Enthalpy Changes
AS & A Level

Question Paper 2

Level	A Level
Subject	Chemistry
Exam Board	OCR
Module	Periodic Table & Energy
Topic	Enthalpy Changes
Paper	AS & A Level
Booklet	Question Paper 2

Time allowed: **70 minutes**

Score: **/52**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E
>85%	73%	60%	47%	34%	21%

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

Compound	$NH_4NO_3(s)$	$H_2O(g)$	$CO_2(g)$
$\Delta_f H$ / kJ mol^{-1}	–366	–242	–394

What is the enthalpy change for the following reaction? **[1]**

$$2NH_4NO_3(s) + C(s) \rightarrow 2N_2(g) + 4H_2O(g) + CO_2(g)$$

A –630 kJ mol^{-1}

B –540 kJ mol^{-1}

C +540 kJ mol^{-1}

D +630 kJ mol^{-1}

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

Compound	$TiCl_4(l)$	$H_2O(l)$	$TiO_2(s)$	$HCl(g)$
$\Delta_f H$ **/ kJ mol^{-1}**	–804	–286	–945	–92

What is the value of the enthalpy change of reaction, $\Delta_r H$, for the reaction in the following equation? **[1]**

$$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(g)$$

A. –63 kJ mol^{-1}

B. –53 kJ mol^{-1}

C +53 kJ mol^{-1}

D +63 kJ mol^{-1}

Enthalpy changes can be determined directly or indirectly.

(a) A student investigates the reaction between magnesium and dilute hydrochloric acid.

$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

The student determines the enthalpy change for this reaction.

In her experiment, she reacts 0.486 g of magnesium with 50.0 cm^3 of 2.00 mol dm^{-3} $HCl(aq)$. The $HCl(aq)$ is in excess.

The temperature of the solution changes from 19.2 °C to 32.0 °C.

(i) Calculate the energy released, in kJ, during this reaction.

The specific heat capacity of the solution = 4.18 J g^{-1} K^{-1}.

The density of the solution is 1.00 g cm^{-3}. [2]

(ii) Calculate the amount, in moles, of magnesium used by the student. [1]

(iii) Calculate the enthalpy change of reaction.

Give your answer to **three** significant figures. [3]

(b) The student wants to determine the enthalpy change of formation of calcium carbonate, $CaCO_3(s)$.

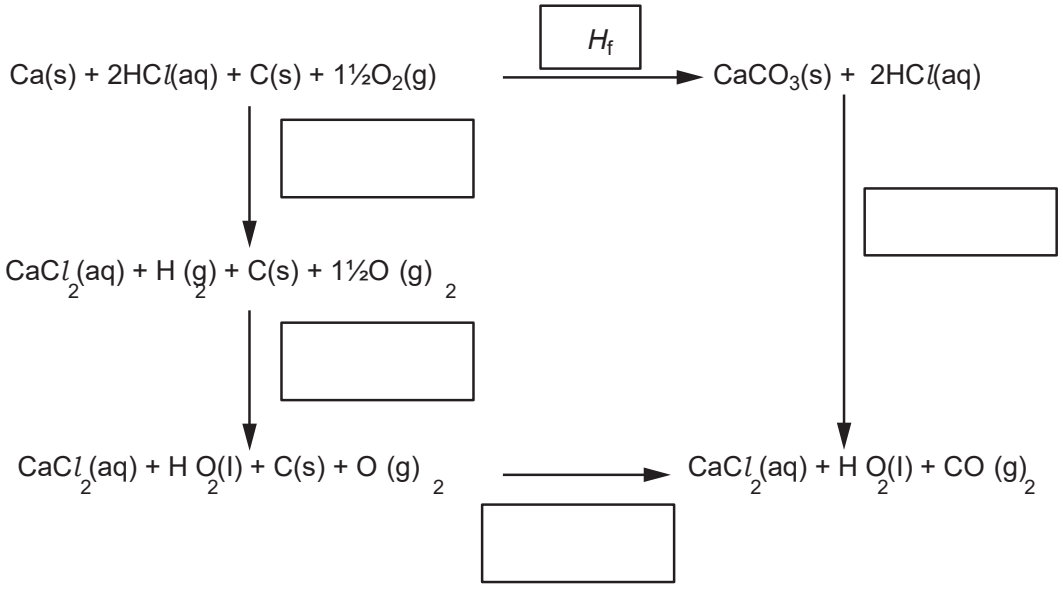
$$Ca(s) + C(s) + 1½O_2(g) \longrightarrow CaCO_3(s)$$

(i) What is meant by the term *standard enthalpy change of formation*? You should state the standard conditions in your answer. [3]

(ii) Using the following data and enthalpy cycle,

- fill in the boxes on the enthalpy cycle with the correct enthalpy change values
- calculate the enthalpy change of formation ΔH_f, of $CaCO_3(s)$.

reaction	enthalpy change, ΔH / kJmol^{-1}
$C(s) + O_2(g) \rightarrow CO_2(g)$	–393
$H_2(g) + ½O_2(g) \rightarrow H_2O(l)$	–285
$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$	–54
$Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$	–168



[3]

[Total: 12 Marks]

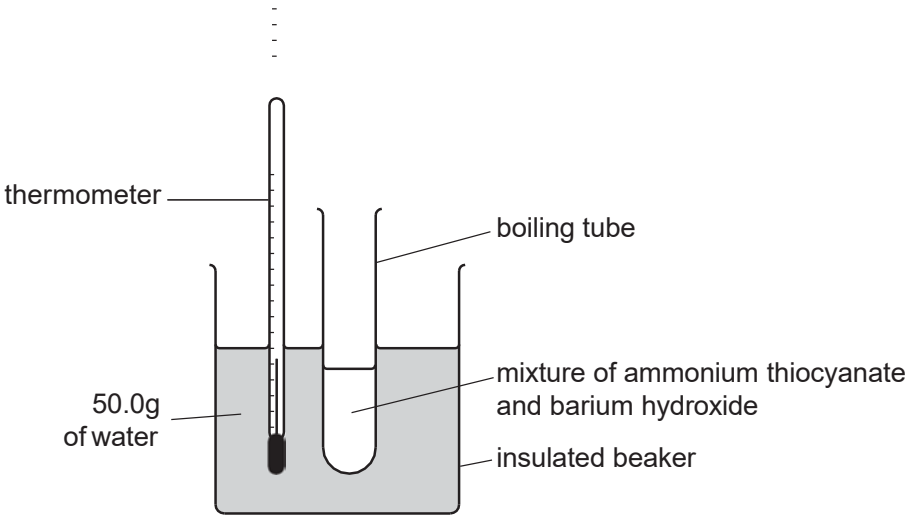
Enthalpy changes of reaction can be determined by experiment or by using bond enthalpies.

(a) What is meant by the term *enthalpy change of reaction*? [2]

(b) Solid ammonium thiocyanate, NH_4SCN, reacts with solid barium hydroxide, $Ba(OH)_2$, as shown in the equation below.

$$2NH_4SCN(s) + Ba(OH)_2(s) \rightarrow Ba(SCN)_2(s) + 2H_2O(l) + 2NH_3(g)$$

A research chemist carries out an experiment to determine the enthalpy change of this reaction.



In the experiment, 15.22 g of NH_4SCN is reacted with a slight excess of $Ba(OH)_2$. The reaction absorbs energy, cooling the 50.0 g of water from 21.9 °C to 10.9 °C.

(i) Calculate the energy absorbed, in kJ, during this reaction.

The specific heat capacity of water = 4.2 J g^{-1} K^{-1}.

[2]

(ii) Calculate the amount, in moles, of NH_4SCN used by the research chemist.

[1]

(iii) Calculate the enthalpy change of reaction.

Include the sign in your answer.

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

[3]

(c) Standard enthalpy changes of reaction can also be determined using average bond enthalpies.

(i) What is meant by the term *average bond enthalpy*? [2]

Table 3.1 below shows some average bond enthalpies.

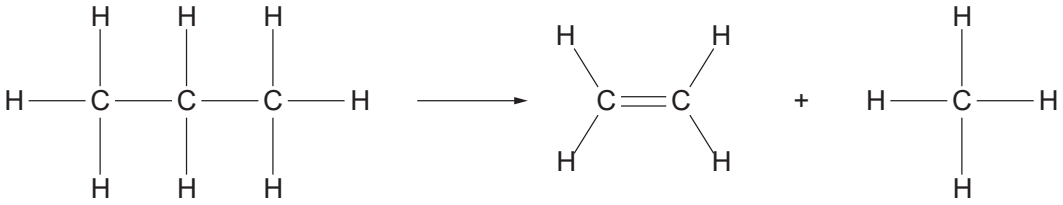
bond	average bond enthalpy / kJ mol^{-1}
C–H	+415
C–C	+345
C=C	+611

Table 3.1

(ii) Explain the bonding in a C=C double bond. Use the orbital overlap model. [2]

(iii) Suggest why the average bond enthalpy of a C=C bond is **not** twice the bond enthalpy of a C–C bond. [1]

(iv) Propane can be cracked to make ethene.



Using the average bond enthalpies in **Table 3.1**, calculate the enthalpy change of this reaction.

[2]

(v) The actual value for the enthalpy change of this reaction is +81 kJ mol^{-1}.

Suggest a reason why the actual value for the enthalpy change of this reaction is different from the calculated value. [1]

[Total: 16 Marks]

Glucose, $C_6H_{12}O_6$, can be completely combusted to give carbon dioxide and water.

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

(a) In the body, the conversion of glucose into carbon dioxide and water takes place in a number of stages catalysed by enzymes.

What name is given to this oxidation process in the body? [1]

(b) A student carries out an experiment to determine the enthalpy change of combustion of glucose.

In the experiment, 0.831 g of glucose is burned. The energy released is used to heat 100 cm^3 of water from 23.7 °C to 41.0 °C.

(i) Calculate the energy released, in kJ, during combustion of 0.831 g glucose.

The specific heat capacity of water = 4.18 $J\,g^{-1}\,K^{-1}$.
Density of water = 1.00 $g\,cm^{-3}$. [2]

(ii) Calculate the amount, in moles, of glucose that is burned. [2]

(iii) Calculate the enthalpy change of combustion of glucose.
Give your answer to **three** significant figures. [2]

(c) The standard enthalpy change of combustion of glucose can also be determined indirectly.

Calculate the standard enthalpy change of combustion of glucose using the standard enthalpy changes of formation below.

substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$C_6H_{12}O_6(s)$	–1250
$CO_2(g)$	–394
$H_2O(l)$	–286

$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ [3]

(d) Suggest **two** reasons why standard enthalpy changes of combustion determined experimentally are less exothermic than the calculated theoretical values. [2]

[Total 12 Marks]

This question is about energy changes and rate of reaction.

(a) Magnesium reacts with aqueous silver nitrate, $AgNO_3(aq)$, as in **equation 23.1**.

$$Mg(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Mg(NO_3)_2(aq) \qquad \textbf{Equation 23.1}$$

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

- The student adds 25.0 cm^3 of 0.512 mol dm^{-3} $AgNO_3$ 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 °C
Maximum temperature	= 47.5 °C

(i) Calculate $\Delta_r H$, in 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.

[4]

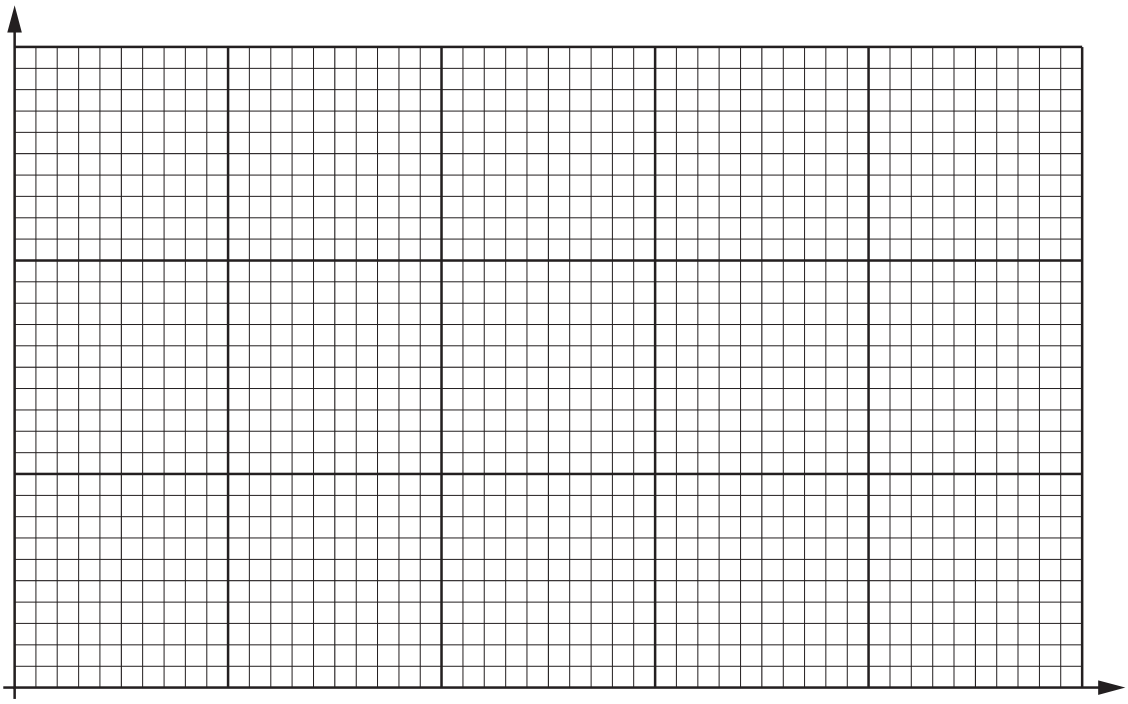
(ii) At the end of the experiment, the student adds a few drops of aqueous sodium chloride to the reaction mixture in the polystyrene cup to test whether all the aqueous silver nitrate has reacted.

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

[2]

(b) Using the Boltzmann distribution model, explain how the rate of a reaction is affected by temperature.

You are provided with the axes below, which should be labelled.



[4]

(Total 10 marks)