

Centre Number						Candidate Number				
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For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
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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

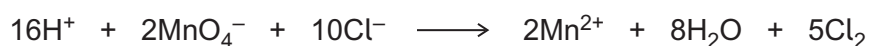
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.



Section AAnswer **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



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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Turn over ►



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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Turn over for the next question

Turn over ►



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ANSWER IN THE SPACES PROVIDED**



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]

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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]

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5

Turn over ►



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



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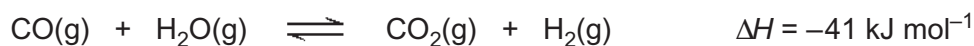
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4 (b) The second stage is carried out in a separate reactor. Carbon monoxide is converted into carbon dioxide and more hydrogen is formed.

The equation for this reaction is



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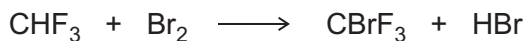
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5 There are many uses of halogenated organic compounds despite environmental concerns.

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



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

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First propagation step

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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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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]



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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



Write **two** equations to show how bromine atoms ($\text{Br}\cdot$) 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

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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
^1H	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

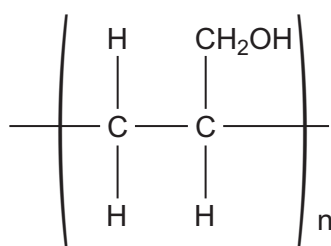
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- 6 (b) Draw a **displayed formula** for the organic product that is formed when propanal is oxidised by warm Tollens' reagent.

[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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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



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]



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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- 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 °C 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 $4.18 \text{ J K}^{-1} \text{ g}^{-1}$)

[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



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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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Turn over for the next question

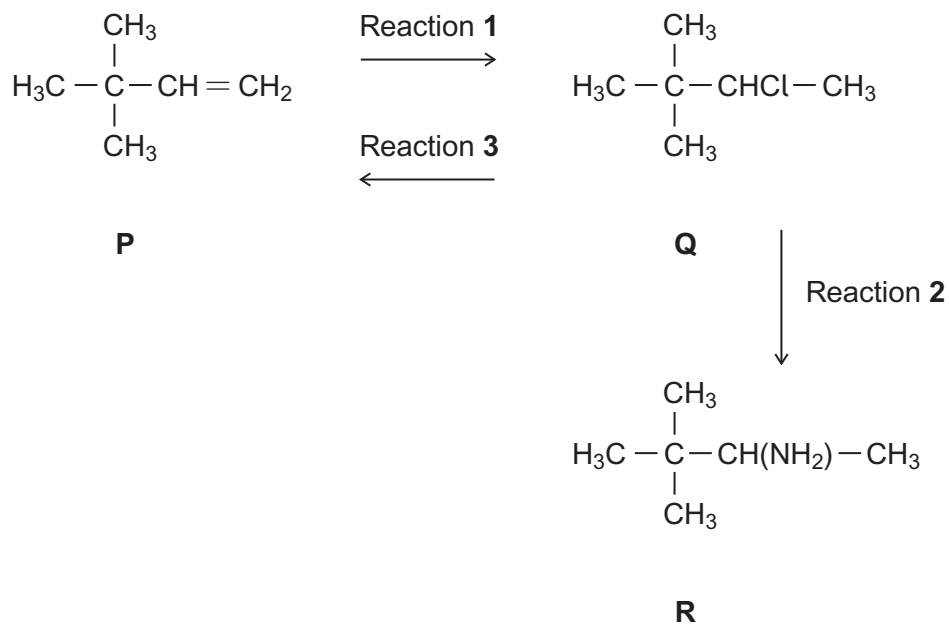
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Section B

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**

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

Turn over ►



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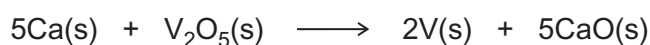
9 Vanadium is an important metal. Ferrovandium, an alloy of iron and vanadium, is used to make a strong type of vanadium-steel. Pure vanadium is used in nuclear reactors.

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

Table 3

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

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



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)** Ferrovandium 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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END OF QUESTIONS

