A-Level Chemistry

Calorimetry

Question Paper

Time available: 57 minutes
Marks available: 48 marks

1. 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 ($CH_3CH_2CH_2OH$, 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 kJ mol^{-1}, for the enthalpy of combustion of propan-1-ol in this experiment.

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

Enthalpy of combustion _____ 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)

2. This question is about enthalpy changes.

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

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(1)

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

$$CaCO_3(s) + 2\ HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

The student follows this method:

- measure out 50 cm^3 of 1.00 mol dm^{-3} aqueous hydrochloric acid using a measuring cylinder and pour the acid into a 100 cm^3 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.

(6)

(c) In a different experiment 50.0 cm^3 of 0.500 mol dm^{-3} aqueous hydrochloric acid are reacted with 50.0 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) \quad \Delta H = -57.1 \text{ kJ mol}^{-1}$$

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 J K^{-1} g^{-1}

Assume that the density of the reaction mixture = 1.00 g cm^{-3}

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)

3. 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_{cal}) of the calorimeter is calculated using a fuel for which the heat change is known.

In an experiment to calculate C_{cal}, 2.00 g of hexane (M_r = 86.0) is ignited. A temperature change (ΔT) of 12.4 °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, $q = C_{cal}\Delta T$

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

C_{cal} _____ 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 kJ mol^{-1}, for octane in this combustion reaction.

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

Heat change _____ 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 ± 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 _____

_____

_____

(2)

(Total 8 marks)

4. This question is about enthalpy changes.

(a) When ethanoic acid reacts with sodium hydroxide, the enthalpy change, ΔH, is –56.1 kJ mol^{-1}

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$$

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

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

Temperature rise _____ °C

(4)

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

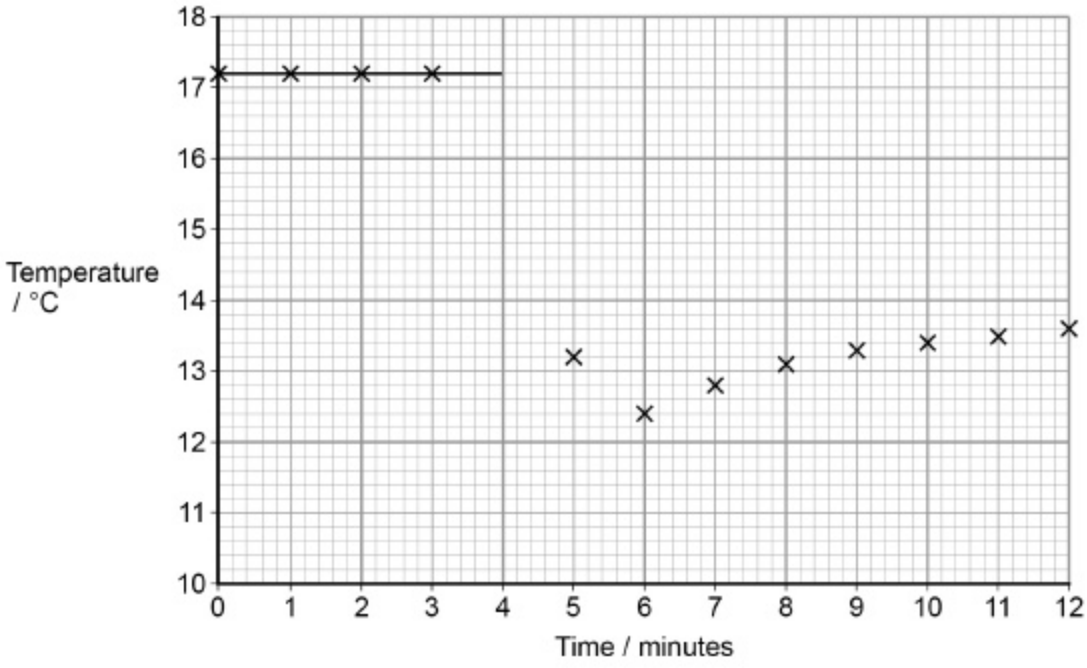
At the fourth minute, the student added sodium hydrogencarbonate.

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)

5. 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 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 J K^{-1} 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 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)	$H_2(g)$	$C_6H_{12}(l)$
Standard enthalpy of combustion, $\Delta_c H^{\ominus}$ / kJ mol^{-1}	−394	−286	−3920

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

$$6\ C(s) + 6\ H_2(g) \rightarrow C_6H_{12}(l)$$

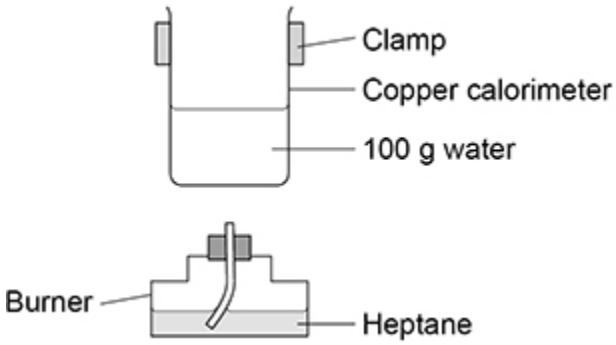
Enthalpy change _____kJ mol^{-1}

(3)

(Total 8 marks)

6. 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.

_____

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(1)

(Total 7 marks)