Surname		Centre Number	Candidate Number
Other Names			2

GCE A level

1095/01

CHEMISTRY CH5

A.M. FRIDAY, 24 June 2011

1¾ hours

FOR EXAMINER'S USE ONLY		
Section	Question	Mark
A	1	
	2	
	3	
B	4	
	5	
TOTAL MARK		

1095
010001

ADDITIONAL MATERIALS

In addition to this examination paper, you will need:
- a calculator
- an 8 page answer book;
- a copy of the **Periodic Table** supplied by WJEC.
  Refer to it for any **relative atomic masses** you require.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions in the spaces provided.
Section B Answer **both** questions in **Section B** in a separate answer book which should then be placed inside this question-and-answer book.

Candidates are advised to allocate their time appropriately between **Section A (40 marks)** and **Section B (40 marks)**.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

You are reminded that marking will take into account the Quality of Written Communication in all written answers.

SECTION A

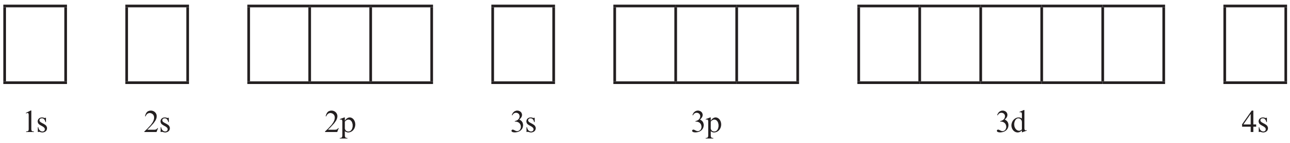
Answer **all** *questions in the spaces provided.*

1. Chromium and aluminium both form amphoteric compounds.

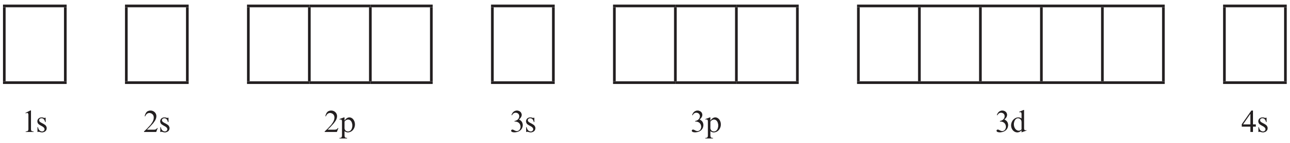
(a) State what is meant by the term *amphoteric*. [1]

(b) Use arrows in boxes to show the electronic structures of the chromium atom and the Cr^{3+} ion. [2]

Chromium atom, Cr



Chromium(III) ion, Cr^{3+}



(c) When sodium hydroxide solution is added to a solution of potassium dichromate(VI), $K_2Cr_2O_7$, the following reaction occurs.

$$Cr_2O_7^{2-} + 2OH^- \longrightarrow 2CrO_4^{2-} + H_2O$$

(i) State the colour change that is seen. [1]

(ii) Use the oxidation states of chromium to show that this is not a redox reaction. [2]

(d) Aluminium chloride is a compound of the amphoteric element aluminium, whilst magnesium chloride contains the non-amphoteric element magnesium. Explain how sodium hydroxide can be used to distinguish between solutions of these two compounds. [3]

(e) Aluminium chloride, $AlCl_3$, commonly exists as the dimer Al_2Cl_6.

(i) Draw the structure of the dimer formed, and explain why the two $AlCl_3$ monomers join together. [3]

(ii) Aluminium chloride monomer may combine with another chloride ion to form tetrachloroaluminate(III) ions, $AlCl_4^-$. Using valence shell electron pair repulsion theory (VSEPR), state and explain the shape of this anion. [2]

Total [14]

Turn over.

2. Fuel cells have been proposed as an alternative method of providing energy for vehicles. These use chemical reactions within electrochemical systems to generate electricity.

(a) A typical fuel cell uses hydrogen as a fuel and reacts this with oxygen. The two half-equations for the processes occurring at the electrodes are given in the table below.

Half-equation	$E^\ominus$ / V
$2H^+ + 2e^- \rightleftharpoons H_2$	0.00
$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightleftharpoons H_2O$	1.23

(i) Write an equation for the overall reaction occurring. [1]

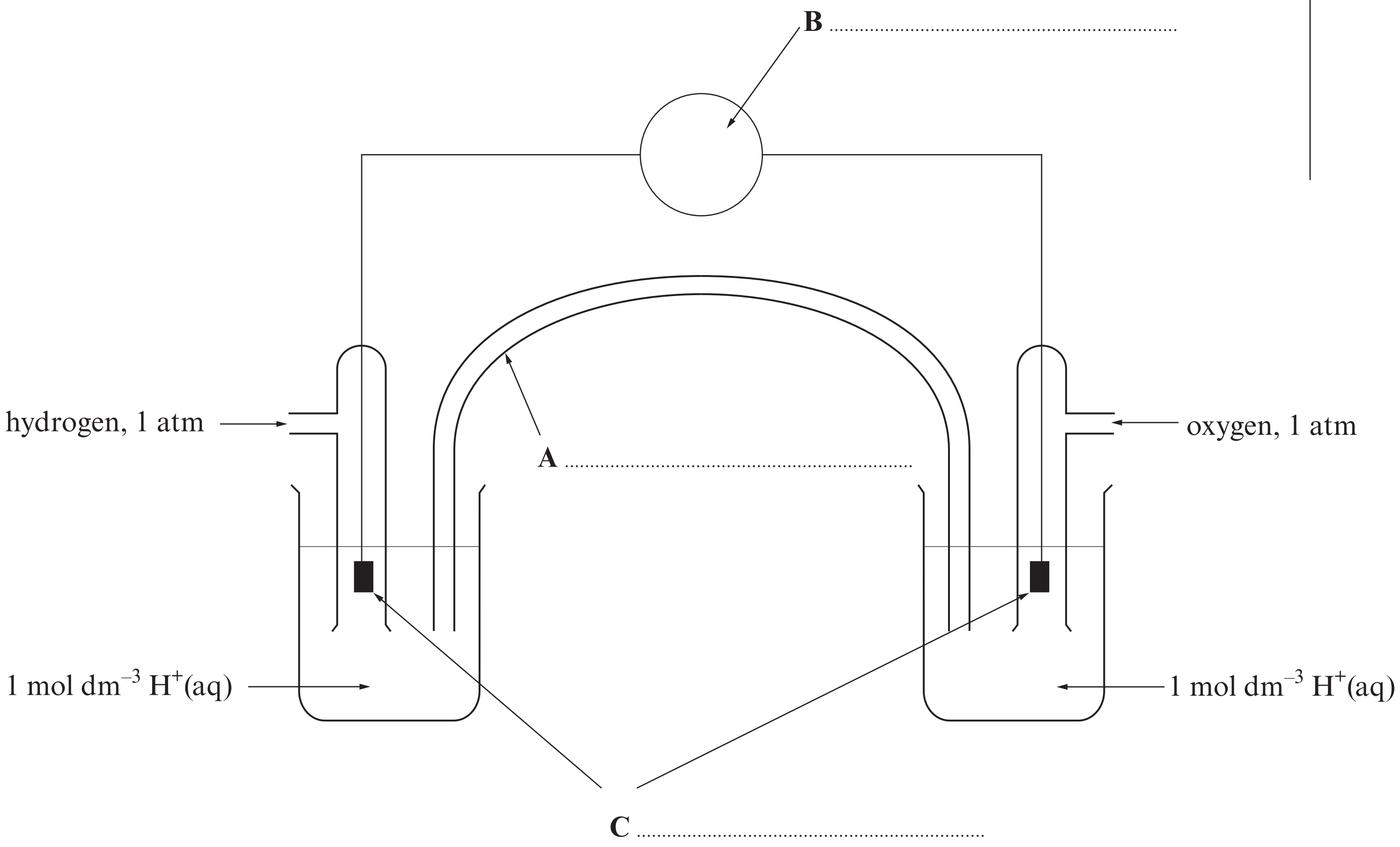
....

(ii) Give **one** benefit of the use of fuel cells as a replacement for traditional vehicle energy sources. [1]

....

....

(iii) The same reaction as above can be undertaken in a traditional electrochemical cell, such as the one below. Name the parts labelled **A**-**C**. [3]



(b) A different fuel for use in fuel cells is methanol, CH_3OH, which would undergo the following reaction with oxygen.

$$CH_3OH(l) + 1\tfrac{1}{2}O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$$

Compound	Standard enthalpy change of formation, $\Delta H_f^\ominus$ / kJ mol^{-1}
CH_3OH	–239
CO_2	–394
H_2O	–286

(i) Calculate the standard enthalpy change of combustion for methanol. [2]

....

....

....

(ii) The entropy change of this reaction is calculated as follows.

ΔS = (Sum of all entropies for products) – (Sum of all entropies for reactants)

$$\Delta S = 354 - 435$$

$$\Delta S = -81 \text{ J K}^{-1} \text{ mol}^{-1}$$

The reaction was repeated using gaseous methanol, $CH_3OH(g)$, in place of the liquid methanol, $CH_3OH(l)$, used above. What effect, if any, would this have on the value of the entropy change ΔS given above? Explain your answer. [2]

....

....

....

(iii) Use the values in parts (i) and (ii) of this question to calculate the value of the Gibbs free energy, ΔG, for this reaction at 298K and state what information this gives about the feasibility of the reaction. [2]

....

....

....

....

Total [11]

3. *Read the passage below and then answer questions (a) to (c) in the spaces provided.*

The oxides of nitrogen

The atmosphere around us consists principally of two elements – nitrogen gas, N_2, and oxygen gas, O_2. The relative stability of this mixture of two elements hides the fact that the elements can combine to form a number of oxides of nitrogen. Their original names are shown below.

Dinitrogen monoxide	N_2O
Nitrogen monoxide	NO
Dinitrogen trioxide	N_2O_3
Nitrogen dioxide	NO_2
Dinitrogen tetroxide	N_2O_4
Dinitrogen pentoxide	N_2O_5
Nitrogen trioxide	NO_3

Many of these oxides are useful but several can also cause environmental problems.

Dinitrogen monoxide, N_2O

This gas was one of the first gaseous compounds to be identified and is probably one of the best known of the oxides of nitrogen. Commonly called ‘laughing gas’, due to the behaviour of those exposed to the gas, this oxide has since been used as an anaesthetic. It was initially used for the relief of pain during dental treatment and it remained one of the dentist’s most useful aids for over a century. It was also commonly used to relieve the pain of childbirth due to the rarity of any adverse reactions to the gas.

Nitrogen dioxide, NO_2

Nitrogen dioxide is a brown gas with a notable sharp odour. It can prove toxic by inhalation. The properties of the pure material are difficult to identify due to the existence of the following equilibrium, which leads to the presence of N_2O_4 in any sample of NO_2.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

Nitrogen dioxide is a key intermediate in the production of nitric acid. The nitrogen dioxide is produced by the oxidation of ammonia and this is then combined with water in a disproportionation reaction.

$$3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$$

Nitrogen dioxide, NO_2, along with nitrogen monoxide, NO, is considered to be a key air pollutant and these two oxides are grouped together as NO_x when air quality measurements are undertaken. Both gases are produced during combustion using air as a source of oxygen, such as in the combustion of fuel in vehicle engines. They contribute to the production of atmospheric nitric acid, a key component of acid rain.

Dinitrogen pentoxide, N_2O_5

Dinitrogen pentoxide is a colourless solid at temperatures around 0 °C, however when warmed to 32 °C the oxide sublimes to form $N_2O_5(g)$. In the gas phase the dinitrogen pentoxide is unstable and decomposes, producing nitrogen dioxide.

$$\begin{array}{ccccc} 2N_2O_5(g) & \longrightarrow & 4NO_2(g) & + & O_2(g) \\ \text{colourless gas} & & \text{brown gas} & & \text{colourless gas} \end{array}$$

Solutions of dinitrogen pentoxide dissolved in trichloromethane, $CHCl_3$, have been used as nitration agents to introduce the —NO_2 grouping into organic compounds. The use of this reagent requires a great deal of care as it is a strong oxidising agent and forms explosive mixtures with a range of organic materials.

– End of passage –

Dinitrogen pentoxide, N_2O_5, decomposes in the gas phase according to the equation shown in *line 38*.

(a) Suggest **two** methods of studying the kinetics of this reaction. [2]

1. ....

....

2. ....

....

(b) The initial rates of this reaction for different concentrations of N_2O_5 were measured and are given in the table below.

Concentration of N_2O_5 / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
4.00×10^{-3}	3.00×10^{-5}
6.00×10^{-3}	4.50×10^{-5}
8.00×10^{-3}	6.00×10^{-5}

The rate equation for this reaction is:

$$\text{Rate} = k[N_2O_5]^1$$

(i) Show that the rate equation is consistent with the data above. [2]

....

....

....

(ii) Calculate the value of the rate constant under these conditions. Give your answer to **three** significant figures and state its units. [3]

....

....

....

Units ....

(iii) Two possible mechanisms have been suggested for this reaction. These are shown below.

Mechanism A	*Mechanism B*
$N_2O_5 \rightarrow NO_2 + NO_3^{\bullet}$	$2N_2O_5 \rightarrow 2NO_3^{\bullet} + N_2O_4$
$NO_3^{\bullet} \rightarrow NO^{\bullet} + O_2$	$NO_3^{\bullet} + N_2O_4 \rightarrow NO^{\bullet} + 2NO_2 + O_2$
$NO^{\bullet} + N_2O_5 \rightarrow 3NO_2$	$NO^{\bullet} + NO_3^{\bullet} \rightarrow 2NO_2$

Giving your reasons, state which of the mechanisms is compatible with the rate equation. [2]

(c) The nitrogen dioxide, NO_2, produced in this reaction exists in dynamic equilibrium with dinitrogen tetroxide, N_2O_4. *(line 24)*

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57.2\ \text{kJ mol}^{-1}$$

(i) Write an expression for the equilibrium constant, K_p, for this reaction. [1]

(ii) State and explain the effect of increasing the temperature on the value of K_p. [2]

(iii) At a temperature of 373 K, the partial pressure of a pure sample of NO_2 was 3.00×10^5 Pa. When the mixture was allowed to reach equilibrium, the partial pressure of the remaining NO_2 was 2.81×10^5 Pa.

Calculate the value of K_p, stating its units. [3]

Units ....

Total [15]

SECTION B

Answer **both** *questions in the separate answer book provided.*

4. *(a)* (i) State what is meant by the term *transition element*. [1]

(ii) Explain why both iron and copper are classed as transition elements, whilst zinc is not. [1]

(b) Transition elements such as copper frequently form coloured complexes. Copper(II) complexes are usually blue, but the exact colour can vary, with $[Cu(H_2O)_6]^{2+}$ being pale blue and $[Cu(NH_3)_4(H_2O)_2]^{2+}$ being royal blue. Copper(I) complexes are usually colourless.

Explain why transition metal complexes are usually coloured. Your answer should include details of:

- The origin of colour in transition metal complexes;
- Why the copper(II) species above are coloured blue;
- Why the colours seen in different copper(II) complexes are different;
- Why copper(I) complexes do not form coloured compounds. [6]

(QWC) [2]

(c) Iron is usually extracted from iron(III) oxide, Fe_2O_3, in a blast furnace using carbon monoxide, CO, as a reducing agent, releasing metallic iron and the gas carbon dioxide.

(i) Write the overall equation for this reaction. [1]

(ii) Explain in terms of oxidation states why carbon monoxide is considered to be the reducing agent in this reaction. [2]

(iii) Explain why carbon monoxide, CO, can be used as a reducing agent but the corresponding oxide of lead, PbO, cannot. [2]

(d) The iron content of an alloy can be determined by a redox titration using acidified potassium dichromate(VI) solution, $K_2Cr_2O_7$. A piece of alloy of mass 1.870 g was dissolved completely in acid to form Fe^{2+} ions, and the solution made up to 250.0 cm^3. A 25.00 cm^3 sample of this solution was titrated against acidified $K_2Cr_2O_7$. This required 23.80 cm^3 of $K_2Cr_2O_7$ solution of concentration 0.0200 mol dm^{-3} for complete reaction.

(i) The half-equations for the processes occurring are:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$$

$$Fe^{3+} + e^- \longrightarrow Fe^{2+}$$

Write an **ionic** equation for the reaction between Fe^{2+} ions and $Cr_2O_7^{2-}$ ions in acid solution. [1]

(ii) Calculate the number of moles of Fe^{2+} ions present in the 25.00 cm^3 sample used in the titration. [2]

(iii) Calculate the percentage of iron in the original alloy sample. [2]

Total [20]

5. *(a)* Give a current use for a named compound of chlorine. [1]

(b) Chlorine gas, Cl_2, is used in the industrial preparation of bromine, Br_2. Sea water contains small amounts of bromide ions and by bubbling chlorine gas through the sea water these can be converted to Br_2.

(i) Write an ionic equation for the reaction occurring. [1]

(ii) Use the standard electrode potentials, $E^\ominus$, listed below to explain why chlorine can react with bromide ions but iodine cannot react with bromide ions. [3]

Half-equation	$E^\ominus$ / V
$I_2 + 2e^- \rightleftharpoons 2I^-$	+0.54
$Br_2 + 2e^- \rightleftharpoons 2Br^-$	+1.09
$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$	+1.36

(c) Sodium chloride and sodium iodide are both compounds which contain halide ions.

(i) Silver nitrate solution may be used to differentiate between solutions of sodium chloride and sodium iodide. Give the observations that would be expected in **both** cases. [1]

(ii) Both sodium chloride and sodium iodide react with concentrated sulfuric acid. The observations made during both reactions are very different. Discuss the reactions occurring. Your answer should include

- the observations made during both reactions,
- the identities of any products,
- the reasons for any differences in the reactions that occur. [5]

(QWC) [1]

(d) Chlorine produces a range of oxoacids, including chloric(I) acid, HOCl, and chloric(VII) acid, $HClO_4$. Chloric(I) acid is considered to be a weak acid whilst chloric(VII) acid is considered to be a strong acid.

(i) What is meant by the term *strong acid*? [1]

(ii) Write an expression for the acid dissociation constant, K_a, of chloric(I) acid, HOCl. [1]

(iii) The pH of a solution of chloric(I) acid of concentration 0.100 mol dm^{-3} was found to be 4.23. Calculate the concentration of hydrogen ions in this solution. [2]

(iv) Using the information from part (iii), calculate the value of the acid dissociation constant, K_a, for chloric(I) acid. [2]

(v) When the weak acid HOCl reacts with the strong base sodium hydroxide it forms the salt sodium chlorate(I), NaOCl. Suggest a pH value for a solution of NaOCl, giving a reason for your answer. [2]

Total [20]

GCE A level

1095/01-A

CHEMISTRY CH5
PERIODIC TABLE

A.M. FRIDAY, 24 June 2011

THE PERIODIC TABLE

Group

s Block

d Block

p Block

Key

A_r — relative atomic mass
Symbol
Name
Z — atomic number

Period	1	2											3	4	5	6	7	0
1	1.01 H Hydrogen 1																	4.00 He Helium 2
2	6.94 Li Lithium 3	9.01 Be Beryllium 4											10.8 B Boron 5	12.0 C Carbon 6	14.0 N Nitrogen 7	16.0 O Oxygen 8	19.0 F Fluorine 9	20.2 Ne Neon 10
3	23.0 Na Sodium 11	24.3 Mg Magnesium 12											27.0 Al Aluminium 13	28.1 Si Silicon 14	31.0 P Phosphorus 15	32.1 S Sulfur 16	35.5 Cl Chlorine 17	40.0 Ar Argon 18
4	39.1 K Potassium 19	40.1 Ca Calcium 20	45.0 Sc Scandium 21	47.9 Ti Titanium 22	50.9 V Vanadium 23	52.0 Cr Chromium 24	54.9 Mn Manganese 25	55.8 Fe Iron 26	58.9 Co Cobalt 27	58.7 Ni Nickel 28	63.5 Cu Copper 29	65.4 Zn Zinc 30	69.7 Ga Gallium 31	72.6 Ge Germanium 32	74.9 As Arsenic 33	79.0 Se Selenium 34	79.9 Br Bromine 35	83.8 Kr Krypton 36
5	85.5 Rb Rubidium 37	87.6 Sr Strontium 38	88.9 Y Yttrium 39	91.2 Zr Zirconium 40	92.9 Nb Niobium 41	95.9 Mo Molybdenum 42	98.9 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
6	133 Cs Caesium 55	137 Ba Barium 56	139 ▶ La Lanthanum 57	179 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	(210) Po Polonium 84	(210) At Astatine 85	(222) Rn Radon 86
7	(223) Fr Francium 87	(226) Ra Radium 88	(227) ▶▶ Ac Actinium 89															

f Block

▶ Lanthanoid elements	140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	(147) Pm Promethium 61	150 Sm Samarium 62	(153) Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	163 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
▶▶ Actinoid elements	232 Th Thorium 90	(231) Pa Protactinium 91	238 U Uranium 92	(237) Np Neptunium 93	(242) Pu Plutonium 94	(243) Am Americium 95	(247) Cm Curium 96	(245) Bk Berkelium 97	(251) Cf Californium 98	(254) Es Einsteinium 99	(253) Fm Fermium 100	(256) Md Mendelevium 101	(254) No Nobelium 102	(257) Lr Lawrencium 103