

**Q1.**

This question is about combustion.

- (a) State the meaning of the term standard enthalpy of combustion.

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**(2)**

- (b) A student does an experiment to determine the enthalpy of combustion of propan-1-ol ( $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ ,  $M_r = 60.0$ ).  
Combustion of 0.497 g of propan-1-ol increases the temperature of 150 g of water from 21.2 °C to 35.1 °C

Calculate a value, in  $\text{kJ mol}^{-1}$ , for the enthalpy of combustion of propan-1-ol in this experiment.

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

Enthalpy of combustion \_\_\_\_\_  $\text{kJ mol}^{-1}$

**(3)**

- (c) The enthalpy of combustion determined experimentally is less exothermic than that calculated using enthalpies of formation.

Give **one** possible reason for this, other than heat loss.

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(1)

(Total 6 marks)

**Q2.**

This question is about enthalpy changes.

- (a) Define the term enthalpy change.

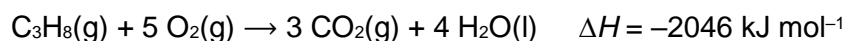
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(1)

- (b) Propane undergoes complete combustion.



The table below shows some bond enthalpy data.

Bond	C–H	C=O	O–H
Mean bond enthalpy / $\text{kJ mol}^{-1}$	412	743	463

The bond enthalpy for O=O is  $496 \text{ kJ mol}^{-1}$

For  $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g}) \Delta H = +41 \text{ kJ mol}^{-1}$

Use these data to calculate a value for the C–C bond enthalpy in propane.

C–C bond enthalpy \_\_\_\_\_  $\text{kJ mol}^{-1}$

(4)

- (c) Explain why the value given for the O=O bond enthalpy in part (b) is **not** a mean value.

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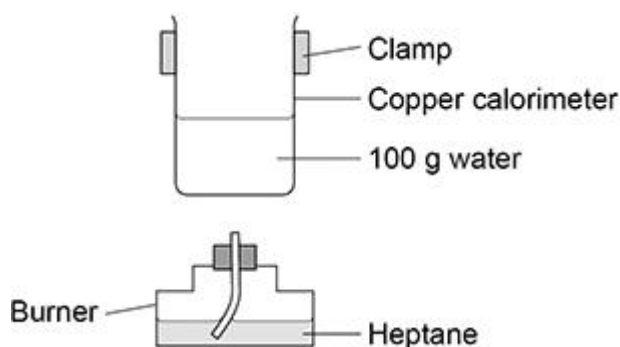
(1)

(Total 6 marks)

**Q3.**

A student does an experiment to determine a value for the enthalpy of combustion of heptane.

The figure below shows some of the apparatus used.



- (a) Design a table to record all the readings necessary to determine an experimental value for the enthalpy of combustion for heptane in this experiment.

(2)

- (b) The student considered using a glass beaker on a tripod and gauze instead of the clamped copper calorimeter.

Suggest **two** disadvantages of using a glass beaker on a tripod and gauze.

Disadvantage 1 \_\_\_\_\_

\_\_\_\_\_

Disadvantage 2 \_\_\_\_\_

\_\_\_\_\_

(2)

- (c) Suggest **two** reasons why the value of enthalpy of combustion from this experiment is less exothermic than a data book value.

Reason 1 \_\_\_\_\_

\_\_\_\_\_

Reason 2 \_\_\_\_\_

\_\_\_\_\_

(2)

- (d) Suggest **one** addition to this apparatus that would improve the accuracy of the enthalpy value obtained.

\_\_\_\_\_

\_\_\_\_\_

(1)

(Total 7 marks)

#### Q4.

This question is about enthalpy changes.

- (a) State the meaning of the term enthalpy change as applied to a chemical reaction.

\_\_\_\_\_

\_\_\_\_\_

(1)

- (b) A student determines the enthalpy change for the reaction between calcium carbonate and hydrochloric acid.



The student follows this method:

- measure out 50 cm<sup>3</sup> of 1.00 mol dm<sup>-3</sup> aqueous hydrochloric acid using a measuring cylinder and pour the acid into a 100 cm<sup>3</sup> glass beaker
- weigh out 2.50 g of solid calcium carbonate on a watch glass and tip the solid into the acid
- stir the mixture with a thermometer
- record the maximum temperature reached.

The student uses the data to determine a value for the enthalpy change.

Explain how the experimental method and use of apparatus can be improved to provide more accurate data.

Describe how this data from the improved method can be used to determine an accurate value for the temperature change.

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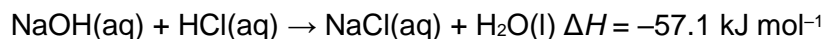
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(6)

- (c) In a different experiment 50.0 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> aqueous hydrochloric acid are reacted with 50.0 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> aqueous sodium hydroxide.



The initial temperature of each solution is 18.5 °C

Calculate the maximum final temperature of the reaction mixture.

Assume that the specific heat capacity of the reaction mixture,  $c = 4.18 \text{ J K}^{-1} \text{ g}^{-1}$

Assume that the density of the reaction mixture = 1.00 g cm<sup>-3</sup>

Final temperature \_\_\_\_\_ °C

(5)

- (d) Suggest how, without changing the apparatus, the experiment in part (c) could be improved to reduce the percentage uncertainty in the temperature change.

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(1)

(Total 13 marks)

**Q5.**

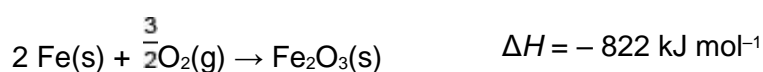
Which reaction has an enthalpy change equal to the standard enthalpy of formation of lithium fluoride?

- A  $\text{Li(g)} + \frac{1}{2}\text{F}_2\text{(g)} \rightarrow \text{LiF(s)}$
- B  $\text{Li}^+\text{(g)} + \text{F}^-\text{(g)} \rightarrow \text{LiF(s)}$
- C  $\text{Li}^+\text{(aq)} + \text{F}^-\text{(aq)} \rightarrow \text{LiF(s)}$
- D  $\text{Li(s)} + \frac{1}{2}\text{F}_2\text{(g)} \rightarrow \text{LiF(s)}$

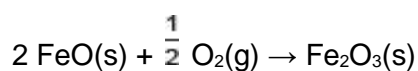
(Total 1 mark)

**Q6.**

Two reactions of iron with oxygen are shown.



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

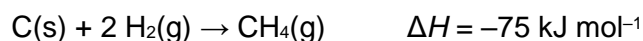
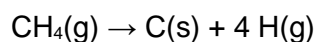


- A +550
- B -278
- C -1094
- D -1372

(Total 1 mark)

**Q7.**

Some enthalpy change data are shown.

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

- A -947
- B -361
- C +361
- D +947

**(Total 1 mark)****Q8.**The temperature changed from  $21.8 \text{ }^\circ\text{C}$  to  $19.2 \text{ }^\circ\text{C}$  during a calorimetry experiment.The uncertainty of each reading of the thermometer is  $\pm 0.1 \text{ }^\circ\text{C}$ 

What is the percentage uncertainty in the temperature change?

- A 0.5%
- B 1.0%
- C 3.8%
- D 7.7%

**(Total 1 mark)****Q9.**

An experiment is done to determine the enthalpy of combustion of a fuel using a calorimeter containing water.

 $b$  = mass of fuel burned / g $w$  = mass of water heated / g $\Delta T$  = temperature rise of water / K $M_r$  = relative molecular mass of fuel $c$  = specific heat capacity of water /  $\text{J K}^{-1} \text{ g}^{-1}$

Which expression gives the enthalpy of combustion (in  $\text{J mol}^{-1}$ ), assuming there is no heat loss?

A  $-\frac{c w \Delta T M_r}{b}$

B  $-\frac{c b \Delta T M_r}{w}$

C  $-\frac{c b w M_r}{\Delta T}$

D  $-\frac{c b w \Delta T}{M_r}$

(Total 1 mark)

**Q10.**

A bomb calorimeter can be used for accurate determination of the heat change during combustion of a fuel.

A bomb calorimeter is a container of fixed volume that withstands the change in pressure during the reaction.

The fuel is mixed with pure oxygen in the calorimeter, ignited and the temperature change is recorded.

The total heat capacity ( $C_{\text{cal}}$ ) of the calorimeter is calculated using a fuel for which the heat change is known.

In an experiment to calculate  $C_{\text{cal}}$ , 2.00 g of hexane ( $M_r = 86.0$ ) is ignited. A temperature change ( $\Delta T$ ) of  $12.4\text{ }^\circ\text{C}$  is recorded.

Under the conditions of the experiment, 1.00 mol of hexane releases 4154 kJ of energy when combusted.

(a) The heat energy released in the calorimeter,  $q = C_{\text{cal}}\Delta T$

Calculate the heat capacity ( $C_{\text{cal}}$ ) in  $\text{kJ K}^{-1}$

$C_{\text{cal}}$  \_\_\_\_\_  $\text{kJ K}^{-1}$

(3)



- (b) When the experiment is repeated with 2.00 g of octane ( $M_r = 114.0$ ) the temperature change recorded is 12.2 °C

Calculate the heat change, in  $\text{kJ mol}^{-1}$ , for octane in this combustion reaction.

If you were unable to calculate a value for  $C_{\text{cal}}$  in part (a), use  $6.52 \text{ kJ K}^{-1}$  (this is **not** the correct value).

Heat change \_\_\_\_\_  $\text{kJ mol}^{-1}$

(2)

- (c) State why the heat change calculated from the bomb calorimeter experiment is **not** an enthalpy change.

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(1)

- (d) The thermometer used to measure the temperature change of 12.2 °C in part (b) has an uncertainty of  $\pm 0.1$  °C in each reading.

Calculate the percentage uncertainty in this use of the thermometer.

Suggest **one** change to this experiment that decreases the percentage uncertainty while using the same thermometer.

Percentage uncertainty \_\_\_\_\_

Change

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(2)

(Total 8 marks)

**Q11.**

This question is about enthalpy changes.

- (a) A student determined the enthalpy of combustion of cyclohexane ( $C_6H_{12}$ ).

The student

- placed a pure sample of cyclohexane in a spirit burner
- placed the spirit burner under a beaker containing 50.0 g of water and ignited the cyclohexane
- extinguished the flame after a few minutes.

The results for the experiment are shown in **Table 1**.

**Table 1**

Initial temperature of the water / °C	19.1
Initial mass of spirit burner and cyclohexane / g	192.730
Final mass of spirit burner and cyclohexane / g	192.100

The student determined from this experiment that the enthalpy of combustion of cyclohexane is  $-1216 \text{ kJ mol}^{-1}$

Use the data to calculate the final temperature of the water in this experiment.

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

The relative molecular mass ( $M_r$ ) of cyclohexane = 84.0

Final temperature of the water \_\_\_\_\_ °C

(4)

- (b) A data book value for the enthalpy of combustion of cyclohexane is  $-3920 \text{ kJ mol}^{-1}$

The student concluded that the temperature rise recorded in the experiment was smaller than it should have been.

Suggest a practical reason for this.

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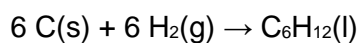
(1)

- (c) **Table 2** gives some values of standard enthalpies of combustion ( $\Delta_c H^\ominus$ ).

**Table 2**

Substance	C(s)	H <sub>2</sub> (g)	C <sub>6</sub> H <sub>12</sub> (l)
Standard enthalpy of combustion, $\Delta_c H^\ominus / \text{kJ mol}^{-1}$	-394	-286	-3920

Use the data in **Table 2** to calculate the enthalpy change for the reaction represented by this equation



Enthalpy change \_\_\_\_\_  $\text{kJ mol}^{-1}$

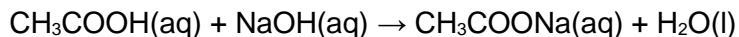
(3)

(Total 8 marks)

**Q12.**

This question is about enthalpy changes.

- (a) When ethanoic acid reacts with sodium hydroxide, the enthalpy change,  $\Delta H$ , is  $-56.1 \text{ kJ mol}^{-1}$



Calculate the temperature rise when  $25 \text{ cm}^3$  of  $2.0 \text{ mol dm}^{-3}$  aqueous ethanoic acid react with  $25 \text{ cm}^3$  of  $2.0 \text{ mol dm}^{-3}$  aqueous sodium hydroxide.

Assume that both solutions have the same initial temperature, have a density of  $1.0 \text{ g cm}^{-3}$  and a specific heat capacity of  $4.18 \text{ J K}^{-1} \text{ g}^{-1}$

Temperature rise \_\_\_\_\_ °C

**(4)**

- (b) A student recorded the temperature of aqueous ethanoic acid in a polystyrene cup for three minutes.

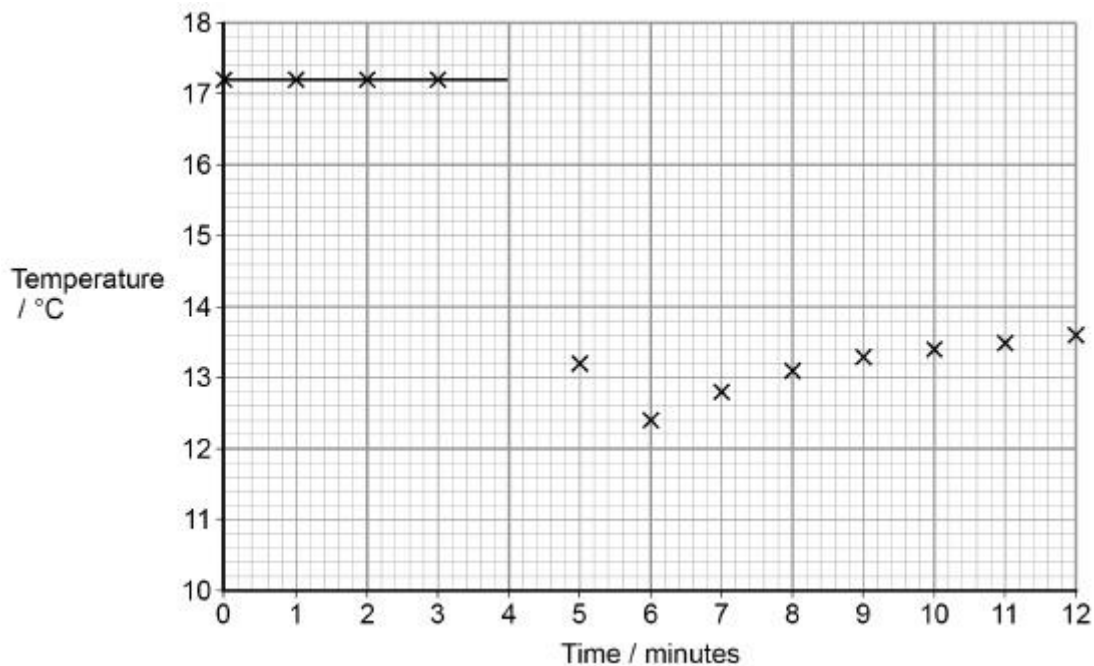
At the fourth minute, the student added sodium hydrogencarbonate.

The student stirred the mixture and carried on recording the temperature every minute for several minutes.

The student's measurements are shown in the graph.

A best-fit line showing the temperature before mixing has been drawn.

Draw an appropriate best-fit line on the graph and use it to find the temperature change at the time of mixing.



Temperature change at time of mixing \_\_\_\_\_ °C

(2)

(Total 6 marks)

### Q13.

This question is about energetics.

- (a) Write an equation, including state symbols, for the reaction with an enthalpy change equal to the enthalpy of formation for iron(III) oxide.

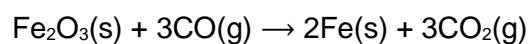
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(1)

- (b) **Table 1** contains some standard enthalpy of formation data.

**Table 1**

	CO(g)	Fe <sub>2</sub> O <sub>3</sub> (s)
$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	-111	-822



$$\Delta H = -19 \text{ kJ mol}^{-1}$$

Use these data and the equation for the reaction of iron(III) oxide with carbon monoxide to calculate a value for the standard enthalpy of formation for carbon dioxide.

Show your working.

$\Delta_f H^\ominus$  \_\_\_\_\_ kJ mol<sup>-1</sup>

(3)

- (c) Some enthalpy data are given in **Table 2**.

**Table 2**

Process	$\Delta H / \text{kJ mol}^{-1}$
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$	-92
$\text{N}_2(\text{g}) \rightarrow 2\text{N}(\text{g})$	+944
$\text{H}_2(\text{g}) \rightarrow 2\text{H}(\text{g})$	+436

Use the data from **Table 2** to calculate the bond enthalpy for N–H in ammonia.

N–H bond enthalpy \_\_\_\_\_ kJ mol<sup>-1</sup>

(3)

- (d) Give one reason why the bond enthalpy that you calculated in part (c) is different from the mean bond enthalpy quoted in a data book (388 kJ mol<sup>-1</sup>).

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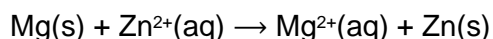
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(1)

(Total 8 marks)

**Q14.**

A student planned and carried out an experiment to determine the enthalpy of reaction when magnesium metal displaces zinc from aqueous zinc sulfate.



The student used this method:

- A measuring cylinder was used to transfer 50 cm<sup>3</sup> of a 1.00 mol dm<sup>-3</sup> aqueous solution of zinc sulfate into a glass beaker.
- A thermometer was placed in the beaker.
- 2.08 g of magnesium metal powder were added to the beaker.
- The mixture was stirred and the maximum temperature recorded.

The student recorded a starting temperature of 23.9 °C and a maximum temperature of 61.2 °C.

(a) Show by calculation which reactant was in excess.

Use the data to calculate the experimental value for enthalpy of reaction in kJ mol<sup>-1</sup> (Assume that the specific heat capacity of the solution is 4.18 J K<sup>-1</sup>g<sup>-1</sup> and the density of the solution is 1.00 g cm<sup>-3</sup>).

Reactant in excess \_\_\_\_\_

Enthalpy of reaction \_\_\_\_\_ kJ mol<sup>-1</sup>

**(6)**

- (b) Another student used the same method and obtained a value for the enthalpy of reaction of  $-142 \text{ kJ mol}^{-1}$

A data book value for the enthalpy of reaction is  $-310 \text{ kJ mol}^{-1}$

Suggest the most likely reason for the large difference between the student's experimental value and the data book value.

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(1)

- (c) Suggest how the students' method, and the analysis of the results, could be improved in order to determine a more accurate value for the enthalpy of reaction.

Justify your suggestions.

Do not refer to the precision of the measuring equipment. Do not change the amounts or the concentration of the chemicals.

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(6)

(Total 13 marks)

### Q15.

This question is about enthalpy changes.

- (a) Write an equation, including state symbols, to show the reaction taking place when the standard enthalpy of combustion for ethanol is measured.

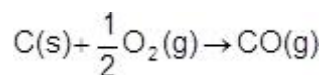
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(2)



- (b) State the name given to the enthalpy change represented by the following chemical equation.

Explain why this enthalpy change would be difficult to determine directly.



Enthalpy change

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Explanation

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(2)

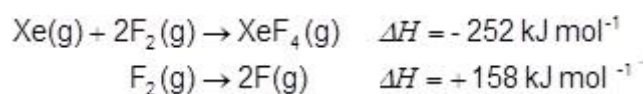
- (c) Standard enthalpies of combustion for carbon and carbon monoxide are  $-393 \text{ kJ mol}^{-1}$  and  $-283 \text{ kJ mol}^{-1}$ , respectively.

Use these data to calculate the enthalpy change for the reaction in part (b).

Enthalpy change = \_\_\_\_\_  $\text{kJ mol}^{-1}$

(2)

- (d) Use the following data to calculate a value for the Xe–F bond enthalpy in  $\text{XeF}_4$



Xe–F bond enthalpy = \_\_\_\_\_  $\text{kJ mol}^{-1}$

(3)

- (e) Suggest a reason why the value calculated in part (d) differs from the mean Xe–F bond enthalpy quoted in a data source.

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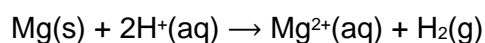
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(1)

(Total 10 marks)

### Q16.

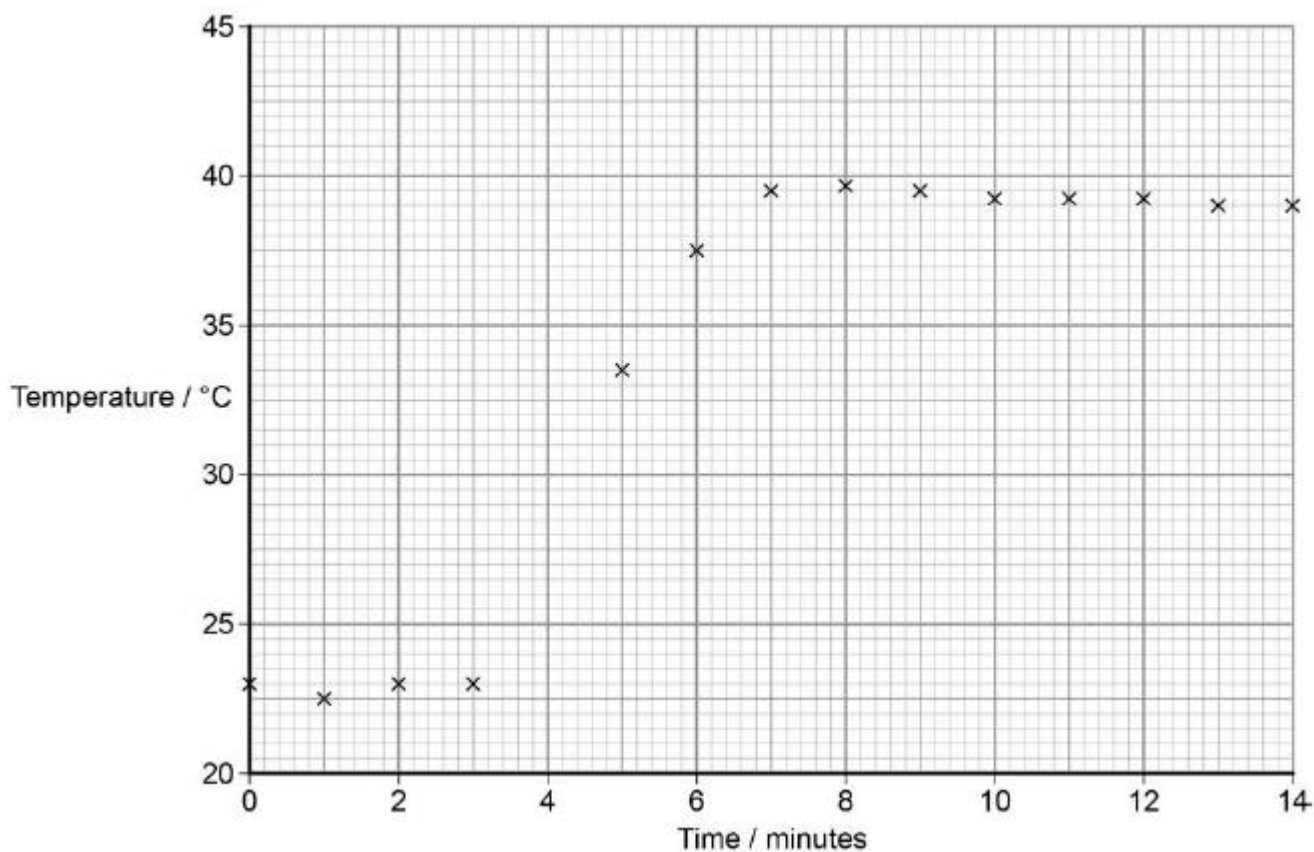
A student carried out a reaction between magnesium ribbon and aqueous trichloroethanoic acid in order to determine the enthalpy change. The equation for the reaction is shown:



The student measured the initial temperature of the trichloroethanoic acid and again every minute for 3 minutes before adding the magnesium ribbon at the fourth minute.

The student continued to measure the temperature every minute for a further 10 minutes.

The graph for these measurements is shown below.



The student used 240 mg of magnesium and 10.0 cm<sup>3</sup> of aqueous trichloroethanoic acid (an excess).

Use these data and information determined from the graph above to calculate the enthalpy change, in kJ mol<sup>-1</sup>, for this reaction.

Show your working.

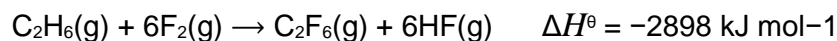
Give your answer to an appropriate precision.

(The specific heat capacity of water = 4.18 J K<sup>-1</sup> g<sup>-1</sup>)

Enthalpy change = \_\_\_\_\_ kJ mol<sup>-1</sup>  
(Total 7 marks)

**Q17.**

The table shows the standard enthalpy of formation,  $\Delta_f H^\ominus$ , for some of the substances in the reaction



	C <sub>2</sub> H <sub>6</sub> (g)	C <sub>2</sub> F <sub>6</sub> (g)
$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	-84	-1344

What is the standard enthalpy of formation, in kJ mol<sup>-1</sup>, for HF(g)?

- A    -1638
- B    -273
- C    +273
- D    +1638

(Total 1 mark)

**Q18.**

What is the temperature rise, in K, when 504 J of heat energy are absorbed by 0.110 kg of solid iron?

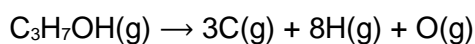
Specific heat capacity of iron =  $0.448 \text{ J K}^{-1} \text{ g}^{-1}$

- A  $9.78 \times 10^{-2}$
- B  $1.02 \times 10^1$
- C  $2.83 \times 10^2$
- D  $1.02 \times 10^4$

(Total 1 mark)

**Q19.**

Calculate the enthalpy change, in kJ, for this dissociation of mole of propan-1-ol.



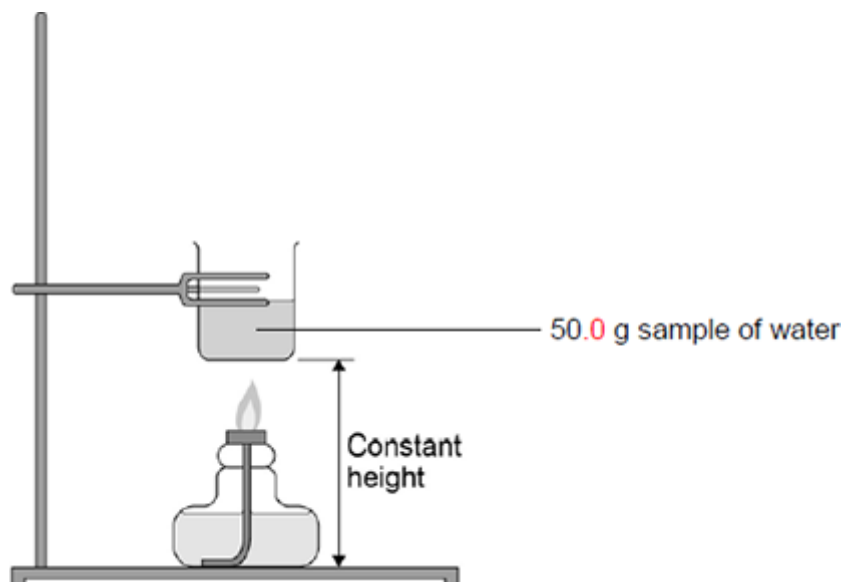
	C—H	C—C	C—O	O—H
Mean bond dissociation enthalpy / $\text{kJ mol}^{-1}$	412	348	360	463

- A -4751
- B -4403
- C +4403
- D +4751

(Total 1 mark)

**Q20.**

The figure below shows apparatus used in an experiment to determine the enthalpy of combustion of leaf alcohol.



The alcohol is placed in a spirit burner and weighed. The burner is lit and the alcohol allowed to burn for a few minutes. The flame is extinguished and the burner is re-weighed. The temperature of the water is recorded before and after heating.

The following table shows the results obtained.

Initial mass of spirit burner and alcohol / g	56.38
Final mass of spirit burner and alcohol / g	55.84
Initial temperature of water / °C	20.7
Final temperature of water / °C	40.8

- (a) Write an equation for the complete combustion of leaf alcohol ( $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}_2\text{OH}$ ).

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(1)

- (b) Use the results from the table above to calculate a value for the enthalpy of combustion of leaf alcohol. Give units in your answer.  
(The specific heat capacity of water is  $4.18 \text{ J K}^{-1} \text{ g}^{-1}$ )

Enthalpy of combustion = \_\_\_\_\_ Units = \_\_\_\_\_

(4)

- (c) State how your answer to part (b) is likely to differ from the value quoted in reference sources.  
Give **one** reason for your answer.

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(2)

- (d) A 50.0 g sample of water was used in this experiment.

Explain how you could measure out this mass of water without using a balance.

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(2)

(Total 9 marks)