Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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6	
7	
8	
9	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
June 2015

Chemistry CHEM2

Unit 2 Chemistry in Action

Tuesday 2 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 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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Section A

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

1 Chlorine is an important industrial chemical.

1 (a) Chlorine is formed when $KMnO_4$ reacts with hydrochloric acid.
The ionic equation for this redox reaction is

$$16H^+ + 2MnO_4^- + 10Cl^- \longrightarrow 2Mn^{2+} + 8H_2O + 5Cl_2$$

1 (a) (i) Deduce the half-equation for the oxidation of chloride ions to chlorine.

[1 mark]

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1 (a) (ii) Give the oxidation state of manganese in the MnO_4^- ion.

[1 mark]

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1 (a) (iii) Deduce the half-equation for the reduction of the MnO_4^- ions in acidified solution to manganese(II) ions and water.

[1 mark]

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1 (b) Chlorine behaves as an oxidising agent in the extraction of bromine from seawater.
In this process, chlorine gas is bubbled through a solution containing bromide ions.

1 (b) (i) Write the **simplest ionic** equation for the reaction of chlorine with bromide ions.

[1 mark]

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1 (b) (ii) Give **one** observation that would be made during this reaction.

[1 mark]

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1 (b) (iii) In terms of electrons, state the meaning of the term **oxidising agent**.

[1 mark]

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1 (c) In sunlight, chlorine can also oxidise water slowly to form oxygen.

Write an equation for this reaction.
Give the oxidation state of chlorine in the chlorine-containing species that is formed.

[2 marks]

Equation

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Oxidation state of chlorine in the species formed .....

1 (d) Explain why chlorine has a lower boiling point than bromine.

[2 marks]

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2 The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair of compounds, give a reagent (or combination of reagents) that, when added separately to each compound, could be used to distinguish between them. State what is observed in each case.

2 (a) Butan-2-ol and 2-methylpropan-2-ol

[3 marks]

Reagent .....

Observation with butan-2-ol

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Observation with 2-methylpropan-2-ol

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2 (b) Propane and propene

[3 marks]

Reagent .....

Observation with propane

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Observation with propene

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2 (c) Aqueous silver nitrate and aqueous sodium nitrate

[3 marks]

Reagent .....

Observation with aqueous silver nitrate

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Observation with aqueous sodium nitrate

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2 (d) Aqueous magnesium chloride and aqueous barium chloride

[3 marks]

Reagent .....

Observation with aqueous magnesium chloride

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Observation with aqueous barium chloride

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12

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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3 The elements in Group 2 from Mg to Ba can be used to show the trends in properties down a group in the Periodic Table.

3 (a) State the trend in atomic radius for atoms of the elements down Group 2 from Mg to Ba Give a reason for this trend.

[2 marks]

Trend .....

Reason .....

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3 (b) The Group 2 elements react with water.

3 (b) (i) State the trend in reactivity with water of the elements down Group 2 from Mg to Ba

[1 mark]

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3 (b) (ii) Write an equation for the reaction of strontium with water.

[1 mark]

.....

3 (c) Give the **formula** of the hydroxide of the element in Group 2 from Mg to Ba that is most soluble in water.

[1 mark]

.....

5

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4 Hydrogen is produced in industry from methane and steam in a two-stage process.

4 (a) In the first stage, carbon monoxide and hydrogen are formed.
The equation for this reaction is

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

4 (a) (i) Use Le Chatelier's principle to state whether a high or low temperature should be used to obtain the highest possible equilibrium yield of hydrogen from this first stage.
Explain your answer.

[3 marks]

Temperature .....

Explanation .....

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4 (a) (ii) Le Chatelier's principle suggests that a high pressure will produce a low yield of hydrogen in this first stage.

Explain, in terms of the behaviour of particles, why a high operating pressure is used in industry.

[2 marks]

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4 (a) (iii) A nickel catalyst is used in the first stage.

Explain why the catalyst is more effective when coated onto an unreactive honeycomb.

[2 marks]

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4 (b) The second stage is carried out in a separate reactor. Carbon monoxide is converted into carbon dioxide and more hydrogen is formed.

The equation for this reaction is

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H = -41 \text{ kJ mol}^{-1}$$

Use Le Chatelier's principle to state the effect, if any, of a **decrease** in the total pressure on the yield of hydrogen in this second stage. Explain your answer.

[2 marks]

Effect .....

Explanation .....

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9

Turn over for the next question

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5 There are many uses of halogenated organic compounds despite environmental concerns.

5 (a) Bromotrifluoromethane is used in fire extinguishers in aircraft.
Bromotrifluoromethane is formed when trifluoromethane reacts with bromine.

$$CHF_3 + Br_2 \longrightarrow CBrF_3 + HBr$$

The reaction is a free-radical substitution reaction similar to the reaction of methane with chlorine.

5 (a) (i) Write an equation for each of the following steps in the mechanism for the reaction of CHF_3 with Br_2

[4 marks]

Initiation step

.....

First propagation step

.....

Second propagation step

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A termination step

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5 (a) (ii) State **one** condition necessary for the initiation of this reaction.

[1 mark]

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Do not write outside the box

5 (b) Bromine-containing and chlorine-containing organic compounds may have a role in the decomposition of ozone in the upper atmosphere.

5 (b) (i) Draw an appropriate **displayed formula** in the space provided to complete the following equation to show how $CBrF_3$ may produce bromine atoms in the upper atmosphere.

[1 mark]

$CBrF_3 \longrightarrow$ ..... + Br•

5 (b) (ii) In the upper atmosphere, it is more likely for $CBrF_3$ to produce bromine atoms than it is for $CClF_3$ to produce chlorine atoms.

Suggest **one** reason for this.

[1 mark]

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Question 5 continues on the next page

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5 (b) (iii) Bromine atoms have a similar role to chlorine atoms in the decomposition of ozone. The overall equation for the decomposition of ozone is

$$2O_3 \longrightarrow 3O_2$$

Write **two** equations to show how bromine atoms (Br•) act as a catalyst in the decomposition of ozone.

Explain how these two decomposition equations show that bromine atoms behave as a catalyst.

[3 marks]

Equation 1

.....

Equation 2

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Explanation .....

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6 Butane and propanal are compounds with M_r = 58.0, calculated using data from your Periodic Table.

6 (a) A mass spectrometer can be used to distinguish between samples of butane and propanal.

Table 1 shows some precise relative atomic mass values.

Table 1

Atom	Precise relative atomic mass
^{1}H	1.00794
^{12}C	12.00000

6 (a) (i) Use data from **Table 1** to show that, to 3 significant figures, a more accurate value for the M_r of butane is 58.1

[1 mark]

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6 (a) (ii) State why the precise relative atomic mass quoted in **Table 1** for the ^{12}C isotope is exactly 12.00000

[1 mark]

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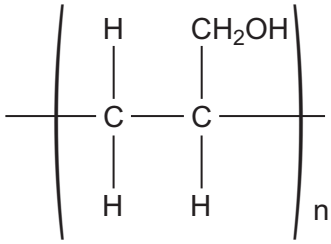
Question 6 continues on the next page

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6 (b) Draw a **displayed formula** for the organic product that is formed when propanal is oxidised by warm Tollens' reagent.

[1 mark]

6 (c) Prop-2-en-1-ol is an isomer of propanal and can be polymerised to form a polymer represented by the following structure.



6 (c) (i) Draw the structure of prop-2-en-1-ol.

[1 mark]

6 (c) (ii) Deduce the type of polymerisation that results in the formation of this polymer from prop-2-en-1-ol.

[1 mark]

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Do not write outside the box

6 (c) (iii) There are two functional groups in prop-2-en-1-ol. Each of these functional groups contains a bond with a characteristic absorption range in the infrared spectrum.

Use **Table A** on the Data Sheet to suggest a bond and its absorption range for each of the two functional groups.

[2 marks]

Bond 1 ..... Absorption range .....

Bond 2 ..... Absorption range .....

6 (d) Compound **X** is another isomer of propanal. The infrared spectrum of **X** shows an absorption in the range 1680–1750 cm^{-1}.

6 (d) (i) Draw the structure of **X**.

[1 mark]

6 (d) (ii) Which of the following, **A**, **B**, **C** or **D**, represents the type of isomerism shown by **X** and propanal?

Write the correct letter, **A**, **B**, **C** or **D**, in the box.

[1 mark]

A chain isomerism
B E–Z isomerism
C functional group isomerism
D position isomerism

9

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7 (a) Propanone can be formed when glucose comes into contact with bacteria in the absence of air.

7 (a) (i) Balance the following equation for this reaction of glucose to form propanone, carbon dioxide and water.

[1 mark]

.....$C_6H_{12}O_6$ $\longrightarrow$ .....CH_3COCH_3 + ...CO_2 + ...H_2O

7 (a) (ii) Deduce the role of the bacteria in this reaction.

[1 mark]

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7 (b) Propanone is also formed by the oxidation of propan-2-ol.

7 (b) (i) Write an equation for this reaction using [O] to represent the oxidising agent.

[1 mark]

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7 (b) (ii) State the class of alcohols to which propan-2-ol belongs.

[1 mark]

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Do not write outside the box

7 (c) A student determined a value for the enthalpy change when a sample of propanone was burned. The heat produced was used to warm some water in a copper calorimeter. The student found that the temperature of 150 g of water increased by 8.0 ºC when 4.50×10^{-3} mol of pure propanone was burned in air.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of propanone is burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

[3 marks]

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Question 7 continues on the next page

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7 (d) Define the term **standard enthalpy of combustion**.

[3 marks]

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7 (e) Use the mean bond enthalpy data in **Table 2** and the equation given below **Table 2** to calculate a value for the standard enthalpy change when gaseous propanone is burned.

[3 marks]

Table 2

	C—H	C—C	C—O	O—H	C=O	O=O
Mean bond enthalpy / kJ mol^{-1}	412	348	360	463	805	496

$$CH_3COCH_3(g) + 4O_2(g) \longrightarrow 3CO_2(g) + 3H_2O(g)$$

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7 (f) Suggest **two** reasons why the value obtained by the student in Question **7 (c)** is different from the value calculated in Question **7 (e)**.

[2 marks]

Reason 1 .....

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Reason 2 .....

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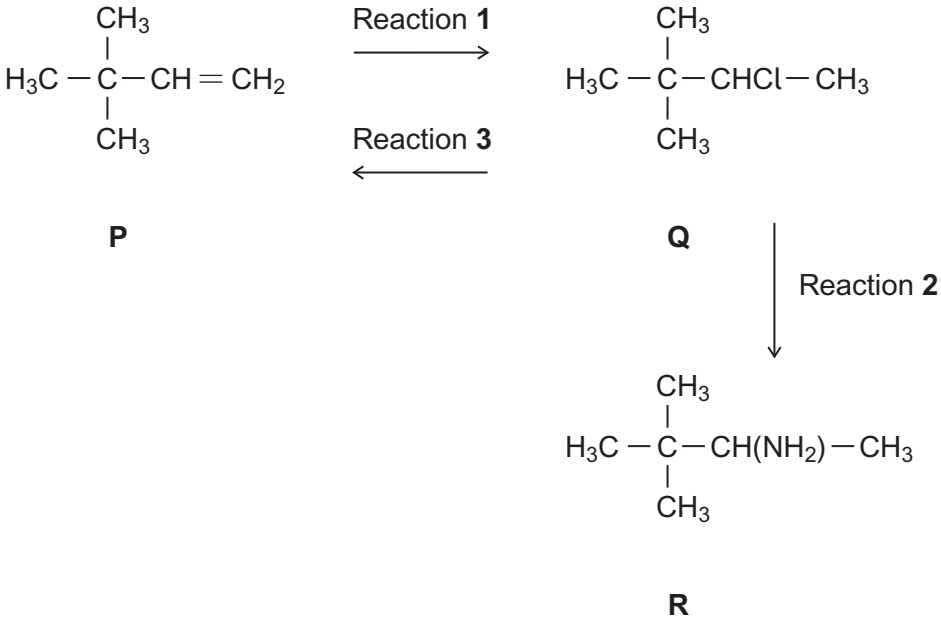
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Section B

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

8 Consider the following scheme of reactions.



8 (a) Give the IUPAC name for compound **P** and that for compound **Q**.

[2 marks]

P .....

Q .....

Do not write outside the box

8 (b) The conversion of **P** into **Q** in Reaction **1** uses HCl

Name and outline a mechanism for this reaction.

[5 marks]

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8 (c) The conversion of **Q** into **R** in Reaction **2** uses NH_3

Name and outline a mechanism for this reaction.

[5 marks]

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Question 8 continues on the next page

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8 (d) State the type of reaction shown by Reaction **3**.

Identify a reagent for this reaction.

Give **one** condition necessary for a high yield of product when **Q** is converted into **P**.

[3 marks]

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8 (e) Hydrogen bromide (HBr) could be used in the overall conversion of **P** into **R**, instead of using HCl

Hydrogen bromide is made by the reaction of NaBr with concentrated phosphoric acid.

Concentrated sulfuric acid is **not** used to make HBr from NaBr

Write an equation for the reaction of NaBr with H_3PO_4 to produce HBr and Na_3PO_4 only.

Identify **two** toxic gases that are formed, together with HBr, when NaBr reacts with concentrated H_2SO_4

State the role of H_2SO_4 in the formation of these two toxic gases.

[4 marks]

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9 Vanadium is an important metal. Ferrovanadium, an alloy of iron and vanadium, is used to make a strong type of vanadium-steel. Pure vanadium is used in nuclear reactors.

9 (a) **Table 3** shows some standard enthalpy of formation data.

Table 3

	$V_2O_5(s)$	CaO(s)
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–1560	–635

In the oldest method of extraction of vanadium, V_2O_5 is reacted with calcium at a high temperature.

$$5Ca(s) + V_2O_5(s) \longrightarrow 2V(s) + 5CaO(s)$$

Use data from **Table 3** and the equation to calculate the standard enthalpy change for this reaction.

State the type of reaction that V_2O_5 has undergone.

Suggest **one** major reason why this method of extracting vanadium is expensive, other than the cost of heating the reaction mixture.

[5 marks]

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Question 9 continues on the next page

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9 (b) Ferrovanadium is produced by the reaction of aluminium with a mixture of V_2O_5 and iron(III) oxide.

Write an equation for the reaction of aluminium with iron(III) oxide.

State the change in oxidation state of aluminium in this reaction.

[2 marks]

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9 (c) Pure vanadium, for nuclear reactors, is formed by the reaction of hydrogen with purified VCl_2

Write an equation for this reaction in which the only other product is HCl gas.

Identify **two** hazards in this process, other than the fact that it operates at a high temperature.

Deduce why this process produces **pure** vanadium, other than the fact that purified VCl_2 is used.

[4 marks]

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11

END OF QUESTIONS

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