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.

	$Mn_2O_3(s)$	$CO(g)$	$Mn(s)$	$CO_2(g)$
$\Delta H_f^\ominus$ / kJ mol^{-1}	−971	−111	0	−394

$$Mn_2O_3(s) + 3CO(g) \longrightarrow 2Mn(s) + 3CO_2(g)$$

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(3)

(ii) State why the value for the standard enthalpy of formation of Mn(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.

.........$FeCr_2O_4$ + ...Na_2CO_3 + ...O_2 $\longrightarrow$ ....Na_2CrO_4 + $2Fe_2O_3$ +
$8CO_2$

(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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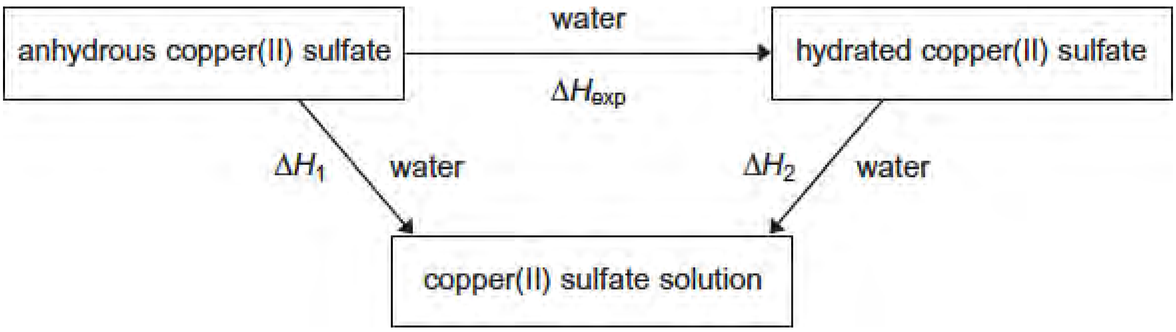
(1)
(Total 10 marks)

Q2. A 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}

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

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(1)

(d) The student added 0.0210 mol of pure anhydrous copper(II) sulfate to 25.0 cm^3 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_1 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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(Extra space) ....

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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.

$$C(s,graphite) + \frac{1}{2}O_2(g) \longrightarrow CO(g)$$

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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) ....

.... **(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.

	$Fe_2O_3(s)$	$CO(g)$	$Fe(l)$	$CO_2(g)$
ΔH_f / kJ mol^{-1}	- 822	- 111	+14	- 394

$$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(l) + 3CO_2(g)$$

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(Extra space) ....

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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 $CO_2(g)$ 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 kJ mol^{-1} and that for fluorine is +158 kJ mol^{-1}. The standard enthalpy of formation of ClF(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, ClF_3(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 kJ mol^{-1}. This is **not** the correct value.)

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(3)

(iv) Explain why the enthalpy of formation of $ClF_3(g)$ 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.

	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
$\Delta H_f^\ominus$/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.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

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(Extra space) ....

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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.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Effect on yield ....

Explanation ....

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(Extra space) ....

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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.

$$CH_4(g) \quad + \quad H_2O(g) \rightleftharpoons C0(g) \quad + \quad 3H_2(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

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.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

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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(Extra space) ....

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(3)
(Total 16 marks)