IB · DP · Chemistry

2 hours 13 questions

Structured Questions: Paper 2

5.1 Energetics

5.1.1 Energy Changes in Reactions / 5.1.2 Standard Enthalpy Change / 5.1.3 Calorimetry / 5.1.4 Calorimetry Experiments / 5.1.5 Hess's Law / 5.1.6 Using Hess's Law - Cycles / 5.1.7 Using Hess's Law - Equations / 5.1.8 Using ΔHf° to Find Enthalpy Changes / 5.1.9 Bond Enthalpy / 5.1.10 Bond Enthalpy Calculations / 5.1.11 Energy Profiles / 5.1.12 Case Study: Ozone

Easy (4 questions)	/35
Medium (5 questions)	/47
Hard (4 questions)	/39
Total Marks	**/121**

Scan here to return to the course
or visit savemyexams.com

Easy Questions

1 (a) Chemical reactions can be exothermic or endothermic. State which type of reaction is indicated by a decrease in temperature.

.....

(1 mark)

(b) State the type of reaction in which the energy of the system decreases.

.....

(1 mark)

(c) The reaction of propane with oxygen is represented by the following equation

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O \qquad \Delta H = -2219 \text{ kJ mol}^{-1}$$

State the classification of the enthalpy change is occurring in this reaction.

.....

(1 mark)

(d) Define the term enthalpy of formation, ΔH_f, and state the standard conditions.

.....

.....

.....

.....

.....

.....

(6 marks)

2 (a) Define the term enthalpy change of reaction, ΔH_r.

.....

.....

(2 marks)

(b) The equations below can be identified as any of the following enthalpy changes. Identify the enthalpy change for each reaction.

- Enthalpy of reaction, ΔH_r
- Enthalpy of formation, ΔH_f
- Enthalpy of combustion, ΔH_c
- Enthalpy of neutralisation, ΔH_{neut}

C_2H_5OH (l) + O_2 (g) → CO_2 (g) + H_2O (l) .....

$CaSO_3$ (s) → CaO (s) + SO_2 (g) .....

HCl (aq) + NaOH (aq) → NaCl (aq) + H_2O (l) .....

.....

.....

.....

(3 marks)

(c) Hydrochloric acid, HCl (aq), and sodium hydroxide, NaOH (aq), react as follows

$$HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l) \quad \Delta H_r = -57.9\ kJ\ mol^{-1}$$

Determine the enthalpy change, in kJ, when 25 cm^3 of 0.5 mol dm^{-3} hydrochloric acid reacts with 25 cm^3 of 0.5 mol dm^{-3} sodium hydroxide. Give your answer to 2 decimal places.

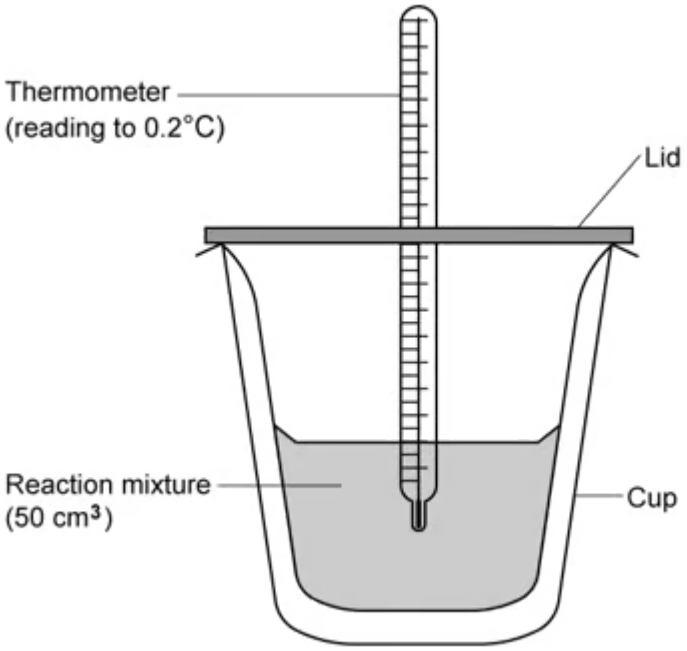
.....

.....

(2 marks)

3 (a) A student set up apparatus for a calorimetry experiment as shown below.

Suggest suitable materials for the lid and cup. Justify your answer.



(3 marks)

(b) The student added excess zinc powder to the cup with 50.0 cm^3 of 1.0 mol dm^{-3} copper(II) sulfate solution in a calorimeter. The reaction equation was as follows:

$$Zn\,(s) + CuSO_4\,(aq) \rightarrow ZnSO_4\,(aq) + Cu\,(s)$$

The maximum temperature rise was 22.6 ^oC. Using section 1 of the data booklet, determine the enthalpy of reaction, in kJ. Give your answer to 2 significant figures.

Calculate the energy change, *q* .....

Calculate the number of moles of copper(II) sulfate solution .....

Calculate the enthalpy change of the reaction .....

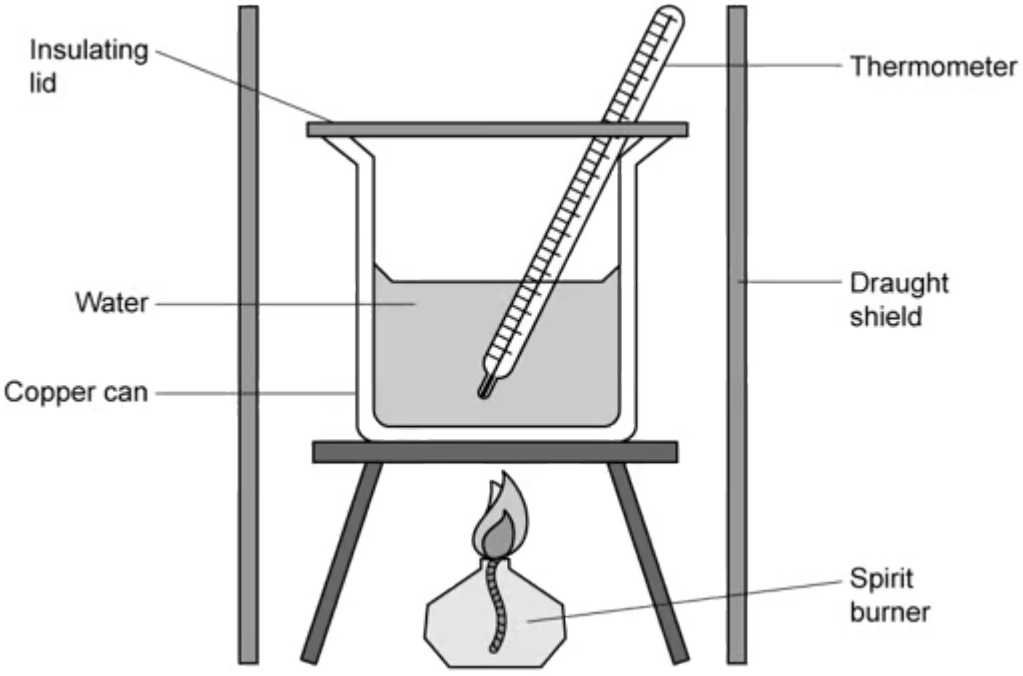
.....

.....

.....

(3 marks)

(c) Another calorimetry experiment was set up to determine the enthalpy of combustion for ethanol.



Define standard enthalpy of combustion, ΔH_c.

.....

.....

(2 marks)

(d) 0.61 g of ethanol, C_2H_5OH, was burned in a spirit burner and used to heat 100 cm^3 of water in a copper calorimeter. The temperature of the water rose by 40 ^oC.

i) Using section 1 and 2 in the data booklet determine the energy, in joules, for this reaction.

ii) Convert your answer to part (i) into kilojoules.

.....

.....

(2 marks)

(e) Calculate the enthalpy change for the combustion of ethanol.

Determine the moles of ethanol .....

Determine the overall enthalpy change .....

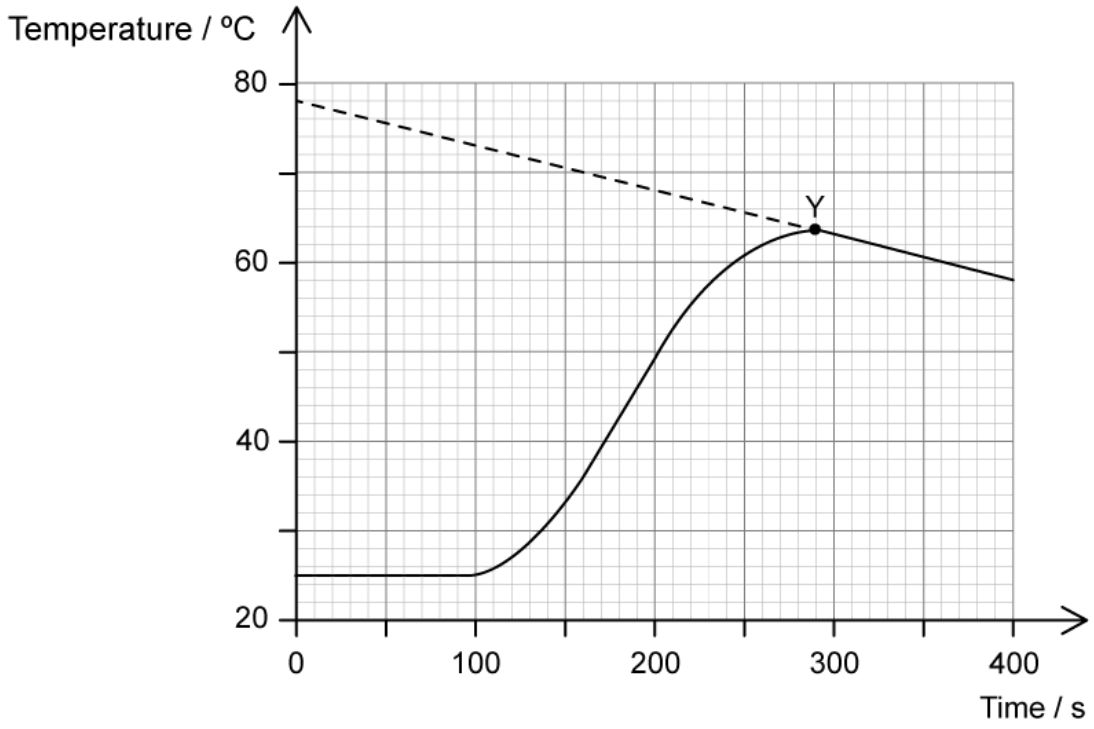
.....

.....

.....

(3 marks)

4 (a) 4.00 g of powdered iron was reacted with 25.0 cm^3 of 2.00 mol dm^{-3} copper(II) sulfate solution in an insulated beaker. Temperature was plotted against time.



Estimate the time at which the powdered iron was added to the beaker.

.....

(1 mark)

(b) A student added point Y to the graph.

i) State what point Y indicates on the graph.

ii) Assuming there is no heat loss in the experiment and the heat change is instantaneous, using the graph, determine the total temperature change.

.....

.....

.....

(3 marks)

(c) Explain why the student has recorded the temperature of the copper sulfate solution for a period of time before adding the iron powder.

.....

(1 mark)

(d) The student used the equation $q = mc\Delta T$ to calculate the enthalpy change for the reaction that took place in the beaker. State the value that the student should use for m.

.....

(1 mark)

Medium Questions

1 (a) The reaction between solid ammonium nitrate and water is one which is often conducted in school laboratories.

(i) Describe how the heat energy transferred (q) for the reaction between solid ammonium nitrate and water could be conducted in a school laboratory. Give the names of the apparatus that is needed and state the measurements that would be taken to find the enthalpy change of reaction.

(ii) Discuss one major source of error in the experiment and suggest how that error would impact on the calculation of the enthalpy change (q).

(5 marks)

(b) State the difference between *accuracy* and *precision* in experimental results.

(1 mark)

(c) Write an equation for the reaction that occurs when ammonium nitrate is added to water.

(1 mark)

(d) A student dissolves 3.5 g of ammonium nitrate in water and determines q to be 1828 J. Determine the enthalpy change for this reaction in kJ mol^{-1}.

(2 marks)

2 (a) Methanol is an important industrial alcohol which is mostly used to create fuel, solvents, and antifreeze. A colorless liquid, it is volatile, flammable, and unlike ethanol, poisonous for human consumption.

The equation to show the enthalpy of combustion of methanol is:

$$CH_3OH\ (l) + 1½O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g)$$

Use the equation and the information in **Table 1** below, to determine the theoretical enthalpy of combustion of methanol.

Table 1

Bond	**C-O**	**O-H**	**C-H**	**O=O**	**C=O**
Mean bond enthalpy ($kJmol^{-1}$)	358	463	414	498	804

.....

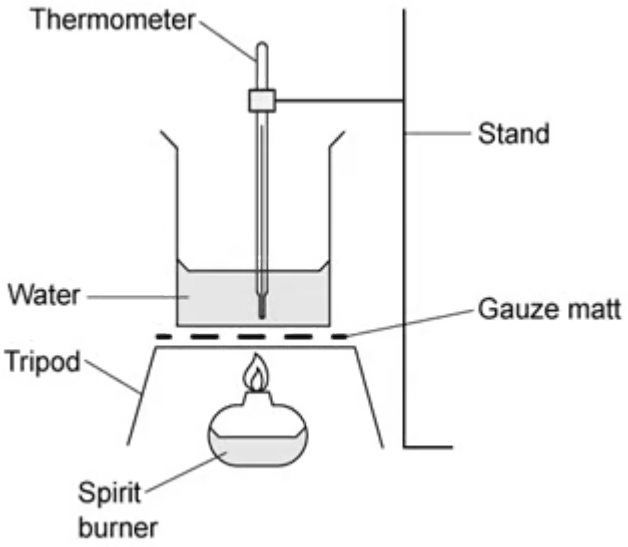
.....

.....

(3 marks)

(b) The enthalpy of combustion of an alcohol can be determined in a school laboratory using the following apparatus.

Figure 1



In an experiment, a spirit burner containing methanol was weighed and used to heat water in a beaker as shown above. The following results were obtained:

Starting mass of spirit burner and methanol / g	80.56
Final mass of spirit burner and methanol / g	80.03
Mass of water in the beaker / g	100.00
Initial water temperature / ^{o}C	21.5
Final water temperature / ^{o}C	32.1

(i) Calculate the amount of methanol combusted in moles.

(ii) Calculate the heat energy transferred to the water, *q*, in kJ. Take the specific heat capacity of water as 4.18 J g^{-1} K^{-1}.

(iii) Find the enthalpy of combustion of methanol in kJ mol^{-1}.

(4 marks)

(c) The accepted data book value for the enthalpy of combustion of methanol is -726 kJ mol^{-1}.

(i) Suggest why the data value is different from the values calculated in part (a).

(ii) Suggest why the data value is different from the values calculated in part (b).

.....

.....

.....

(3 marks)

(d) Suggest one improvement that could be made to the apparatus in part (b) that would give a more accurate result.

.....

(1 mark)

3 (a) A teacher instructs a class to complete a calorimetry practical, to calculate the enthalpy change that occurs when hydrochloric acid and sodium hydroxide react together.

Each student was given roughly 60 cm^3 of 0.35 mol dm^{-3} hydrochloric acid, roughly 60 cm^3 of 0.35 mol dm^{-3} sodium hydroxide, a polystyrene cup and access to all standard laboratory equipment.

Draw a diagram to demonstrate the practical set up that the students would need to use to determine the enthalpy change during this neutralisation reaction, and state the key measurements that the students would have to make.

(3 marks)

(b) The students then completed the practical from part (a), using their own method and measurements that they had chosen.

One student found that when they reacted 35.0 cm^3 of the hydrochloric acid with 35.0 cm^3 of the sodium hydroxide, the temperature rose from 19.6 ^oC to 22.3 ^oC.

Determine the enthalpy change, ΔH, for this reaction in kJ mol^{-1}. Assume that both solutions have a density of 1.00 g cm^{-3} and a specific heat capacity of 4.18 J g^{-1} K^{-1}.

(5 marks)

(c) Explain why the value that you have calculated for the students' practical in part (b), might be different from the correct value given in a data book.

(1 mark)

(d) State how the students' practical could be improved to allow the students to calculate a more accurate value which is closer to the correct value given in data books.

.....

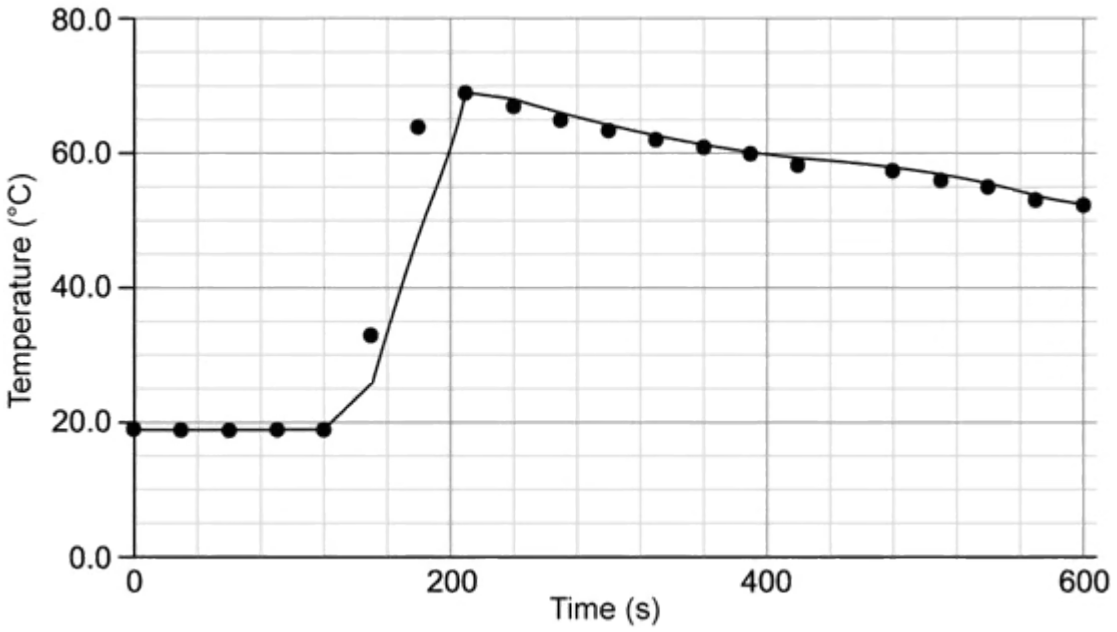
(1 mark)

4 (a) A group of students carried out a calorimetry experiment to determine the enthalpy change for the decomposition of hydrogen peroxide using manganese dioxide as a catalyst.

Each group added 1 g of manganese dioxide to 50.00 cm^3 of 2.00 mol dm^{-3} of hydrogen peroxide.

They recorded their data and drew a graph shown in **Figure 1**.

Figure 1



Use the graph to determine the temperature in the experiment.

.....

(1 mark)

(b) Using your answer to part (a) determine the enthalpy change, ΔH, for this reaction in kJ mol^{-1}.

Assume the solution has a density of 1.00 g cm^{-3} and a specific heat capacity of 4.18 J g^{-1} K^{-1} .

.....

.....

(4 marks)

(c) Determine the enthalpy of reaction outlined in part (a) using the data in **Table 1**.

Table 1

	H_2O_2 (aq)	O_2 (g)	H_2O (l)
$\Delta H_f^{\ominus}$ (kJ mol^{-1})	-190	0	-285.8

(2 marks)

(d) Draw the Lewis structure for hydrogen peroxide.

(1 mark)

5 (a) Define the term *standard enthalpy of neutralisation* , $\Delta H^{\ominus}_{neut}$.

(3 marks)

(b) A student carried out a neutralisation reaction and recorded the temperature change.25.00 cm^3 of 1.0 mol dm^{-3} nitric acid, HNO_3 (aq) was neutralised by 50.00 cm^3 of 1.0 mol dm^{-3} of potassium hydroxide, KOH (aq).

The initial temperature of the potassium hydroxide was 20.5 ^oC and the reaction reached a maximum temperature of 24.5 ^oC.

Determine the enthalpy of neutralisation, $\Delta H^{\ominus}_{neut}$, assuming the solutions has a density of 1.00 g cm^{-3} and a specific heat capacity of 4.18 J g^{-1} K^{-1} . Give your answer in kJ mol^{-1} to **three** significant figures.

(4 marks)

(c) Write an equation to demonstrate how nitric acid can behave as a Brønsted-Lowry acid when it reacts with water.

(1 mark)

(d) The accepted theoretical value from the literature of this enthalpy change is -57 kJ mol^{-1}. Calculate the percentage error to **two** significant figures.

(1 mark)

Hard Questions

1 (a) When anhydrous copper(II) sulfate is left in the atmosphere it will slowly turn to a blue pentahydrate solid. It is possible to measure the heat changes directly when both anhydrous and pentahydrated copper(II) sulfate are **separately** dissolved in water.

i) Write an equation for the reaction of anhydrous copper(II) sulfate with water to form pentahydrated copper(II) sulfate.

[1]

ii) Construct an energy cycle which can be used to determine the enthalpy change indirectly.

[2]

.....

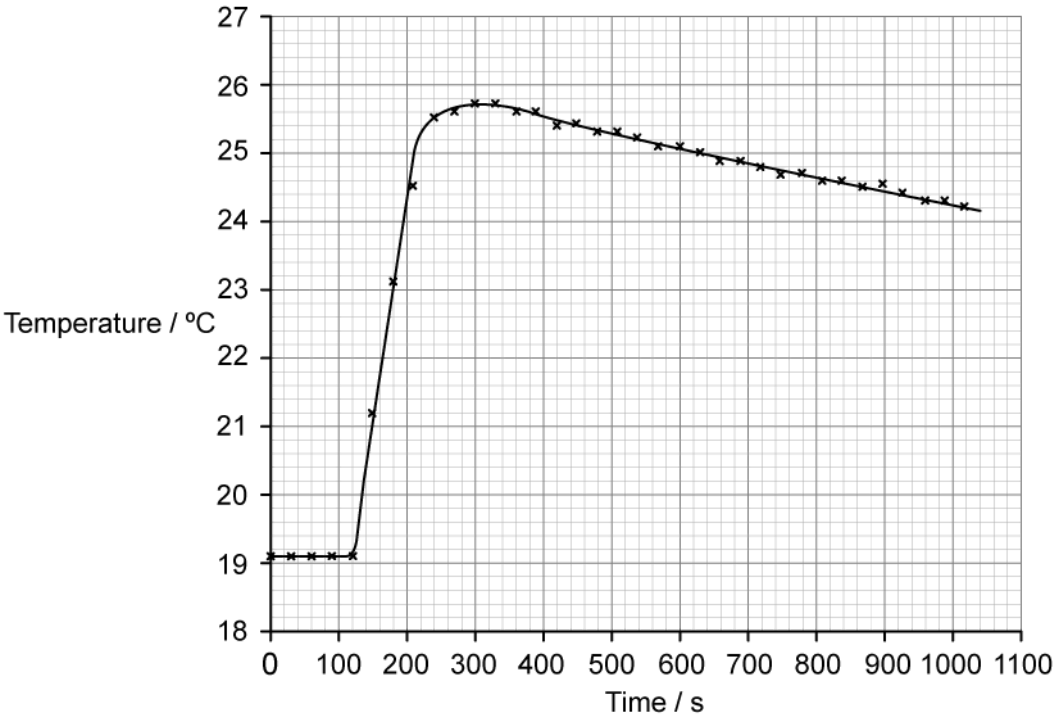
.....

.....

(3 marks)

(b) To determine the enthalpy change a student placed 50 cm^3 of water in a polystyrene cup and used a data logger to measure the temperature.

After two minutes she dissolved 6.30 g of anhydrous copper(II) sulfate in the water and continued to record the temperature while continuously stirring. She obtained the following results.



i) Using section 6 in the data booklet, determine the amount, in moles, of copper(II) sulfate.

[1]

ii) Determine the temperature change, in °C, for the reaction assuming no heat had been lost to the surroundings.

[1]

iii) Using sections 1 and 2 in the data booklet, determine the heat change, in kJ mol^{-1}, for the reaction.

[2]

.....

.....

.....

.....

(4 marks)

(c) The student repeated the experiment using 7.83 g of pentahydrated copper(II) sulfate and observed the temperature decreased by 2.5 °C. The student used the same volume of water.

i) Use section 6 of the data booklet to determine the amount, in moles, of pentahydrated copper(II) sulfate.

[1]

ii) Use sections 1 and 2 in the data booklet to determine the heat change, in kJ mol^{-1}.

[2]

.....

.....

.....

(3 marks)

(d) Use your answers to parts a), b) and c) to determine the energy change for dissolving copper(II) sulfate.

.....

.....

(2 marks)

2 (a) A student investigated the temperature change for the neutralisation of malonic acid, $HOOCCH_2COOH$, and sodium hydroxide solution.

$25.0\ cm^3$ of $0.400\ mol\ dm^{-3}$ of malonic acid was added to a beaker and the temperature was recorded every minute for three minutes using using a thermometer with an uncertainty of ±0.1° C. On the fourth minute the student added $50.0\ cm^3$ of $0.500\ mol\ dm^{-3}$ sodium hydroxide solution.

Finally, she recorded the temperature every minute for eight minutes.

Determine the percentage uncertainty in the student's 2.9 °C temperature rise.

.....

.....

(2 marks)

(b) Another student completed the same investigation and recorded a maximum temperature of 23.5 °C. The student calculated the heat energy, *q*, for the reaction to be 8.923×10^{-1} kJ.

Use sections 1 and 2 in the data booklet and the information in part a) to estimate the initial temperature for this student's investigation.

.....

.....

.....

(3 marks)

(c) State the balanced symbol equation for the neutralisation of malonic acid with sodium hydroxide solution.

.....

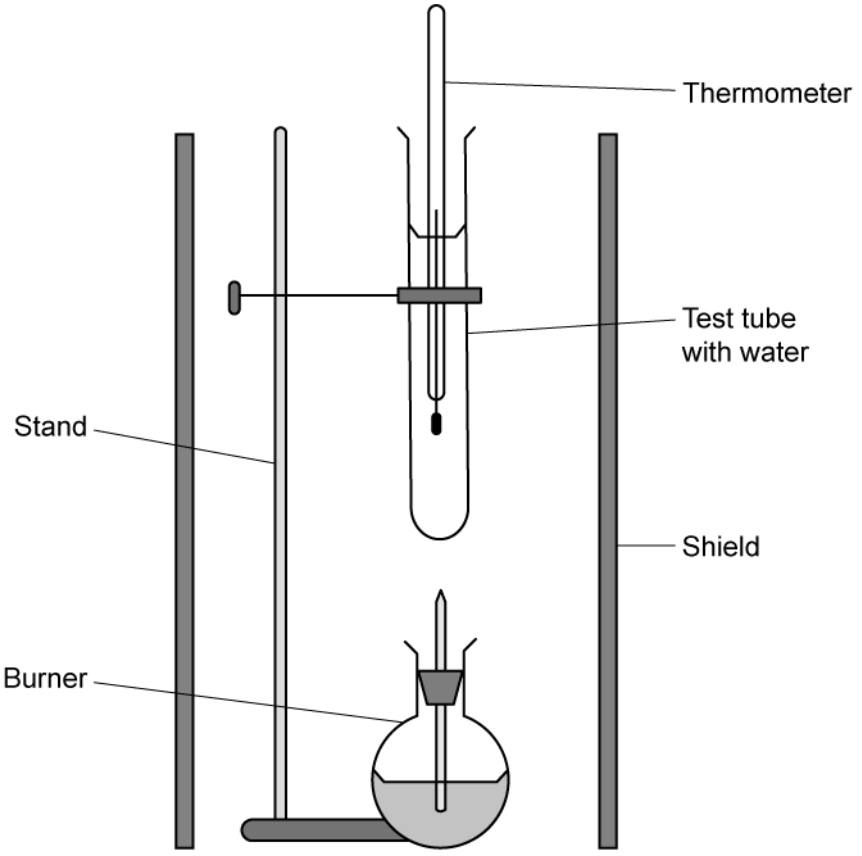
(1 mark)

(d) The student determined that the enthalpy change of neutralisation, ΔH_{neut}, was -35.7 kJ mol^{-1}. Deduce if the student is correct and justify your answer.

(4 marks)

3 (a) Ethanol is made in large quantities via the hydration of ethene in the presence of a concentrated phosphoric acid catalyst or via the fermentation of glucose. Ethanol is widely used as a fuel.

The enthalpy of combustion of ethanol can also be determined experimentally in a school laboratory. A burner containing ethanol was weighed and used to heat water in a test tube as illustrated below.



The following data was obtained from the combustion of ethanol.

Initial mass of burner and ethanol / g	76.137
Final mass of burner and ethanol / g	75.614
Volume of water in test tube / g	20.000
Initial temperature of water / °C	19.2
Final temperature of water / °C	24.3

i) State the equation for the combustion of ethanol.

[2]

ii) Using the information from Table 11 of the Data booklet, determine the theoretical enthalpy of combustion of ethanol.

[3]

(5 marks)

(b) Use the information in part a) and sections 1, 2 and 6 in the data booklet to determine.

i) The amount, in moles, of ethanol burned.

[1]

ii) The heat absorbed, in kJ, by the water.

[3]

iii) The enthalpy change, in kJ mol^{-1}, for the combustion of 1 mole of ethanol.

[2]

(6 marks)

(c) Compare the data book value in section 13 with your answer to part b) and suggest why these values differ.

(1 mark)

4 (a) The enthalpy change of solution for lithium chloride can be measured using calorimetry.

1.20 g of lithium chloride is dissolved in 20.0 cm^3 of water at 19.5 °C.

Use section 6 in the data booklet to determine the amount, in moles, of the lithium chloride dissolved.

.....

(1 mark)

(b) Use your answer to part a) and section 19 in the data booklet to determine the energy released, in J, when 1.20 g of lithium chloride is dissolved in 20.0 cm^3 of water.

.....

(1 mark)

(c) Use your answer to part b) and sections 1 and 2 in the data booklet, determine the change in temperature, in °C, when the lithium chloride is dissolved.

.....

.....

(2 marks)

(d) Use your answer to part c) determine the maximum temperature, in °C, of the solution that was reached during the reaction.

.....

(1 mark)