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

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(2 marks)

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

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(1 mark)

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

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(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

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(2 marks)

7

Turn over for the next question

There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED

2 When potassium nitrate (KNO_3) dissolves in water the value of the enthalpy change $\Delta H = +34.9 \text{ kJ mol}^{-1}$ and the value of the entropy change $\Delta S = +117 \text{ J K}^{-1} \text{ mol}^{-1}$.

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

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(1 mark)

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

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(1 mark)

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

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(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)**.

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(1 mark)

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

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(1 mark)

7

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.

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(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.

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(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.

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(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.)

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(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.

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(1 mark)

11

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 ....

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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 ....

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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..

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(3 marks)

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

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(2 marks)

(Extra space) ....

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

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(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

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(1 mark)

4 (e) (ii) aqueous sodium hydroxide.

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(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.

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(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 ....

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(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 ....

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Equation ....

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(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.

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(2 marks)

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

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(1 mark)

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

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(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.

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(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.

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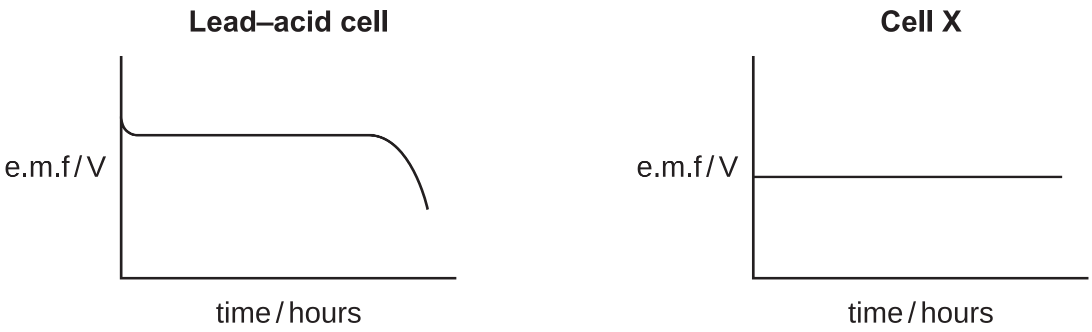
(2 marks)

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.



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

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(1 mark)

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

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(1 mark)

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

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(2 marks)

(Extra space) ....

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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 ....

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(2 marks)

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

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(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.

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(3 marks)

(Extra space) ....

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

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(3 marks)

(Extra space) ....

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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.

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(3 marks)

(Extra space) ....

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

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(2 marks)

Question 7 continues on the next page

Turn over ▶

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.

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(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.

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(5 marks)

(Extra space) ....

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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.

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(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).

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(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.

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(3 marks)

16

END OF QUESTIONS

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