

OCR A-LEVEL CHEMISTRY A • H432

# CHEMISTRY



**EXAM QUESTION PACK**

**3.2.1 ENTHALPY CHANGES**

**SCORE**

**/121**

**PERCENTAGE**

**%**

**STEMUP**

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1(a) Hydrogen iodide, HI, is a colourless gas that can be made from the reaction of hydrogen, H<sub>2</sub>, and iodine, I<sub>2</sub>.

This reversible reaction is shown in **equilibrium 3.1** below.

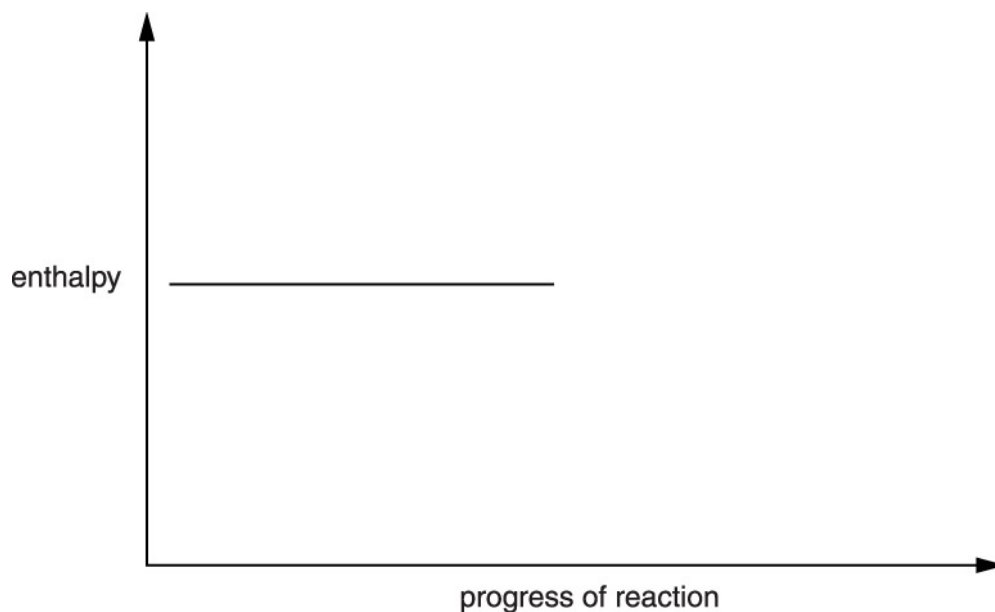


The activation energy for the forward reaction is 173 kJ mol<sup>-1</sup>.

Complete the enthalpy profile diagram below for the forward reaction in **equilibrium 3.1**.

On your diagram:

- Label the activation energy,  $E_a$
- Label the enthalpy change of reaction,  $\Delta H$
- Include the formulae of the reactants and products.



[2]

(b) Calculate the activation energy,  $E_a$ , for the reverse reaction.

$E_a$  (reverse reaction) = \_\_\_\_\_  $\text{kJ mol}^{-1}$  [1]

(c) When the reverse reaction takes place hydrogen iodide, HI, decomposes to form iodine and hydrogen.

Calculate the enthalpy change when  $336 \text{ dm}^3$  of hydrogen iodide, measured at room temperature and pressure, decomposes.

Include the sign for enthalpy change in your answer.

enthalpy change \_\_\_\_\_  $\text{kJ}$  [2]

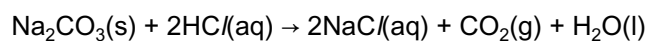
(d) Calculate the bond enthalpy for the H-I bond in **equilibrium 3.1**, given the following information.

| Bond | Bond Enthalpy / $\text{kJ mol}^{-1}$ |
|------|--------------------------------------|
| H-H  | 436                                  |
| I-I  | 151                                  |

bond enthalpy \_\_\_\_\_  $\text{kJ mol}^{-1}$  [2]

2(a) This question is about the determination of enthalpy changes.

A student carries out an experiment to find the enthalpy change of reaction,  $\Delta H_r$ , for the reaction below.



In the experiment, 3.18 g of  $\text{Na}_2\text{CO}_3$  are added to 50.0 g of 2.00 mol  $\text{dm}^{-3}$   $\text{HCl}$ , an excess.

The temperature of the reaction mixture increases by 5.5 °C.

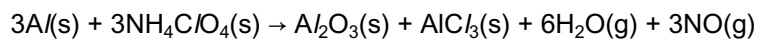
Calculate  $\Delta H_r$ , in  $\text{kJ mol}^{-1}$ .

Give your answer to **three** significant figures.

The specific heat capacity,  $c$ , of the reaction mixture is 4.18  $\text{J g}^{-1} \text{K}^{-1}$ .

$\Delta H_r =$  \_\_\_\_\_  $\text{kJ mol}^{-1}$  [4]

- (b) The booster rocket of a spacecraft uses a mixture of aluminium and ammonium chlorate(VII),  $\text{NH}_4\text{ClO}_4$ , as a fuel. The equation and some enthalpy changes are shown below.



$$\Delta H = -2677 \text{ kJ mol}^{-1}$$

| Substance                           | Standard enthalpy change of formation, $\Delta H_f^\circ$ / kJ |
|-------------------------------------|----------------------------------------------------------------|
| $\text{NH}_4\text{ClO}_4\text{(s)}$ | -295                                                           |
| $\text{Al}_2\text{O}_3\text{(s)}$   | -1676                                                          |
| $\text{AlCl}_3\text{(s)}$           | -704                                                           |
| $\text{H}_2\text{O(g)}$             | -242                                                           |

- (i) What is meant by the term *standard enthalpy change of formation*?

Give the standard conditions.

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----- [3]

- (ii) Write the equation, including state symbols, for the reaction that represents the standard enthalpy change of formation of  $\text{NH}_4\text{ClO}_4\text{(s)}$ .

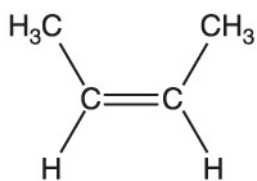
----- [2]

- (iii) Calculate the enthalpy change of formation of  $\text{NO(g)}$  using the data above.

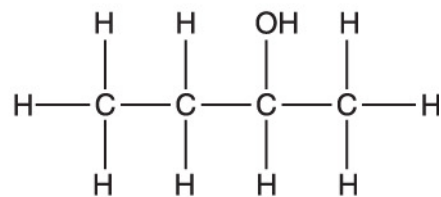
enthalpy change of formation of  $\text{NO(g)}$  = \_\_\_\_\_  $\text{kJ mol}^{-1}$  [3]

- 3 Butan-2-ol can be prepared using two different methods.

**Method 1**

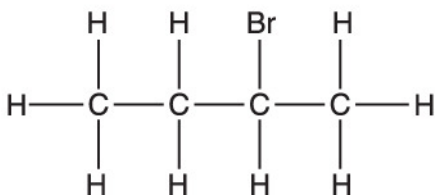


$\text{H}_2\text{O(g)}$



**butan-2-ol**

**Method 2**



$\text{NaOH(aq)}$

Average bond enthalpies can be used to calculate enthalpy changes.

- (i) What is meant by the term *average bond enthalpy*?

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[2]

- (ii) Calculate the enthalpy change of reaction,  $\Delta H_r$ , for preparing 1 mol of butan-2-ol by **Method 1**.

Average bond enthalpies are given below.

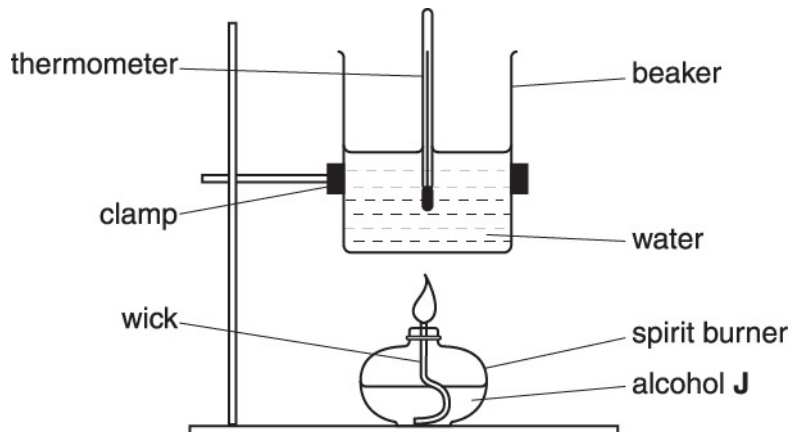
| Bond | Average bond enthalpy / $\text{kJ mol}^{-1}$ |
|------|----------------------------------------------|
| O—H  | 464                                          |
| C—H  | 413                                          |
| C—C  | 347                                          |
| C—O  | 358                                          |
| C=C  | 612                                          |

$$\Delta H_r = \text{-----} \text{ kJ mol}^{-1} \text{ [3]}$$

4(a) A branched-chain alcohol J is a liquid and has the molecular formula  $C_5H_{12}O$ .

A student does an experiment to measure the enthalpy change of combustion,  $\Delta H_c$ , of alcohol J.

(i) The student burns alcohol J using the apparatus below.



The student found that combustion of 1.54 g of alcohol J changes the temperature of 180 g of water from 22.8 °C to 75.3 °C.

The specific heat capacity of water is  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ .

- Calculate the amount, in mol, of alcohol J that burns.
- Calculate the enthalpy change of combustion,  $\Delta H_c$ , of alcohol J, in  $\text{kJ mol}^{-1}$ .

Give your final answer to **three** significant figures.

$\Delta H_c = \text{-----} \text{ kJ mol}^{-1}$  [4]

(ii) The calculated value of  $\Delta H_c$  from this experiment is different from the value obtained from data books.

Apart from heat loss, suggest **two** reasons for the difference.

Assume that the calculation has been carried out correctly.

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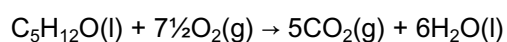
----- [2]

- (b) The enthalpy change of combustion for alcohol J can also be determined indirectly from standard enthalpy changes of formation.

- (i) Write an equation, including state symbols, for the chemical change that represents the standard enthalpy change of formation of the liquid alcohol J, C<sub>5</sub>H<sub>12</sub>O.

----- [1]

- (ii) The equation for the complete combustion of alcohol J is shown below.



Enthalpy changes of formation,  $\Delta H_f$ , are shown in the table.

| Substance                         | C <sub>5</sub> H <sub>12</sub> O(l) | CO <sub>2</sub> (g) | H <sub>2</sub> O(l) |
|-----------------------------------|-------------------------------------|---------------------|---------------------|
| $\Delta H_f / \text{kJ mol}^{-1}$ | –366                                | –394                | –286                |

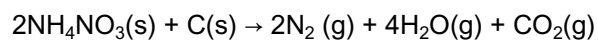
Calculate the enthalpy change of combustion,  $\Delta H_c$ , of alcohol J from the information given above.

$\Delta H_c =$  ----- kJ mol<sup>–1</sup> [3]

5 The table below shows standard enthalpy changes of formation,  $\Delta_f H$ .

| Compound                          | $\text{NH}_4\text{NO}_3(\text{s})$ | $\text{H}_2\text{O}(\text{g})$ | $\text{CO}_2(\text{g})$ |
|-----------------------------------|------------------------------------|--------------------------------|-------------------------|
| $\Delta_f H / \text{kJ mol}^{-1}$ | -366                               | -242                           | -394                    |

What is the enthalpy change for the following reaction?



A  $-630 \text{ kJ mol}^{-1}$

B  $-540 \text{ kJ mol}^{-1}$

C  $+540 \text{ kJ mol}^{-1}$

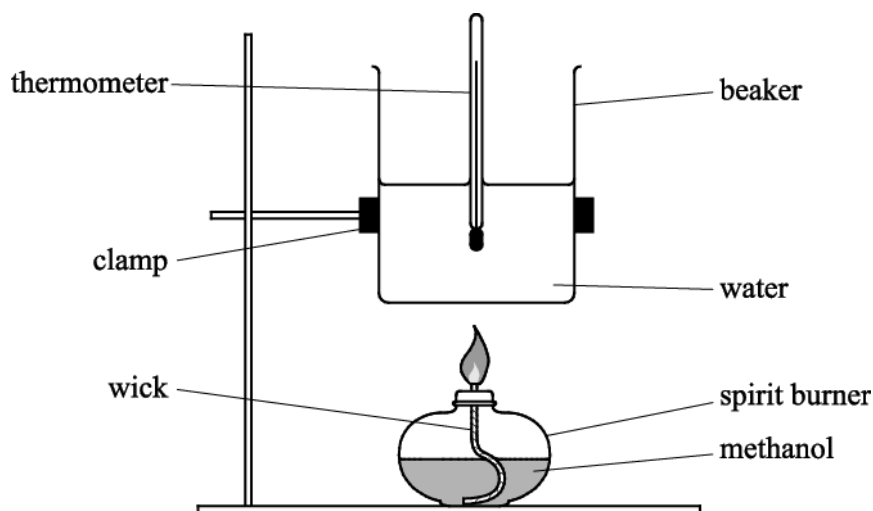
D  $+630 \text{ kJ mol}^{-1}$

Your answer

[1]

6(a) A student used the apparatus below in an experiment to determine the enthalpy change of combustion of methanol.

The student measured  $100\text{ cm}^3$  and poured it into the beaker.



The student measured a temperature rise of  $10.5\text{ }^{\circ}\text{C}$ .

The student calculated the amount of energy transferred to the water.

Which of the following uses the appropriate number of significant figures and correct standard form to represent the result of the calculation?

- A  $4.389 \times 10^3\text{ J}$
- B  $4.39 \times 10^3\text{ J}$
- C  $43.9 \times 10^2\text{ J}$
- D  $44.0 \times 10^2\text{ J}$

Your answer

[1]

(b) The student's calculated enthalpy change was less exothermic than the value in data books.

Which of the following errors could have contributed to this result?

- Error 1:** After the final temperature was recorded, the student removed the burner from under the beaker. The flame burnt for a further 5 minutes before weighing the spirit burner.
- Error 2:** The student recorded the final temperature 5 minutes after removing the burner.
- Error 3:** The student spilt some water on the bench when pouring the water from the measuring cylinder into the beaker.

- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

☐

[1]

7 This question looks at neutralisation reactions.

A student carries out an experiment to determine the enthalpy change for a neutralisation reaction.

The student measures out  $35.0 \text{ cm}^3$  of  $2.40 \text{ mol dm}^{-3}$  KOH and  $35.0 \text{ cm}^3$  of  $1.20 \text{ mol dm}^{-3}$   $\text{H}_2\text{SO}_4$ .  
The temperature of each solution is  $19.5^\circ\text{C}$ .

The student mixes the solutions. The KOH is all neutralised and the maximum temperature reached is  $36.0^\circ\text{C}$ .

(i) Write the overall equation for the reaction that takes place.

[1]

(ii) Calculate the enthalpy change for the reaction between 1 mol KOH and 1 mol HCl.

Assume that the density of the mixture is  $1.00 \text{ g cm}^{-3}$  and that the specific heat capacity for the solution is the same as for water.

$\Delta H =$  \_\_\_\_\_ kJ [3]

(iii) Explain, why the answer to (ii) is the enthalpy change of neutralisation.

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----- [1]

(iv) In this experiment, the student uses a thermometer with an uncertainty of  $\pm 0.5^\circ\text{C}$  in each reading.

Calculate the percentage uncertainty in the temperature rise.

percentage uncertainty = \_\_\_\_\_ % [1]

8 Bromine reacts with iodine to form iodine monobromide, IBr.

The table below lists some average bond enthalpies which are required in different parts of this question.

| Bond  | Average bond enthalpy / $\text{kJ mol}^{-1}$ |
|-------|----------------------------------------------|
| Br-Br | +193                                         |
| I-I   | +151                                         |
| I-Br  | +175                                         |

(i) Average bond enthalpy is the enthalpy change for the breaking of 1 mole of bonds in gaseous molecules.

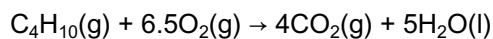
Why do  $\text{Br}_2$  and  $\text{I}_2$  **not** exist in the gaseous state under standard conditions?

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----- [1]

(ii) Calculate the enthalpy change of formation,  $\Delta_f H$ , for IBr.

$\Delta_f H =$  -----  $\text{kJ mol}^{-1}$  [2]

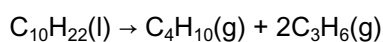
- 9(a) Butane,  $C_4H_{10}$ , is a highly flammable gas, used as a fuel for camping stoves. Butane reacts with oxygen as in the equation below:



Explain why this equation represents the standard enthalpy change of combustion of butane.

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----- [1]

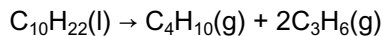
- (b) Butane can be produced from decane,  $C_{10}H_{22}$ , as shown in the equation below.



Standard enthalpy changes of combustion,  $\Delta_c H^\ominus$ , are shown in the table below.

| Substance         | $\Delta_c H^\ominus / \text{kJ mol}^{-1}$ |
|-------------------|-------------------------------------------|
| $C_{10}H_{22}(l)$ | -6778                                     |
| $C_4H_{10}(g)$    | -2877                                     |
| $C_3H_6(g)$       | -2058                                     |

Calculate the standard enthalpy change of reaction,  $\Delta_r H^\ominus$ , for the reaction. Include the sign.



$\Delta_r H^\ominus = \text{-----} \text{ kJ mol}^{-1}$  [2]

10 Nitrogen forms several different oxides.

$\text{N}_2\text{O}$  is a useful anaesthetic and  $\text{NO}$  has been linked to the depletion of ozone in the stratosphere.

The standard enthalpy changes of formation of  $\text{N}_2\text{O}$  and  $\text{NO}$  are given in the table.

| Compound                 | $\Delta_f H^\ominus / \text{kJ mol}^{-1}$ |
|--------------------------|-------------------------------------------|
| $\text{N}_2\text{O (g)}$ | + 82.0                                    |
| $\text{NO (g)}$          | + 90.2                                    |

- (i) Explain, in terms of bond breaking and bond making, why the enthalpy change of formation of  $\text{NO}$  is endothermic.

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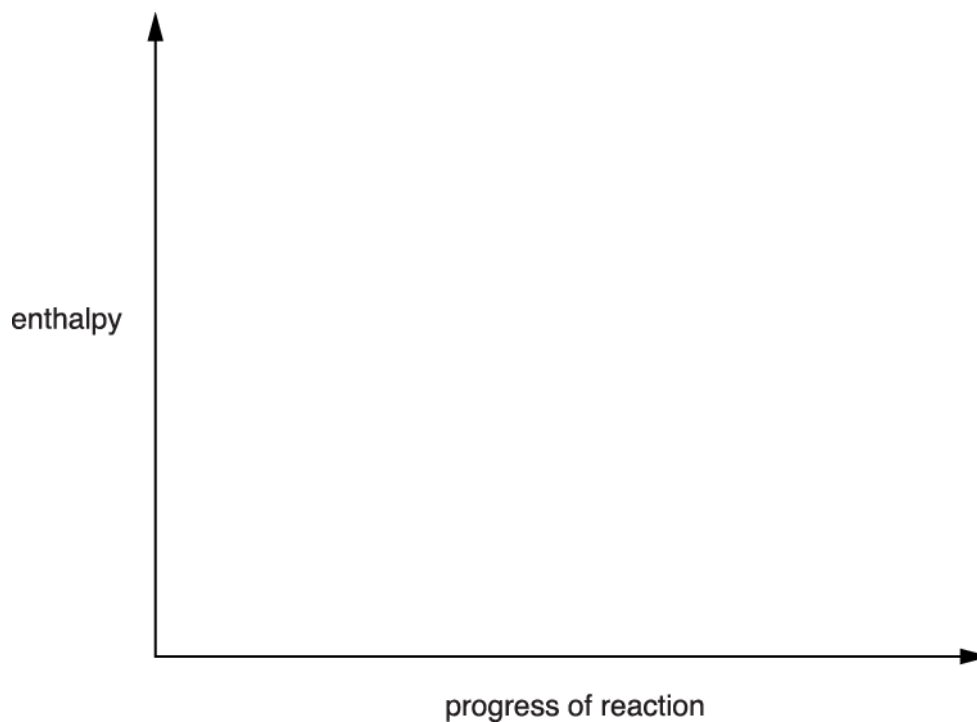
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----- [1]

- (ii) Draw a fully labelled enthalpy profile diagram to represent the enthalpy change of formation of  $\text{N}_2\text{O}$ .

The formulae, with state symbols, of the reactants and products should be included as part of the diagram.

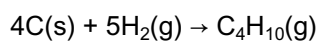
You are **not** expected to show the activation energy for the reaction.



- 11 The enthalpy change of formation of butane can be calculated using the enthalpy changes of combustion,  $\Delta_c H$ , below.

| Substance                         | C(s) | H <sub>2</sub> (g) | C <sub>4</sub> H <sub>10</sub> (s) |
|-----------------------------------|------|--------------------|------------------------------------|
| $\Delta_c H / \text{kJ mol}^{-1}$ | -394 | -286               | -2877                              |

Calculate the enthalpy change of formation of C<sub>4</sub>H<sub>10</sub>(g).

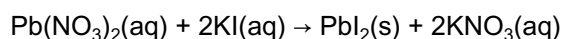


- A      -2197 kJ mol<sup>-1</sup>  
 B      -129 kJ mol<sup>-1</sup>  
 B      +129 kJ mol<sup>-1</sup>  
 D      +2197 kJ mol<sup>-1</sup>

Your answer

12(a) Aqueous lead(II) nitrate,  $\text{Pb}(\text{NO}_3)_2(\text{aq})$ , and aqueous potassium iodide,  $\text{KI}(\text{aq})$ , react together.

The equation is shown below.



A student carries out an experiment to determine the enthalpy change of reaction,  $\Delta_r H$ , of this reaction.

The student follows the method outlined below.

- Add  $50.0 \text{ cm}^3$  of  $1.50 \text{ mol dm}^{-3}$   $\text{Pb}(\text{NO}_3)_2(\text{aq})$  to a polystyrene cup.
- Measure out  $50.0 \text{ cm}^3$  of a solution of  $\text{KI}(\text{aq})$ , which is in excess.
- Measure the temperature of both solutions.
- Add the  $\text{KI}(\text{aq})$  to the polystyrene cup, stir the mixture and record the maximum temperature.

**Temperature readings**

Initial temperature of both solutions =  $19.5^\circ\text{C}$

Maximum temperature of mixture =  $30.0^\circ\text{C}$

Calculate  $\Delta_r H$ , in  $\text{kJ mol}^{-1}$ , for the reaction shown in the equation above.

Give your answer to an **appropriate** number of significant figures.

Assume that the density of all solutions and specific heat capacity,  $c$ , of the reaction mixture is the same as for water.

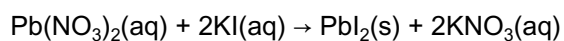
$\Delta_r H =$  \_\_\_\_\_  $\text{kJ mol}^{-1}$  [4]

(b) Write an ionic equation for the reaction that the student carries out.

Include state symbols.

----- [1]

- (c) The  $50.0 \text{ cm}^3$  of  $\text{KI(aq)}$  used in the experiment contains 10% more KI than is needed to react with  $50.0 \text{ cm}^3$  of  $1.50 \text{ mol dm}^{-3} \text{ Pb(NO}_3)_2\text{(aq)}$ .

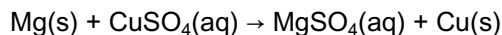


Calculate the concentration, in  $\text{mol dm}^{-3}$ , of KI that the student used.

concentration of KI = \_\_\_\_\_  $\text{mol dm}^{-3}$  [2]

13(a) This question is about different ways of determining enthalpy changes.

A student carries out an experiment to determine directly the enthalpy change of reaction,  $\Delta H_r$ , shown below.



- The student measures the initial temperature of 25.0 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> CuSO<sub>4</sub>(aq).
- The student adds an excess of magnesium powder and stirs the mixture.
- The student measures the maximum temperature of the solution.

### Results

Initial temperature of solution = 21.5 °C

Maximum temperature of solution = 63.0 °C

Density of the solution = 1.00 g cm<sup>-3</sup>; specific heat capacity of the solution = 4.18 J g<sup>-1</sup> K<sup>-1</sup>.

- (i) Calculate the enthalpy change of reaction,  $\Delta H_r$ , in kJ mol<sup>-1</sup>.

Give your answer to **three** significant figures.

$\Delta H_r =$  \_\_\_\_\_ kJ mol<sup>-1</sup> [4]

- (ii) The student weighed out enough magnesium so that it would be in excess by **at least** 25%. The student had access to a two decimal-place balance.

Calculate the minimum mass of magnesium that the student would need to weigh out on this balance.

mass = \_\_\_\_\_ g [1]

- (b) Enthalpy changes of formation can be determined indirectly from standard enthalpy changes of combustion,  $\Delta H_c^\ominus$ .

Three enthalpy changes of combustion are shown below.

| Substance                          | $\Delta H_c^\ominus / \text{kJ mol}^{-1}$ |
|------------------------------------|-------------------------------------------|
| C(s)                               | -394                                      |
| H <sub>2</sub> (g)                 | -286                                      |
| C <sub>9</sub> H <sub>20</sub> (l) | -6125                                     |

- (i) Define *standard enthalpy change of combustion*.

Include the standard conditions that are used.

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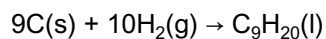
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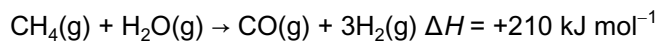
- (ii) The equation that represents the enthalpy change of formation,  $\Delta H_f^\ominus$ , of nonane is shown below.

Calculate the standard enthalpy change of formation of nonane.



$\Delta H_f^\ominus =$  \_\_\_\_\_  $\text{kJ mol}^{-1}$  [2]

(c) The bond enthalpy for the bond in carbon monoxide can be calculated from the information below.



| Bond | Average bond enthalpy / $\text{kJ mol}^{-1}$ |
|------|----------------------------------------------|
| C-H  | 413                                          |
| O-H  | 464                                          |
| H-H  | 436                                          |

(i) What is meant by the term *average bond enthalpy*?

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----- [2]

(ii) Calculate the bond enthalpy for the bond in carbon monoxide.

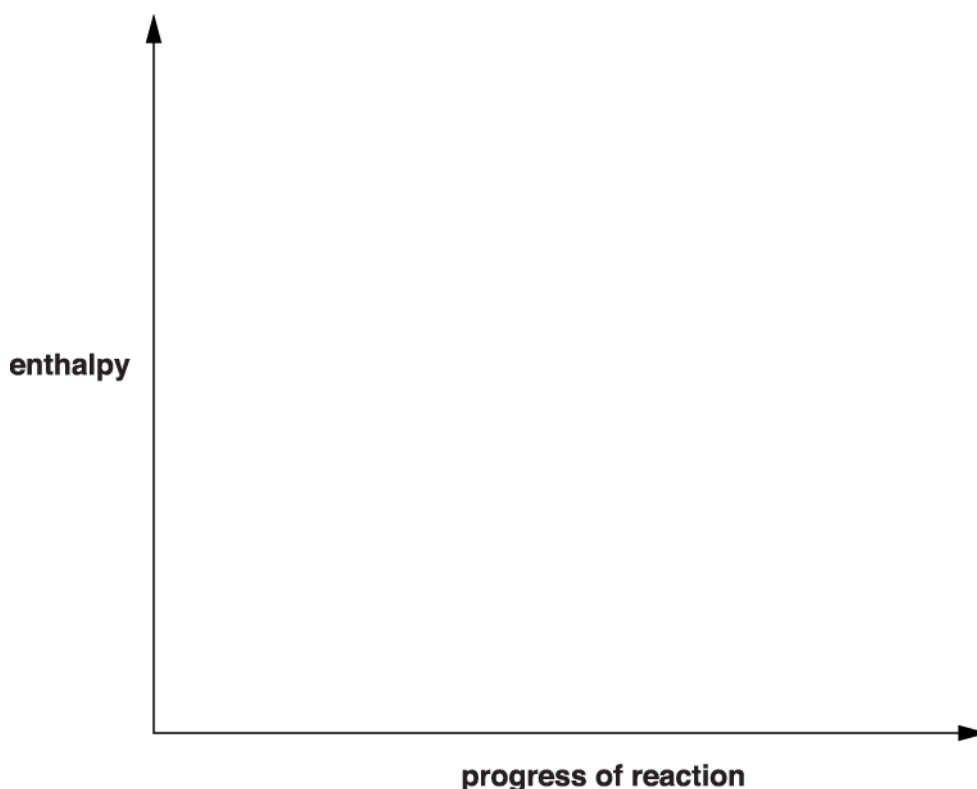
Show your working.

bond enthalpy = \_\_\_\_\_  $\text{kJ mol}^{-1}$  [3]

- (i) Zinc and sulfuric acid react together to form a solution of zinc sulfate,  $\text{ZnSO}_4$ , and hydrogen gas. The reaction is exothermic.

The rate of the reaction increases when a catalyst is added.

- Complete the enthalpy profile diagram for this reaction using the formulae of the reactants and products.
- Label activation energies,  $E_a$  (without catalyst) and  $E_c$  (with catalyst).
- Label the enthalpy change of reaction,  $\Delta H$ .



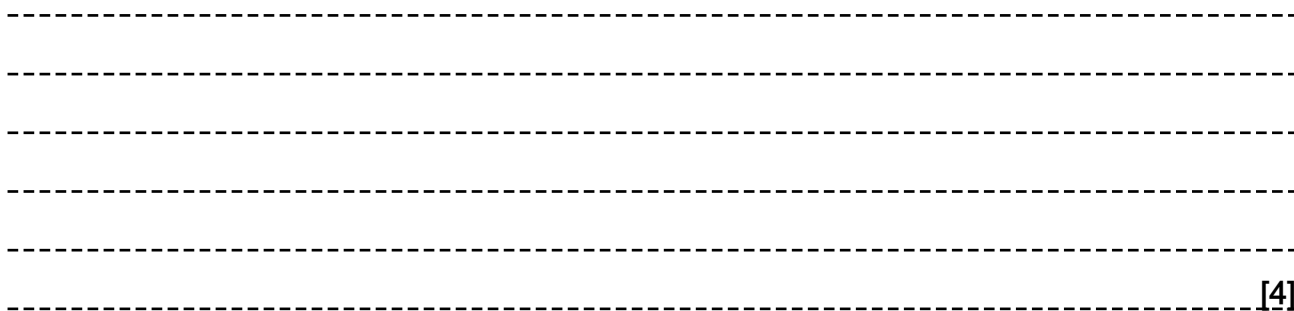
[3]

- (ii) Using a Boltzmann distribution, explain how a catalyst increases the rate of a chemical reaction.

Include a labelled sketch of your Boltzmann distribution on the grid below. Label the axes and any other important features.



*Your answer needs to be clear and well organised using the correct terminology.*



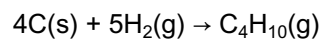
- Your answer

[1]

16 The table shows standard enthalpy changes of combustion,  $\Delta_c H$ .

| Substance                          | $\Delta_c H / \text{kJ mol}^{-1}$ |
|------------------------------------|-----------------------------------|
| C(s)                               | -393.5                            |
| H <sub>2</sub> (g)                 | -285.8                            |
| C <sub>4</sub> H <sub>10</sub> (g) | -2876.5                           |

What is the enthalpy change for the following reaction?



- A -2197.2 kJ mol<sup>-1</sup>
- B -126.5 kJ mol<sup>-1</sup>
- C +126.5 kJ mol<sup>-1</sup>
- D +2197.2 kJ mol<sup>-1</sup>

Your answer

[1]

17(a) Alkanes are saturated hydrocarbons with the general formula  $C_nH_{2n+2}$ .

A student carries out an experiment to measure the enthalpy change of combustion,  $\Delta_c H$ , of hexane.

The student finds that combustion of 1.29 g of hexane changes the temperature of 200 g of water from 20.5 °C to 65.5 °C.

(i) Calculate the enthalpy change of combustion,  $\Delta_c H$ , of hexane, in  $\text{kJ mol}^{-1}$ .

Give your final answer to an **appropriate** number of significant figures.

$\Delta_c H$  \_\_\_\_\_  $\text{kJ mol}^{-1}$  [4]

(ii) The calculated value of  $\Delta_c H$  for hexane from this experiment is different from the data book value.

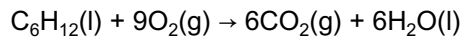
Suggest **two** reasons for this difference.

1 \_\_\_\_\_  
\_\_\_\_\_

2 \_\_\_\_\_

[2]

(b) The equation for the complete combustion of cyclohexane is shown below.



Standard enthalpy changes of formation,  $\Delta_f H^\theta$ , are shown in the table.

| Substance                                | $\text{C}_6\text{H}_{12}(\text{l})$ | $\text{CO}_2(\text{g})$ | $\text{H}_2\text{O}(\text{l})$ |
|------------------------------------------|-------------------------------------|-------------------------|--------------------------------|
| $\Delta_f H^\theta / \text{kJ mol}^{-1}$ | -156.3                              | -393.5                  | -285.8                         |

Calculate the standard enthalpy change of combustion,  $\Delta_c H^\theta$ , of cyclohexane.

$\Delta_c H^\theta =$  \_\_\_\_\_  $\text{kJ mol}^{-1}$  [3]

The combustion of ethene is shown in **equation 25.1** below.



- (i) Explain, in terms of bond breaking and bond forming, why a reaction can be exothermic.

-----

-----

-----

----- [1]

- (ii) Average bond enthalpies are shown in the table.

| Bond | Average bond enthalpy<br>/kJ mol <sup>-1</sup> |
|------|------------------------------------------------|
| O–H  | +464                                           |
| O=O  | +498                                           |
| C–H  | +413                                           |
| C=O  | +805                                           |

Calculate the average bond enthalpy of the C=C bond.

Use the average bond enthalpies in the table and **equation 25.1**.

average bond enthalpy = \_\_\_\_\_ kJ mol<sup>-1</sup> [3]

19(a) Hydrogen reacts with chlorine to form hydrogen chloride, HCl:

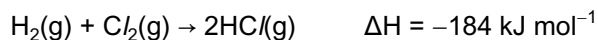


Table 3.1 shows bond enthalpies.

| Bond | Bond Enthalpy / $\text{kJ mol}^{-1}$ |
|------|--------------------------------------|
| H–H  | +436                                 |
| C–C  | +243                                 |

Table 3.1

Calculate the bond enthalpy for the H–C bond from the information above.

bond enthalpy = \_\_\_\_\_  $\text{kJ mol}^{-1}$  [2]

(b) 'Enthalpy change of vaporisation' is the enthalpy change when one mole of a substance changes from a liquid to a gas at its boiling point.

(i) Write an equation, including state symbols, to represent the enthalpy change of vaporisation of bromine.

\_\_\_\_\_ [1]

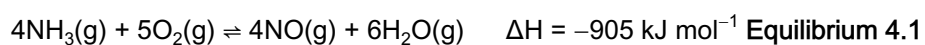
(ii) Suggest whether the enthalpy change of vaporisation of bromine is exothermic or endothermic.

Explain your answer.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [1]

20 The reaction of ammonia,  $\text{NH}_3$ , with oxygen to form nitrogen monoxide,  $\text{NO}$ , is an important industrial process.

The equation for this reaction is shown in **equilibrium 4.1** below.

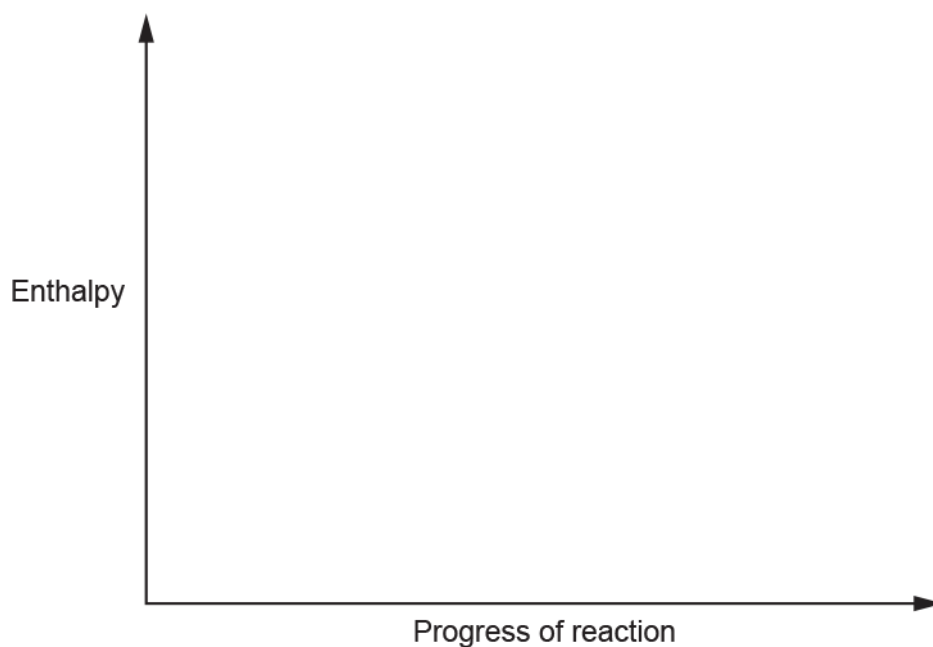


The forward reaction in **equilibrium 4.1** converts  $\text{NH}_3$  into  $\text{NO}$ .

(i) Complete the enthalpy profile diagram for this reaction.

On your diagram:

- Label the activation energy,  $E_a$
- Label the enthalpy change of reaction,  $\Delta H$
- Include the formulae of the reactants and products.



[2]

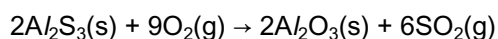
(ii) 5.10 tonnes of  $\text{NH}_3$  are converted into  $\text{NO}$ .

Calculate the energy released, in kJ, for this conversion.

Give your answer in **standard form** and to an **appropriate** number of significant figures.

energy released = ----- kJ [4]

21 The equation for the reaction of aluminium sulfide,  $\text{Al}_2\text{S}_3$ , with oxygen is shown below.



The table shows standard enthalpy changes of formation,  $\Delta_f H^\ominus$ .

| Substance                                 | $\text{Al}_2\text{S}_3(\text{s})$ | $\text{O}_2(\text{g})$ | $\text{Al}_2\text{O}_3(\text{s})$ | $\text{SO}_2(\text{g})$ |
|-------------------------------------------|-----------------------------------|------------------------|-----------------------------------|-------------------------|
| $\Delta_f H^\ominus / \text{kJ mol}^{-1}$ | -723.8                            | 0                      | -1675.7                           | -296.8                  |

What is the standard enthalpy change of combustion of  $\text{Al}_2\text{S}_3(\text{s})$ , in  $\text{kJ mol}^{-1}$ ?

A -3684.6

B -1842.3

C +1842.3

D +3684.6

Your answer

[1]

22 A student carried out an experiment to measure the enthalpy change of combustion of methanol.

The energy from the combustion of methanol was used to heat a beaker containing water.

The student's calculated enthalpy change of combustion was **more** exothermic than the value in data books.

Which error could have caused this difference?

- A Some methanol had evaporated from the wick before the final weighing.
- B In the calculation, the student used the molar mass of ethanol instead of methanol.
- C There was incomplete combustion.
- D The water boiled for 5 minutes before the final temperature was taken.

Your answer

[1]

23 This question is about energy changes and rate of reaction.

Magnesium reacts with aqueous silver nitrate,  $\text{AgNO}_3(\text{aq})$ , as in **equation 23.1**.



A student carries out an experiment to determine the enthalpy change of this reaction,  $\Delta_r H$ .

- The student adds  $25.0 \text{ cm}^3$  of  $0.512 \text{ mol dm}^{-3} \text{ AgNO}_3$  to a polystyrene cup.
- The student measures the temperature of the solution.
- The student adds a small spatula measure of magnesium powder, stirs the mixture and records the maximum temperature

#### Temperature readings

|                     |                        |
|---------------------|------------------------|
| Initial temperature | = $19.5^\circ\text{C}$ |
| Maximum temperature | = $47.5^\circ\text{C}$ |

(i) Calculate  $\Delta_r H$ , in  $\text{kJ mol}^{-1}$ , for the reaction shown in **equation 23.1**.

Give your answer to an **appropriate** number of significant figures.

Assume that the density and specific heat capacity,  $c$ , of the solution are the same as for water and that all the aqueous silver nitrate has reacted.

$\Delta_r H =$  .....  $\text{kJ mol}^{-1}$  [4]

- (ii) At the end of the experiment, the student adds a few drops of aqueous sodium chloride to the reaction mixture in the polystyrene cup to test whether all the aqueous silver nitrate has reacted.

Explain how the results would show whether all the aqueous silver nitrate has reacted. Include an equation with state symbols in your answer.

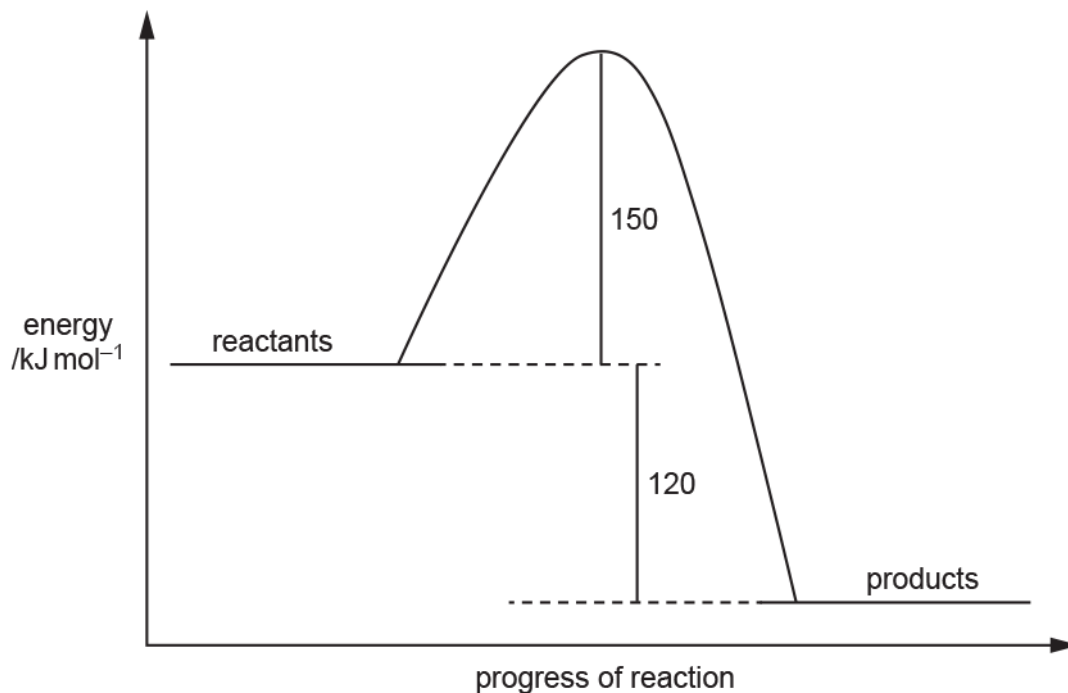
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----- [2]

24 A reversible reaction has the enthalpy profile diagram shown below.



Which statement about this reaction is correct?

- A The activation energy of the forward reaction is  $120 \text{ kJ mol}^{-1}$ .
- B The activation energy of the reverse reaction is  $270 \text{ kJ mol}^{-1}$ .
- C The enthalpy change of the forward reaction is  $-30 \text{ kJ mol}^{-1}$ .
- D The reverse reaction is exothermic.

Your answer

[1]

25 Hydrogen and chlorine react as shown below.



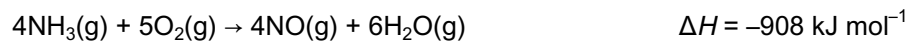
Which statement about this reaction is correct?

- A Less energy is released on bond making than is taken in during bond breaking.
- B The enthalpy change for the reverse equation is  $+184.6 \text{ kJ mol}^{-1}$ .
- C The enthalpy change of formation of  $\text{HCl}(\text{g})$  is  $-184.6 \text{ kJ mol}^{-1}$ .
- D The temperature decreases during the reaction.

Your answer

[1]

26 Ammonia is used to make nitric acid. The first stage of the reaction is shown below.



Standard enthalpy changes of formation,  $\Delta_f H^\ominus$ , are given in the table.

| Substance                      | $\Delta_f H^\ominus / \text{kJ mol}^{-1}$ |
|--------------------------------|-------------------------------------------|
| $\text{NH}_3(\text{g})$        | -46                                       |
| $\text{O}_2(\text{g})$         | 0                                         |
| $\text{H}_2\text{O}(\text{g})$ | -242                                      |

(i) State the conditions of temperature and pressure used for standard enthalpy measurements.

Temperature -----

Pressure -----

[1]

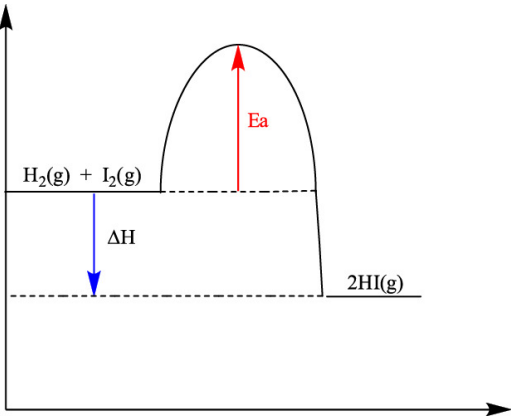
(ii) Calculate the standard enthalpy change of formation for  $\text{NO}(\text{g})$ .

Give your answer to a **whole number**.

$\Delta_f H^\ominus$  for  $\text{NO}(\text{g}) = \dots\dots\dots \text{kJ mol}^{-1}$  [3]

**END OF QUESTION PAPER**

# Mark Scheme

| Question |   | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1        | a | <p>There are 3 marking points required for 2 marks</p>  <p> <math>\text{H}_2(\text{g}) + \text{I}_2(\text{g})</math><br/> <math>\Delta H</math><br/> <math>2\text{HI}(\text{g})</math> </p> <p> <math>\text{H}_2</math> and <math>\text{I}_2</math> on LHS<br/> <b>AND</b> <math>2\text{HI}</math> on RHS<br/> <b>AND</b> correctly labelled <math>E_a</math> ✓         </p> <p> <math>\Delta H</math> labelled with product below reactant<br/> <b>AND</b> arrow downwards ✓         </p> | 2     | <p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p><b>IGNORE</b> state symbols.</p> <p><math>E_a</math>:</p> <p><b>ALLOW</b> (+)173 only as an alternative label for <math>E_a</math></p> <p><b>ALLOW</b> no arrowhead or arrowheads at both ends of activation energy line</p> <p>The <math>E_a</math> line must point to maximum (or near to the maximum) on the curve <b>OR</b> span approximately 80% of the distance between reactants and maximum regardless of position</p> <p><b>ALLOW</b> <math>A_E</math> or <math>A_E</math> for <math>E_a</math></p> <p><math>\Delta H</math>:</p> <p><b>IF</b> there is no <math>\Delta H</math> labelled <b>ALLOW</b> -9 as an alternative label for <math>\Delta H</math>.</p> <p><b>IF</b> <math>\Delta H</math> is labelled <b>IGNORE</b> any numerical value.</p> <p><b>DO NOT ALLOW</b> <math>-\Delta H</math>.</p> <p><b>ALLOW</b> this arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line</p> <p><b>Examiner's Comments</b></p> <p>Many candidates are well-rehearsed for this type of question, however there are still some issues regarding the use of double headed arrows to indicate an enthalpy change. Whilst allowed by the examiners for showing <math>E_a</math>, a correct single headed arrow was required to illustrate <math>\Delta H</math>.</p> |
|          | b | (+)182 ✓                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1     | <p>This is the <b>ONLY</b> acceptable answer</p> <p><b>Examiner's Comments</b></p> <p>Most candidates were able to correctly process the <math>E_a</math> and <math>\Delta H</math> values provided to calculate the activation energy of the reverse reaction. Some candidates subtracted <math>\Delta H</math> from the <math>E_a</math> value to give an answer of <math>164 \text{ kJ mol}^{-1}</math>. Other candidates reversed the sign of the activation energy provided to give <math>-173 \text{ kJ mol}^{-1}</math>.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

### Mark Scheme

| Question |   |  | Answer/Indicative content                                                                                                                                                      | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------|---|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          | c |  | <p>Look at answer if +63 kJ AWARD 2 marks<br/>If 63 (no sign) OR -63 (incorrect sign) AWARD 1 mark</p> <p>No of moles of HI = 14 moles ✓</p> <p>Enthalpy Change = +63 kJ ✓</p> | 2     | <p>ALLOW one mark for +126 kJ</p> <p>Sign and value required.<br/>ALLOW ECF from incorrect number of moles of HI</p> <p><b>Examiner's Comments</b></p> <p>Many candidates were able to tackle the first part of this question confidently to obtain the correct value for the moles of hydrogen iodide that decomposed. The second marking point proved more difficult, and candidates were expected to scale the enthalpy change given, in addition to providing the correct sign for this process, which is the reverse reaction of the equilibrium shown. The very best candidates were able to achieve the second mark. Common errors included incorrect scaling, to give the enthalpy change as +126 kJ mol<sup>-1</sup>, or showing the incorrect sign, -63 kJ mol<sup>-1</sup> or not providing the sign, 63 kJ mol<sup>-1</sup>.</p> |

# Mark Scheme

| Question |   |  | Answer/Indicative content                                                                                                                                                                                                                                                                                                   | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------|---|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          | d |  | <p>Look at answer if (+)298 AWARD 2 marks<br/>If answer is -298 AWARD 1 mark (incorrect sign)</p> <p>2 x H-I bond enthalpy correctly calculated<br/>(436 +151-(-9) =) (+)596 ✓</p> <p>H-I bond enthalpy correctly calculated<br/>(Bond energy for H-I <math>\frac{(+596)}{2}</math> =) (+)298 kJ mol<sup>-1</sup><br/>✓</p> | 2     | <p>ALLOW 1 mark for (+)293.5 kJ mol<sup>-1</sup><br/>(bonds broken divided by 2)<br/>ALLOW 1 mark for (+)289 kJ mol<sup>-1</sup><br/>(incorrect expression i.e. <math>\frac{[436 +151+(-9)]}{2}</math>)</p> <p><b>Examiner's Comments</b></p> <p>This question required candidates to process the bond enthalpy data and value for <math>\Delta H</math> to obtain a value of the bond enthalpy of H—I. In general the responses were much better than for a similar question asked in the January 2012 session and most candidates were able to score at least one mark. The most common error was a failure to divide by two, resulting in an answer of +596 kJ mol<sup>-1</sup>. Another common incorrect response included the incorrect subtraction of <math>\Delta H</math> from the bond enthalpy to give a value of +289 kJ mol<sup>-1</sup>. Some candidates neglected to use <math>\Delta H</math> and arrived at a value of +293.5 kJ mol<sup>-1</sup>. All these responses received one mark.</p> <p>This question discriminated well and the most able candidates scored both marks.</p> |
|          |   |  | Total                                                                                                                                                                                                                                                                                                                       | 7     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

# Mark Scheme

| Question |   |  | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|----------|---|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2        | a |  | <p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = <math>-38.3 \text{ (kJ mol}^{-1}\text{)}</math> award 4 marks</p> <p>IF answer = <math>(+)38.3 \text{ (kJ mol}^{-1}\text{)}</math> award 3 marks (incorrect sign)</p> <p>IF answer = <math>-38,300 \text{ (kJ mol}^{-1}\text{)}</math> award 3 marks (used J instead of kJ).</p> <p><b>Energy</b><br/> <math>q</math> calculated correctly = <math>1149.5 \text{ (J)}</math> ✓ OR <math>1.1495 \text{ (kJ)}</math> ✓</p> <p><b>Moles</b><br/> Amount, <math>n</math>, of <math>\text{Na}_2\text{CO}_3</math> calculated correctly = <math>0.03(00)</math> ✓</p> <p><b>Calculating <math>\Delta H</math></b><br/> correctly calculates <math>\Delta H</math> in <math>\text{kJ mol}^{-1}</math> to 3 or more sig figs ✓</p> <p><b>Rounding and Sign</b><br/> calculated value of <math>\Delta H</math> rounded to 3 sig. fig. with minus sign ✓</p> | 4     | <p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>Note: <math>q = 50.0 \times 4.18 \times 5.5</math><br/> ALLOW <math>1149.5</math> OR correctly rounded to 3 sig figs (J)<br/> IGNORE sign<br/> IGNORE working<br/> ALLOW <math>53.18 \times 4.18 \times 5.5</math> OR <math>1222.6082</math><br/> OR <math>1220</math> OR correctly rounded to 3 or more sig figs in J or kJ</p> <p>IGNORE working<br/> IGNORE trailing zeros</p> <p>IGNORE sign at this intermediate stage<br/> ALLOW ECF from incorrect <math>q</math> and / or incorrect <math>n</math></p> <p>Final answer must have <b>correct sign</b> and <b>three sig figs</b></p> <p>ALLOW <math>-40.8 \text{ kJ mol}^{-1}</math> if <math>53.18</math> used in calculation of <math>q</math><br/> ALLOW <math>-40.7 \text{ kJ mol}^{-1}</math> if <math>q</math> is rounded to <math>1220</math> from <math>53.18</math> earlier</p> <p><b>Examiner's Comments</b></p> <p>Candidates coped well with this unstructured calculation. Almost all candidates recognised the first step was to use the <math>mc\Delta T</math> expression to determine the energy change and subsequently divided this by the moles of <math>\text{Na}_2\text{CO}_3</math> to obtain a value for <math>\Delta H_r</math>.</p> <p>A significant proportion of responses across the whole ability range did not include a sign for the enthalpy change. Candidates should be encouraged to quote all enthalpy changes with the appropriate</p> |

### Mark Scheme

| Question |   |   | Answer/Indicative content                                                                                                                                       | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------|---|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |   |   |                                                                                                                                                                 |       | <p>sign, so that they receive the credit they deserve.</p> <p>Common incorrect responses included using the mass of the carbonate rather than the volume of acid as <math>m</math> in the <math>mc\Delta T</math> expression. Some candidates used the moles of <math>\text{HCl}</math> rather than <math>\text{Na}_2\text{CO}_3</math> when calculating <math>\Delta H_r</math>. Error carried forward marks were awarded, where appropriate, in each of these cases. Consequently the majority of candidates scored in this part. The most common marks were 3 and 4, which were awarded in roughly equal proportions.</p> |
|          | b | i | <p>(Enthalpy change) when one mole of a compound ✓</p> <p>is formed from its elements ✓</p> <p>298 K / 25 °C <b>AND</b> 1 atm / 100 kPa / 101 kPa / 1 bar ✓</p> | 3     | <p><b>ALLOW</b> energy required <b>OR</b> energy released</p> <p><b>ALLOW</b> one mole of substance <b>OR</b> one mole of product</p> <p><b>DO NOT ALLOW</b> one mole of element</p> <p><b>IGNORE</b> reference to concentration</p> <p><b>Examiner's Comments</b></p> <p>Candidate were well prepared to quote this definition and many candidates scored full marks. Some candidates neglected to give the standard conditions or quoted incorrect values.</p>                                                                                                                                                             |

# Mark Scheme

| Question |  |     | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------|--|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |  | ii  | $\frac{1}{2}\text{N}_2(\text{g}) + 2\text{H}_2(\text{g}) + \frac{1}{2}\text{Cl}_2(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{NH}_4\text{ClO}_4(\text{s})$<br><br>correct species ✓<br><br>correct state symbols and balancing ✓                                                                                                                                                                                                                                                | 2     | <p>Second mark can only be awarded if all species in the equation are correct</p> <p>DO NOT ALLOW multiples of this equation</p> <p>Examiner's Comments</p> <p>This question required candidates to apply the knowledge of the definition given in the previous part and provide an equation for the formation of ammonium chlorate(VII). Stronger candidates were able to do this, but some balanced the equation incorrectly and formed two moles of the compound. It was common to see incorrect formulae and weaker candidates were unable to state the formula of chlorine, which was given as Cl. Nitrogen was also show as N. Candidates should be aware that being able to state formulae of elements is required at this level.</p> |
|          |  | iii | <p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = (+)90 award 3 marks</p> <p>IF answer = -90 award 2 marks</p> <p>IF answer = ±270 award 2 marks</p> <p>IF answer = ±2947 award 1 mark</p> <p>Processing <math>\Delta H_f</math> values</p> <p>±(3832 – 885) ±2947 ✓</p> <p>OR</p> <p>± (3832 – 885)</p> <p>subtraction using <math>\Delta H</math> reaction</p> <p>±(2947–2677)= ±270 ✓</p> <p>Calculation of <math>\Delta H</math> formation NO</p> <p>270/3 = (+)90 ✓</p> | 3     | <p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>Note: <math>\pm 2947 = \pm [-1676 + (-704) + (6 \times -242)] - (3 \times -295)</math></p> <p>ALLOW ECF for dividing by 3 from working that includes at least one <math>\Delta H_f</math> and one balancing number and <math>\Delta H</math> (–2677) for 1 mark</p> <p>Examiner's Comments</p> <p>The majority of candidates made a good attempt at this question and provided</p>                                                                                                                                                                                                                                                                                                      |

### Mark Scheme

| Question |  |  | Answer/Indicative content | Marks     | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------|--|--|---------------------------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |  |  |                           |           | <p>structured responses. The most common approach adopted by candidates was to use the <math>\Delta H_f</math> data given in the table and the stoichiometry ratios from the equation to calculate the difference between the reactants and products, <math>-2497 \text{ kJ mol}^{-1}</math>. This value was then subtracted from the enthalpy change of the reaction to give <math>+270 \text{ kJ mol}^{-1}</math>. The strongest candidates recognised the need to divide this by three to obtain the enthalpy change of formation of NO.</p> <p>Some candidates carried out their subtractions in the intermediate stages incorrectly and consequently arrived at a value of <math>-90 \text{ kJ mol}^{-1}</math>. This response received two marks.</p> <p>Error carried forward credit was awarded to candidates who incorrectly processed <math>\Delta H_f</math> data, stoichiometric ratios and the enthalpy change of the reaction provided their final answer was divided by three. Consequently the majority of candidates scored at least one mark in this question.</p> |
|          |  |  | <b>Total</b>              | <b>12</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

### Mark Scheme

| Question |  |   | Answer/Indicative content                                                                                | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----------|--|---|----------------------------------------------------------------------------------------------------------|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3        |  | i | <p>(Average enthalpy change) when one mole of bonds ✓</p> <p>of (gaseous covalent) bonds is broken ✓</p> | 2     | <p><b>IGNORE</b> energy required <b>OR</b> energy released</p> <p><b>DO NOT ALLOW</b> bonds formed</p> <p><b>Examiner's Comments</b></p> <p>Candidates were required to recall the definition of bond enthalpy in this question and a range of responses were seen. Most candidates recognised that bond breaking was important, but weaker responses included contradictions by also referring to bond formation. The strongest candidates were able to state that bond enthalpy referred to one mole of bonds but it was not uncommon to see answers such as 'one mole of compound' and 'one mole of substance'.</p> |

### Mark Scheme

| Question |  |    | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                           | Marks    | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------|--|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |  | ii | <p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF enthalpy change = <math>-42 \text{ (kJ mol}^{-1}\text{)}</math> award 3 marks</p> <p>IF enthalpy change = <math>+42 \text{ (kJ mol}^{-1}\text{)}</math> award 2 marks</p><br><p>(Energy for bonds broken) = 5538 (kJ) ✓</p> <p>(Energy for bonds made) = 5580 (kJ) ✓</p><br><p><math>\Delta H_r = -42 \text{ (kJ mol}^{-1}\text{)}</math> ✓</p> | 3        | <p>IF there is an alternative answer, check to see if there is any ECF credit possible.</p><br><p>two common incorrect answers are:<br/> <math>-970 \text{ (kJ mol}^{-1}\text{)}</math> award 2 marks<br/> <math>+970 \text{ (kJ mol}^{-1}\text{)}</math> award 1 mark</p><br><p>IGNORE signs<br/> ALLOW 1076 (bonds broken); 1118 (bonds made)</p><br><p>Correct sign required</p><br><p>ALLOW ECF for bonds broken – bonds made IF at least one molar ratio is used<br/> e.g. <math>8 \times \text{C-H}</math></p><br><p><b>Examiner's Comments</b></p> <p>Candidates approached this question well and the majority of responses were clearly and logically presented. The strongest candidates were able to identify all the bonds broken and formed and calculate the correct enthalpy change. Some candidates carried out the final step incorrectly, arriving at a value of <math>+42 \text{ kJ mol}^{-1}</math>. A common mistake was to omit the bonds broken in water, giving an enthalpy change of <math>-970 \text{ kJ mol}^{-1}</math>. Other mistakes were seen and error carried forward marks were awarded where appropriate. Candidates are advised to draw displayed formulae to help identify the number of each type of bond to be used in their calculation.</p><br><p>Answer: <math>-42 \text{ kJ mol}^{-1}</math></p> |
|          |  |    | <b>Total</b>                                                                                                                                                                                                                                                                                                                                                                                        | <b>5</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

# Mark Scheme

| Question |   |   | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------|---|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4        | a | i | <p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF <math>\Delta H_c = -2260</math> (kJ mol<sup>-1</sup>) award 4 marks</p> <p>IF <math>\Delta H_c = (+)2260</math> (kJ mol<sup>-1</sup>) award 3 marks (incorrect sign)</p> <p>IF <math>\Delta H_c = (\pm)2257(.2)</math> (kJ mol<sup>-1</sup>) award 3 marks (not 3 sf)</p> <p><b>Moles</b><br/>Amount, <math>n</math>, C<sub>5</sub>H<sub>12</sub>O calculated correctly = 0.0175 (mol) ✓</p> <p><b>Energy</b><br/><math>q</math> calculated correctly = 39501 (J) OR 39.5(01) (kJ) ✓</p> <p><b>Calculating <math>\Delta H</math></b><br/>correctly calculates <math>\Delta H</math> in kJ mol<sup>-1</sup> to 3 or more sig figs ✓</p> <p><b>Rounding and Sign</b><br/>calculated value of <math>\Delta H</math> rounded to 3 sig. fig. with minus sign ✓</p> | 4     | <p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p><b>Note:</b> <math>q = 180 \times 4.18 \times 52.5</math><br/><b>ALLOW</b> 39501 OR correctly rounded to 3 sig. fig. (J)<br/><b>IGNORE</b> sign<br/><b>IGNORE</b> working</p> <p><b>Note:</b> from 39501 J and 0.0175 mol <math>\Delta H = (-)2257.2</math> kJ mol<sup>-1</sup></p> <p><b>IGNORE</b> sign at this intermediate stage<br/><b>ALLOW</b> ECF from incorrect <math>q</math> and / or incorrect <math>n</math></p> <p>Final answer must have <b>correct sign</b> and <b>three sig figs</b></p> <p><b>Examiner's Comments</b></p> <p>Candidates coped well with this unstructured calculation. Almost all candidates recognised the first step was to use the <math>mc\Delta T</math> expression to determine the energy change and subsequently divided this by the moles of alcohol <math>J</math> to obtain a value for <math>\Delta H_c</math>. A significant proportion of responses across the whole ability range did not include a sign for the enthalpy change or did not round the final answer to three significant figures and so only scored three marks. Candidates should be aware that when a question includes a requirement to round the final answer to a stated number of significant figures, failure</p> |

### Mark Scheme

| Question |   |    | Answer/Indicative content                                                                                                                                                                  | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------|---|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |   |    |                                                                                                                                                                                            |       | to do so will prevent full marks from being awarded.<br><br>Answer: $-2260 \text{ kJ mol}^{-1}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|          |   | ii | <b>ANY TWO FROM THE FOLLOWING ✓✓</b><br><br>incomplete combustion<br><br>non-standard conditions<br><br>evaporation of alcohol / water<br><br>specific heat capacity of beaker / apparatus | 2     | <b>IGNORE</b> heat loss ( <i>in question</i> )<br><br><b>ALLOW</b> burns incompletely<br><b>IGNORE</b> incomplete reaction<br><br><b>Examiner's Comments</b><br><br>This question proved hard for candidates and although one of incomplete combustion or reference to non-standard conditions was frequently mentioned, such responses were often accompanied by vaguer statements. These statements included reference to data books containing average values, or mention of human or equipment error, e.g. the mass of alcohol was measured incorrectly. Consequently many candidates scored one, with only the best candidates securing both marks. |
|          | b | i  | $5\text{C(s)} + 6\text{H}_2\text{(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{C}_5\text{H}_{12}\text{O(l)}$ ✓                                                                  | 1     | Balancing numbers <b>AND</b> species <b>AND</b> states all required<br><br><b>DO NOT ALLOW</b> multiples of this equation<br><br><b>Examiner's Comments</b><br><br>Many candidates were able to provide a correctly balanced equation for the enthalpy of formation of alcohol J. However, it was often the case that no state symbol was provided for J. A significant proportion of candidates suggested an incorrect state symbol for J, viz. (aq). While others gave no state symbols at all. Candidates should be encouraged to check questions carefully when asked to give an equation to avoid omitting required information.                    |

### Mark Scheme

| Question |   |    | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Marks     | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------|---|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |   | ii | <p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF enthalpy change = <math>-3320 \text{ (kJ mol}^{-1}\text{)}</math><br/>award 3 marks</p> <p>IF enthalpy change = <math>(+)3320 \text{ (kJ mol}^{-1}\text{)}</math><br/>award 2 marks</p> <p>-----</p> <p>Working for <math>\text{CO}_2</math> AND <math>\text{H}_2\text{O}</math> seen anywhere</p> <p><math>5 \times (-)394</math> AND <math>6 \times (-)286</math><br/>OR <math>(-)1970</math> AND <math>(-)1716</math><br/>OR <math>(-)3686</math> ✓</p> <p>Calculates <math>\Delta H_c</math></p> <p>A further 2 marks for correct answer AND correct sign<br/> <math>= 5 \times -394 + 6 \times -286 - -366</math><br/> <math>= -3320 \text{ (kJ mol}^{-1}\text{)}</math> ✓✓</p> <p>A further 1 mark for correct answer AND incorrect or no sign<br/> <math>= (+)3320 \text{ (kJ mol}^{-1}\text{)}</math> ✓<br/> <i>Cycle wrong way around:</i><br/> <math>-366 - (5 \times -394 + 6 \times -286)</math></p> | 3         | <p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>IF there is an alternative answer, check to see if there is any ECF credit possible</p> <p>Common incorrect answers are shown below<br/> Award 2 marks for<br/> <math>-1744</math> OR <math>-1890</math> OR <math>-314</math> OR <math>-4052</math><br/> Award 1 mark for<br/> <math>1744</math> OR <math>1890</math> OR <math>314</math> OR <math>4052</math></p> <p>Examiner's Comments</p> <p>Candidates appeared well prepared for this type of calculation and the majority scored full marks. A significant proportion failed to give the correct sign, and received two marks.</p> <p>Answer: <math>-3320 \text{ kJ mol}^{-1}</math></p> |
|          |   |    | <b>Total</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>10</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 5        |   |    | A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|          |   |    | <b>Total</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>1</b>  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 6        | a |    | B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|          | b |    | B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|          |   |    | <b>Total</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>2</b>  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

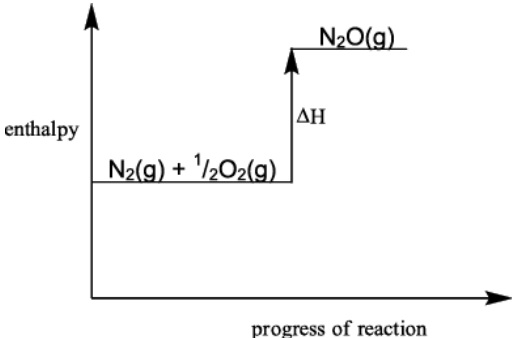
# Mark Scheme

| Question |  |     | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Marks    | Guidance                                                                                                                                                                                                         |
|----------|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7        |  | i   | $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$ (1)                                                                                                                                                                                                                                                                                                                                                                                   | 1        | allow multiples                                                                                                                                                                                                  |
|          |  | ii  | <p><i>Energy (into water) mark</i><br/> <math>70.0 \times 4.18 \times 16.5 = 4827.9</math> (J) or 4.8279 (kJ) (1)</p> <p><i>amount of substance mark</i><br/> <math>n(\text{H}_2\text{O}) = \frac{35.0}{1000} \times 2.40 = 0.084(0)</math> (mol)</p> <p><i><math>\Delta_{\text{neut}}H</math> mark</i><br/> <math>(-4.8279 / 0.084(0)) =</math><br/> <math>(-57.475 \text{ OR } (-57.48 \text{ OR } (-57.5</math> (1)</p> <p>Correctly rounded to at least 3 significant figures</p> | 3        | <p>allow rounding to 4828 OR 4830</p> <p>allow amount of substance mark to be based upon either HCl or NaOH</p> <p>allow ecf for</p> <p><u>Energy (into water) mark</u><br/> <u>Amount of substance mark</u></p> |
|          |  | iii | 1 mole of water had been formed (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1        |                                                                                                                                                                                                                  |
|          |  | iv  | $\frac{2 \times 0.5}{16.5} \times 100 = 6\%$ (1)                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1        |                                                                                                                                                                                                                  |
|          |  |     | <b>Total</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>6</b> |                                                                                                                                                                                                                  |
| 8        |  | i   | (because energy is needed to break)<br>induced dipole–dipole interactions / London forces between molecules (1)                                                                                                                                                                                                                                                                                                                                                                       | 1        | allow forces of attraction between molecules OR van der Waals' forces<br>ignore reference to strong or weak                                                                                                      |
|          |  | ii  | <p>Bond breaking (+193) + (+151) = (+)344<br/> <b>AND</b><br/> Bond making 2(–175) = (–)350 (1)</p> <p><math>\Delta_{\text{f}}H = \frac{(+344) + (-350)}{2} = -3</math> (kJ mol<sup>–1</sup>) (1)</p>                                                                                                                                                                                                                                                                                 | 2        | Correct answer scores 2 marks                                                                                                                                                                                    |
|          |  |     | <b>Total</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>3</b> |                                                                                                                                                                                                                  |

### Mark Scheme

| Question |   |  | Answer/Indicative content                                                                                                                                                                                                                                                                                              | Marks    | Guidance                                                                                |
|----------|---|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-----------------------------------------------------------------------------------------|
| 9        | a |  | One mole of butane completely combusts in oxygen                                                                                                                                                                                                                                                                       | 1        | <b>allow</b> One mole forms CO <sub>2</sub> and H <sub>2</sub> O only                   |
|          | b |  | <b>FIRST CHECK THE ANSWER ON THE ANSWER LINE</b><br>IF answer = +215 (kJ mol <sup>-1</sup> ) award 2 marks<br>IF answer = -215 (kJ mol <sup>-1</sup> ) award 1 mark<br><br>RHS (-2877 + (2 x -2058) = (-)6993 (kJ mol <sup>-1</sup> ) (1)<br><br>( $\Delta_r H$ ) = -6778 + (+6993) = +215 (kJ mol <sup>-1</sup> ) (1) | 2        | <b>ignore</b> incorrect sign at this stage<br><br><b>sign required</b> for final answer |
|          |   |  | <b>Total</b>                                                                                                                                                                                                                                                                                                           | <b>3</b> |                                                                                         |

# Mark Scheme

| Question |  |    | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                            | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------|--|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 10       |  | i  | More energy is required for bond breaking than is released by bond making ✓                                                                                                                                                                                                                                                                                                                                                          | 1     | <p><b>Examiner's Comments</b></p> <p>The poor quality of answers observed surprised the Examiners as this question had featured a number of times on legacy papers which would have been used in Centres to prepare candidates for this examination. Many candidates were not able to explain that bond breaking requires energy whereas bond making produces energy. For the reaction to be endothermic more energy is required to break bonds than is evolved when bonds are formed. In their answers candidates frequently stated that both processes required energy or that more bonds were broken than were formed.</p>                                                                                                                                                               |
|          |  | ii | <p>Enthalpy profile diagram</p> <ul style="list-style-type: none"> <li>• <math>\Delta H</math> labelled OR 82 on vertical arrow</li> <li>• Products above reactants (either chemical symbols or the words products and reactants)</li> <li>• Arrow upwards ✓</li> </ul> <p>Formulae <b>AND</b> state symbols<br/> <math>\text{N}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{N}_2\text{O}(\text{g})</math> ✓</p> | 2     |  <p><b>IGNORE</b> activation energy</p> <p><b>DO NOT ALLOW</b> multiples of equation:<br/>1 mole of <math>\text{N}_2\text{O}</math> is formed</p> <p><b>Examiner's Comments</b></p> <p>Half of the candidates scored zero for this question, many failing to label the enthalpy change or to show this as an arrow pointing upwards. Although the question stated that the activation energy was not required, candidates frequently included it in their diagrams and then labelled it <math>\Delta H</math>. Many Candidates did not write the formula of the reactants or products and those who did multiplied the species by two so as the diagram did not represent the enthalpy of formation.</p> |

### Mark Scheme

| Question |  |  | Answer/Indicative content | Marks | Guidance                                             |
|----------|--|--|---------------------------|-------|------------------------------------------------------|
|          |  |  | Total                     | 3     |                                                      |
| 11       |  |  | B                         | 1     | <u>Examiner's Comments</u><br>Generally scored well. |
|          |  |  | Total                     | 1     |                                                      |

# Mark Scheme

| Question |   | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 12       | a | <p>FIRST, CHECK THE ANSWER ON ANSWER LINE<br/>IF <math>\Delta_r H = -58.5 \text{ (kJ mol}^{-1}\text{)}</math> award 4 marks</p> <hr/> <p><i>Energy released in J OR kJ</i></p> <p><math>= 100.0 \times 4.18 \times 10.5 = 4389 \text{ (J) OR } 4.389 \text{ (kJ) } \checkmark</math></p> <p><i>Correctly calculates <math>n(\text{Pb}(\text{NO}_3)_2)</math></i></p> <p><math>= 1.50 \times \frac{50}{1000} = 0.075(0) \text{ (mol) } \checkmark</math></p> <p><math>\Delta H</math> value in J OR kJ<br/>Answer <b>MUST</b> divide energy by <math>n(\text{Pb}(\text{NO}_3)_2)</math><br/> <math>(-)\frac{4389}{0.0750}</math> <b>OR</b> <math>(-)\text{58520 (J)}</math><br/> <b>OR</b><br/> <math>(-)\frac{4.389}{0.0750}</math> <b>OR</b> <math>(-)\text{58.52 (kJ) } \checkmark</math><br/> <i>(Sign ignored and/or more than 3 SF)</i></p> <p>Correct <math>\Delta_r H</math> in kJ <b>AND</b> – sign AND 3 SF<br/> <math>= -58.5 \text{ (kJ mol}^{-1}\text{)} \checkmark</math></p> | 4     | <p><b>FULL ANNOTATIONS MUST BE USED</b></p> <p>-----</p> <p>ALLOW 4390 J; 4.39 kJ<br/> <b>DO NOT ALLOW</b> less than 3 SF<br/> <b>IGNORE</b> units<br/> <i>i.e. ALLOW correctly calculated number in J OR kJ</i></p> <p>ALLOW ECF from <math>n(\text{Pb}(\text{NO}_3)_2)</math> <b>AND/OR</b> Energy</p> <p>ALLOW 58500 (from 4390)</p> <p><b>IGNORE</b> absence of – sign and 3 SF requirement</p> <p>Final mark requires – sign, kJ <b>AND</b> 3 SF<br/> <b>Note:</b> From 4390 J, <math>\Delta_r H = -58.5 \text{ (kJ mol}^{-1}\text{)}</math> (SAME)</p> <p>-----</p> <p><b>Common error</b><br/> –29.3 3 marks (50 g instead of 100 g in <math>mc\Delta T</math>)</p> <p><b><u>Examiner's Comments</u></b></p> <p>Although similar in style to unstructured direct enthalpy calculations on the legacy specification, this question was harder for two reasons. Firstly, two volumes of 50 cm<sup>3</sup> had to be added together to generate m as 100 g for <math>mc\Delta T</math>. Secondly, candidates were asked to quote their final answer to an ‘appropriate’ number of significant figures. This will be the least accurate measurement (to 3 significant figures in this example).</p> <p>Many incorrect answers used <i>m</i> as 50 g or</p> |

# Mark Scheme

| Question |   |  | Answer/Indicative content                                                                                                                            | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----------|---|--|------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |   |  |                                                                                                                                                      |       | <p>quoted a final numerical value to more than 3 significant figures.</p> <p>Even after obtaining a correct final value for <math>\Delta H</math>, this was often not given a negative sign to indicate the exothermic change.</p> <p>It is important for candidates to show clear working so that markers can see what is intended and able to apply credit using error carried forward.</p> <p>Answer: <math>\Delta H = -58.5 \text{ kJ mol}^{-1}</math></p>                                                                                                                                         |
|          | b |  | <p><math>\text{Pb}^{2+}(\text{aq}) + 2\text{I}^{-}(\text{aq}) \rightarrow \text{PbI}_2(\text{s}) \checkmark</math></p> <p>State symbols required</p> | 1     | <p><b>ALLOW</b> <math>\text{Pb}^{+2}(\text{aq})</math></p> <p><b>IGNORE</b> spectator ions, <math>\text{K}^{+}(\text{aq})</math> and <math>2\text{NO}_3^{-}(\text{aq})</math> on both sides</p> <p><u><b>Examiner's Comments</b></u></p> <p>Only the best candidates were able to construct the required equation. Even when written correctly, state symbols (asked for in the question) were often omitted or shown incorrectly. Although very similar to the ionic equation for formation of silver halides, this equation was beyond most candidates at this stage of their chemistry studies.</p> |

# Mark Scheme

| Question |   |  | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------|---|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          | c |  | <p>FIRST, CHECK ANSWER ON ANSWER LINE</p> <p>IF [KI(aq)] rounds to 3.3 mol dm<sup>-3</sup><br/>e.g. 3.30, 3.33, 3.3 recurring</p> <p>-----</p> <p><b>Method 1</b><br/>[KI(aq)] for complete reaction</p> $= 2 \times 0.0750 = 0.150 \text{ mol} \times \frac{1000}{50} = 3 \text{ (mol dm}^{-3}\text{)} \checkmark$ <p>10% greater gives <math>3 \times 1.1 = 3.3(0) \checkmark</math></p> <p>OR-----</p> <p><b>Method 2</b><br/><math>n(\text{KI(aq)})</math> required = <math>2.2 \times 0.0750 = 0.165 \text{ mol} \checkmark</math></p> $[\text{KI(aq)}] = 0.165 \times \frac{1000}{50} = 3.3(0) \text{ (mol dm}^{-3}\text{)} \checkmark$ | 2     | <p>ALLOW ECF from incorrect <math>n(\text{Pb(NO}_3)_2)</math> from 24(a)<br/>BUT if (a) is incorrect but 0.0750 used here, treat as a fresh start and IGNORE response from 24(a)</p> <p>ALLOW 2 marks for 3.3/3.3 recurring<br/><i>Attempt at increasing concentration by 10%</i></p> $= 2 \times 0.0750 = 0.150 \text{ mol} \times \frac{1000}{45} = 3.33 \text{ (mol dm}^{-3}\text{)}$ <p>ALLOW ECF from incorrect <math>n(\text{KI})</math></p> <p><u>Common errors</u></p> <p>3 1 mark (Correct for KI with no extra 10%)<br/>1.6 1 mark (no factor of 2 used for KI)<br/>5<br/>2.7 1 mark (10% less rather than 10% more)<br/>2.7 1 mark (10% increase in volume: 55 3/2. cm<sup>3</sup>)<br/>72</p> <p><u>Examiner's Comments</u></p> <p>This part was well attempted with many candidates able to score at least one of the two marks. Errors related to use of an incorrect mole ratio, applying 10% incorrectly, or ignoring 10% altogether.</p> <p>Answer: 3.30 mol dm<sup>-3</sup></p> |
|          |   |  | Total                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 7     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

# Mark Scheme

| Question |   |   | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------|---|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13       | a | i | <p>IF <math>\Delta H_r = -347</math> (<math>\text{kJ mol}^{-1}</math>) award 4 marks<br/> IF <math>\Delta H_r = (+)347</math> (<math>\text{kJ mol}^{-1}</math>) award 3 marks<br/> (incorrect sign)</p> <p>-----</p> <p><b>Moles</b><br/> Amount, <math>n(\text{CuSO}_4)</math>, calculated correctly =<br/> 0.0125 (mol) ✓</p> <p><b>Energy</b><br/> <math>q</math> calculated correctly = 4336.75 (J) OR<br/> 4.33675 (kJ) ✓</p> <p><b>Calculating <math>\Delta H</math></b><br/> correctly calculates <math>\Delta H</math> in <math>\text{kJ mol}^{-1}</math> to 3 or<br/> more sig figs ✓</p> <p><b>Rounding and Sign</b><br/> calculated value of <math>\Delta H</math> rounded to 3 sig.<br/> fig. with minus sign ✓</p> | 4     | <p>ANNOTATE ANSWER WITH TICKS AND<br/> CROSSES</p> <p><b>Note:</b> <math>q = 25.0 \times 4.18 \times 41.5</math></p> <p>ALLOW 3 SF up to calculator value of<br/> 4336.75 J<br/> IGNORE sign<br/> IGNORE working</p> <p><b>Note:</b> from 4336.75 J and 0.0125 mol <math>\Delta H =</math><br/> (-)346.940 <math>\text{kJ mol}^{-1}</math><br/> IGNORE sign at this intermediate stage<br/> ALLOW ECF from <math>n(\text{CuSO}_4)</math> and / or<br/> energy released</p> <p>Final answer must have <b>correct sign</b> and<br/> <b>three sig figs</b></p> <p>Answer is still -347 from rounding of <math>q</math> to<br/> 4340 J</p> <p><b>Examiner's Comments</b></p> <p>Almost all candidates recognised the first<br/> step of this unstructured calculation was to<br/> use the <math>mc \Delta T</math> expression to determine the<br/> energy change. The majority of the cohort<br/> subsequently divided this by the moles of<br/> <math>\text{CuSO}_4</math> to obtain a value for <math>\Delta H_r</math>. A<br/> significant proportion of responses did not<br/> include a sign for the enthalpy change and<br/> so only scored three marks. A small<br/> number of candidates gave incomplete<br/> responses, often rounding the energy<br/> change to three significant figures, rather</p> |

### Mark Scheme

| Question |   |    | Answer/Indicative content                                                                                                                                                                                            | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------|---|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |   |    |                                                                                                                                                                                                                      |       | than processing it further.<br><br>Answer: $-347 \text{ kJ mol}^{-1}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|          |   | ii | Minimum mass = $0.0125 \times 24.3 \times 1.25 = 0.38(0) \text{ g}$ ✓                                                                                                                                                | 3     | <b>ALLOW ECF</b> for mass correctly rounded to 2 dp from incorrect moles of $\text{CuSO}_4$ in 3(a)(i)<br><br><b>Examiner's Comments</b><br><br>The majority of candidates were able to link the moles of $\text{CuSO}_4$ with the balanced equation to determine the moles of Mg reacting and hence suggest a mass. However, only the strongest candidates were able to scale the quantity required to take into account the excess.                                                                                                                                                                                                                                                          |
|          | b | i  | (enthalpy change that occurs) when one mole of a substance ✓<br><br>completely combusts <b>OR</b> reacts fully with oxygen ✓<br><br>298 K / 25 °C <b>AND</b> 1 atm / 100 kPa / 101 kPa / $10^5 \text{ Pa}$ / 1 bar ✓ | 3     | <b>ALLOW</b> energy required <b>OR</b> energy released<br><b>ALLOW</b> one mole of a compound <b>OR</b> one mole of an element<br><br><b>ALLOW</b> combusts in excess oxygen<br><b>ALLOW</b> burns in excess oxygen<br>Combusts in excess air is <b>not</b> sufficient<br><br><b>IGNORE</b> reference to concentration<br><br><b>Examiner's Comments</b><br><br>This definition is well known by candidates and the majority scored all three marks. A significant proportion of the cohort only scored two as the standard conditions were often omitted. Candidates should be encouraged to read questions carefully to ensure they include all the required information in their responses. |

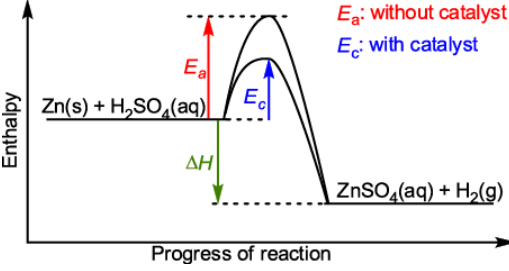
# Mark Scheme

| Question |   |    | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------|---|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |   | ii | <p>IF answer = <math>-281 \text{ (kJ mol}^{-1}\text{)}</math>, award 2 marks<br/> IF answer = <math>(+281 \text{ (kJ mol}^{-1}\text{)})</math>, award 1 mark</p> <p>-----</p> <p>Working for C AND <math>\text{H}_2</math> seen anywhere</p> <p><math>9 \times (-)394</math> AND <math>10 \times (-)286</math><br/> OR <math>(-)3546</math> AND <math>(-)2860</math><br/> OR <math>(-)6406 \checkmark</math></p> <p>Calculates <math>\Delta H_c</math> correctly</p> <p><math>-6406 - -6125 = -281 \text{ kJ mol}^{-1} \checkmark</math></p> | 2     | <p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES</b></p> <p>IF there is an alternative answer, check to see if there is any ECF credit possible</p> <p>Common incorrect answers are shown below</p> <p>Award 1 mark for<br/> 5445 (not used <math>\times 9</math> and <math>\times 10</math>)<br/> 2871 (not used <math>\times 9</math>)<br/> 2293 (not used <math>\times 10</math>)</p> <p><b>Examiner's Comments</b></p> <p>In general candidates approached this calculation confidently and applied Hess' law accurately. Some candidates failed to take into account the mole ratios, but subsequently processed their values correctly. Consequently the majority of candidates scored one or two marks.</p> <p>Answer: <math>-281 \text{ kJ mol}^{-1}</math></p> |
|          | c | i  | <p>(Average enthalpy change) when one mole of bonds <math>\checkmark</math></p> <p>of (gaseous covalent) bonds is broken <math>\checkmark</math></p>                                                                                                                                                                                                                                                                                                                                                                                         | 2     | <p><b>IGNORE</b> energy required <b>OR</b> energy released</p> <p><b>DO NOT ALLOW</b> bonds formed</p> <p><b>IGNORE</b> heterolytic / homolytic</p> <p><b>Examiner's Comments</b></p> <p>Most candidates were able to recall that bond enthalpy referred to the energy change occurring when bonds are broken, but weaker responses included contradictions by also mentioning bond formation. The strongest candidates were able to state that bond enthalpy referred to one mole of bonds but a significant proportion of candidates incorrectly referred to one mole of molecules or made no reference to this quantity.</p>                                                                                                                                     |

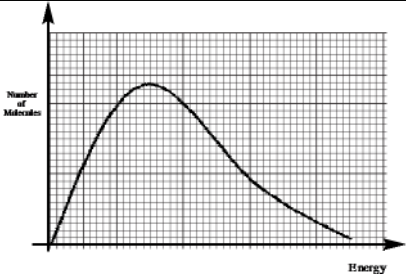
### Mark Scheme

| Question |  |    | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                              | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------|--|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |  | ii | <p>IF answer = (+)1062 (kJ mol<sup>-1</sup>), award 3 marks<br/> IF answer = -1062 (kJ mol<sup>-1</sup>), award 2 marks</p> <p>-----</p> <p>(<math>\Delta H</math> for bonds broken =) 2580 (kJ mol<sup>-1</sup>)<br/> OR 1652 AND 928 (kJ mol<sup>-1</sup>) ✓</p> <p>(<math>\Delta H</math> for bonds formed =) 1308 (kJ mol<sup>-1</sup>) ✓</p> <p>(bond enthalpy CO = 2580 – 1308 – 210) =<br/> (+)1062 (kJ mol<sup>-1</sup>) ✓</p> | 3     | <p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>IGNORE sign</p> <p>IGNORE sign</p> <p>ALLOW ECF</p> <p>IGNORE rounding of 1062 to 1060 and credit 1062 from working</p> <p>Award 2 marks for<br/> ±1272 (from ±(2580 – 1308))<br/> ±1482 (from ±(2580 – 1308 + 210))</p> <p>Examiner's Comments</p> <p>Almost all candidates were able to process the bond enthalpy data and mole ratios to arrive at values for the energy required to break bonds in the reactants and the energy released by the formation of H–H bonds in the products. The most able candidates processed these values alongside the enthalpy change provided in the question to arrive at the correct answer. Common incorrect responses included +1482 kJ mol<sup>-1</sup> and +1272 kJ mol<sup>-1</sup>, the latter of which was caused by failure to use the <math>\Delta H</math> value provided.</p> <p>Answer: +1062 kJ mol<sup>-1</sup>.</p> |
|          |  |    | Total                                                                                                                                                                                                                                                                                                                                                                                                                                  | 15    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

# Mark Scheme

| Question | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 14       | <p>i</p>  <p>Zn and H<sub>2</sub>SO<sub>4</sub> on LHS<br/>AND ZnSO<sub>4</sub> + H<sub>2</sub> on RHS ✓</p> <p>ΔH labelled with product below reactant<br/>AND arrow downwards ✓</p> <p>E<sub>a</sub> AND E<sub>c</sub> correctly labelled with E<sub>c</sub> below E<sub>a</sub> ✓</p> | 3     | <p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>IGNORE state symbols.</p> <p>ΔH:<br/>DO NOT ALLOW -ΔH<br/>ALLOW this arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line</p> <p>E<sub>a</sub>:<br/>ALLOW no arrowhead or arrowheads at both ends of activation energy line<br/>The E<sub>a</sub> line must point to maximum (or near to the maximum) on the curve OR span approximately 80% of the distance between reactants and maximum regardless of position<br/>ALLOW AE or A<sub>E</sub> for E<sub>a</sub></p> <p><b>Examiner's Comments</b></p> <p>Many candidates are well-prepared for this type of question however there are still some issues regarding the use of double headed arrows to indicate an enthalpy change. Whilst allowed by the examiners for showing activation energies, a correct single headed arrow was required to illustrate ΔH. A small proportion of candidates omitted hydrogen as a product, despite it being stated in the question.</p> |
|          | <p>ii</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 4     | <p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>Curve must start at origin. The limit of acceptability is that the curve must start within the first small square nearest the</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

# Mark Scheme

| Question | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |  <p>Correct drawing of a Boltzmann distribution curve ✓</p> <p>Axes labelled<br/>y axis: (number of) molecules <b>AND</b> x axis: (kinetic) energy ✓</p> <p>Catalyst lowers the activation energy (by providing an alternative route) ✓</p> <p><b>QWC</b> - (With a catalyst a) greater proportion of molecules with energy greater than activation energy<br/><b>OR</b><br/>(With a catalyst a) greater proportion of molecules with energy equal to the activation energy<br/><b>OR</b><br/>(With a catalyst there is a) greater area under curve above the activation energy ✓</p> |       | <p>origin.</p> <p>Curve must not touch the x-axis at higher energy</p> <p><b>IGNORE</b> a slight inflexion on the curve</p> <p><b>DO NOT ALLOW</b> two curves<br/><b>DO NOT ALLOW</b> a curve that bends up at the end by more than one small square</p> <p><b>ALLOW</b> particles instead of molecules on y axis<br/><b>DO NOT ALLOW</b> enthalpy for x-axis label<br/><b>DO NOT ALLOW</b> atoms instead of particles or molecules<br/><b>ALLOW ECF</b> for the subsequent use of atoms (instead of molecules or particles)</p> <p><b>ALLOW</b> annotations on Boltzmann distribution diagram</p> <p><b>QWC</b> requires more molecules have / exceed activation energy / <math>E_a</math>.<br/><b>IGNORE</b> more molecules have enough energy to react for the <b>QWC</b> mark (as not linked to <math>E_a</math>)<br/><b>ORA</b> if states the effect with no catalyst</p> <p><b>IGNORE</b> (more) successful collisions</p> <p><b>Examiner's Comments</b></p> <p>Candidates are very familiar with the Boltzmann distribution curve and there were many examples of excellent diagrams. The majority of candidates scored maximum marks in this part. Failure to identify that more molecules have an energy greater than the activation energy when a catalyst is used, was a common reason why only three marks were scored.</p> |
|          | Total                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 7     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

### Mark Scheme

| Question |  |  | Answer/Indicative content | Marks | Guidance                                                                                                                                                                                                                                                                                               |
|----------|--|--|---------------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15       |  |  | C                         | 1     | <b>Examiner's Comments</b><br>Very few candidates obtained the correct temperature change and this proved to be the most difficult of the multiple choice questions. The majority of candidates incorrectly answered as B, based on halving the quantities, leading to halving the temperature change. |
|          |  |  | Total                     | 1     |                                                                                                                                                                                                                                                                                                        |
| 16       |  |  | B                         | 1     | <b>Examiner's Comments</b><br>The majority of candidates obtained the correct answer. As expected, the common incorrect answer was C: the correct value but the incorrect sign.                                                                                                                        |
|          |  |  | Total                     | 1     |                                                                                                                                                                                                                                                                                                        |

# Mark Scheme

| Question |   |   | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------|---|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 17       | a | i | <p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = <math>-2510 \text{ (kJ mol}^{-1}\text{)}</math> award 4 marks</p> <p>IF answer = <math>2508 / 2507 \text{ (kJ mol}^{-1}\text{)}</math> award 3 marks<br/>(not rounded to 3SF, ignore sign)</p> <p>IF answer = <math>+ 2510 \text{ (kJ mol}^{-1}\text{)}</math> award 3 marks<br/>(incorrect sign)</p> <p>IF answer = <math>-2510000 \text{ (kJ mol}^{-1}\text{)}</math> award 3 marks<br/>(used J instead of kJ)</p> <p>.....</p> <p><b>Moles</b><br/> <math>n(\text{C}_6\text{H}_{14}) = 0.0150 \text{ mol}</math> ✓</p> <p><b>Energy</b><br/> q calculated correctly = <math>37620 \text{ (J)}</math> OR <math>37.620 \text{ (kJ)}</math> ✓</p> <p><b>Calculating <math>\Delta H</math></b><br/> Correctly calculates <math>\Delta H</math> in <math>\text{kJ mol}^{-1}</math><br/> AND to 3 or more SF ✓</p> <p><b>Rounding AND sign</b><br/> calculated value of <math>\Delta H</math> rounded to 3 SF<br/> AND '-' sign ✓</p> | 4     | <p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>moles = <math>1.29/86.0</math><br/> <b>IGNORE</b> trailing zeros</p> <p><math>q = 200 \times 4.18 \times 45.0</math><br/> <b>ALLOW</b> correctly rounded to 3 sig figs:<br/> <math>37.6 \text{ kJ}</math></p> <p><b>ALLOW</b> ECF from incorrect q</p> <p><b>ALLOW</b> ECF from incorrect molar mass or incorrect moles of hexane to 3 SF or more correctly rounded</p> <p><b>IGNORE</b> sign at this intermediate stage<br/> <b>IGNORE</b> working<br/> <math>\Delta H = 37.62/0.015 = 2508 \text{ (kJ mol}^{-1}\text{)}</math><br/> <math>\Delta H = 37.6/0.015 = 2507 \text{ (kJ mol}^{-1}\text{)}</math></p> <p><math>\Delta H = -2510 \text{ (kJ mol}^{-1}\text{)}</math><br/> Final answer must have '-' sign and 3 SF</p> <p><b>Examiner's Comments</b></p> <p>A high proportion of candidates lost marks on this question for a variety of reasons including errors in the calculation of moles and / or energy change. Many candidates did not express their final answer to three significant figures and so failed to score the final mark. An incorrect or missing sign also resulted in loss of the final mark.</p> |

# Mark Scheme

| Question |  |    | Answer/Indicative content                                                                                                                                                                     | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------|--|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |  | ii | <p>Any two from the following:<br/>✓✓</p> <ul style="list-style-type: none"> <li>Heat released to the surroundings</li> <li>Incomplete combustion</li> <li>Non-standard conditions</li> </ul> | 3     | <p><b>ALLOW</b> heat loss</p> <p><b>ALLOW</b> incomplete reaction <b>OR</b> not everything burns</p> <p><b>IGNORE</b> reference to evaporation</p> <p><b>Examiner's Comment:</b></p> <p>Almost all candidates scored at least one mark for this well-rehearsed practical question. There was some confusion regarding the use of average bond enthalpy values obtained from a data book which was not relevant to this question.</p> |

# Mark Scheme

| Question |   |  | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------|---|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          | b |  | <p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF enthalpy change = <math>-3919.5 \text{ (kJ mol}^{-1}\text{)}</math> award 3 marks</p> <p>IF enthalpy change = <math>(+)3919.5 \text{ (kJ mol}^{-1}\text{)}</math> award 2 marks</p> <p>.....</p> <p><i>Working for CO<sub>2</sub> AND H<sub>2</sub>O seen anywhere (1 mark)</i></p> <p><math>6 \times (-)393.5</math> AND <math>6 \times (-)285.8</math><br/> OR <math>(-)2361</math> AND <math>(-)1714.8</math><br/> OR <math>(-)4075.8</math> ✓</p> <p><i>Calculates <math>\Delta_c H</math></i></p> <p>A further 2 marks for correct answer AND correct sign</p> <p><math>= (6 \times -393.5) + (6 \times -285.8) - (-156.3)</math></p> <p><math>= -3919.5 \text{ (kJ mol}^{-1}\text{)}</math> ✓ ✓</p> | 3     | <p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>IF there is an alternative answer, check to see if there is any ECF credit possible</p> <p>ALLOW 3 marks for <math>\Delta_c H = -3920</math><br/> <i>FINAL answer rounded to 3 SF</i></p> <p>Common incorrect answers are shown below</p> <p>ALLOW 2 marks for <math>\Delta_c H = -3924</math><br/> From <math>\Delta_c H = (6 \times -394 + 6 \times -286) - (-156)</math></p> <p><i>Data rounded to 3 sig figs</i><br/> ALLOW 2 marks for <math>\Delta_c H = -4232.1</math><br/> All data added together<br/> <math>(6 \times -393.5) + (6 \times -285.8) + (-156.3)</math></p> <p>ALLOW 1 mark for <math>\Delta_c H = (+)4232.1</math></p> <p>Examiner's Comment:</p> <p>This calculation was generally well answered but there were a variety of errors that could lead to candidates scoring just one or two marks. These included incorrect signs associated with the data during the calculation, adding all the data together or missing out the sign associated with the final answer.</p> |
|          |   |  | Total                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 9     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

# Mark Scheme

| Question |                     |                | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |                  |                |       |                     |                |
|----------|---------------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------------------|----------------|-------|---------------------|----------------|
| 18       |                     | i              | <p>More energy is released by forming bonds than energy required when breaking bonds ✓</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1     | <p><b>ORA</b></p> <p>Response needs link between energy, breaking and making bonds</p> <p><b>ALLOW</b> 'bond breaking is endothermic'</p> <p><b>AND</b> 'bond making is exothermic'</p> <p><b>ALLOW</b> within labelled energy diagram</p> <p><b>Examiner's Comments</b></p> <p>Able candidates provided well- constructed and structured responses, which demonstrated their clear understanding of this key concept. Weaker candidates often responded in terms of bond making requiring energy and that breaking bonds releasing energy. Many responses referred to more bonds instead of more energy.</p> |        |                  |                |       |                     |                |
|          |                     | ii             | <p><b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b></p> <p>IF bond enthalpy = (+)612 (kJ mol<sup>-1</sup>) award 3 marks</p> <p>IF bond enthalpy = (-)316 (kJ mol<sup>-1</sup>) award 2 marks</p> <p><i>Energy for bonds made (4 × C=O + 4 × O-H)</i></p> <p>4 × 805 + 4 × 464</p> <p><b>OR</b> 3220 + 1856</p> <p><b>OR</b> 5076 (kJ) ✓</p> <p><i>Energy for bonds broken (4 × C-H + 3 × O=O)</i></p> <p>4 × 413 + 3 × 498</p> <p><b>OR</b> 1652 + 1494</p> <p><b>OR</b> 3146 (kJ) ✓</p> <p><i>C=C bond enthalpy correctly calculated</i></p> <p>C=C bond enthalpy = -1318 - 3146 + 5076</p> <p>= (+)612 kJ mol<sup>-1</sup> ✓</p> <p><i>Mark is for answer</i></p> | 3     | <p><b>FULL ANNOTATIONS MUST BE USED</b></p> <p>-----</p> <p><b>IGNORE</b> sign</p> <p><b>IGNORE</b> sign</p> <p>-----</p> <p><b>ALLOW</b> ECF</p> <p><b>DO NOT ALLOW</b> – sign</p> <p><b>COMMON ERRORS</b></p> <table><tr><td>+ 2106</td><td>omission of 3O=O</td><td><b>2 marks</b></td></tr><tr><td>-3248</td><td>-1318 + 3146 - 5076</td><td><b>2 marks</b></td></tr></table>                                                                                                                                                                                                                             | + 2106 | omission of 3O=O | <b>2 marks</b> | -3248 | -1318 + 3146 - 5076 | <b>2 marks</b> |
| + 2106   | omission of 3O=O    | <b>2 marks</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |                  |                |       |                     |                |
| -3248    | -1318 + 3146 - 5076 | <b>2 marks</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |        |                  |                |       |                     |                |

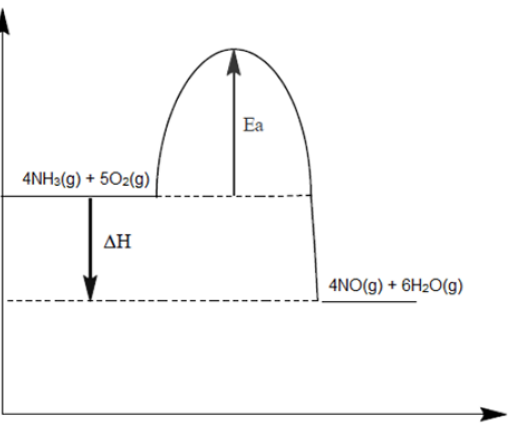
### Mark Scheme

| Question |  |  | Answer/Indicative content | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------|--|--|---------------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |  |  |                           |       | <p><b>Examiner's Comments</b></p> <p>This question tested both chemical and mathematical ability. Two marks were available for calculating the energies involved in bond making and bond breaking. Many candidates miscounted the number of bonds involved in the calculation, especially for <math>3 \times \text{O}=\text{O}</math> and <math>4 \times \text{O}-\text{H}</math>. Candidates can avoid this error by drawing out each molecule and counting the bonds being broken and made.</p> <p>In calculating the bond enthalpy, weaker candidates often omitted the enthalpy change of reaction, <math>-1318 \text{ kJ mol}^{-1}</math>, instead simply subtracting the energies already calculated for bonds broken and bonds made.</p> <p>Answer: <math>612 \text{ kJ mol}^{-1}</math></p> |
|          |  |  | Total                     | 4     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

# Mark Scheme

| Question |   |    | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                           | Marks    | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------|---|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 19       | a |    | <p><b>FIRST CHECK ON ANSWER LINE</b><br/>           If answer = (+) 431.5 (kJ mol<sup>-1</sup>) award 2 marks<br/>           If answer = -431.5 (kJ mol<sup>-1</sup>) award 1 mark (wrong sign)</p> <hr/> <p>2 × H-C/ bond enthalpy correctly calculated</p> <p>= +436 +243 +184 = +863 (kJ mol<sup>-1</sup>) ✓</p> <p>H-C/ bond enthalpy correctly calculated</p> <p>+863/2 = (+)431.5 (kJ mol<sup>-1</sup>) ✓</p> | 2        | <p><b>ALLOW</b> to 3 SF i.e. 432</p> <p><b>ALLOW</b> 1 mark for (+)247.5 / 248 (wrong expression) i.e. (436+243-184)/2</p> <p><u><b>Examiner's Comments</b></u></p> <p>Most candidates made a good attempt at this question. The most common mistake was to use the wrong sign when incorporating the enthalpy change into the calculation, or not to incorporate it at all.</p>                                                                    |
|          | b | i  | Br <sub>2</sub> (l) → Br <sub>2</sub> (g) ✓                                                                                                                                                                                                                                                                                                                                                                         | 1        | <p><u><b>Examiner's Comments</b></u></p> <p>A good attempt by many candidates but some lost marks by having the wrong state of bromine, even though the question stated it was a liquid changing to a gas. Many added water or oxygen, some confused the equation with bond enthalpy and answers such as Br<sub>2</sub>(l) → 2Br(g) were commonly seen.</p>                                                                                         |
|          |   | ii | <p>Endothermic<br/> <b>AND</b><br/>           Energy required to overcome induced dipole-dipole forces/London forces ✓</p>                                                                                                                                                                                                                                                                                          | 1        | <p><b>Mark independently of 3 (d) (i)</b></p> <p><b>ALLOW</b> endo to break intermolecular forces/bonds<br/> <b>ALLOW</b> bonds between molecules</p> <p><b>DO NOT ALLOW</b> van der Waals' forces</p> <p><u><b>Examiner's Comments</b></u></p> <p>The majority of candidates answered this question incorrectly. Only 10% of candidates mentioned intermolecular/London forces. Most stated 'exothermic' or described breaking covalent bonds.</p> |
|          |   |    | <b>Total</b>                                                                                                                                                                                                                                                                                                                                                                                                        | <b>4</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

# Mark Scheme

| Question | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 20       | <p>i</p>  <p><b>Reactants, products and <math>E_a</math></b><br/>         Reactants on LHS <math>4\text{NH}_{3(g)} + 5\text{O}_{2(g)}</math><br/> <b>AND</b><br/>         Products on RHS <math>4\text{NO}_{(g)} + 6\text{H}_2\text{O}_{(g)}</math><br/> <b>AND</b><br/>         Activation energy correctly labelled / <math>E_a</math><br/>         ✓</p> <p><b><math>\Delta H</math></b><br/> <math>\Delta H</math> labelled with product below reactant<br/> <b>AND</b><br/>         Arrow downwards ✓</p> | 2     | <p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p><b>IGNORE</b> state symbols</p> <p>ALLOW 1 mark for a correctly labelled endothermic diagram</p> <p><math>E_a</math> <b>ALLOW</b> no arrowhead or arrowheads at both end of <math>E_a</math> line.</p> <p><math>E_a</math> line must reach maximum (or near to maximum) on curve</p> <p>For <math>E_a</math>, <b>ALLOW</b> AE OR <math>A_E</math></p> <p><math>\Delta H</math> <b>DO NOT ALLOW</b> <math>-\Delta H</math><br/> <b>DO NOT ALLOW</b> double headed arrow on <math>\Delta H</math></p> <p><b>ALLOW</b> <math>\Delta H</math> arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line.</p> <p><b>ALLOW</b> <math>-905</math> for <math>\Delta H</math></p> <p><b><u>Examiner's Comments</u></b></p> <p>Most candidates were able to gain the first mark, but many lost the second mark by putting a double headed arrow or <math>-\Delta H</math>.</p> |

# Mark Scheme

| Question |  |    | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Marks    | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------|--|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |  | ii | <p><b>FIRST CHECK ON ANSWER LINE</b><br/>           If answer = <math>6.79 \times 10^7</math> (kJ) award 4 marks<br/>           If answer = <math>2.72 \times 10^8</math> (kJ) award 3 marks<br/>           (no <math>\div 4</math>)</p> <hr/> <p><math>n(\text{NH}_3)</math><br/> <math>= \frac{5.1 \times 10^6}{17} = 3.00 \times 10^5</math> (mol) ✓</p> <p><b>Stoichiometry and <math>\Delta H</math></b><br/>           1 mol <math>\text{NH}_3</math> releases <math>\frac{905}{4}</math> OR 226.25 (kJ) ✓</p> <p><b>Energy released</b><br/> <math>(3.00 \times 10^5) \times \frac{905}{4}</math> OR 67875000 (kJ) ✓</p> <p><b>Final answer to 3SF AND standard form</b><br/> <math>= 6.79 \times 10^7</math> (kJ) ✓<br/> <i>standard form AND 3 SF required</i></p> | 4        | <p><b>IGNORE (-) SIGN</b><br/>           Throughout: <b>IGNORE</b> trailing zeroes in intermediate working,<br/>           e.g. For <math>n(\text{NH}_3)</math> <b>ALLOW</b> <math>3 \times 10^5</math> for <math>3.00 \times 10^5</math></p> <hr/> <p><b>ALLOW ECF</b> from incorrect <math>n(\text{NH}_3)</math> OR 905/4</p> <p><b>ALLOW 3 SF</b> up to calc value correctly rounded.<br/>           Value will depend on intermediate rounding</p> <p><b>Common Errors</b><br/> <math>1.09 \times 10^9</math> (<math>\times 4</math> instead of <math>\div 4</math>) 3 marks<br/> <math>2.72 \times 10^8</math> (no <math>\div 4</math>) 3 marks<br/> <math>6.79 \times 10^1</math> (no tonnes <math>\rightarrow</math> g) 3 marks</p> <p><b><u>Examiner's Comments</u></b></p> <p>Most candidates were able to convert from tonnes to moles and then went on to complete the majority of the calculation steps. Many omitted to divide by 4 and were credited 3 marks. Some candidates lost marks by not stating the answer to standard form or quoted their answer to more than 3 significant figures. A number of candidates attempted to use <math>Q = mc\Delta T</math> and did not get very far in the calculation.</p> |
|          |  |    | <b>Total</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>6</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

### Mark Scheme

| Question |  |  | Answer/Indicative content | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------|--|--|---------------------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 21       |  |  | B                         | 1     | <p><b><u>Examiner's Comments</u></b></p> <p>This question proved to be the most difficult of the multiple-choice questions. Most candidates constructed a correct energy cycle using the provided equation. This gave an energy change of <math>-3684.6 \text{ kJ mol}^{-1}</math> (A). The question asks for the enthalpy change of combustion for <math>\text{Al}_2\text{S}_3</math>, which is half this value (option B). As with question 2, candidates are advised to read the question carefully.</p> |
|          |  |  | Total                     | 1     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 22       |  |  | B                         | 1     | <p><b><u>Examiner's Comments</u></b></p> <p>Candidates find questions based on practical procedures difficult and this question proved to be no exception. A similar number of candidates selected each option, suggesting that most guessed. The correct option is B.</p>                                                                                                                                                                                                                                  |
|          |  |  | Total                     | 1     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

# Mark Scheme

| Question | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 23       | <p>i</p> <p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF <math>\Delta_r H = -457</math> OR <math>-458</math> (<math>\text{kJ mol}^{-1}</math>) award 4 marks</p> <p>IF <math>\Delta_r H = \pm 229</math> OR <math>457</math> (<math>\text{kJ mol}^{-1}</math>) award 3 marks</p> <p>-----</p> <p><i>Energy released in J OR kJ</i></p> <p><math>= 25.0 \times 4.18 \times 28.0 = 2926</math> (J) OR 2.926 (kJ)✓</p> <p><i>Correctly calculates <math>n(\text{AgNO}_3)</math></i></p> <p><math>= 0.512 \times \frac{25.0}{1000} = 1.28 \times 10^{-2}</math> (mol) ✓</p> <p><math>\Delta H</math> per mole <math>\text{AgNO}_3</math> in kJ AND 3 SF</p> <p>Answer <i>MUST</i> divide energy by <math>n(\text{AgNO}_3)</math></p> <p><math>\pm \frac{2.926}{1.28 \times 10^{-2}} = \pm 228.59375</math></p> <p><math>= \pm 229</math> (kJ) ✓</p> <p>3 SF needed Sign NOT needed</p> <p><math>\Delta H</math> for 2 mol <math>\text{AgNO}_3</math> AND – sign AND 3 SF</p> <p><math>\Delta H_r = 2 \times -228.59375 = -457</math> (<math>\text{kJ mol}^{-1}</math>)</p> <p>OR <math>2 \times -229 = -458</math> (<math>\text{kJ mol}^{-1}</math>) ✓</p> | 4     | <p><b>FULL ANNOTATIONS MUST BE USED</b></p> <p>-----</p> <p>ALLOW ECF throughout</p> <p>-----</p> <p>ALLOW 2930 J OR 2.93 kJ</p> <p>DO NOT ALLOW &lt; 3 SF</p> <p>IGNORE any sign and units</p> <p>i.e. <b>ALLOW</b> correctly calculated number in J OR kJ</p> <p>-----</p> <p><b>Alternative approach using 1 mol Mg</b></p> <p>Energy released = 2926 (J) OR 2.926 (kJ) ✓</p> <p><math>n(\text{AgNO}_3) = 1.28 \times 10^{-2}</math> (mol) ✓</p> <p><math>n(\text{Mg}) = \frac{1.28 \times 10^{-2}}{2} = 6.4 \times 10^{-3}</math> (mol) ✓</p> <p><math>\Delta H_r = \frac{2.926}{6.4 \times 10^{-3}} = -457</math> (<math>\text{kJ mol}^{-1}</math>)</p> <p>– sign AND 3 SF needed</p> <p><b><u>Examiner's Comments</u></b></p> <p>Candidates are well-versed with the relationship <math>q = mc\Delta T</math> and most were able to calculate that 2.926 kJ of energy was released in this reaction. It was also common to see the amount of <math>\text{AgNO}_3</math> correctly calculated as <math>1.28 \times 10^{-3}</math> mol. Candidates were expected to determine the amount of energy released from 1 mol <math>\text{AgNO}_3</math> as 229 kJ and finally to multiply this value by 2 for the molar quantities in the equation to match the 'enthalpy change of reaction'. It was common to see –229 given as the final answer but this was rarely multiplied by 2. The question also required the final answer to be given to an appropriate number of significant figures. Many candidates seemed to be unaware that this reflects the least significant figure provided in the data, in this case 3</p> |

# Mark Scheme

| Question |  |    | Answer/Indicative content                                                                                                                                                                                                                                                                                                | Marks | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------|--|----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |  |    |                                                                                                                                                                                                                                                                                                                          |       | <p>significant figures. The exemplar shows a typical response for 3 of the available 4 marks. Many omitted the negative sign in their <math>\Delta H</math> value to consider the exothermicity of the reaction. Candidates are also advised to only round at the end of a multi-step calculation. Rounding of intermediate values introduces rounding errors in the final answer.</p> <p>Answer = <math>-457 \text{ kJ mol}^{-1}</math></p> <p><b>Exemplar 4</b></p> <p>(i) Calculate <math>\Delta H</math>, in <math>\text{kJ mol}^{-1}</math>, for the reaction shown in equation 23.1.</p> <p>Give your answer to an appropriate number of significant figures.</p> <p>Assume that the density and specific heat capacity, <math>c</math>, of the solution are the same as for water and that all the aqueous silver nitrate has reacted.</p> <p><math>c = 4.18</math> density = <math>1.00 \text{ g cm}^{-3}</math> <math>Q = mc\Delta T</math></p> <p><math>\Delta T =</math></p> <p><math>Q = 25 \times 4.18 \times 28</math> <math>n = \frac{m}{M_r}</math> <math>n = CV</math></p> <p><math>Q = 2926 \text{ J}</math> <math>n = \frac{25}{1000} \times 0.512</math></p> <p><math>Q = 2.926 \text{ kJ}</math> <math>n = 0.0128</math></p> <p><math>\frac{2.926}{0.0128} = 228.60</math> <math>228.59375</math></p> <p><math>\Delta H = 229 \text{ kJ mol}^{-1}</math> [4]</p> |
|          |  | ii | <p><math>\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})</math> ✓</p> <p>State symbols required</p> <p>White precipitate AND <math>\text{AgNO}_3/\text{Ag}^+</math> NOT ALL reacted</p> <p>OR</p> <p>NO white precipitate AND <math>\text{AgNO}_3/\text{Ag}^+</math> ALL reacted ✓</p> | 2     | <p>ALLOW <math>\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})</math></p> <p>Observation needs to be linked to conclusion</p> <p><b>Examiner's Comments</b></p> <p>Most candidates recognised that silver nitrate and chloride ions react together to form a white precipitate, but many did not make the link between this observation and whether any silver nitrate was left unreacted. Many candidates did not give a correct equation, with missing or incorrect state symbols being common. This question discriminated extremely well.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|          |  |    | Total                                                                                                                                                                                                                                                                                                                    | 6     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

### Mark Scheme

| Question |  |  | Answer/Indicative content | Marks     | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|----------|--|--|---------------------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 24       |  |  | B                         | 1 (AO1.2) | <p><b><u>Examiner's Comments</u></b></p> <p>This part discriminated extremely well. Most candidates correctly identified option B but a sizeable number of less able candidates chose the different options in almost equal amounts. It was difficult to recognise where candidates were having problems and the incorrect responses were probably mainly guesses.</p>                                                                                                                                                                                                                                                  |
|          |  |  | <b>Total</b>              | <b>1</b>  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 25       |  |  | B                         | 1 (AO1.1) | <p><b><u>Examiner's Comments</u></b></p> <p>Many candidates found this question difficult with less than half choosing the correct option of B. Options A and C proved to be the main discriminators in almost equal amounts. Although first encountered at GCSE level, energies associated with bond breaking and bond making continue to cause candidates problems at AS and A Level. The discriminator C would have been chosen by candidates who did not recognise that <math>-184.6 \text{ kJ}</math> is released when 2 mol HCl is formed and that the enthalpy change of formation would be half this value.</p> |
|          |  |  | <b>Total</b>              | <b>1</b>  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

# Mark Scheme

| Question        |                                             |    | Answer/Indicative content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Marks          | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                 |                          |                |                          |                 |                           |             |                        |                |                                            |                |                                           |                |                                             |            |                                      |
|-----------------|---------------------------------------------|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|--------------------------|----------------|--------------------------|-----------------|---------------------------|-------------|------------------------|----------------|--------------------------------------------|----------------|-------------------------------------------|----------------|---------------------------------------------|------------|--------------------------------------|
| 26              |                                             | i  | 298 K/25°C<br>AND<br>100 kPa ✓                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 (AO1.1)      | <p>ALLOW 'a stated temperature'<br/><i>To accept that other standard temperatures can be used and 298 should strictly be added as <math>\Delta H_{298 \theta}</math></i></p> <p>ALLOW <math>1 \times 10^5</math> Pa, 101 kPa, <math>1.01 \times 10^5</math> Pa, 1 atm, 1 bar</p> <p><u>Examiner's Comments</u></p> <p>Only just over half of the candidates were able to quote standard conditions for enthalpy measurements. Errors included an incorrect temperature, often 273 and 293 K, or incorrect pressure (e.g. 1000 kPa, 100 atm). Candidates are reminded that 'room temperature' is not a standard temperature – a specific figure must be stated.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                 |                          |                |                          |                 |                           |             |                        |                |                                            |                |                                           |                |                                             |            |                                      |
|                 |                                             | ii | <p>FIRST, CHECK THE ANSWER ON ANSWER LINE</p> <p>IF answer = (+)90 (kJ mol<sup>-1</sup>) award 3 marks</p> <p>IF answer = -90 (kJ mol<sup>-1</sup>) award 2 marks</p> <p>IF answer = (+)360 (kJ mol<sup>-1</sup>) award 2 marks</p> <p>-----</p> <p>Use of <math>\Delta_f H</math> values and balancing numbers<br/><math>\pm (4 \times -46)</math> OR <math>\pm 184</math><br/>AND<br/><math>\pm (6 \times -242)</math> OR <math>\pm 1452</math> seen anywhere ✓</p> <p>Correct subtraction using <math>\Delta H = -908</math><br/><math>4 \times \Delta_f H(\text{NO})</math><br/><math>= (4 \times -46) - (6 \times -242) - 908</math><br/><math>= -184 + 1452 - 908</math><br/><math>= (+)360 \text{ (kJ mol}^{-1}\text{)} \checkmark</math><br/>Calculation of <math>\Delta_f H(\text{NO})</math> formation by <math>\div 4</math></p> $\Delta_f H(\text{NO}) = \frac{360}{4} = (+)90 \text{ (kJ mol}^{-1}\text{)} \checkmark$ | 3<br>(AO2.6×3) | <p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>ALLOW ECF if common errors not seen</p> <p>IF <math>\Delta H</math> of -908 has NOT been used, ONLY award 1st mark</p> <p>-----</p> <p>COMMON ERRORS</p> <p>1 mark</p> <p>Incorrect signs(s) AND missing <math>\div 4</math></p> <table><tr><td><math>\pm 2544</math> from</td><td><math>\pm (184 + 1452 + 908)</math></td></tr><tr><td><math>\pm 728</math> from</td><td><math>\pm (184 + 1452 - 908)</math></td></tr><tr><td><math>\pm 2176</math> from</td><td><math>\pm (-184 + 1452 + 908)</math></td></tr><tr><td><math>-360</math> from</td><td><math>-(-184 + 1452 - 908)</math></td></tr></table> <p>2 marks</p> <p>Incorrect signs(s)</p> <table><tr><td><math>\pm 636</math> from</td><td><math>\pm (184 + 1452 + 908) = \pm 2544 \div 4</math></td></tr><tr><td><math>\pm 182</math> from</td><td><math>\pm (184 + 1452 - 908) = \pm 728 \div 4</math></td></tr><tr><td><math>\pm 544</math> from</td><td><math>\pm (-184 + 1452 + 908) = \pm 2176 \div 4</math></td></tr><tr><td><math>-90</math> from</td><td><math>-(-184 + 1452 - 908) = -360 \div 4</math></td></tr></table> | $\pm 2544$ from | $\pm (184 + 1452 + 908)$ | $\pm 728$ from | $\pm (184 + 1452 - 908)$ | $\pm 2176$ from | $\pm (-184 + 1452 + 908)$ | $-360$ from | $-(-184 + 1452 - 908)$ | $\pm 636$ from | $\pm (184 + 1452 + 908) = \pm 2544 \div 4$ | $\pm 182$ from | $\pm (184 + 1452 - 908) = \pm 728 \div 4$ | $\pm 544$ from | $\pm (-184 + 1452 + 908) = \pm 2176 \div 4$ | $-90$ from | $-(-184 + 1452 - 908) = -360 \div 4$ |
| $\pm 2544$ from | $\pm (184 + 1452 + 908)$                    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                 |                          |                |                          |                 |                           |             |                        |                |                                            |                |                                           |                |                                             |            |                                      |
| $\pm 728$ from  | $\pm (184 + 1452 - 908)$                    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                 |                          |                |                          |                 |                           |             |                        |                |                                            |                |                                           |                |                                             |            |                                      |
| $\pm 2176$ from | $\pm (-184 + 1452 + 908)$                   |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                 |                          |                |                          |                 |                           |             |                        |                |                                            |                |                                           |                |                                             |            |                                      |
| $-360$ from     | $-(-184 + 1452 - 908)$                      |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                 |                          |                |                          |                 |                           |             |                        |                |                                            |                |                                           |                |                                             |            |                                      |
| $\pm 636$ from  | $\pm (184 + 1452 + 908) = \pm 2544 \div 4$  |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                 |                          |                |                          |                 |                           |             |                        |                |                                            |                |                                           |                |                                             |            |                                      |
| $\pm 182$ from  | $\pm (184 + 1452 - 908) = \pm 728 \div 4$   |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                 |                          |                |                          |                 |                           |             |                        |                |                                            |                |                                           |                |                                             |            |                                      |
| $\pm 544$ from  | $\pm (-184 + 1452 + 908) = \pm 2176 \div 4$ |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                 |                          |                |                          |                 |                           |             |                        |                |                                            |                |                                           |                |                                             |            |                                      |
| $-90$ from      | $-(-184 + 1452 - 908) = -360 \div 4$        |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                 |                          |                |                          |                 |                           |             |                        |                |                                            |                |                                           |                |                                             |            |                                      |

# Mark Scheme

| Question |  |  | Answer/Indicative content | Marks    | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----------|--|--|---------------------------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|          |  |  |                           |          | <p><b>Examiner's Comments</b></p> <p><b>Exemplar 6</b></p> <p>Give your answer to a whole number. <math>\Delta P-R = -9081</math></p> $NH_3 \times 4 = (46 \times 4) = -184$ $P = -908 + (-184)$ $P = -1092$ $6 \times -242 = -1452$ $H_2O + NO = -1092$ $NO = -1092 - (-1452)$ $NO = 360$ <p><math>\Delta_f H^\circ</math> for NO(g) = <u>360</u> kJ mol<sup>-1</sup> [3]</p> <p>Most candidates were able to make some progress with the enthalpy calculation. Most recognised that the provided <math>\Delta_f H</math> values had to be multiplied by the balancing numbers in the equation. Correct processing of these values with <math>\Delta H</math> for the reaction discriminated well between candidates. The response shows a response that was given 2 out of the 3 available marks. The candidate has correctly calculated +360 kJ mol<sup>-1</sup> from their enthalpy cycle but has not realised that this value is for 4 mol NH<sub>3</sub> and must be divided by 4 to obtain the enthalpy change of formation of 1 mol of NH<sub>3</sub>. It was impressive that the correct answer of +90 kJ mol<sup>-1</sup> was achieved by about one-third of candidates.</p> |
|          |  |  | <b>Total</b>              | <b>4</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |