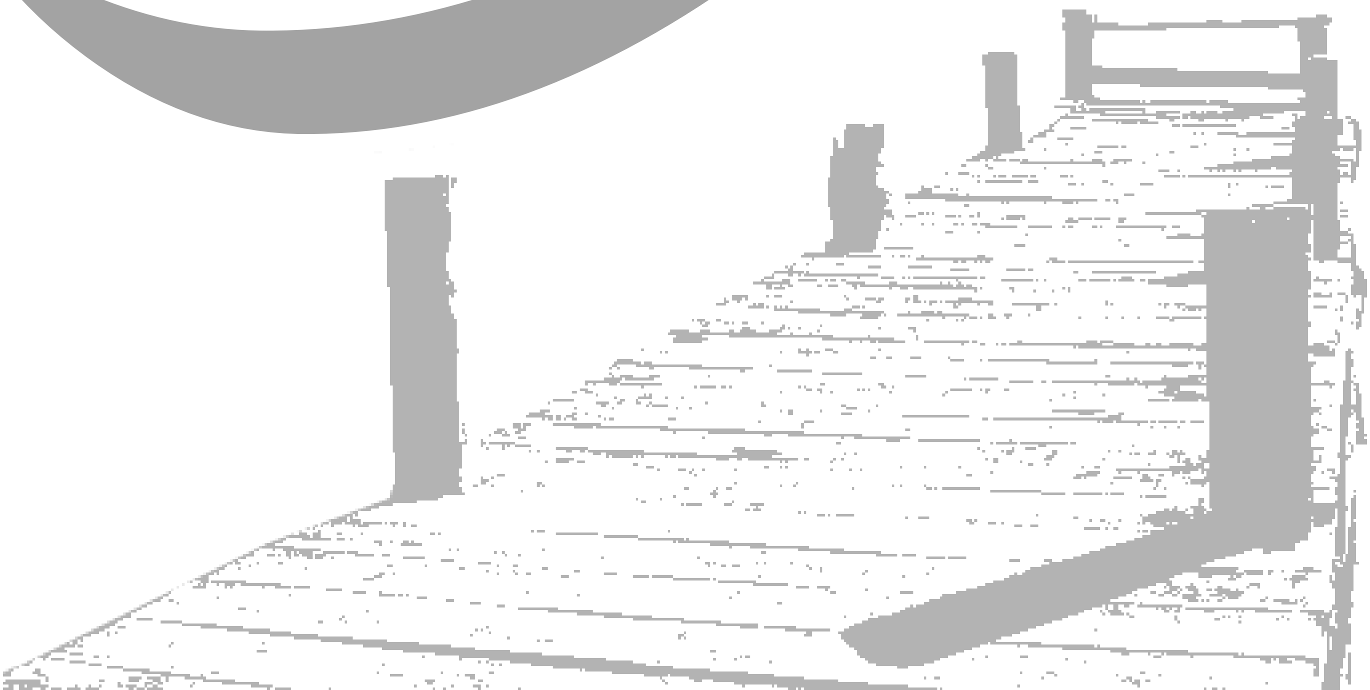
GCE
AS and A Level

Chemistry

AS exams 2009 onwards
A2 exams 2010 onwards

Unit 5:
Specimen question paper

Version 1.1



Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
2009
Advanced Level Examination

CHEMISTRY **CHEM5**
Unit 5 Energetics, Redox and Inorganic Chemistry

SPECIMEN PAPER

For this paper you must have
- A calculator
- Data Sheet / Periodic Table

Time allowed: 1¾ hours

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.

Information
- The maximum mark for this paper is 100.
- The marks for the questions are shown in brackets.
- You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use			
Number	Mark	Number	Mark
1		6	
2		7	
3		8	
4		9	
5			
Total (Column 1)			
Total (Column 2)			
TOTAL			
Examiner's Initials			

SECTION A

Answer **all** questions in the spaces provided

1 (a) The melting points of some of the oxides formed by Period 3 elements are given in a random order below.

Oxide	**A**	**B**	**C**	**D**	**E**
T_m/°C	2852	–73	1610	1275	300

(i) Using the letters **A** to **E**, give **two** oxides which have simple molecular structures.

Explain your answer.

Oxide 1 ....

Oxide 2 ....

Explanation ....

....

(ii) Give a simple chemical test which could be used to show which of the oxides in the table is sodium oxide. State the observation you would make.

Chemical test ....

....

Observation ....

(6 marks)

(b) The base calcium oxide can be used to remove sulfur dioxide from flue-gases produced when fossil fuels are burnt in coal-fired power stations. Calcium oxide is produced when calcium carbonate, is decomposed by heat.

(i) Write an equation for the action of heat on calcium carbonate.

....

(ii) Identify the product formed when sulfur dioxide reacts with calcium oxide.

....

(iii) Despite the additional cost, operators of power stations are encouraged to remove the sulfur dioxide from flue-gases. Explain why this may not be environmentally beneficial.

....

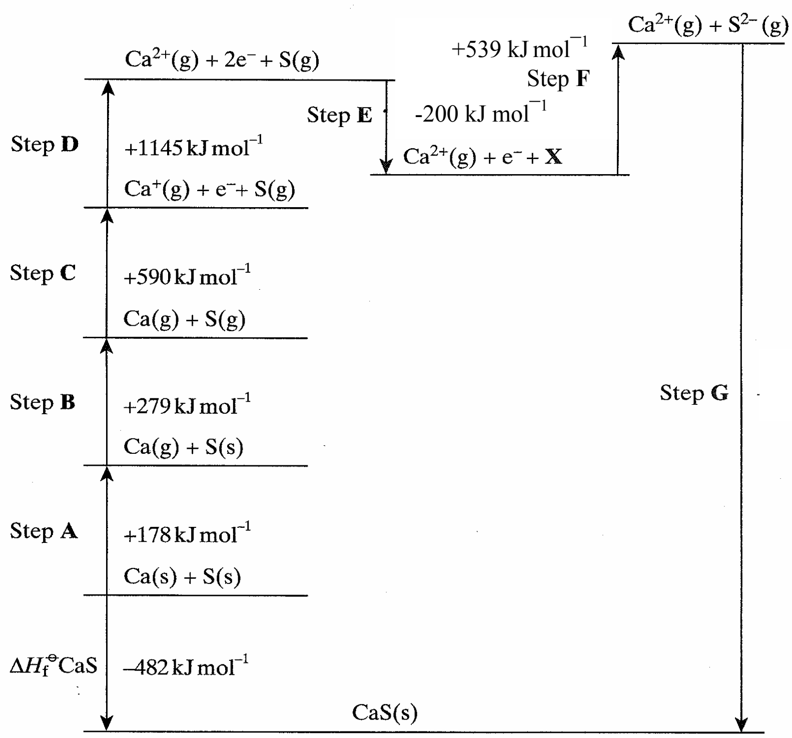
....

(4 marks)

10

Turn over for the next question

2 (a) A Born–Haber cycle for the formation of calcium sulphide is shown below. The cycle includes enthalpy changes for all steps except step **G**. (The cycle is not drawn to scale.)



(i) Give the full electronic configuration of the ion S^{2-}

....

(ii) Suggest why step **F** is an endothermic process.

....

....

(iii) Name the enthalpy changes in steps **B** and **D**.

*Step **B***..

*Step **D*** ....

(iv) Explain why the enthalpy change for step **D** is larger than that for step **C**.

....

....

(v) Use the data shown in the cycle to calculate a value for the enthalpy change for step **G**.

....

....

....

(9 marks)

(b) Using a Born–Haber cycle, a value of -905 kJ mol^{-1} was determined for the lattice enthalpy of silver chloride. A value for the lattice enthalpy of silver chloride using the ionic model was -833 kJ mol^{-1}.

Explain what a scientist would be able to deduce from a comparison of these values.

....

....

....

....

(3 marks)

Question 2 continues on the next page

(c) Some endothermic reactions occur spontaneously at room temperature. Some exothermic reactions do not occur if the reactants are heated together to a very high temperature.

In order to explain the following observations, another factor, the entropy change, ΔS, must be considered. The equation which relates ΔS to ΔH is given below.

$$\Delta G = \Delta H - T\Delta S$$

(i) Explain why the following reaction occurs at room temperature even though the reaction is endothermic.

$$NaHCO_3(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$$

....

....

....

....

(ii) Explain why the following reaction does not occur at very high temperatures even though the reaction is exothermic.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

....

....

....

....

(6 marks)

18

3 (a) The term oxidation was used originally to describe a reaction in which a substance gained oxygen. The oxygen was provided by the oxidising agent. Later the definition of oxidation was revised when the importance of electron transfer was recognised.

An aqueous solution of sulfur dioxide was reacted in separate experiments as follows.

Reaction **1** with HgO

$$H_2O + SO_2 + HgO \rightarrow H_2SO_4 + Hg$$

Reaction **2** with chlorine

$$2H_2O + SO_2 + Cl_2 \rightarrow H_2SO_4 + 2HCl$$

(i) In Reaction **1**, identify the substance that donates oxygen and therefore is the oxidising agent.

....

(ii) Show, by writing a half-equation, that this oxidising agent in reaction **1** is an electron acceptor.

....

(iii) Write a half-equation for the oxidation process occurring in reaction **2**.

....

(iv) Write a half-equation for the reduction process occurring in reaction **2**.

....

(4 marks)

Question 3 continues on the next page

(b) Use the standard electrode potential data given in the able below to answer the questions which follow.

	E / V
$V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$	−0.26
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow H_2SO_3(aq) + H_2O(l)$	+0.17
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+1.52

Each of the above can be reversed under suitable conditions

(i) An excess of potassium manganate(VII) was added to a solution containing V^{2+}(aq) ions. Determine the vanadium species present in the solution at the end of this reaction. State the oxidation state of vanadium in this species and write a half-equation for its formation from V^{2+}(aq).

Vanadium species present at the end of the reaction ....

....

Oxidation state of vanadium in the final species ....

....

Half–equation ....

(ii) The cell represented below was set up under standard conditions.

$$Pt|H_2SO_3(aq),SO_4^{2-}(aq),H^+(aq)||Fe^{3+}(aq),Fe^{2+}(aq)|Pt$$

Calculate the e.m.f. of this cell and state, with an explanation, how this e.m.f. will change if the concentration of Fe^{3+}(aq) ions is increased.

Cell e.m.f. ....

Change in cell e.m.f ....

Explanation ....

....

(7 marks)

(c) Consider the cell below

$$\overset{-}{}\mathrm{Pt}|\mathrm{H_2(g)}|\mathrm{H^+(aq)}||\mathrm{O_2(g)}|\mathrm{OH^-(aq)}|\mathrm{Pt}\overset{+}{}$$

(i) Using half-equations, deduce an overall equation for the cell reaction.

....

....

....

(ii) State how, if at all, the e.m.f. of this cell will change if the surface area of each platinum electrode is doubled.

....

(3 marks)

(d) Currently, almost all hydrogen is produced by the high–temperature reaction between methane, from North Sea gas, and steam. Give one economic and one environmental disadvantage of this method of producing hydrogen.

Economic disadvantage ....

Environmental disadvantage...

(2 marks)

(e) Hydrogen can also be produced by the electrolysis of acidified water using electricity produced using solar cells. Give one reason why this method is not used on a large scale.

....

(1 mark)

17

Turn over for the next question

4 (a) When aqueous ammonia was added to an aqueous solution of cobalt(II) sulfate, a blue precipitate **M** was formed. Identify the cobalt-containing species present in aqueous cobalt(II) sulphate and in the precipitate **M**.

Cobalt-containing species ....

*Precipitate **M***..

(2 marks)

(b) Precipitate **M** dissolved when an excess of concentrated aqueous ammonia was added. The solution formed was pale brown due to the presence of the cobalt-containing species **P**. Identify **P**.

....

(1 mark)

(c) On standing in air, the colour of the solution containing **P** slowly darkened as the cobalt-containing species **Q** was formed. State the type of reaction occurring when **P** changes into **Q** and identify the reactant responsible for this change.

Type of reaction ....

Reactant responsible ....

(2 marks)

(d) When potassium iodide was added to the solution containing **Q** and the mixture was acidified, a dark brown solution due to the presence of **R** was formed. On addition of starch solution the mixture turned blue-black.

Identify **R** and explain its formation.

*Identity of **R***..

Explanation ....

....

(2 marks)

7

5 Iron from the Blast Furnace contains carbon. In the steel–making process, oxygen is blown through molten impure iron. At stages during this process samples of iron are taken and analysed to determine the remaining carbon content. One method of analysis involves a redox titration.

At one stage a 1.27g sample of this impure iron was reacted with an excess of dilute sulphuric acid. All of the iron in the sample was converted into iron(II) sulfate, and hydrogen was evolved. The solution formed was made up to 250 cm^3. A 25.0 cm^3 sample of this solution reacted completely with exactly 19.6 cm^3 of a 0.0220 mol dm^{-1} solution of potassium manganate(VII).

(a) Write an equation for the reaction between iron and dilute sulphuric acid.

....

(1 mark)

(b) Write an equation for the reaction of iron(II) ions with manganate(VII) ions in acid solution.

....

....

....

(1 mark)

(c) Assuming that carbon is the only impurity, calculate the percentage by mass of carbon in the 1.27g sample.

....

....

....

....

....

(5 marks)

(d) How would you ensure the reliability of the result obtained in this experiment?

....

(1 mark)

(e) Suggest one way in which the reliability of this analysis could be improved.

....

(1 mark)

9

6 The characteristic properties of transition metals include complex formation and the formation of coloured ions.

(a) Some complex ions can undergo a ligand substitution reaction in which both the co-ordination number of the metal and the colour of complex ions change in the reaction.

Write an equation for one such reaction and state the colours of the complex ions involved.

Equation ....

....

Colours of complex ions ....

....

(4 marks)

(b) The frequency, v, of light absorbed by a transition–metal complex ion can be determined using the relationship $\Delta E = hv$.

(i) State what is meant by the symbols ΔE and h.

Meaning of symbol ΔE ....

Meaning of symbol h ....

(ii) Give three factors which may cause the frequency of light absorbed to change when a complex ion reacts.

Factor 1 ....

Factor 2 ....

Factor 3 ....

(5 marks)

9

SECTION B

Answer all questions in the space provided on pages 14 to 18 of this booklet

7 A method of synthesising ammonia directly from nitrogen and hydrogen was developed by Fritz Haber. On an industrial scale, this synthesis requires a high temperature, a high pressure and a catalyst and is very expensive to operate.

(a) Use the data given below to calculate a value for the enthalpy of formation of ammonia

Bond	N ≡ N	H – H	N – H
Mean bond enthalpy/kJ mol^{-1}	945	436	391

(3 marks)

(b) A manager in charge of ammonia production wished to increase the daily production of ammonia and reduce the production costs. How would a chemist explain the factors that would influence the commercial efficiency of this production process?

(8 marks)

8 When anhydrous iron(III) chloride is added to water the following reactions occur.

$$FeCl_3 + 6H_2O \rightarrow [Fe(H_2O)_6]^{3+} + 3Cl^-$$

$$[Fe(H_2O)_6]^{3+} + H_2O \rightarrow [Fe(H_2O)_5(OH)]^{2+} + H_3O^+$$

(a) State the type of acidity shown by $FeCl_3$ and by $[Fe(H_2O)_6]^{3+}$ in these reactions. Explain your answers.

(4 marks)

(b) Explain why the pH of a solution of iron(II) chloride is higher than that of a solution of iron(III) chloride of the same concentration.

(2 marks)

(c) Transition metals have variable oxidation states. This is an important factor in their ability to act as heterogeneous and homogeneous catalysts.

(i) Vanadium(V) oxide acts as a heterogeneous catalyst in the Contact Process. Write equations to show the role of vanadium(V) oxide in this process.

(ii) In aqueous solution, Fe^{2+} ions act as a homogeneous catalyst in the reaction between I^- and $S_2O_8^{2-}$ ions. Give one reason why the reaction is slow in the absence of a catalyst. Write equations to show how Fe^{2+} ions act as a catalyst for this reaction.

(7 marks)

9 A student studying GCSE science is puzzled by data which indicate that a sodium atom is larger than a chlorine atom and that a sodium ion is smaller than a chloride ion. How should an A–level Chemistry student explain this apparently conflicting information.

(6 marks)

END OF QUESTIONS

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