



A-Level Chemistry

Enthalpy Change

Question Paper

Time available: 58 minutes

Marks available: 53 marks

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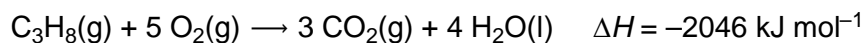
1.

This question is about enthalpy changes.

(a) Define the term enthalpy change.

(1)

(b) Propane undergoes complete combustion.



The table below shows some bond enthalpy data.

Bond	C–H	C=O	O–H
Mean bond enthalpy / kJ mol ⁻¹	412	743	463

The bond enthalpy for O=O is 496 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 _____ kJ mol⁻¹

(4)

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

(1)

(Total 6 marks)

2.

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, $q = C_{\text{cal}}\Delta T$

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.

(1)

- (d) The thermometer used to measure the temperature change of $12.2\text{ }^{\circ}\text{C}$ in part (b) has an uncertainty of $\pm 0.1\text{ }^{\circ}\text{C}$ 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)

3.

A student calculated that a value for the enthalpy change of neutralisation is -51.2 kJ mol^{-1} .

The design of a possible hand-warmer using hydrochloric acid and sodium hydroxide was discussed. It was proposed that 500 cm^3 of hydrochloric acid should be used in a flexible, sealed plastic container with a breakable tube of solid sodium hydroxide also in the container. On breaking the tube, the sodium hydroxide would be released, react with the acid and produce heat.

A $40\text{ }^{\circ}\text{C}$ temperature rise was thought to be suitable.

- (a) Calculate the heat energy, in J, required to raise the temperature of the reaction mixture by $40\text{ }^{\circ}\text{C}$. Assume that the reaction mixture has a density of 1.00 g cm^{-3} and a specific heat capacity of $4.18\text{ J K}^{-1}\text{ g}^{-1}$.
Assume that all of the heat energy given out is used to heat the reaction mixture.

(2)

- (b) Use your answer from part (a) and the value for the enthalpy change of neutralisation of $-51.2 \text{ kJ mol}^{-1}$ to calculate the minimum amount, in moles, and hence the minimum mass of sodium hydroxide required in the breakable tube.
(If you could not complete the calculation in part (a) assume that the heat energy required was $77\,400 \text{ J}$. This is **not** the correct answer).

Show your working.

Moles of NaOH _____

Mass of NaOH _____

(3)

- (c) Use the amount, in moles, of sodium hydroxide from part (b) to calculate the minimum concentration, in mol dm^{-3} , of hydrochloric acid required in the 500 cm^3 of solution used in the sealed container.

(1)

- (d) Suggest **one** possible risk to a person who uses a hand-warmer containing sodium hydroxide and hydrochloric acid.

(1)

- (e) A commercial hand-warmer uses powdered iron sealed in a plastic container.
A valve allows air to enter the container, and oxygen in the air reacts slowly with the iron to form solid iron(III) oxide. The heat released warms the container.

- (i) Write an equation for this reaction between iron and oxygen to form iron(III) oxide.

(1)

- (ii) One version of an iron-oxygen hand-warmer advertises that it is designed to stay warm for up to four hours.
Other than by increasing the amount of iron in the container, state **one** change to the iron in the hand-warmer that would increase this time.
Explain why this change to the iron might **not** be an advantage.

Change to the iron _____

Explanation _____

(3)

- (f) Another type of hand-warmer uses sodium thiosulfate. Sodium thiosulfate is very soluble in water at 80 °C but is much less soluble at room temperature.
When a hot, concentrated solution of sodium thiosulfate is cooled it does not immediately crystallise. The sodium thiosulfate stays dissolved as a stable 'super-saturated' solution until crystallisation is triggered.
Heat energy is then released when the sodium thiosulfate crystallises.

- (i) This type of hand-warmer is re-usable.
Suggest **one** environmental advantage that a sodium thiosulfate hand-warmer has over the other two types.

(1)

- (ii) Describe the **two** steps that you would take to make the sodium thiosulfate hand-warmer ready for re-use.

Step 1 _____

Step 2 _____

(2)

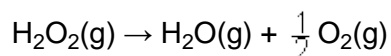
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4.

- (a) The table below contains some mean bond enthalpy data.

Bond	H–O	O–O	O=O
Mean bond enthalpy/kJ mol ⁻¹	463	146	496

The bonding in hydrogen peroxide, H₂O₂, can be represented by H–O–O–H. Use these data to calculate the enthalpy change for the following reaction.



(3)

- (b) The standard enthalpy of formation, ΔH_f^\ominus for methane, is $-74.9 \text{ kJ mol}^{-1}$. Write an equation, including state symbols, for the reaction to which this enthalpy change applies.

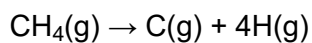
(2)

- (c) The enthalpy changes for the formation of atomic hydrogen and atomic carbon from their respective elements in their standard states are as follows.



- (i) By reference to its structure, suggest why a large amount of heat energy is required to produce free carbon atoms from solid carbon.

- (ii) Parts (b) and (c) give enthalpy data for the formation of $\text{CH}_4(\text{g})$, $\text{H}(\text{g})$ and $\text{C}(\text{g})$. Use these data and Hess's Law to calculate the value of the enthalpy change for the following reaction.



- (iii) Use your answer from part (c)(ii) to calculate a value for the mean bond enthalpy of a C–H bond in methane.

(5)

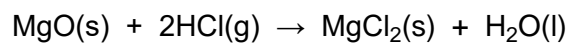
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5.

- (a) Define the term *standard enthalpy of formation*.

(3)

- (b) State Hess's Law and use it, together with the data given in the table below, to calculate the standard enthalpy change for the following reaction.



	MgO	HCl(g)	MgCl ₂	H ₂ O
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-602	-92	-642	-286

(4)

- (c) In an experiment, an excess of solid magnesium oxide was added to 50 cm³ of 3.0 mol dm⁻³ hydrochloric acid. The initial temperature of the solution was 21 °C. After reaction, the temperature had risen to 53 °C. (The specific heat capacity of water is 4.2 J K⁻¹ g⁻¹)

Use this information to calculate the enthalpy change for the reaction of one mole of magnesium oxide with hydrochloric acid. For your calculation you should assume that all the heat from the reaction is used to raise the temperature of 50 g of water.

[illegible]

(8)

(Total 15 marks)