

Application of Hess's Law

Question Paper 2

Level	A Level
Subject	Chemistry
Exam Board	AQA
Module	3.1 Physical Chemistry
Topic	3.1.4 Energetics
Sub-Topic	3.1.4.3 Application of Hess's Law
Booklet	Question Paper 2

Time Allowed: 59 minutes

Score: /57

Percentage: /100

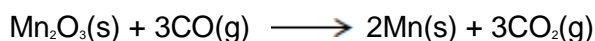
Grade Boundaries:

A*	A	B	C	D	E	U
>85%	75%	70%	60%	55%	50%	<50%

Q1. This question is about the extraction of metals.

- (a) Manganese can be extracted from Mn_2O_3 by reduction with carbon monoxide at high temperature.
- (i) Use the standard enthalpy of formation data from the table and the equation for the extraction of manganese to calculate a value for the standard enthalpy change of this extraction.

	$\text{Mn}_2\text{O}_3(\text{s})$	$\text{CO}(\text{g})$	$\text{Mn}(\text{s})$	$\text{CO}_2(\text{g})$
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-971	-111	0	-394



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(3)

- (ii) State why the value for the standard enthalpy of formation of $\text{Mn}(\text{s})$ is zero.

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(1)

- (b) Titanium is extracted in industry from titanium(IV) oxide in a two-stage process.

- (i) Write an equation for the first stage of this extraction in which titanium(IV) oxide is converted into titanium(IV) chloride.

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(2)

- (ii) Write an equation for the second stage of this extraction in which titanium(IV)

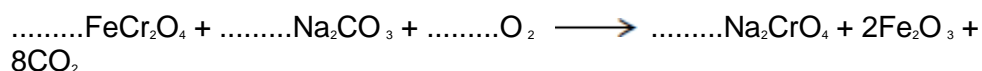
chloride is converted into titanium.

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(2)

(c) Chromium is extracted in industry from chromite (FeCr_2O_4).

(i) In the first stage of this extraction, the FeCr_2O_4 is converted into Na_2CrO_4 . Balance the equation for this reaction.



(1)

(ii) In the final stage, chromium is extracted from Cr_2O_3 by reduction with aluminium.

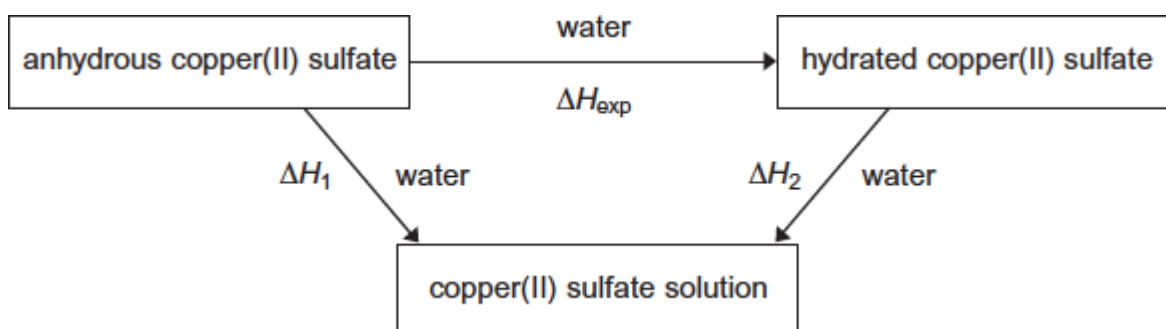
Write an equation for this reaction.

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(1)

(Total 10 marks)

Q2.A A student used Hess's Law to determine a value for the enthalpy change that occurs when anhydrous copper(II) sulfate is hydrated. This enthalpy change was labelled ΔH_{exp} by the student in a scheme of reactions.



(a) State Hess's Law.

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(1)

- (b) Write a mathematical expression to show how ΔH_{exp} , ΔH_1 and ΔH_2 are related to each other by Hess's Law.

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(1)

- (c) Use the mathematical expression that you have written in part (b), and the data book values for the two enthalpy changes ΔH_1 and ΔH_2 shown, to calculate a value for ΔH_{exp}

$$\Delta H_1 = -156 \text{ kJ mol}^{-1}$$
$$\Delta H_2 = +12 \text{ kJ mol}^{-1}$$

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(1)

- (d) The student added 0.0210 mol of pure anhydrous copper(II) sulfate to 25.0 cm³ of deionised water in an open polystyrene cup. An exothermic reaction occurred and the temperature of the water increased by 14.0 °C.

- (i) Use these data to calculate the enthalpy change, in kJ mol⁻¹, for this reaction of copper(II) sulfate. This is the student value for ΔH_1

In this experiment, you should assume that all of the heat released is used to raise the temperature of the 25.0 g of water. The specific heat capacity of water is 4.18 J K⁻¹ g⁻¹.

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(3)

- (ii) Suggest **one** reason why the student value for ΔH_f calculated in part (d)(i) is less accurate than the data book value given in part (c).

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(1)

- (e) Suggest **one** reason why the value for ΔH_{exp} **cannot** be measured directly.

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(1)

(Total 8 marks)

Q3.(a) Iron is extracted from iron(III) oxide using carbon at a high temperature.

- (i) State the type of reaction that iron(III) oxide undergoes in this extraction.

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(1)

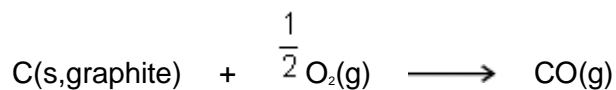
- (ii) Write a half-equation for the reaction of the iron(III) ions in this extraction.

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(1)

(b) At a high temperature, carbon undergoes combustion when it reacts with oxygen.

- (i) Suggest why it is **not** possible to measure the enthalpy change directly for the following combustion reaction.



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(1)

(ii) State Hess's Law.

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(1)

(iii) State the meaning of the term *standard enthalpy of combustion*.

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(Extra space)

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(3)

(c) Use the standard enthalpies of formation in the table below and the equation to calculate a value for the standard enthalpy change for the extraction of iron using carbon monoxide.

	Fe ₂ O ₃ (s)	CO(g)	Fe(l)	CO ₂ (g)
ΔH/ kJ mol ⁻¹	- 822	- 111	+14	- 394



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(3)

- (d) (i) Write an equation for the reaction that represents the standard enthalpy of formation of carbon dioxide.

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(1)

- (ii) State why the value quoted in part (c) for the standard enthalpy of formation of $\text{CO}_2(\text{g})$ is the same as the value for the standard enthalpy of combustion of carbon.

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(1)

(Total 12 marks)

Q4. This question is about bond dissociation enthalpies and their use in the calculation of enthalpy changes.

- (a) Define *bond dissociation enthalpy* as applied to chlorine.

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(2)

- (b) Explain why the enthalpy of atomisation of chlorine is exactly half the bond dissociation enthalpy of chlorine.

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(1)

- (c) The bond dissociation enthalpy for chlorine is $+242 \text{ kJ mol}^{-1}$ and that for fluorine is $+158 \text{ kJ mol}^{-1}$. The standard enthalpy of formation of $\text{ClF}(\text{g})$ is -56 kJ mol^{-1} .

- (i) Write an equation, including state symbols, for the reaction that has an enthalpy change equal to the standard enthalpy of formation of gaseous ClF

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(1)

- (ii) Calculate a value for the bond enthalpy of the Cl – F bond.

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(2)

- (iii) Calculate the enthalpy of formation of gaseous chlorine trifluoride, $\text{ClF}_3(\text{g})$. Use the bond enthalpy value that you obtained in part (c)(ii).

(If you have been unable to obtain an answer to part (c)(ii), you may assume that the Cl – F bond enthalpy is $+223 \text{ kJ mol}^{-1}$. This is **not** the correct value.)

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(3)

- (iv) Explain why the enthalpy of formation of $\text{ClF}_3(\text{g})$ that you calculated in part (c)(iii) is likely to be different from a data book value.

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(1)

- (d) Suggest why a value for the Na – Cl bond enthalpy is **not** found in any data book.

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(1)

(Total 11 marks)

Q5. Methanol (CH_3OH) is an important fuel that can be synthesised from carbon dioxide.

- (a) The table shows some standard enthalpies of formation.

	$\text{CO}_2(\text{g})$	$\text{H}_2(\text{g})$	$\text{CH}_3\text{OH}(\text{g})$	$\text{H}_2\text{O}(\text{g})$
$\Delta H_f^\ominus/\text{kJ mol}^{-1}$	– 394	0	– 201	– 242

- (i) Use these standard enthalpies of formation to calculate a value for the standard enthalpy change of this synthesis.



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(3)

(ii) State why the standard enthalpy of formation for hydrogen gas is zero.

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(1)

(b) State and explain what happens to the yield of methanol when the total pressure is increased in this synthesis.



Effect on yield

Explanation

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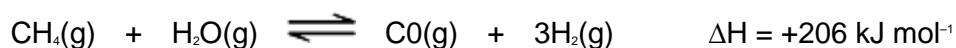
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(3)

(c) The hydrogen required for this synthesis is formed from methane and steam in a

reversible reaction. The equation for this reaction is shown below.



State and explain what happens to the yield of hydrogen in this reaction when the temperature is increased.

Effect on yield

Explanation

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(Extra space)

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(3)

(d) The methanol produced by this synthesis has been described as a carbon-neutral fuel.

(i) State the meaning of the term *carbon-neutral*.

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(Extra space)

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(1)

(ii) Write an equation for the complete combustion of methanol.

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(1)

(iii) The equation for the synthesis of methanol is shown below.



Use this equation and your answer to part (d)(ii) to deduce an equation to represent the overall chemical change that occurs when methanol behaves as a carbon-neutral fuel.

Equation

(1)

(e) A student carried out an experiment to determine the enthalpy change when a sample of methanol was burned.

The student found that the temperature of 140 g of water increased by 7.5 °C when 0.011 mol of methanol was burned in air and the heat produced was used to warm the water.

Use the student's results to calculate a value, in kJ mol⁻¹, for the enthalpy change when one mole of methanol was burned.
(The specific heat capacity of water is 4.18 J K⁻¹ g⁻¹).

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(3)

(Total 16 marks)

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