Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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9	
10	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
January 2013

Chemistry CHEM2

Unit 2 Chemistry in Action

Wednesday 16 January 2013 9.00 am to 10.45 am

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- 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**.

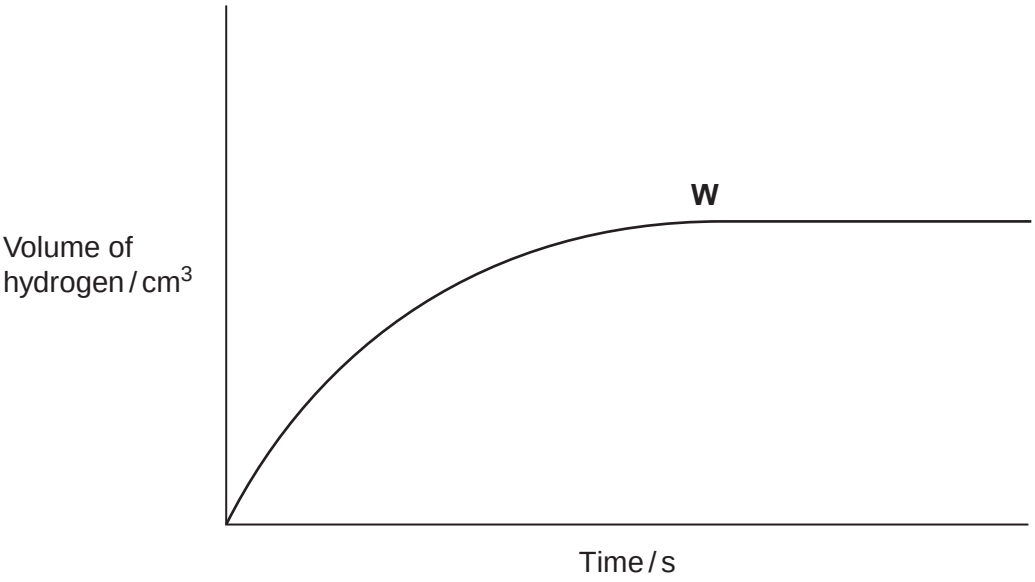
Section A

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

1 (a) **Figure 1** shows the volume of hydrogen gas collected when a sample of magnesium reacted with an excess of dilute hydrochloric acid.

The rate of this reaction can be studied by measuring the time it takes for a given volume of hydrogen to be collected.

Figure 1



1 (a) (i) State the meaning of the term *rate of reaction*.

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(1 mark)

1 (a) (ii) State and explain what has happened to the rate of this reaction at point **W** in **Figure 1**.

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(2 marks)

1 (a) (iii) In terms of collision theory explain why, at a fixed temperature, the rate of this reaction doubles when the concentration of the hydrochloric acid doubles.

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(2 marks)

1 (b) In a study of the reaction in part **(a)**, a student referred to activation energy.

1 (b) (i) State the meaning of the term *activation energy*.

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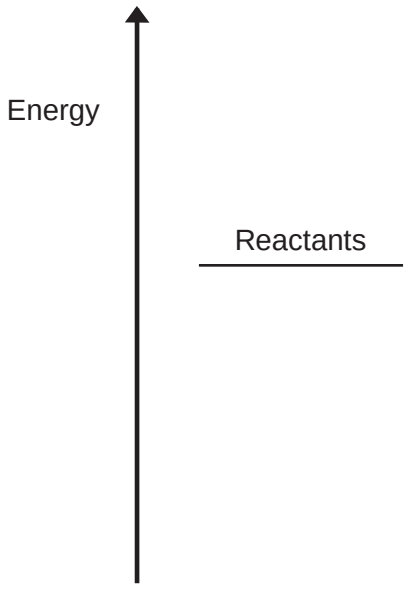
(1 mark)

1 (b) (ii) Complete **Figure 2** by drawing the shape of the reaction profile from reactants to products for an exothermic reaction.
Show the position of the products. Show and label the activation energy.

Figure 2



(2 marks)

Question 1 continues on the next page

1 (c) Barium metal reacts very quickly with dilute hydrochloric acid, but it reacts more slowly with water.

1 (c) (i) Write an equation for the reaction of barium with water.

.....

(1 mark)

1 (c) (ii) A solution containing barium ions can be used to show the presence of sulfate ions in an aqueous solution of sodium sulfate.

Write the **simplest ionic** equation for the reaction that occurs and state what is observed.

Simplest ionic equation

.....

Observation

.....

(2 marks)

1 (c) (iii) State **one** use of barium sulfate in medicine.
Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .....

.....

Explanation .....

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(2 marks)

13

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

2 A study of equilibrium is important for understanding chemical reactions.

2 (a) State Le Chatelier's principle.

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(1 mark)

(Extra space) .....

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2 (b) Catalysts play an important role in many reactions.

2 (b) (i) State the meaning of the term *catalyst*.
Explain, in general terms, how catalysts work.

Meaning of the term *catalyst* .....

.....

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How catalysts work .....

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(3 marks)

(Extra space) .....

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2 (b) (ii) State the effect, if any, of a catalyst on the time taken to reach equilibrium.

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(1 mark)

2 (b) (iii) State the effect, if any, of a catalyst on the position of an equilibrium.

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(1 mark)

2 (c) Consider the following equilibrium reactions.

		$\Delta H^{\ominus}$ / kJ mol^{-1}
P	$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$	–10
Q	$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$	–49
R	$N_2O_4(g) \rightleftharpoons 2NO_2(g)$	+58
S	$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$	–92
T	$C_2H_4(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g)$	–42

In each of parts **(c) (i)** to **(c) (v)**, you should record in the box **one** of the letters, **P**, **Q**, **R**, **S** or **T**, that corresponds to the equilibrium that best fits the information provided. You may use each letter once, more than once or not at all.

2 (c) (i) A decrease in temperature at constant pressure shifts the position of this equilibrium from right to left.

(1 mark)

2 (c) (ii) This equilibrium uses concentrated phosphoric acid as a catalyst in a hydration reaction.

(1 mark)

2 (c) (iii) A decrease in pressure at constant temperature shifts the position of this equilibrium from left to right.

(1 mark)

2 (c) (iv) There is no change in the position of this equilibrium when the pressure is increased at constant temperature.

(1 mark)

2 (c) (v) An increase in the concentration of steam at constant temperature and constant pressure shifts the position of this equilibrium from right to left.

(1 mark)

11

3 This question is about the extraction of metals.

3 (a) Manganese can be extracted from Mn_2O_3 by reduction with carbon monoxide at high temperature.

3 (a) (i) Use the standard enthalpy of formation data from the table and the equation for the extraction of manganese to calculate a value for the standard enthalpy change of this extraction.

	$Mn_2O_3(s)$	$CO(g)$	$Mn(s)$	$CO_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 971	– 111	0	– 394

$$Mn_2O_3(s) + 3CO(g) \longrightarrow 2Mn(s) + 3CO_2(g)$$

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(3 marks)

3 (a) (ii) State why the value for the standard enthalpy of formation of Mn(s) is zero.

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(1 mark)

Do not write outside the box

3 (b) Titanium is extracted in industry from titanium(IV) oxide in a two-stage process.

3 (b) (i) Write an equation for the first stage of this extraction in which titanium(IV) oxide is converted into titanium(IV) chloride.

.....

(2 marks)

3 (b) (ii) Write an equation for the second stage of this extraction in which titanium(IV) chloride is converted into titanium.

.....

(2 marks)

3 (c) Chromium is extracted in industry from chromite ($FeCr_2O_4$).

3 (c) (i) In the first stage of this extraction, the $FeCr_2O_4$ is converted into Na_2CrO_4

Balance the equation for this reaction.

..... $FeCr_2O_4$ + ... Na_2CO_3 + ... O_2 $\longrightarrow$ ..... Na_2CrO_4 + $2Fe_2O_3$ + $8CO_2$

(1 mark)

3 (c) (ii) In the final stage, chromium is extracted from Cr_2O_3 by reduction with aluminium.

Write an equation for this reaction.

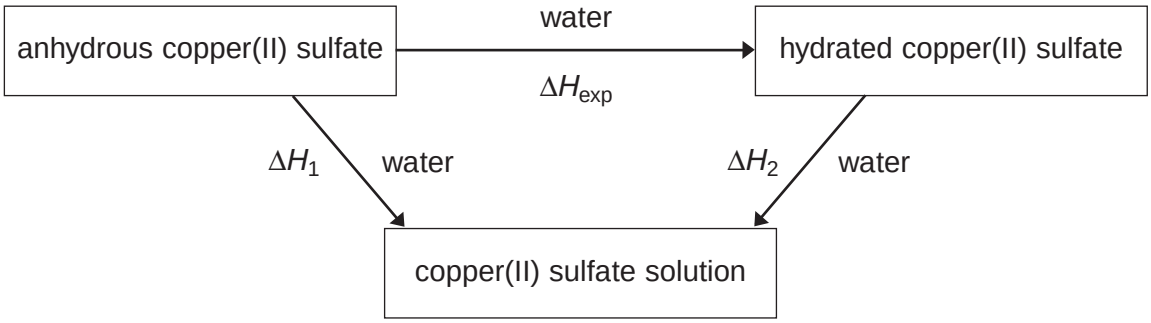
.....

(1 mark)

10

Turn over for the next question

4 A student used Hess's Law to determine a value for the enthalpy change that occurs when anhydrous copper(II) sulfate is hydrated.
This enthalpy change was labelled ΔH_{exp} by the student in a scheme of reactions.



4 (a) State Hess's Law.

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(1 mark)

4 (b) Write a mathematical expression to show how ΔH_{exp}, ΔH_1 and ΔH_2 are related to each other by Hess's Law.

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(1 mark)

4 (c) Use the mathematical expression that you have written in part **(b)**, and the data book values for the two enthalpy changes ΔH_1 and ΔH_2 shown, to calculate a value for ΔH_{exp}

$\Delta H_1 = -156\,kJ\,mol^{-1}$
$\Delta H_2 = +12\,kJ\,mol^{-1}$

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(1 mark)

4 (d) The student added 0.0210 mol of pure anhydrous copper(II) sulfate to 25.0 cm^3 of deionised water in an open polystyrene cup. An exothermic reaction occurred and the temperature of the water increased by 14.0 ºC.

4 (d) (i) Use these data to calculate the enthalpy change, in $kJ\,mol^{-1}$, for this reaction of copper(II) sulfate. This is the student value for ΔH_1

In this experiment, you should assume that all of the heat released is used to raise the temperature of the 25.0 g of water. The specific heat capacity of water is $4.18\,J\,K^{-1}\,g^{-1}$.

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(3 marks)

4 (d) (ii) Suggest **one** reason why the student value for ΔH_1 calculated in part **(d) (i)** is less accurate than the data book value given in part **(c)**.

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(1 mark)

4 (e) Suggest **one** reason why the value for ΔH_{exp} **cannot** be measured directly.

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(1 mark)

(Extra space) .....

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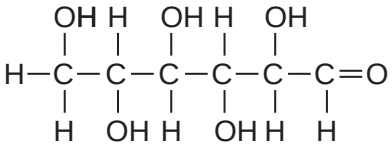
8

5 Glucose is an organic molecule. Glucose can exist in different forms in aqueous solution.

5 (a) In aqueous solution, some glucose molecules have the following structure.



5 (a) (i) Deduce the empirical formula of glucose.

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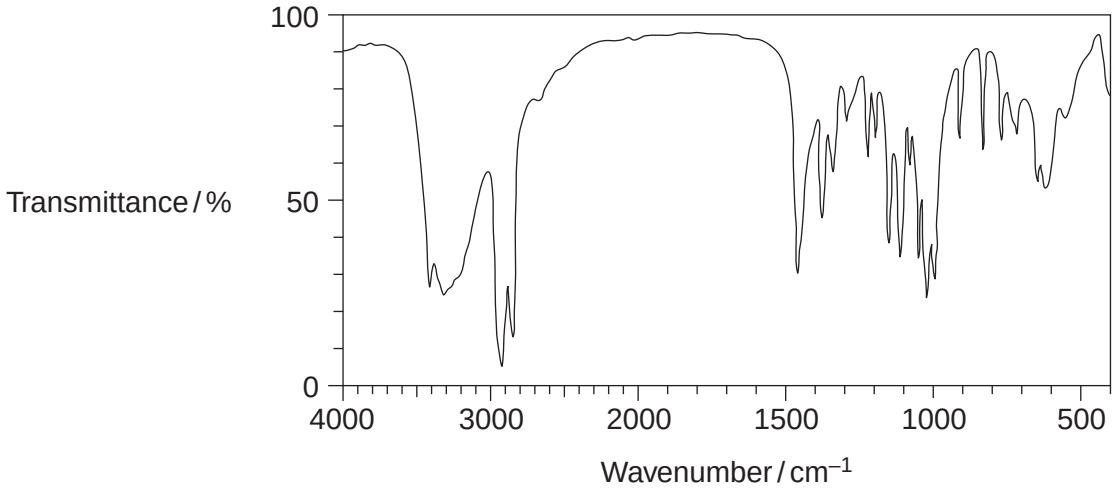
(1 mark)

5 (a) (ii) Consider the infrared spectrum of solid glucose.



State why it is possible to suggest that in the solid state very few molecules have the structure shown.
You may find it helpful to refer to **Table 1** on the Data Sheet.

.....

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(1 mark)

5 (b) In the absence of oxygen, an aqueous solution of glucose can be fermented to produce ethanol for use in alcoholic drinks.

Write an equation for this fermentation reaction.
Give **two** other essential conditions for the production of ethanol in this fermentation.

Equation

.....

Condition 1 .....

Condition 2 .....

(3 marks)

5 (c) Any ethanol present in the breath of a drinker can be detected by using a breathalyser. The ethanol is converted into ethanoic acid. The breathalyser has negative and positive electrodes. A current is measured and displayed in terms of alcohol content.

The overall redox equation is as follows

$$CH_3CH_2OH(l) + O_2(g) \longrightarrow CH_3COOH(l) + H_2O(l)$$

5 (c) (i) Draw the displayed formula for ethanoic acid.

(1 mark)

5 (c) (ii) Deduce a half-equation for the reduction of atmospheric oxygen to water in acidic solution at one electrode of the breathalyser.

.....

(1 mark)

5 (c) (iii) Deduce a half-equation for the oxidation of ethanol in water to ethanoic acid at the other electrode of the breathalyser.

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(1 mark)

Question 5 continues on the next page

Turn over ▶

5 (c) (iv) The earliest breathalysers used laboratory chemicals to oxidise the ethanol to ethanoic acid. Detection was by a colour change.

Identify a reagent or combination of reagents that you would use in the laboratory to oxidise ethanol to ethanoic acid.
State the colour **change** that you would expect to see.

Reagent or combination of reagents .....

Colour change .....
(2 marks)

5 (d) The fermentation of glucose from crops is the main method for the production of ethanol. The product is called bioethanol. The European Union has declared that bioethanol is carbon-neutral.

5 (d) (i) State the meaning of the term *carbon-neutral*.

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(1 mark)

(Extra space) .....

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5 (d) (ii) Other than carbon-neutrality, state the **main** advantage of the use of glucose from crops as the raw material for the production of ethanol.

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(1 mark)

5 (d) (iii) Give **one** disadvantage of the use of crops for the production of ethanol.

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(1 mark)

13

6 Hydrazine (N_2H_4) decomposes in an exothermic reaction. Hydrazine also reacts exothermically with hydrogen peroxide when used as a rocket fuel.

6 (a) Write an equation for the decomposition of hydrazine into ammonia and nitrogen only.

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(1 mark)

6 (b) State the meaning of the term *mean bond enthalpy*.

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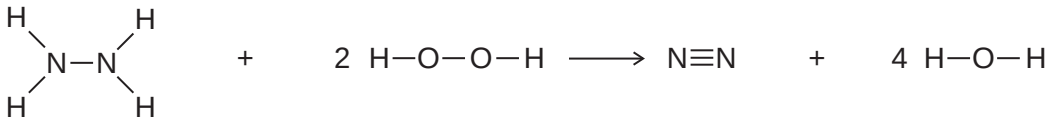
(2 marks)

6 (c) Some mean bond enthalpies are given in the table.

	N—H	N—N	N≡N	O—H	O—O
Mean bond enthalpy / kJ mol^{-1}	388	163	944	463	146

Use these data to calculate the enthalpy change for the gas-phase reaction between hydrazine and hydrogen peroxide.



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(3 marks)

6

7 The refrigerant R410A, used in air conditioners, is a mixture of two fluoroalkanes, pentafluoroethane and difluoromethane.

7 (a) (i) The mechanism for the reaction of fluorine with either an alkane or a fluoroalkane is similar to that for the reaction of chlorine with methane.

Name the type of mechanism for the reaction of chlorine with methane.

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(1 mark)

7 (a) (ii) Write equations for the following steps in the mechanism for the reaction of fluorine with fluoromethane (CH_3F) to form difluoromethane (CH_2F_2).

Initiation step

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First propagation step

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Second propagation step

.....

A termination step leading to the formation of 1,2-difluoroethane.

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(4 marks)

7 (a) (iii) Write an overall equation for the reaction of fluorine with ethane to form pentafluoroethane (CF_3CHF_2) by this mechanism.

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(1 mark)

7 (b) The refrigerant R112A (CCl_3CF_2Cl) has been banned because of concerns about ozone depletion.

Give the IUPAC name for CCl_3CF_2Cl

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(1 mark)

7 (c) Nitrogen monoxide (NO) catalyses the decomposition of ozone into oxygen.

7 (c) (i) Write the overall equation for this decomposition.

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(1 mark)

7 (c) (ii) Use the overall equation to deduce Step **3** in the following mechanism that shows how nitrogen monoxide catalyses this decomposition.

Step **1** $O_3 \longrightarrow O + O_2$

Step **2** $NO + O_3 \longrightarrow NO_2 + O_2$

Step **3** .....

(1 mark)

9

Turn over for the next question

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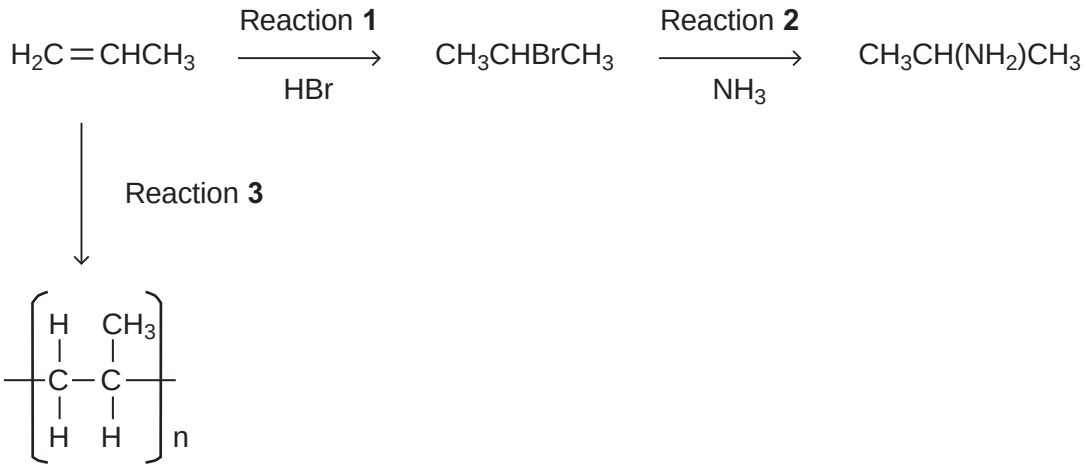
Section B

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

8 Consider the following reactions.



substance **X**

8 (a) Name and outline a mechanism for Reaction **1**.

Name of mechanism .....

Mechanism

(5 marks)

8 (b) Name and outline a mechanism for Reaction **2**.

Name of mechanism .....

Mechanism

(5 marks)

8 (c) State the type of reaction in Reaction **3**.
Give the name of substance **X**.

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(2 marks)

Question 8 continues on the next page

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8 (d) The haloalkane produced in Reaction **1** can be converted back into propene in an elimination reaction using ethanolic potassium hydroxide.

$$CH_3CHBrCH_3 \xrightarrow{KOH} H_2C{=}CHCH_3$$

Outline a mechanism for this conversion.

(3 marks)

15

9 Concentrated sulfuric acid reacts with solid potassium iodide as shown in the equation.

$$8KI + 9H_2SO_4 \longrightarrow 4I_2 + 8KHSO_4 + H_2S + 4H_2O$$

Give **two** observations that you would make when this reaction occurs.

In terms of electrons, state what happens to the iodide ions in this reaction.

State the **change** in oxidation state of sulfur that occurs during this formation of H_2S and deduce the half-equation for the conversion of H_2SO_4 into H_2S

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(5 marks)

5

Turn over for the next question

10 Chlorine is a powerful oxidising agent.

10 (a) Write the **simplest ionic** equation for the reaction between chlorine and aqueous potassium bromide.

State what is observed when this reaction occurs.

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(2 marks)

(Extra space) .....

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10 (b) Write an equation for the reaction between chlorine and cold, dilute, aqueous sodium hydroxide.

Give a major use for the solution that is formed by this reaction.

Give the IUPAC name of the chlorine-containing compound formed in this reaction in which chlorine has an oxidation state of +1.

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(3 marks)

(Extra space) .....

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Do not write outside the box

10 (c) Write an equation for the equilibrium reaction that occurs when chlorine gas reacts with cold water.

Give **one** reason why chlorine is used for the treatment of drinking water even though the gas is very toxic.

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(2 marks)

(Extra space) .....

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10 (d) State how you could test a sample of water to show that it contains chloride ions.

In your answer, give a reagent, **one** observation and the **simplest ionic** equation for the reaction with the reagent.

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(3 marks)

(Extra space) .....

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10

END OF QUESTIONS

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