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	
8	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2011

Chemistry CHEM5

Unit 5 Energetics, Redox and Inorganic Chemistry

Friday 24 June 2011 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 70 minutes on **Section A** and about 35 minutes on **Section B**.

Section A

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

1 Thermodynamics can be used to investigate the changes that occur when substances such as calcium fluoride dissolve in water.

1 (a) Give the meaning of each of the following terms.

1 (a) (i) enthalpy of lattice formation for calcium fluoride

.....

.....

.....

.....

(2 marks)

1 (a) (ii) enthalpy of hydration for fluoride ions

.....

.....

.....

(1 mark)

1 (b) Explain the interactions between water molecules and fluoride ions when the fluoride ions become hydrated.

.....

.....

.....

.....

(2 marks)

1 (c) Consider the following data.

	$\Delta H^{\ominus}$/ kJ mol^{-1}
Enthalpy of lattice formation for CaF_2	–2611
Enthalpy of hydration for Ca^{2+} ions	–1650
Enthalpy of hydration for F^- ions	–506

Use these data to calculate a value for the enthalpy of solution for CaF_2

.....

.....

.....

.....

(2 marks)

7

Turn over for the next question

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

2 When potassium nitrate (KNO_3) dissolves in water the value of the enthalpy change ΔH = +34.9 kJ mol^{-1} and the value of the entropy change ΔS = +117 J K^{-1} mol^{-1}.

2 (a) Write an equation, including state symbols, for the process that occurs when potassium nitrate dissolves in water.

.....

(1 mark)

2 (b) Suggest why the entropy change for this process is positive.

.....

.....

(1 mark)

2 (c) Calculate the temperature at which the free-energy change, ΔG, for this process is zero.

.....

.....

.....

.....

.....

.....

(3 marks)

2 (d) (i) Deduce what happens to the value of ΔG when potassium nitrate dissolves in water at a temperature lower than your answer to part **2 (c)**.

.....

.....

(1 mark)

2 (d) (ii) What does this new value of ΔG suggest about the dissolving of potassium nitrate at this lower temperature?

.....

.....

(1 mark)

7

Turn over ▶

3 Ammonia can be manufactured by the Haber Process.

The equation for the reaction that occurs is shown below.

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

3 (a) The table below contains some bond enthalpy data.

	N≡N	H—H	N—H
Mean bond enthalpy / kJ mol^{-1}	944	436	388

3 (a) (i) Use data from the table to calculate a value for the enthalpy of formation for one mole of ammonia.

.....

.....

.....

.....

.....

.....

(3 marks)

3 (a) (ii) A more accurate value for the enthalpy of formation of ammonia is –46 kJ mol^{-1}. Suggest why your answer to part **3 (a) (i)** is different from this value.

.....

.....

(1 mark)

3 (b) The table below contains some entropy data.

	$H_2(g)$	$N_2(g)$	$NH_3(g)$
$S^{\ominus}$ / J K^{-1} mol^{-1}	131	192	193

Use these data to calculate a value for the entropy change, with units, for the formation of one mole of ammonia from its elements.

.....

.....

.....

.....

.....

(3 marks)

3 (c) The synthesis of ammonia is usually carried out at about 800 K.

3 (c) (i) Use the ΔH value of -46 kJ mol^{-1} and your answer from part **3 (b)** to calculate a value for ΔG, with units, for the synthesis at this temperature.
(If you have been unable to obtain an answer to part **3 (b)**, you may assume that the entropy change is –112 J K^{-1} mol $^{-1}$. This is not the correct answer.)

.....

.....

.....

.....

.....

.....

(3 marks)

3 (c) (ii) Use the value of ΔG that you have obtained to comment on the feasibility of the reaction at 800 K.

.....

(1 mark)

11

Turn over ▶

4 This question is about the chemistry of the Period 3 elements and the trends in their properties.

4 (a) (i) Describe what you would observe when magnesium burns in oxygen. Write an equation for the reaction that occurs. State the type of bonding in the oxide formed.

Observations .....

.....

.....

.....

Equation .....

Type of bonding .....

(4 marks)

4 (a) (ii) Describe what you would observe when sulfur burns in oxygen. Write an equation for the reaction that occurs. State the type of bonding in the oxide formed.

Observations .....

.....

.....

.....

Equation .....

Type of bonding .....

(4 marks)

4 (b) State the type of bonding in sodium oxide. Explain why sodium oxide reacts to form an alkaline solution when added to water.

Type of bonding.....

Explanation.....

.....

.....

.....

(3 marks)

4 (c) Outline an experiment that could be used to show that aluminium oxide contains ions.

.....

.....

.....

(2 marks)

(Extra space) .....

.....

4 (d) Suggest **one** reason why a thin layer of aluminium oxide protects aluminium from corrosion in moist air.

.....

.....

(1 mark)

4 (e) Write an ionic equation in each case to show how aluminium oxide reacts with the following

4 (e) (i) hydrochloric acid

.....

(1 mark)

4 (e) (ii) aqueous sodium hydroxide.

.....

(1 mark)

16

Turn over for the next question

5 Redox reactions occur in the discharge of all electrochemical cells. Some of these cells are of commercial value.
The table below shows some redox half-equations and standard electrode potentials.

Half-equation	$E^{\ominus}$ / V
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	–0.76
$Ag_2O(s) + 2H^+(aq) + 2e^- \longrightarrow 2Ag(s) + H_2O(l)$	+0.34
$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O(l)$	+1.23
$F_2(g) + 2e^- \longrightarrow 2F^-(aq)$	+2.87

5 (a) In terms of electrons, state what happens to a reducing agent in a redox reaction.

.....

(1 mark)

5 (b) Use the table above to identify the strongest reducing agent from the species in the table.

Explain how you deduced your answer.

Strongest reducing agent .....

Explanation .....

.....

(2 marks)

5 (c) Use data from the table to explain why fluorine reacts with water.
Write an equation for the reaction that occurs.

Explanation .....

.....

.....

Equation .....

.....

(3 marks)

5 (d) An electrochemical cell can be constructed using a zinc electrode and an electrode in which silver is in contact with silver oxide. This cell can be used to power electronic devices.

5 (d) (i) Give the conventional representation for this cell.

.....

(2 marks)

5 (d) (ii) Calculate the e.m.f. of the cell.

.....

(1 mark)

5 (d) (iii) Suggest **one** reason why the cell cannot be electrically recharged.

.....

.....

(1 mark)

5 (e) The electrode half-equations in a lead–acid cell are shown in the table below.

Half-equation	$E^{\ominus}$ / V
$PbO_2(s) + 3H^+(aq) + HSO_4^-(aq) + 2e^- \longrightarrow PbSO_4(s) + 2H_2O(l)$	+1.69
$PbSO_4(s) + H^+(aq) + 2e^- \longrightarrow Pb(s) + HSO_4^-(aq)$	to be calculated

5 (e) (i) The $PbO_2/PbSO_4$ electrode is the positive terminal of the cell and the e.m.f. of the cell is 2.15 V.

Use this information to calculate the missing electrode potential for the half-equation shown in the table.

.....

.....

(1 mark)

5 (e) (ii) A lead–acid cell can be recharged.
Write an equation for the overall reaction that occurs when the cell is being recharged.

.....

.....

.....

.....

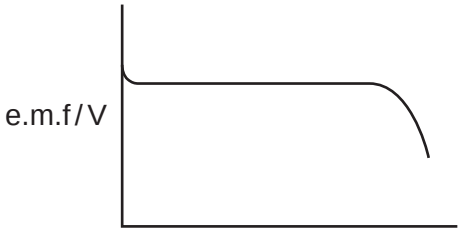
(2 marks)

Question 5 continues on the next page

Turn over ▶

5 (f) The diagrams below show how the e.m.f. of each of two cells changes with time when each cell is used to provide an electric current.

Lead–acid cell



Cell X

5 (f) (i) Give **one** reason why the e.m.f. of the **lead–acid cell** changes after several hours.

.....

.....

(1 mark)

5 (f) (ii) Identify the type of cell that behaves like **cell X**.

.....

(1 mark)

5 (f) (iii) Explain why the voltage remains constant in **cell X**.

.....

.....

.....

(2 marks)

(Extra space) .....

.....

17

6 Transition metals and their complexes have characteristic properties.

6 (a) Give the electron configuration of the Zn^{2+} ion.
Use your answer to explain why the Zn^{2+} ion is **not** classified as a transition metal ion.

Electron configuration .....

Explanation .....

.....

(2 marks)

6 (b) In terms of bonding, explain the meaning of the term *complex*.

.....

.....

.....

.....

(2 marks)

6 (c) Identify **one** species from the following list that does **not** act as a ligand. Explain your answer.

H_2 O^{2-} O_2 CO

Not a ligand .....

Explanation .....

(2 marks)

6 (d) The element palladium is in the d block of the Periodic Table. Consider the following palladium compound which contains the sulfate ion.

$[Pd(NH_3)_4]SO_4$

6 (d) (i) Give the oxidation state of palladium in this compound.

.....

(1 mark)

6 (d) (ii) Give the names of two possible shapes for the complex palladium ion in this compound.

Shape 1 .....

Shape 2 .....

(2 marks)

9

Section B

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

7 This question is about copper chemistry.

7 (a) Aqueous copper(II) ions $[Cu(H_2O)_6]^{2+}(aq)$ are blue.

7 (a) (i) With reference to electrons, explain why aqueous copper(II) ions are blue.

.....

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

7 (a) (ii) By reference to aqueous copper(II) ions, state the meaning of each of the **three** terms in the equation $\Delta E = h\nu$.

.....

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

Do not write outside the box

7 (a) (iii) Write an equation for the reaction, in aqueous solution, between $[Cu(H_2O)_6]^{2+}$ and an excess of chloride ions.
State the shape of the complex produced and explain why the shape differs from that of the $[Cu(H_2O)_6]^{2+}$ ion.

.....

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

7 (b) Draw the structure of the ethanedioate ion ($C_2O_4^{2-}$).
Explain how this ion is able to act as a ligand.

.....

.....

.....

.....

.....

(2 marks)

Question 7 continues on the next page

Turn over ▶

Do not write outside the box

7 (c) When a dilute aqueous solution containing ethanedioate ions is added to a solution containing aqueous copper(II) ions, a substitution reaction occurs. In this reaction four water molecules are replaced and a new complex is formed.

7 (c) (i) Write an ionic equation for the reaction. Give the co-ordination number of the complex formed and name its shape.

.....

.....

.....

.....

.....

.....

(4 marks)

7 (c) (ii) In the complex formed, the two water molecules are opposite each other.
Draw a diagram to show how the ethanedioate ions are bonded to a copper ion and give a value for one of the O—Cu—O bond angles. You are **not** required to show the water molecules.

(2 marks)

17

8 Iron is an important element in living systems. It is involved in redox and in acid–base reactions.

8 (a) Explain how and why iron ions catalyse the reaction between iodide ions and $S_2O_8^{2-}$ ions. Write equations for the reactions that occur.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(5 marks)

(Extra space) .....

.....

.....

Question 8 continues on the next page

8 (b) Iron(II) compounds are used as moss killers because iron(II) ions are oxidised in air to form iron(III) ions that lower the pH of soil.

8 (b) (i) Explain, with the aid of an equation, why iron(III) ions are more acidic than iron(II) ions in aqueous solution.

.....

.....

.....

.....

.....

.....

(3 marks)

8 (b) (ii) In a titration, 0.321 g of a moss killer reacted with 23.60 cm^3 of acidified 0.0218 mol dm^{-3} $K_2Cr_2O_7$ solution.

Calculate the percentage by mass of iron in the moss killer. Assume that all of the iron in the moss killer is in the form of iron(II).

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(5 marks)

Do not write outside the box

8 (c) Some sodium carbonate solution was added to a solution containing iron(III) ions. Describe what you would observe and write an equation for the reaction that occurs.

.....

.....

.....

.....

.....

.....

(3 marks)

END OF QUESTIONS

16

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED