Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2010

Chemistry CHEM5

Unit 5 Energetics, Redox and Inorganic Chemistry

Monday 28 June 2010 9.00 am to 10.45 am

For this paper you must have:
- the Periodic Table/Data Sheet provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use accurate scientific terminology.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

Section A

Answer **all** questions in the spaces provided.

1 Calcium fluoride occurs naturally as the mineral fluorite, a very hard crystalline solid that is almost insoluble in water and is used as a gemstone.

Tables 1 and **2** contain thermodynamic data.

Table 1

Process	$\Delta H^\ominus$/ kJ mol^{-1}
$Ca(s) \rightarrow Ca(g)$	+193
$Ca(g) \rightarrow Ca^{+}(g) + e^{-}$	+590
$Ca^{+}(g) \rightarrow Ca^{2+}(g) + e^{-}$	+1150
$F_2(g) \rightarrow 2F(g)$	+158
$F(g) + e^{-} \rightarrow F^{-}(g)$	–348

Table 2

Name of enthalpy change	$\Delta H^\ominus$/ kJ mol^{-1}
Enthalpy of lattice dissociation for calcium fluoride	+2602
Enthalpy of lattice dissociation for calcium chloride	+2237
Enthalpy of hydration for F^{-} ions	–506
Enthalpy of hydration for Cl^{-} ions	–364
Enthalpy of hydration for Ca^{2+} ions	–1650

1 (a) Write an equation, including state symbols, for the process that occurs when the calcium fluoride lattice dissociates and for which the enthalpy change is equal to the lattice enthalpy.

....

(1 mark)

Do not write outside the box

1 (b) (i) Define the term *standard enthalpy of formation*.

....

....

....

....

(3 marks)

(Extra space) ....

....

....

1 (b) (ii) Write an equation, including state symbols, for the process that has an enthalpy change equal to the standard enthalpy of formation of calcium fluoride.

....

(1 mark)

1 (b) (iii) Use data from the **Tables 1** and **2** to calculate the standard enthalpy of formation for calcium fluoride.

....

....

....

....

....

....

(3 marks)

(Extra space) ....

....

....

Question 1 continues on the next page

Do not write outside the box

1 (c) Explain why the enthalpy of lattice dissociation for calcium fluoride is greater than that for calcium chloride.

....

....

....

....

(2 marks)

1 (d) Calcium chloride dissolves in water. After a certain amount has dissolved, a saturated solution is formed and the following equilibrium is established.

$$CaCl_2(s) \rightleftharpoons Ca^{2+}(aq) + 2Cl^{-}(aq)$$

1 (d) (i) Using data from **Table 2**, calculate the enthalpy change for this reaction.

....

....

....

....

....

....

(2 marks)

1 (d) (ii) Predict whether raising the temperature will increase, decrease or have no effect on the amount of solid calcium chloride that can dissolve in a fixed mass of water.
Explain your prediction.
(If you have been unable to obtain an answer to part **(d) (i)**, you may assume that the enthalpy change = $-60\,\text{kJ mol}^{-1}$. This is **not** the correct answer.)

Effect on amount of solid that can dissolve ....

Explanation ....

....

....

....

(3 marks)

Do not write outside the box

1 (e) Calcium fluoride crystals absorb ultra-violet light. Some of the energy gained is given out as visible light. The name of this process, fluorescence, comes from the name of the mineral, fluorite.

Use your knowledge of the equation $\Delta E = h\nu$ to suggest what happens to the electrons in fluorite when ultra-violet light is absorbed and when visible light is given out.

....

....

....

....

(2 marks)

(Extra space) ....

....

17

Turn over for the next question

Turn over ▶

2 Sodium, aluminium and silicon are solid elements with a silver colour. These elements react with oxygen to form oxides with high melting points. Aluminium is a reactive metal, but it resists corrosion in water because it has a surface coating of aluminium oxide.

2 (a) In terms of its structure and bonding, explain why silicon dioxide has a high melting point.

....

....

....

(3 marks)

(Extra space) ....

....

....

2 (b) State the type of bonding in aluminium oxide.

....

(1 mark)

2 (c) Write an equation for the reaction of aluminium with oxygen.

....

(1 mark)

2 (d) Suggest **one** property of the aluminium oxide coating that causes aluminium to resist corrosion in water.

....

(1 mark)

2 (e) Sodium metal is **not** resistant to corrosion in water, despite having a surface coating of sodium oxide. Write an equation to show how sodium oxide reacts with water.

....

(1 mark)

Do not write outside the box

2 (f) Aluminium oxide is amphoteric. It reacts with acids and alkalis.

2 (f) (i) Write an equation for the reaction between aluminium oxide and hydrochloric acid.

....

(1 mark)

2 (f) (ii) Write an equation for the reaction between aluminium oxide and an excess of aqueous sodium hydroxide.

....

(1 mark)

2 (g) Silicon dioxide does **not** react with hydrochloric acid but it does react with sodium hydroxide. State **one** property of silicon dioxide that can be deduced from this information and write an equation for its reaction with sodium hydroxide.

Property ....

Equation ....

(2 marks)

11

Turn over for the next question

3 Transition metal ions can act as homogeneous catalysts in redox reactions. For example, iron(II) ions catalyse the reaction between peroxodisulfate ($S_2O_8^{2-}$) ions and iodide ions.

3 (a) State the meaning of the term *homogeneous*.

....

(1 mark)

3 (b) Suggest why ions from s block elements do **not** usually act as catalysts.

....

....

(1 mark)

3 (c) Write an equation for the overall reaction that occurs, in aqueous solution, between $S_2O_8^{2-}$ ions and I^- ions.

....

(1 mark)

3 (d) Give **one** reason why, in the absence of a catalyst, the activation energy for the reaction between $S_2O_8^{2-}$ ions and I^- ions is high.

....

....

(1 mark)

3 (e) Write two equations to show how Fe^{2+} ions can catalyse the reaction between $S_2O_8^{2-}$ ions and I^- ions. Suggest **one** reason why the activation energy for each of these reactions is low.

Equation 1 ....

Equation 2 ....

Reason ....

....

(3 marks)

Do not write outside the box

3 (f) Explain why Fe^{3+} ions are as effective as Fe^{2+} ions in catalysing this reaction.

....

....

(1 mark)

8

Turn over for the next question

Do not write outside the box

4 Transition elements form complex ions with a range of colours and shapes.

4 (a) By considering its electron arrangement, state how an element can be classified as a transition element.

....

....

(1 mark)

4 (b) Explain the meaning of the term *complex ion*.

....

....

....

(2 marks)

4 (c) In terms of electrons, explain why an aqueous solution of cobalt(II) sulfate has a red colour.

....

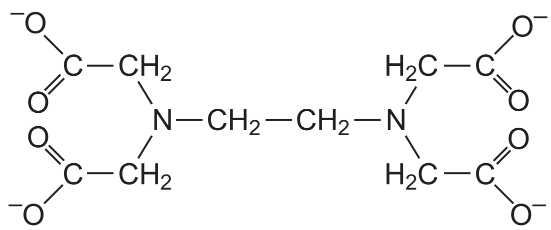
....

....

....

(3 marks)

4 (d) The ligand $EDTA^{4-}$ is shown below.



4 (d) (i) Draw circles around the atoms of **two** different elements that link to a transition metal ion by a co-ordinate bond when $EDTA^{4-}$ behaves as a ligand.

(2 marks)

4 (d) (ii) Write an equation for the reaction between $EDTA^{4-}$ and a $[Co(H_2O)_6]^{2+}$ ion. Use the abbreviation $EDTA^{4-}$ in your equation.

....

(1 mark)

Do not write outside the box

4 (d) (iii) Explain why the complex ion, formed as a product of the reaction in part **(d) (ii)**, is more stable than the $[Co(H_2O)_6]^{2+}$ ion.

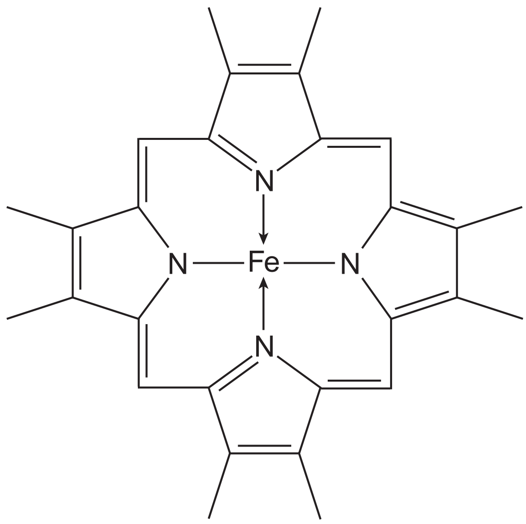
....

....

....

(2 marks)

4 (e) The diagram below shows part of the structure of haemoglobin.



Haemoglobin contains an iron(II) ion bonded to five nitrogen atoms and one other ligand. The fifth nitrogen atom and the additional ligand are not shown in this diagram.

4 (e) (i) In this diagram, bonds between nitrogen and iron are shown as N→Fe and as N—Fe. State the meaning of each of these symbols.

Meaning of → ....

Meaning of — ....

(2 marks)

4 (e) (ii) State the function of haemoglobin in the blood.

....

(1 mark)

4 (e) (iii) With reference to haemoglobin, explain why carbon monoxide is toxic.

....

....

....

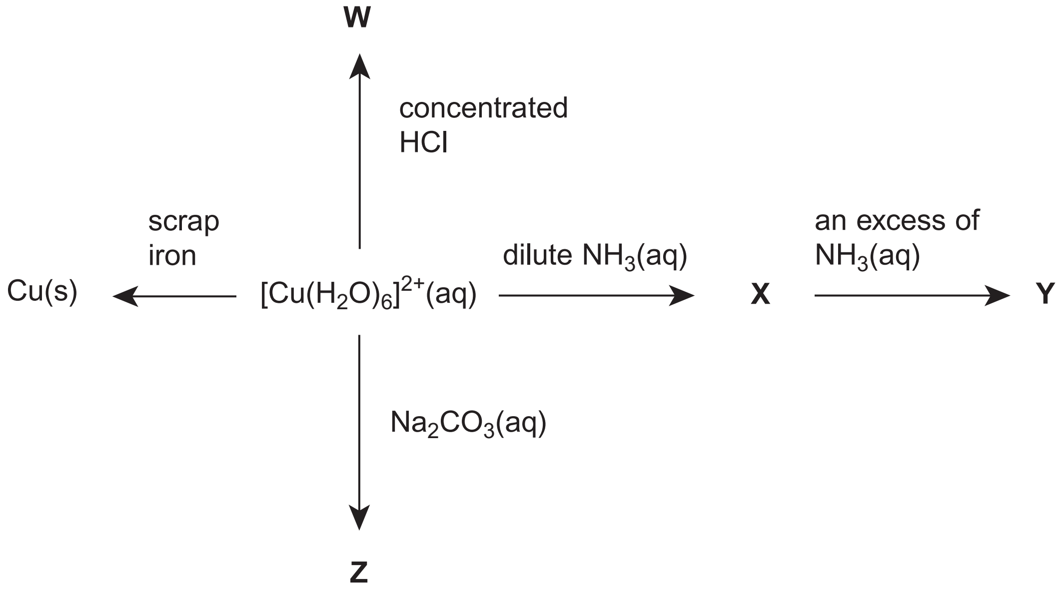
(2 marks)

16

Turn over ▶

Do not write outside the box

5 The scheme below shows some reactions of copper(II) ions in aqueous solution.
W, **X**, **Y** and **Z** are all copper-containing species.



5 (a) Identify ion **W**. Describe its appearance and write an equation for its formation from $[Cu(H_2O)_6]^{2+}(aq)$ ions.

Ion **W** ....

Appearance ....

Equation ....

(3 marks)

5 (b) Identify compound **X**. Describe its appearance and write an equation for its formation from $[Cu(H_2O)_6]^{2+}(aq)$ ions.

Compound **X**..

Appearance ....

Equation ....

(3 marks)

Do not write outside the box

5 (c) Identify ion **Y**. Describe its appearance and write an equation for its formation from **X**.

Ion **Y** ....

Appearance ....

Equation ....

(3 marks)

5 (d) Identify compound **Z**. Describe its appearance and write an equation for its formation from $[Cu(H_2O)_6]^{2+}(aq)$ ions.

Compound **Z**..

Appearance ....

Equation ....

(3 marks)

5 (e) Copper metal can be extracted from a dilute aqueous solution containing copper(II) ions using scrap iron.

5 (e) (i) Write an equation for this reaction and give the colours of the initial and final aqueous solutions.

Equation ....

Initial colour ....

Final colour ....

(3 marks)

5 (e) (ii) This method of copper extraction uses scrap iron. Give **two** other reasons why this method of copper extraction is more environmentally friendly than reduction of copper oxide by carbon.

Reason 1 ....

Reason 2 ....

(2 marks)

17

Turn over ▶

Section B

Answer **all** questions in the spaces provided.

6 Methanol can be regarded as a carbon-neutral fuel because it can be synthesised from carbon dioxide as shown in the equation below.

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

Standard enthalpy of formation and standard entropy data for the starting materials and products are shown in the following table.

	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
$\Delta H_f^{\ominus}$/ kJ mol^{-1}	–394	0	–201	–242
$S^{\ominus}$/ J K^{-1} mol^{-1}	214	131	238	189

6 (a) Calculate the standard enthalpy change for this reaction.

....

....

....

....

....

....

(3 marks)

6 (b) Calculate the standard entropy change for this reaction.

....

....

....

....

....

....

(3 marks)

Do not write outside the box

6 (c) Use your answers to parts **(a)** and **(b)** to explain why this reaction is **not** feasible at high temperatures.

Calculate the temperature at which the reaction becomes feasible.

Suggest why the industrial process is carried out at a higher temperature than you have calculated.

(If you have been unable to calculate values for ΔH and ΔS you may assume that they are –61 kJ mol^{-1} and –205 J K^{-1} mol^{-1} respectively. These are **not** the correct values.)

....

....

....

....

....

....

....

....

....

....

....

....

(6 marks)

(Extra space) ....

....

....

Question 6 continues on the next page

Turn over ▶

Do not write outside the box

6 (d) Write an equation for the complete combustion of methanol. Use your equation to explain why the combustion reaction in the gas phase is feasible at all temperatures.

....

....

....

....

....

....

....

....

(4 marks)

(Extra space) ....

....

....

....

6 (e) Give **one** reason why methanol, synthesised from carbon dioxide and hydrogen, may **not** be a carbon-neutral fuel.

....

....

....

(1 mark)

17

Turn over for the next question

Turn over ▶

Do not write outside the box

7 The electrons transferred in redox reactions can be used by electrochemical cells to provide energy.

Some electrode half-equations and their standard electrode potentials are shown in the table below.

Half-equation	***E*[⊖]/ V**
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Li^+(aq) + e^- \rightarrow Li(s)$	–3.04

7 (a) Describe a standard hydrogen electrode.

....

....

....

....

....

....

....

....

(4 marks)

Do not write outside the box

7 (b) A conventional representation of a lithium cell is given below.
This cell has an e.m.f. of +2.91 V

$$Li(s)\ |\ Li^+(aq)\ ||\ Li^+(aq)\ |\ MnO_2(s)\ ,\ LiMnO_2(s)\ |\ Pt(s)$$

Write a half-equation for the reaction that occurs at the positive electrode of this cell.

Calculate the standard electrode potential of this positive electrode.

....

....

....

....

....

....

(2 marks)

7 (c) Suggest what reactions occur, if any, when hydrogen gas is bubbled into a solution containing a mixture of iron(II) and iron(III) ions. Explain your answer.

....

....

....

....

(2 marks)

Question 7 continues on the next page

Do not write outside the box

7 (d) A solution of iron(II) sulfate was prepared by dissolving 10.00 g of $FeSO_4.7H_2O$ (M_r = 277.9) in water and making up to 250 cm^3 of solution. The solution was left to stand, exposed to air, and some of the iron(II) ions became oxidised to iron(III) ions. A 25.0 cm^3 sample of the partially oxidised solution required 23.70 cm^3 of 0.0100 mol dm^{-3} potassium dichromate(VI) solution for complete reaction in the presence of an excess of dilute sulfuric acid.

Calculate the percentage of iron(II) ions that had been oxidised by the air.

....

....

....

....

....

....

....

....

....

....

....

....

(6 marks)

(Extra space) ....

....

....

....

14

END OF QUESTIONS