Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
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7	
8	
9	
TOTAL	

AQA

General Certificate of Education
Advanced Level Examination
June 2015

Chemistry CHEM5

Unit 5 Energetics, Redox and Inorganic Chemistry

Monday 15 June 2015 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- 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.
- You are expected to use a calculator, where appropriate.
- 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 scientific terminology accurately.

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 (a) Define the term **electron affinity** for chlorine.

[2 marks]

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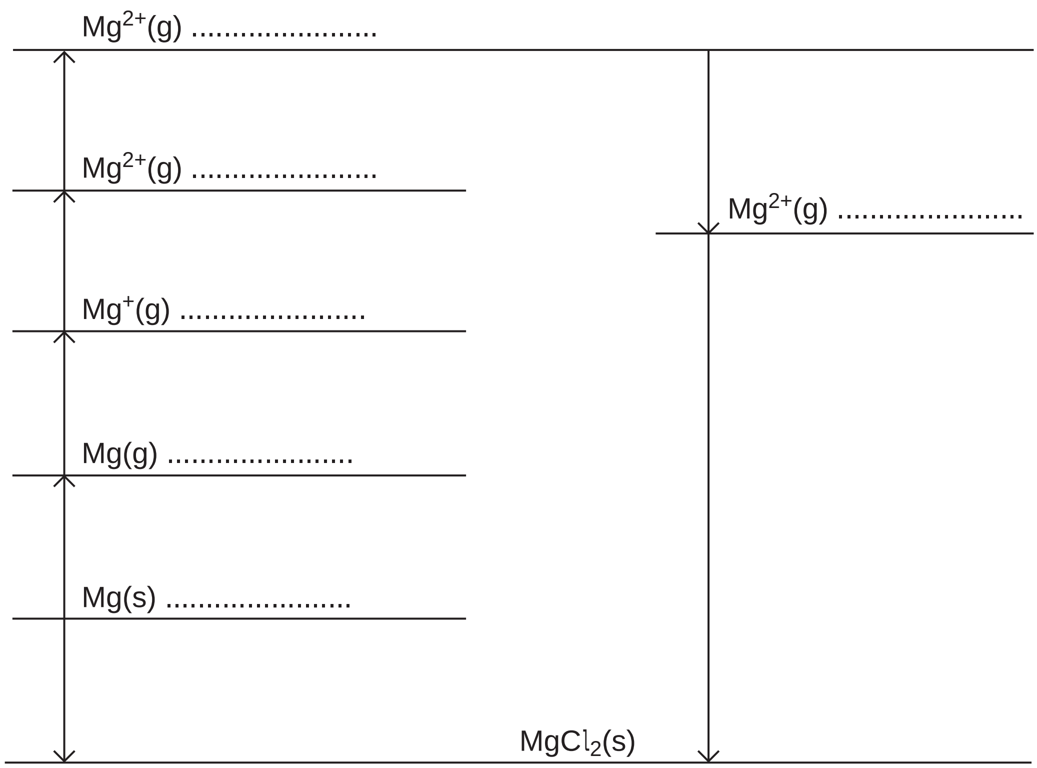
1 (b) Complete this Born–Haber cycle for magnesium chloride by giving the missing species on the dotted lines. Include state symbols where appropriate.

The energy levels are **not** drawn to scale.

[6 marks]



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1 (c) **Table 1** contains some enthalpy data.

Table 1

	Enthalpy change / kJ mol^{-1}
Enthalpy of atomisation of magnesium	+150
Enthalpy of atomisation of chlorine	+121
First ionisation energy of magnesium	+736
Second ionisation energy of magnesium	+1450
Enthalpy of formation of magnesium chloride	–642
Lattice enthalpy of formation of magnesium chloride	–2493

Use your Born–Haber cycle from Question **1 (b)** and data from **Table 1** to calculate a value for the electron affinity of chlorine.

[3 marks]

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Question 1 continues on the next page

1 (d) **Table 2** contains some more enthalpy data.

Table 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of hydration of Mg^{2+} ions	–1920
Enthalpy of hydration of Na^{+} ions	–406
Enthalpy of hydration of Cl^{-} ions	–364

1 (d) (i) Explain why there is a difference between the hydration enthalpies of the magnesium and sodium ions.

[2 marks]

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1 (d) (ii) Use data from **Table 1** and **Table 2** to calculate a value for the enthalpy change when one mole of magnesium chloride dissolves in water.

[2 marks]

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Turn over for the next question

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2 **Table 3** contains some bond enthalpy data.

Table 3

Bond	H—H	O═O	H—O
Bond enthalpy / kJ mol^{-1}	436	496	464

2 (a) The value for the H—O bond enthalpy in **Table 3** is a mean bond enthalpy.

State the meaning of the term **mean bond enthalpy** for the H—O bond.

[2 marks]

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2 (b) Use the bond enthalpies in **Table 3** to calculate a value for the enthalpy of formation of water in the gas phase.

[3 marks]

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2 (c) The standard enthalpy of combustion of hydrogen, forming water in the gas phase, is almost the same as the correct answer to Question **2 (b)**.

2 (c) (i) Suggest **one** reason why you would expect the standard enthalpy of combustion of hydrogen to be the same as the answer to Question **2 (b)**.

[1 mark]

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2 (c) (ii) Suggest **one** reason why you would expect the standard enthalpy of combustion of hydrogen to differ slightly from the answer to Question **2 (b)**.

[1 mark]

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Turn over for the next question

Turn over ▶

3 Hydrogen can be manufactured from the reaction of steam with methane.

$$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g)$$

3 (a) **Table 4** contains some enthalpy of formation and entropy data.

Table 4

Substance	**$\Delta H^{\ominus}_f$ / kJ mol^{-1}**	**$S^{\ominus}$ / J K^{-1} mol^{-1}**
$CH_4(g)$	–75	186
$H_2O(g)$	–242	189
$CO(g)$	–111	198
$H_2(g)$	0	131
$CO_2(g)$	–394	214

3 (a) (i) Use data from **Table 4** to calculate the enthalpy change, ΔH, for the reaction of steam with methane.

[3 marks]

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3 (a) (ii) Use data from **Table 4** to calculate the entropy change, ΔS, for the reaction of steam with methane.

[2 marks]

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3 (b) Use your values of ΔH and ΔS from Questions **3 (a) (i)** and **3 (a) (ii)** to calculate the temperature above which this reaction is feasible.

[4 marks]

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3 (c) The temperature used for this manufacture of hydrogen is usually about 1300 K.

Suggest **one** reason, other than changing the position of equilibrium, why this temperature is used rather than the value that you calculated in Question **3 (b)**.

[1 mark]

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Question 3 continues on the next page

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3 (d) Hydrogen can also be obtained by reaction of carbon monoxide with steam.

$$CO(g) + H_2O(g) \longrightarrow CO_2(g) + H_2(g) \qquad \Delta H = -41 \text{ kJ mol}^{-1}, \ \Delta S = -42 \text{ J K}^{-1} \text{ mol}^{-1}$$

3 (d) (i) Explain, using a calculation, why this reaction should **not** occur at 1300 K.

[3 marks]

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3 (d) (ii) Explain how the conditions for the reaction could be changed to allow this reaction to take place.

[2 marks]

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4 (a) Write an equation for the reaction that occurs when magnesium is heated in steam.
Describe what you would observe when this reaction occurs.

[3 marks]

Equation ....

Observations ....

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4 (b) Write an equation for the reaction that occurs when sodium is heated in oxygen.
Describe what you would observe when this reaction occurs.

[3 marks]

Equation ....

Observations ....

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6

Turn over for the next question

5 (a) **Table 5** contains data that show a trend in the melting points of some oxides of the Period 3 elements.

Table 5

Oxide	Sodium oxide	Magnesium oxide	Aluminium oxide	Silicon(IV) oxide	Phosphorus(V) oxide	Sulfur(IV) oxide
Melting point / K		3125	2345	1883	573	

5 (a) (i) Use data from **Table 5** to predict an approximate melting point for sodium oxide.

Tick (✓) **one** box.

[1 mark]

250 K ☐

500 K ☐

1500 K ☐

3500 K ☐

5 (a) (ii) Explain, in terms of structure and bonding, why sodium oxide has a high melting point.

[2 marks]

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Do not write outside the box

5 (a) (iii) Use data from **Table 5** to predict a value for the melting point of sulfur(IV) oxide.

Suggest, in terms of structure and bonding, why the melting point of sulfur(IV) oxide is different from that of phosphorus(V) oxide.

[3 marks]

Predicted melting point of sulfur(IV) oxide ....

Why the melting point is different from phosphorus(V) oxide ....

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5 (b) Write an equation for the reaction of sulfur(IV) oxide with water.

Suggest the pH value of the resulting solution.

[2 marks]

Equation

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pH value ....

5 (c) Silicon(IV) oxide is insoluble in water.

Explain, using an equation, why silicon(IV) oxide is classified as an acidic oxide.

[2 marks]

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6 **Table 6** contains some standard electrode potential data.

Table 6

Electrode half-equation	$E^\ominus$ / V
$F_2 + 2e^- \longrightarrow 2F^-$	+2.87
$Au^+ + e^- \longrightarrow Au$	+1.68
$2HOCl + 2H^+ + 2e^- \longrightarrow Cl_2 + 2H_2O$	+1.64
$Cl_2 + 2e^- \longrightarrow 2Cl^-$	+1.36
$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	+1.23
$Ag^+ + e^- \longrightarrow Ag$	+0.80
$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	+0.77
$2H^+ + 2e^- \longrightarrow H_2$	0.00
$Fe^{2+} + 2e^- \longrightarrow Fe$	–0.44

6 (a) In terms of electrons, explain the meaning of the term **oxidising agent**.

[1 mark]

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6 (b) Identify the weakest oxidising agent in **Table 6**.
Explain your choice.

[2 marks]

Weakest oxidising agent ....

Explanation ....

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Do not write outside the box

6 (c) Write the conventional representation of the cell used to measure the standard electrode potential for the Ag^+/Ag electrode.

State the conditions necessary when measuring this value.

[4 marks]

Conventional representation ....

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Conditions ....

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6 (d) Use data from **Table 6** to explain, in terms of redox, what happens when a soluble gold(I) compound containing Au^+ ions is added to water.

State what you would observe.

Write an equation for the reaction that occurs.

[4 marks]

Explanation ....

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Observation ....

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Equation ....

Question 6 continues on the next page

Turn over ▶

Table 6 is repeated below to help you answer these questions**.**

Table 6

Electrode half-equation	***E***$^{\ominus}$ ***/ V***
$F_2 + 2e^- \longrightarrow 2F^-$	+2.87
$Au^+ + e^- \longrightarrow Au$	+1.68
$2HOCl + 2H^+ + 2e^- \longrightarrow Cl_2 + 2H_2O$	+1.64
$Cl_2 + 2e^- \longrightarrow 2Cl^-$	+1.36
$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	+1.23
$Ag^+ + e^- \longrightarrow Ag$	+0.80
$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	+0.77
$2H^+ + 2e^- \longrightarrow H_2$	0.00
$Fe^{2+} + 2e^- \longrightarrow Fe$	–0.44

6 (e) A cell is made by connecting Fe^{2+}/Fe and Ag^+/Ag electrodes with a salt bridge.

6 (e) (i) Calculate the e.m.f. of this cell.

[1 mark]

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Answer = ...

6 (e) (ii) Suggest why potassium chloride would **not** be suitable for use in the salt bridge of this cell.

[1 mark]

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6 (f) Use data from **Table 6** to explain what happens when a solution of iron(II) chloride is exposed to the air.

[2 marks]

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Turn over ▶

Section B

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

7 (a) A sample of solid chromium(III) hydroxide displays amphoteric character when treated separately with dilute hydrochloric acid and with dilute aqueous sodium hydroxide.

Write an ionic equation for each of these reactions. Include the formula of each complex ion formed.
Describe the changes that you would observe in each reaction.

[5 marks]

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7 (b) Aqueous solutions of copper(II) sulfate and cobalt(II) sulfate undergo ligand substitution reactions when treated separately with an excess of dilute aqueous ammonia.

Write equations for these reactions. Include the formulae for any complex ions. Describe the changes that you would observe in each reaction.

[6 marks]

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Turn over for the next question

8 A green solution, **X**, is thought to contain $[Fe(H_2O)_6]^{2+}$ ions.

8 (a) The presence of these ions can be confirmed by reacting separate samples of solution **X** with aqueous ammonia and with aqueous sodium carbonate.

Write equations for each of these reactions and describe what you would observe.

[4 marks]

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8 (b) A 50.0 cm^3 sample of solution **X** was added to 50 cm^3 of dilute sulfuric acid and made up to 250 cm^3 of solution in a volumetric flask.

A 25.0 cm^3 sample of this solution from the volumetric flask was titrated with a 0.0205 mol dm^{-3} solution of $KMnO_4$
At the end point of the reaction, the volume of $KMnO_4$ solution added was 18.70 cm^3.

8 (b) (i) State the colour change that occurs at the end point of this titration and give a reason for the colour change.

[2 marks]

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8 (b) (ii) Write an equation for the reaction between iron(II) ions and manganate(VII) ions.

Use this equation and the information given to calculate the concentration of iron(II) ions in the original solution **X**.

[5 marks]

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Turn over for the next question

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9 The redox reaction, in aqueous solution, between acidified potassium manganate(VII) and sodium ethanedioate is autocatalysed.

9 (a) Write an equation for this redox reaction.

Identify the species that acts as the catalyst.

Explain how the properties of the species enable it to act as a catalyst in this reaction.

[6 marks]

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9 (b) Sketch a graph to show how the concentration of MnO_4^- ions varies with time in this reaction.
Explain the shape of the graph.

[4 marks]

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END OF QUESTIONS

There are no questions printed on this page

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