| Centre Number | | | | | | Candidate Number | | | | |
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| For Examiner's Use | |
|---|---|
| Examiner's Initials | |
| Question | Mark |
| 1 | |
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| 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**.



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## 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)*

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

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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, $\Delta G$, for this process is zero.

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*(3 marks)*

**2 (d) (i)** Deduce what happens to the value of $\Delta G$ 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 $\Delta G$ suggest about the dissolving of potassium nitrate at this lower temperature?

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*(1 mark)*

**7**

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**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)*

Do not write outside the box

**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 $\Delta H$ value of $-46$ kJ mol$^{-1}$ and your answer from part **3 (b)** to calculate a value for $\Delta G$, 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 $\Delta G$ that you have obtained to comment on the feasibility of the reaction at 800 K.

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*(1 mark)*

11

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**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)*

Do not write outside the box

**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**

Do not write outside the box

**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)*

Do not write outside the box

**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)*

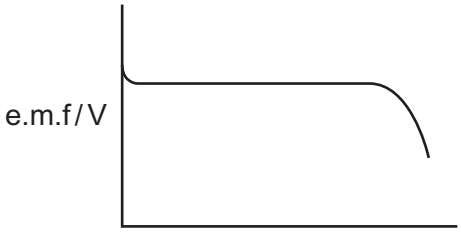
**Question 5 continues on the next page**

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**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.

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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

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**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.

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*(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

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## 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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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.

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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**

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.

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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**

Do not write outside the box

**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**

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**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)*

**END OF QUESTIONS**

16

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