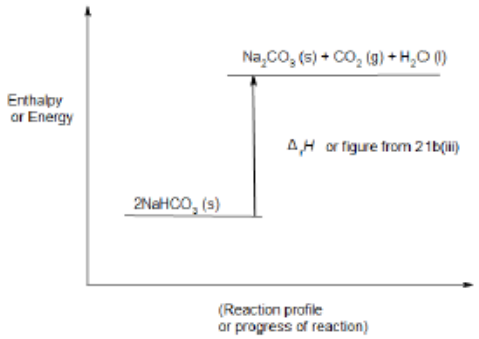
Q14.

Question number	Answer	Additional guidance	Mark
(a)	• hard to measure the temperature change when you're heating something or • heat losses due to high temperatures involved or • at 300 °C/high temperatures the water will be gaseous	Allow it is difficult to measure the temperature of a solid	1

Question number	Answer	Additional guidance	Mark
(b)(i)	An answer that makes reference to the following points: • (the enthalpy change when) one mole of the substance (is formed) • from its elements in their standard states (under standard conditions).		2

Question number	Answer	Additional guidance	Mark
(b)(ii)	A diagram that includes: • all species correct (1) • all state symbols correct and species balanced. (1)	 Do not penalise missing graphite	2

Question number	Answer	Additional guidance	Mark
(b)(iii)	• correct application of Hess's law (1) • correct figures used (1) • correct calculation (1) • units and sign (1)	Example of calculation: $\Delta_r H = -\Delta H_1 + \Delta H_2$ or $\Delta_f H\ (Na_2CO_3) + \Delta_f H\ (CO_2) + \Delta_f H\ (H_2O) = 2\Delta_f H(NaHCO_3) + \Delta_r H$ $-1130.7 + (-285.8) + (-393.5) = 2 \times (-950.8) + \Delta_r H$ $\Delta_r H = 91.6$ $\Delta_r H = +91.6\ kJ\ mol^{-1}$ Correct answer with no working scores (4) TE from M1 TE from incorrect M2	4

Question number	Answer	Additional guidance	Mark
(b)(iv)	• products energy level above reactants **and** arrow (1) • label on vertical arrow **and** vertical axis label (1)	 Allow reactants/products in place of chemical formulae Horizontal axis label not required Direction of arrow and endothermic/exothermic diagram must agree with sign in 21b(iii) Allow a correct exothermic enthalpy level diagram for an exothermic answer in 21b(iii)	2

Q15.

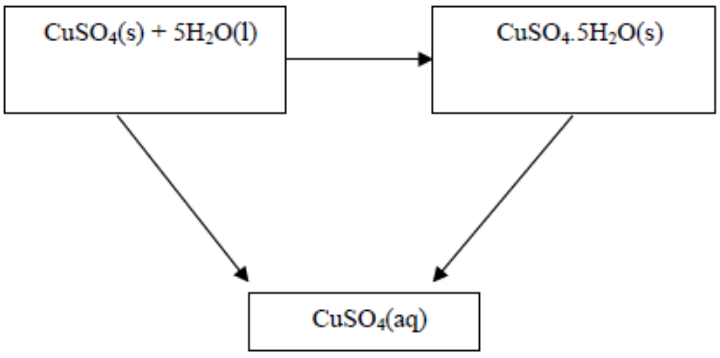
Question Number	Answer	Mark
	The only correct answer is C (+121.5) ***A*** *is incorrect because this is the enthalpy of atomisation of 2 mol of chlorine atoms* ***B*** *is incorrect because the enthalpy of atomisation is endothermic and refers to 2 mol of chlorine atoms* ***D*** *is incorrect because the enthalpy of atomisation is endothermic*	**(1)**

Q16.

Q	Answer	Mark
	The only correct answer is D ($\Delta_r H$) ***A*** *is incorrect because this is not an enthalpy of atomisation* ***B*** *is incorrect because carbon monoxide is not the final combustion product of carbon* ***C*** *is incorrect because two moles of carbon monoxide are formed*	**1**

Q17.

Question Number	Answer	Additional Guidance	Mark
(a)	• M1 moles of $CuSO_4.5H_2O$ (1) • M2 energy change (1) • M3 enthalpy change per mole (1) • M4 correct sign **and** units **and** 2 or 3 SF (1) Note M4 is not a stand-alone mark it depends on a sensible calculation by dividing joules by a number of moles.	Example of calculation: $10.68 \div 249.6 = 0.042788$/ $89 \div 2080$ $2.5 \times 55 \times 3.70 = 508.75$ (J) = 0.50875 (kJ) $508.75 \div 0.042788 = 11890$ (J mol^{-1}) Or $0.50875 \div 0.042788 = 11.890$ (kJ mol^{-1}) (+)11900 J mol^{-1} / (+)11.9 kJ mol^{-1} / (+)12000 J mol^{-1} / (+) 12 kJ mol^{-1} TE throughout Correct answer with sign and units and 2-3 SF score (4)	4

Question Number	Answer	Additional Guidance	Mark
(b)(i)	A diagram which shows • both arrows pointing down (1) • correct product in box (1)	Example of diagram  Ignore any extra water in the box e.g. + $5H_2O$ Ignore any numbers on the arrows Allow ions separated Cu^{2+} (aq) and SO_4^{2-} (aq) Allow $CuSO_4$ + (aq)	2

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• correct use of data (1) • correct sign and answer (1) Note the only TE is using their value from (a).	Example of calculation: (+) – 67.4 (kJ mol^{-1}) (–) +11.9 (kJ mol^{-1}) –79.3 / –79 (kJ mol^{-1}) Ignore units unless wrong but not award mixed units Allow –79.16(kJ mol^{-1}) for rounding moles to 0.43 Allow TE on value from (a). No TE on incorrect cycle Ignore SF	2

Q18.

Question number	Answer	Mark
	The only correct answer is A ($2Al(s) + 1½O_2(g) \rightarrow Al_2O_3(s)$) ***B*** *is incorrect because oxygen exists as O_2 in its standard state* ***C*** *is incorrect because standard enthalpy change of formation is for the formation of 1 mol of a compound* ***D*** *is incorrect because standard enthalpy change of formation is for the formation of 1 mol of a compound and oxygen exists as O_2 in its standard state*	(1)

Q19.

Question Number	Answer	Mark
	The only correct answer is D (–193 kJ mol^{-1}) ***A*** *is not correct because 4 × H_2 has been used, not 2 and the sign is incorrect* ***B*** *is not correct because 4 × H_2 has been used, not 2* ***C*** *is not correct because the sign is incorrect*	1

Q20.

Question Number	Answer	Mark
	The only correct answer is B (–16.6 kJ mol^{-1}) ***A*** *is incorrect because this is the energy change divided by the* M_r ***C*** *is incorrect because this is the energy change divided by the* M_r *and multiplied by the mass* ***D*** *is incorrect because this is the energy change but has not been correctly converted into kilojoules*	**(1)**

Q21.

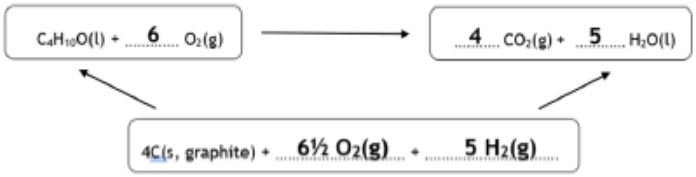
Question Number	Correct Answer	Mark
	The only correct answer is B (+1.2 kJ mol^{-1}) ***A*** *is incorrect as +113.2 is the value for* $CH_3COO^- + 2H_2O \rightarrow CH_3COOH + H^+ + 2OH^-$ ***C*** *is incorrect as −1.2 is the value for* $CH_3COO^- + H^+ \rightarrow CH_3COOH$ ***D*** *is incorrect as −113.2 is the value for* $CH_3COOH + H^+ + 2OH^- \rightarrow CH_3COO^- + 2H_2O$	**1**

Q22.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• mass change = 0.57(g) **and** temperature change = 45.8(°C)	Accept –0.57(g) Do not award –45.8 Ignore extra SF	**(1)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: • M_r calculated correctly for 2-methylpropan-2-ol **(1)** • moles calculated correctly **(1)** • correct use of $\Delta H = mc\Delta T$ **(1)** • answer with units **and** minus sign **(1)**	Example answer: $M_r = 74$ $0.57 \div 74 = 0.0077027$ mol / 7.7027×10^{-3} mol $\Delta H = 75 \times 4.18 \times 45.8 = 14358$ (J) $\Delta H = \frac{-(75 \times 4.18 \times 45.8)}{0.0077027} = \frac{-14358}{0.0077027}$ $\Delta H = -1\,864\,100 / -1.8641 \times 10^6$ J mol^{-1} OR $\Delta H = -1864.1$ kJ mol^{-1} / -1900 kJ mol^{-1} Ignore extra M_r calculations Ignore SF except 1 SF TE throughout including from 21(a)(i) Correct answer with some working scores (4)	**(4)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• oxygen is an element **and** in its standard state	Allow description of standard state of an element Allow oxygen is an element and gas in standard conditions Allow because ($\Delta_f H^\ominus$) value for an element is 0	**(1)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	An answer that makes reference to the following points: • balanced reactants and products **(1)** • balanced elements with state symbols **(1)**	An example of a completed cycle:  Accept elements in any order Allow top heavy fractions throughout	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An answer that makes reference to the following points: • expression for calculation of enthalpy change of combustion **(1)** • answer **(1)** **and** negative sign	<u>Example of calculation</u>: $\Delta H = -\Delta_f H$ reactants + $\Delta_f H$ products OR $= -(-359) + (4 \times -394) + (5 \times -286)$ $= -2647$ (kJ mol^{-1}) Ignore SF except 1 SF Ignore units even if incorrect TE from balancing in 21(b)(ii)	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to any two of the following points: • heat is lost (in the enthalpy experiment) OR no account has been taken of the heat capacity of the beaker **(1)** • incomplete combustion (of alcohol) **(1)** • some alcohol evaporates **(1)**	Allow energy lost Allow heat transfer Ignore heat lost/transferred to the thermometer Ignore incomplete burning Do not award references to time Ignore evaporation of water / mass change Allow "no stirrer so temperature is not uniform" for 1 of the marks Ignore human error Ignore non-standard conditions	**(2)**

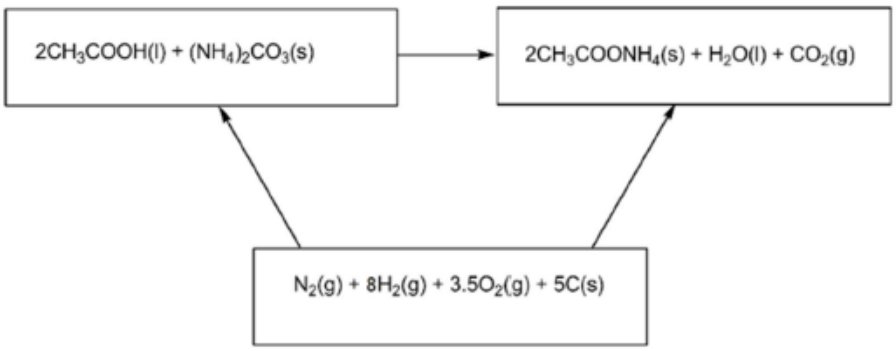
Q23.

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**

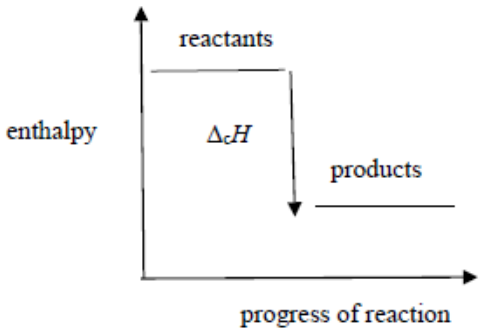
Q24.

Question Number	Answer	Mark
	The only correct answer is D (exothermic, neutralisation) ***A*** *is incorrect because the reaction is exothermic and is not formation* ***B*** *is incorrect because the reaction is exothermic* ***C*** *is incorrect because the equation does not show formation*	**(1)**

Q25.

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)

Q26.

Question Number	Answer	Mark
	The only correct answer is D ($\Delta_c H$ (carbon monoxide) = −110.5 kJ mol^{-1}) *A is incorrect because there are 2 mol of carbon in the equation and combustion is incomplete* *B is incorrect because there are 2 mol of carbon monoxide in the equation* *C is incorrect because the combustion is incomplete*	(1)

Q27.

Question Number	Answer	Mark
	The only correct answer is A (exothermic, increases) ***B** is incorrect because in exothermic reactions, temperatures increase* ***C** is incorrect because reactions with a negative enthalpy change are not endothermic* ***D** is incorrect because reactions with a negative enthalpy change are not endothermic and the temperature increases*	**(1)**

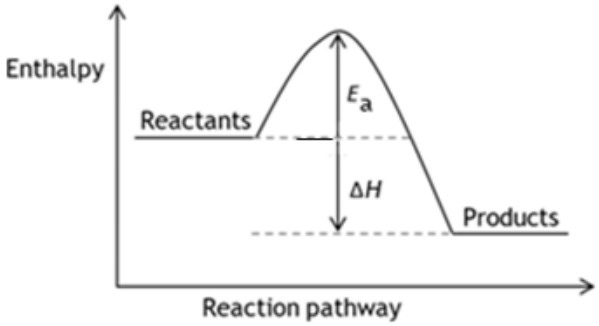
Q28.

Question Number	Answer	Mark
(a)	**The only correct answer is B** (v) ***A** is incorrect because u is the activation energy for the reaction R→P* ***C** is incorrect because w is the activation energy for the reaction P→R* ***D** is incorrect because x is the enthalpy change for the reaction P→R*	**(1)**

Question Number	Answer	Mark
(b)	**The only correct answer is C** (w) ***A** is incorrect because u is the activation energy for the reaction R→P* ***B** is incorrect because v is the enthalpy change for the reaction R→P* ***D** is incorrect because x is the enthalpy change for the reaction P→R*	**(1)**

Question Number	Answer	Mark
(c)	**The only correct answer is C** (u –w = v) ***A*** *is incorrect because v+**x** =0 and u+w is the sum of the activation energies* ***B*** *is incorrect because w-**x** = u* ***D*** *is incorrect because u-v = w (not **x**)*	**(1)**

Q29.

Q	Answer	Mark
	 **The only correct answer is A** ( ) ***B*** *is incorrect because the labels are incorrect* ***C*** *is incorrect because the labels are incorrect and this is for an endothermic reaction* ***D*** *is incorrect because the labels are incorrect and is for an endothermic reaction*	**1**

Q30.

Question Number	Answer	Additional Guidance	Mark
(a)	• Silver is oxidised from 0 to +1 **(1)** • Nitrogen is reduced from +5 to +4 **(1)**	These may be shown on the equation ALLOW one mark for silver is oxidised **and** nitrogen is reduced or all oxidation numbers correct ALLOW 1 or 1+ for +1	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• calculation of energy change (1) • calculation of no of moles (1) • calculation of concentration (1)	Examples of calculation Q = 50.0 ÷ 1000 x 4.18 x 5.2 = 1.0868 (kJ)/1086.8(J) 1.0868 ÷ 36.1 = 0.030105/3.0105 x10^{-2} (moles) 0.030105 ÷ 50 x 1000 = 0.602105(mol dm^{-3}) = 0.602/0.60/0.6 (mol dm^{-3}) Ignore SF	(3)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• calculation of moles of ppt (1) • calculation of concentration (1)	Example of calculation 5.96 ÷ 187.8 = 0.0317359 (moles) 0. 00317359 ÷ 50 x 1000 = 0.634718(mol dm^{-3}) Ignore SF except 1 SF ALLOW use of 188 as M_r Penalise incorrect rounding once only	(2)

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An explanation that makes reference to: • the calorimetry method (student A) is lower because heat may be lost to the surroundings /absorbed by the container or apparatus (1) • the gravimetric method (student B) is higher because the product may have been wet/ have impurities (1)	Do not award: non-standard conditions, just "incomplete reaction", human error, incorrect solution density/heat capacity ALLOW: not all the **solution** reacted	(2)