Enthalpy Changes
AS & A Level

Question Paper 3

Level	A Level
Subject	Chemistry
Exam Board	OCR
Module	Periodic Table & Energy
Topic	Enthalpy Changes
Paper	AS & A Level
Booklet	Question Paper 3

Time allowed: **77 minutes**

Score: **/57**

Percentage: **/100**

Grade Boundaries:

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

Alkanes are saturated hydrocarbons with the general formula C_nH_{2n+2}.

(a) A student carries out an experiment to measure the enthalpy change of combustion, $\Delta_c H$, of hexane.

The student finds that combustion of 1.29 g of hexane changes the temperature of 200 g of water from 20.5 °C to 65.5 °C.

(i) Calculate the enthalpy change of combustion, $\Delta_c H$, of hexane, in $kJ\,mol^{-1}$.

Give your final answer to an **appropriate** number of significant figures.

[4]

(ii) The calculated value of $\Delta_c H$ for hexane from this experiment is different from the data book value.

Suggest **two** reasons for this difference.

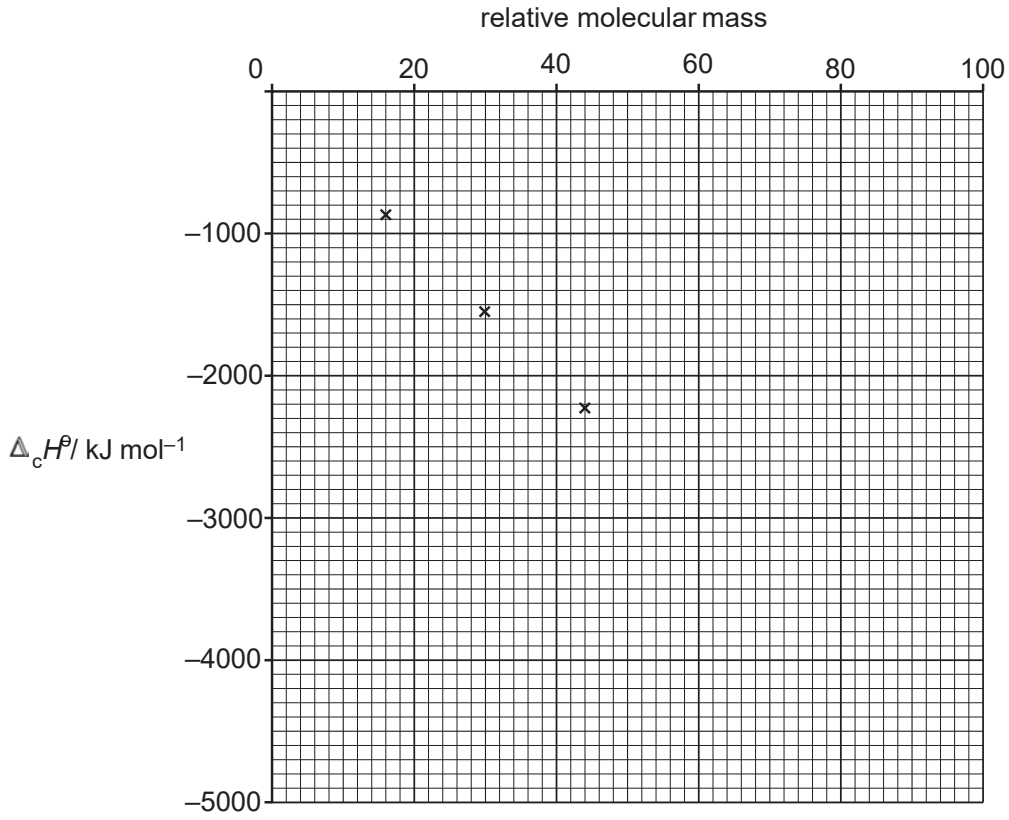
[2]

(b) Data book values for the standard enthalpy changes of combustion, $\Delta_c H^{\ominus}$, of the first four alkanes are shown in the table.

Alkane	methane	ethane	propane	butane
$\Delta_c H^{\ominus}$ **/ kJ mol^{-1}**	–890	–1560	–2219	–2877

(i) The values for the first three alkanes are plotted on the graph below.

Plot the value for butane on the graph.



[1]

(ii) Use the graph to estimate the energy released during complete combustion of 1.80 g of pentane.

Show relevant working below and on the graph. **[3]**

(c) The equation for the complete combustion of cyclohexane is shown below.

$$C_6H_{12}(l) + 9O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

Standard enthalpy changes of formation, $\Delta_f H^{\ominus}$, are shown in the table.

Substance	$C_6H_{12}(l)$	$CO_2(g)$	$H_2O(l)$
$\Delta_f H^{\ominus}$ **/ kJ mol^{-1}**	–156.3	–393.5	–285.8

Calculate the standard enthalpy change of combustion, $\Delta_c H^{\ominus}$, of cyclohexane.

[3]

(Total 13 marks)

Aqueous lead(II) nitrate, $Pb(NO_3)_2(aq)$, and aqueous potassium iodide, KI(aq), react together. The equation is shown below.

$$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$$

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

The student follows the method outlined below.

- Add 50.0 cm^3 of 1.50 mol dm^{-3} $Pb(NO_3)_2(aq)$ to a polystyrene cup.
- Measure out 50.0 cm^3 of a solution of KI(aq), which is in excess.
- Measure the temperature of both solutions.
- Add the KI(aq) to the polystyrene cup, stir the mixture and record the maximum temperature.

Temperature readings

Initial temperature of both solutions	= 19.5°C
Maximum temperature of mixture	= 30.0°C

(a) Calculate $\Delta_r H$, in kJ mol^{-1}, for the reaction shown in the equation above.

Give your answer to an **appropriate** number of significant figures.

Assume that the density of all solutions and specific heat capacity, *c*, of the reaction mixture is the same as for water.

[4]

(b) Write an ionic equation for the reaction that the student carries out.

Include state symbols.

[1]

(c) The 50.0 cm^3 of KI(aq) used in the experiment contains 10% more KI than is needed to react with 50.0 cm^3 of 1.50 mol dm^{-3} $Pb(NO_3)_2$(aq).

$$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$$

Calculate the concentration, in mol dm^{-3}, of KI that the student used.

[2]

(Total 7 marks)

This question is about different ways of determining enthalpy changes.

(a) A student carries out an experiment to determine directly the enthalpy change of reaction, $\otimes H_r$, shown below.

$$Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s)$$

- The student measures the initial temperature of 25.0 cm^3 of 0.500 $mol dm^{-3}$ $CuSO_4(aq)$.
- The student adds an excess of magnesium powder and stirs the mixture.
- The student measures the maximum temperature of the solution.

Results

Initial temperature of solution = 21.5°C
Maximum temperature of solution = 63.0°C

Density of the solution = 1.00 $g\,cm^{-3}$; specific heat capacity of the solution = 4.18 $J\,g^{-1}\,K^{-1}$.

(i) Calculate the enthalpy change of reaction, $\otimes H_r$, in $kJ\,mol^{-1}$.

Give your answer to **three** significant figures. [4]

(ii) The student weighed out enough magnesium so that it would be in excess by **at least** 25%. The student had access to a two decimal-place balance.

Calculate the minimum mass of magnesium that the student would need to weigh out on this balance. [1]

(b) Enthalpy changes of formation can be determined indirectly from standard enthalpy changes of combustion, $\otimes H_c^{\ominus}$.

Three enthalpy changes of combustion are shown below.

Substance	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
C(s)	–394
$H_2(g)$	–286
$C_9H_{20}(l)$	–6125

(i) Define *standard enthalpy change of combustion*.

Include the standard conditions that are used. [3]

(ii) The equation that represents the enthalpy change of formation, $\otimes H_f$, of nonane is shown below.

Calculate the standard enthalpy change of formation of nonane.

$$9C(s) + 10H_2(g) \longrightarrow C_9H_{20}(l)$$ [2]

(c) The bond enthalpy for the bond in carbon monoxide can be calculated from the information below.

$$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g) \qquad \otimes H = +210\,kJ\,mol^{-1}$$

Bond	Average bond enthalpy /kJ mol^{-1}
C–H	413
O–H	464
H–H	436

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

(ii) Calculate the bond enthalpy for the bond in carbon monoxide.

Show your working. [3]

[Total 15 Marks]

Phosphoric acid, H_3PO_4, can be manufactured by a two step process involving the reaction of phosphorus with oxygen, followed by a reaction with water.

$$P_4(s) + 5O_2(g) \longrightarrow P_4O_{10}(s) \qquad \Delta H_1 = -2984\ kJ\ mol^{-1}$$

$$P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(l) \qquad \Delta H_2$$

(a) Explain why ΔH_1 represents the enthalpy change of formation of P_4O_{10}. [2]

(b) Enthalpy changes of formation are shown in the table below.

Substance	Enthalpy change of formation, ΔH_f / kJ mol^{-1}
$P_4O_{10}(s)$	–2984
$H_2O(l)$	–286
$H_3PO_4(l)$	–1267

Calculate the enthalpy change of reaction, ΔH_2 [3]

(c) Write the overall equation for the manufacture of H_3PO_4 from P_4.

Use this equation to explain why this process has a 100% atom economy. [2]

[Total 7 Marks]

Methanol can be manufactured by the reaction of carbon dioxide with hydrogen.

$$3H_2(g) + CO_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \quad \textbf{equation 4.1}$$

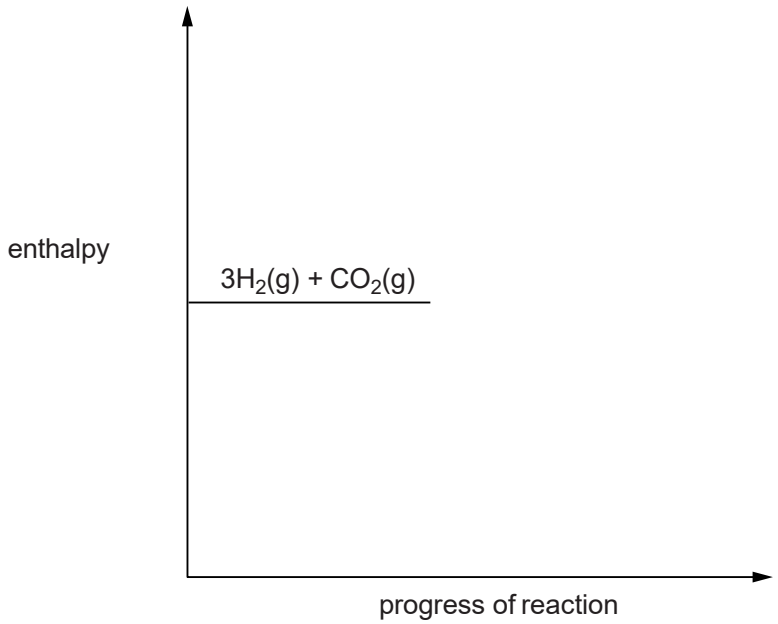
In this reaction, 49.0 kJ of energy are released when 3 moles of H_2 react completely. This enthalpy change is called the enthalpy change of reaction, ΔH_r,

(a) Calculate the energy released when 1000 dm^3 of hydrogen, measured at room temperature and pressure, react completely with carbon dioxide.

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

(b) Complete the enthalpy profile diagram for the forward reaction.

Label the activation energy, E_a, and the enthalpy change, ΔH_r, [3]



(c) What is the enthalpy change of reaction for the **reverse** reaction? [1]

(d) A scientist estimates the activation energy for the forward reaction as +225 kJ mol^{-1}.

Using this information, estimate the activation energy of the **reverse** reaction. [1]

(e) The temperature of the equilibrium mixture in **equation 4.1** is **increased**.

Describe and explain what happens to the position of equilibrium. [2]

(f) The total pressure of the equilibrium mixture in **equation 4.1** is **decreased**.

Describe and explain what happens to the position of equilibrium. [2]

(g) The reaction uses a solid catalyst. This catalyst functions in a similar way to the catalyst used in catalytic converters.

Outline the stages that allow H_2 to react with CO_2 in the presence of a solid catalyst. [3]

[Total 15 Marks]