Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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7	
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TOTAL	

General Certificate of Education
Advanced Level Examination
January 2010

Chemistry CHEM5

Unit 5 Energetics, Redox and Inorganic Chemistry

Monday 1 February 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. **Answers written in margins or on blank pages will not be marked.**
- 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 This question is about the use of transition metals as catalysts.

1 (a) State how a catalyst speeds up a chemical reaction.

....

....
(2 marks)

1 (b) State the characteristic property of transition metals that enables them to act as catalysts in redox reactions.

....
(1 mark)

1 (c) In the Contact Process for the conversion of sulfur dioxide into sulfur trioxide, vanadium(V) oxide acts as a heterogeneous catalyst.

1 (c) (i) Write **two** equations to show how the catalyst is involved in this reaction.

Equation 1 ....

Equation 2 ....
(2 marks)

1 (c) (ii) Suggest **one** reason why poisoning reduces the effectiveness of a heterogeneous catalyst.

....
(1 mark)

1 (c) (iii) Suggest how poisoning of a catalyst, used in an industrial process, can be minimised.

....
(1 mark)

7

2 Nickel−cadmium cells are used to power electrical equipment such as drills and shavers. The electrode reactions are shown below.

$$\mathrm{NiO(OH)} + \mathrm{H_2O} + \mathrm{e^-} \longrightarrow \mathrm{Ni(OH)_2} + \mathrm{OH^-} \qquad E^\ominus = +0.52\ \mathrm{V}$$

$$\mathrm{Cd(OH)_2} + 2\mathrm{e^-} \longrightarrow \mathrm{Cd} + 2\mathrm{OH^-} \qquad E^\ominus = -0.88\ \mathrm{V}$$

2 (a) Calculate the e.m.f. of a nickel−cadmium cell.

....

(1 mark)

2 (b) Deduce an overall equation for the reaction that occurs in the cell when it is used.

....

....

....

(2 marks)

2 (c) Identify the oxidising agent in the overall cell reaction and give the oxidation state of the metal in this oxidising agent.

Oxidising agent ....

Oxidation state ....

(2 marks)

5

Turn over for the next question

3 Hydrogen – oxygen fuel cells can operate in acidic or in alkaline conditions but commercial cells use porous platinum electrodes in contact with concentrated aqueous potassium hydroxide. The table below shows some standard electrode potentials measured in acidic and in alkaline conditions.

Half-equation	**$E^\ominus$/V**
$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O(l)$	+1.23
$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$	+0.40
$2H^+(aq) + 2e^- \longrightarrow H_2(g)$	0.00
$2H_2O(l) + 2e^- \longrightarrow 2OH^-(aq) + H_2(g)$	−0.83

3 (a) State why the electrode potential for the standard hydrogen electrode is equal to 0.00 V.

....

(1 mark)

3 (b) Use data from the table to calculate the e.m.f. of a hydrogen – oxygen fuel cell operating in alkaline conditions.

....

(1 mark)

3 (c) Write the conventional representation for an alkaline hydrogen – oxygen fuel cell.

....

(2 marks)

3 (d) Use the appropriate half-equations to construct an overall equation for the reaction that occurs when an alkaline hydrogen – oxygen fuel cell operates. Show your working.

....

....

....

....

(2 marks)

3 (e) Give **one** reason, other than cost, why the platinum electrodes are made by coating a porous ceramic material with platinum rather than by using platinum rods.

....

....

(1 mark)

3 (f) Suggest why the e.m.f. of a hydrogen–oxygen fuel cell, operating in acidic conditions, is exactly the same as that of an alkaline fuel cell.

....

(1 mark)

3 (g) Other than its lack of pollution, state briefly the main advantage of a fuel cell over a re-chargeable cell such as the nickel–cadmium cell when used to provide power for an electric motor that propels a vehicle.

....

....

(1 mark)

3 (h) Hydrogen–oxygen fuel cells are sometimes regarded as a source of energy that is carbon neutral. Give **one** reason why this may **not** be true.

....

(1 mark)

10

Turn over for the next question

4 The table below gives some values of standard enthalpy changes. Use these values to answer the questions.

Name of enthalpy change	**$\Delta H^\ominus$/ kJ mol^{-1}**
Enthalpy of atomisation of chlorine	+121
Electron affinity of chlorine	–364
Enthalpy of atomisation of silver	+289
First ionisation enthalpy of silver	+732
Enthalpy of formation of silver chloride	–127

4 (a) Calculate the bond enthalpy of a Cl−Cl bond.

....

(1 mark)

4 (b) Explain why the bond enthalpy of a Cl−Cl bond is greater than that of a Br−Br bond.

....

....

....

....

(2 marks)

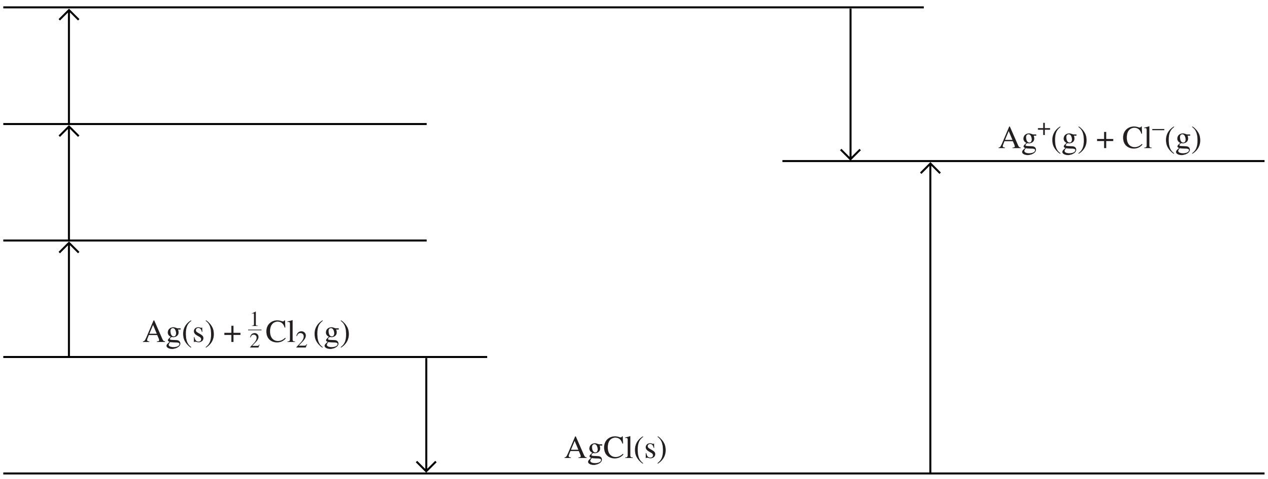
4 (c) Suggest why the electron affinity of chlorine is an exothermic change.

....

....

(1 mark)

4 (d) The diagram below is an incomplete Born–Haber cycle for the formation of silver chloride. The diagram is not to scale.



4 (d) (i) Complete the diagram by writing the appropriate chemical symbols, with state symbols, on each of the three blank lines. *(3 marks)*

4 (d) (ii) Calculate a value for the enthalpy of lattice dissociation for silver chloride.

....

....

....

....

(2 marks)

Question 4 continues on the next page

Turn over ▶

4 (e) The enthalpy of lattice dissociation for silver chloride can also be calculated theoretically assuming a perfect ionic model.

4 (e) (i) Explain the meaning of the term *perfect ionic model.*

....

....

(1 mark)

4 (e) (ii) State whether you would expect the value of the theoretical enthalpy of lattice dissociation for silver chloride to be greater than, equal to or less than that for silver bromide. Explain your answer.

Theoretical lattice enthalpy for silver chloride ....

Explanation ....

....

....

(3 marks)

(Extra space) ....

....

....

4 (e) (iii) Suggest why your answer to part (d) (ii) is greater than the theoretical value for the enthalpy of lattice dissociation for silver chloride.

....

....

....

(2 marks)

15

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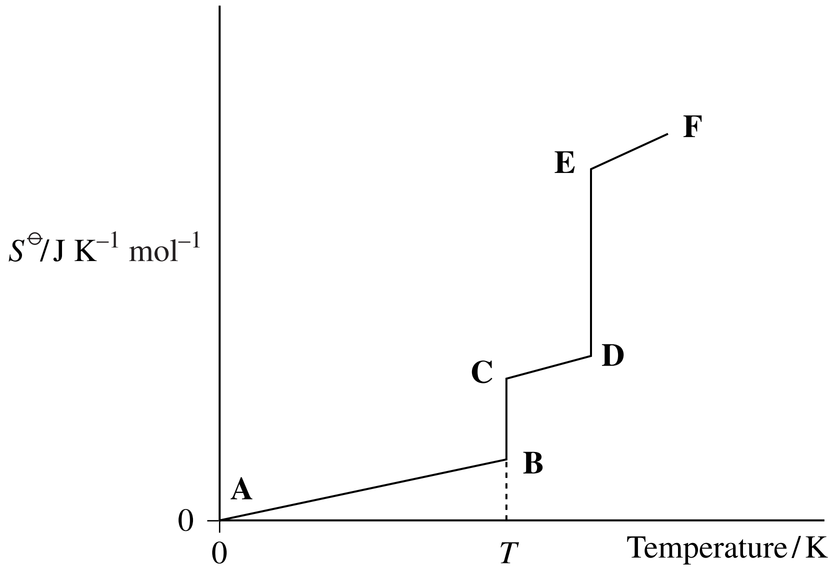
5 The simplified diagram below shows how the entropy of ammonia varies with temperature at a pressure of 100 kPa. In this diagram, ammonia is a solid at point **A** and a gas at point **F**.



5 (a) State why the entropy value for ammonia is equal to zero at 0 K.

(1 mark)

5 (b) Explain, in terms of the movement of particles, why the entropy value increases between points **A** and **B** on the diagram.

(1 mark)

5 (c) Temperature *T* is marked on the diagram. What does the value of this temperature represent?

(1 mark)

5 (d) Explain why there is a large entropy change between points **D** and **E** on the diagram.

(2 marks)

5 (e) An equation for the reaction in the Haber Process is shown below, together with some entropy data.

$$\tfrac{1}{2}N_2(g) + \tfrac{3}{2}H_2(g) \rightleftharpoons NH_3(g) \qquad \Delta H^\ominus = -46.2\,\text{kJ mol}^{-1}$$

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

5 (e) (i) Calculate a value for the entropy change, $\Delta S^\ominus$, for the formation of one mole of ammonia.

....

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(2 marks)

5 (e) (ii) Give the equation that relates free-energy change, $\Delta G^\ominus$, to enthalpy change, $\Delta H^\ominus$, and entropy change, $\Delta S^\ominus$.

Use this equation to calculate the temperature at which the value of $\Delta G^\ominus = 0$ for the formation of ammonia in the Haber Process.
(If you have been unable to calculate an answer to part (e) (i), you may assume that $\Delta S^\ominus = -81.4$ J K mol^{-1} but this is not the correct value.)

Equation ....

Calculation ....

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(4 marks)

(Extra space) ....

5 (e) (iii) What can you deduce about the formation of ammonia if the reaction mixture is heated to a temperature above the value that you have calculated in part (e) (ii)?

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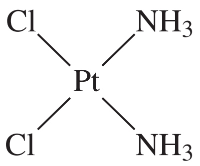
(1 mark)

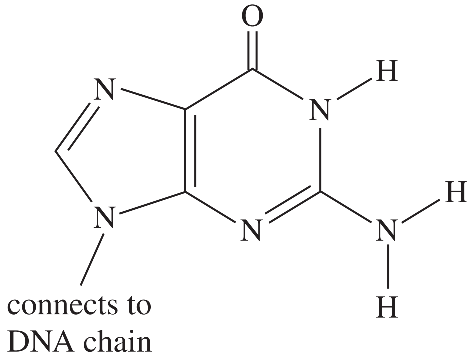
12

Turn over ▶

6 The complex cisplatin acts as an anticancer drug by changing the properties of DNA when it reacts with guanine, a component of DNA.



cisplatin



guanine

When cisplatin is absorbed into the human body, it undergoes a ligand substitution reaction and one chloride ligand is replaced by a water molecule forming a complex ion **Q**.

6 (a) Write an equation for this substitution reaction to form the complex ion **Q**.

....

(2 marks)

6 (b) The complex ion **Q** can bond to guanine in two different ways.

6 (b) (i) The first way involves a hydrogen atom, from one of the ammonia ligands on **Q**, bonding to an atom in a guanine molecule. State the type of bond formed to guanine and identify an atom in guanine that could form a bond to this hydrogen atom.

Type of bond ....

Atom in guanine ....

(2 marks)

6 (b) (ii) The second way involves a ligand substitution reaction in which an atom in a guanine molecule bonds to platinum by displacing the water molecule from **Q**. State the type of bond formed between guanine and platinum when a water molecule is displaced and identify an atom in guanine that could bond to platinum in this way.

Type of bond ....

Atom in guanine ....

(2 marks)

6 (c) State and explain **one** risk associated with the use of cisplatin as an anticancer drug.

Risk ....

Explanation ....

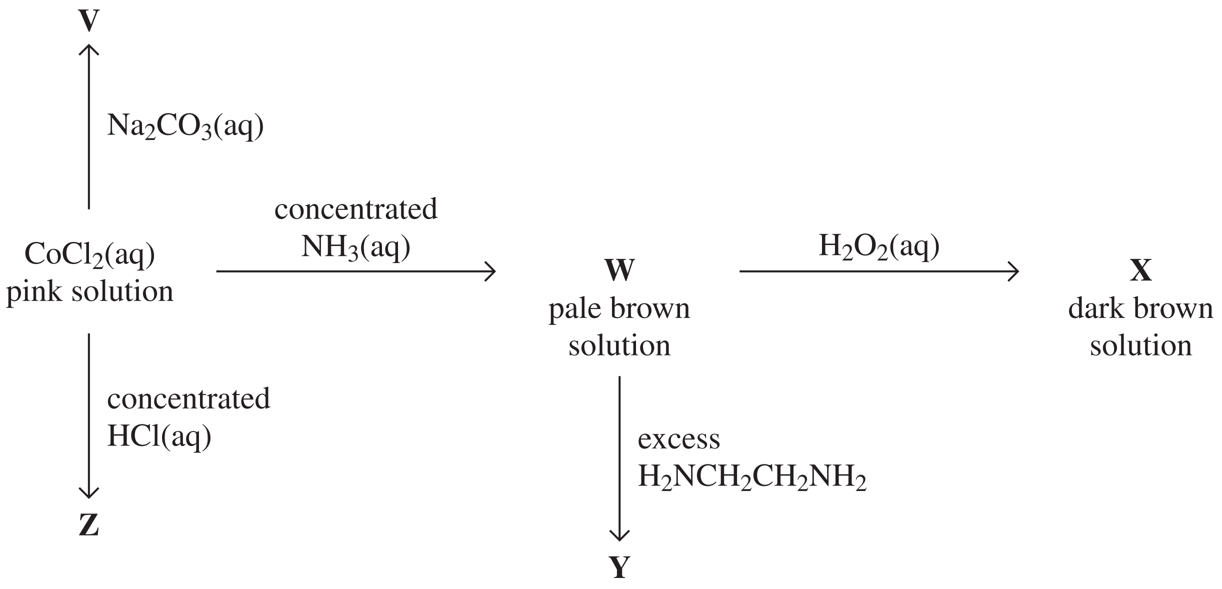
(2 marks)

8

Turn over for the next question

Turn over ▶

7 This question is about some reactions of cobalt compounds.



7 (a) Give the formula of the complex responsible for the pink colour in aqueous $CoCl_2$ and name its shape.

Formula ....

Name of shape ....

(2 marks)

7 (b) Give the formula of the cobalt-containing compound **V** and describe its appearance.

Formula ....

Appearance ....

(2 marks)

7 (c) Write an equation for the reaction that occurs when the pink solution is converted into **W**.

....

(2 marks)

7 (d) Give the formula of the cobalt-containing complex in **X** and state the role of the H_2O_2 in this reaction.

Formula ....

Role of H_2O_2 ....

(2 marks)

7 (e) Give the formula of the cobalt-containing complex in **Y** and explain why this complex is more stable than the cobalt-containing complex in **W**.

Formula ....

Explanation ....

....

....

(3 marks)

7 (f) Identify the cobalt-containing complex in solution **Z** and explain why its co-ordination number is different from that in the pink solution of $CoCl_2$

Complex ....

Explanation ....

....

(2 marks)

13

Turn over for the next question

SECTION B

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

8 (a) State and explain the trend in electronegativities across Period 3 from sodium to sulfur.

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(4 marks)

(Extra space) ....

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8 (b) Explain why the oxides of the Period 3 elements sodium and phosphorus have different melting points. In your answer you should discuss the structure of and bonding in these oxides, and the link between electronegativity and the type of bonding.

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(6 marks)

(Extra space) ....

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Question 8 continues on the next page

Turn over ▶

8 (c) A chemical company has a waste tank of volume 25 000 dm^3. The tank is full of phosphoric acid (H_3PO_4) solution formed by adding some unwanted phosphorus(V) oxide to water in the tank.

A 25.0 cm^3 sample of this solution required 21.2 cm^3 of 0.500 mol dm^{-3} sodium hydroxide solution for complete reaction.

Calculate the mass, in kg, of phosphorus(V) oxide that must have been added to the water in the waste tank.

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(5 marks)

(Extra space) ....

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9 (a) State the electron configuration of a Ti(III) ion and that of a Ti(IV) ion. Explain, in terms of electron configurations and electron transitions, why Ti(III) compounds are usually coloured but Ti(IV) compounds are colourless.

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(5 marks)

(Extra space) ....

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Question 9 continues on the next page

Turn over ▶

9 (b) Transition metal ions and their complexes can often be identified from their colours. For each of the following, identify a complex ion responsible for the colour of the aqueous solution. Restrict your answers to complexes formed from the elements Cr, Fe, Co and Cu.

A deep blue solution formed in an excess of concentrated aqueous ammonia.

A green solution formed in an excess of aqueous sodium hydroxide.

A yellow−green solution formed in an excess of concentrated hydrochloric acid.

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(3 marks)

9 (c) An experiment is carried out to investigate the rate of the autocatalysed reaction between aqueous potassium manganate(VII) and ethanedioate ions in an excess of dilute sulfuric acid. When these reagents are mixed together, the colour of the reaction mixture gradually fades. The concentration of the manganate(VII) ions is recorded at different times using a spectrometer. The temperature of the reaction mixture is constant.

9 (c) (i) Give **two** reasons why the use of a spectrometer is the most appropriate method for measuring the concentration of the coloured ions in this experiment.

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(2 marks)

(Extra space) ....

....

9 (c) (ii) Sketch a curve to show how you would expect the concentration of manganate(VII) ions to change with time until the colour has faded because the concentration has reached a very low value. Explain the shape of the curve.

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(5 marks)

(Extra space) ....

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END OF QUESTIONS

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