Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
June 2010

Chemistry CHEM2

Unit 2 Chemistry in Action

Monday 7 June 2010 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.
- 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 accurate scientific terminology

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

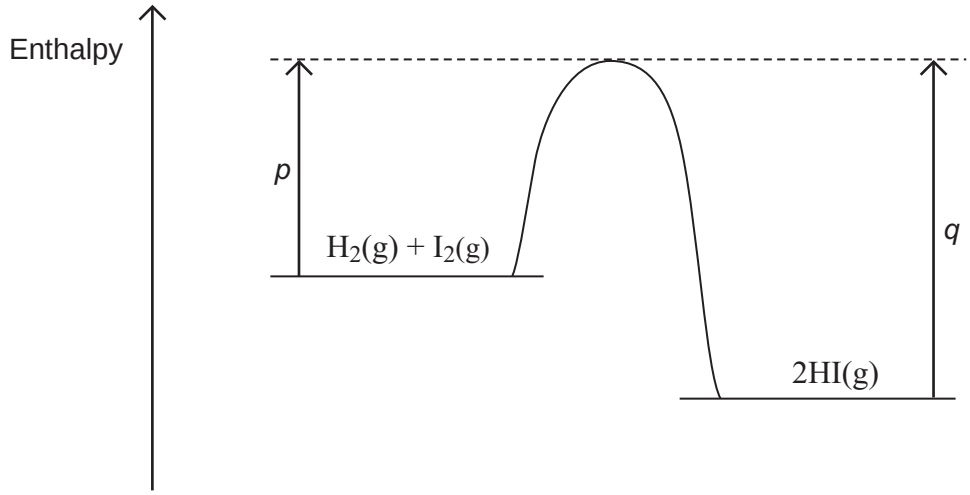
Section A

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

1 An equation for the equilibrium reaction between hydrogen, iodine and hydrogen iodide is shown below.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

1 (a) The curve in the diagram below illustrates the reaction profile for this equilibrium reaction without a catalyst.



1 (a) (i) Draw on the diagram a curve to illustrate the reaction profile for this equilibrium reaction **with** a catalyst. *(2 marks)*

1 (a) (ii) Use the diagram to deduce whether the formation of hydrogen iodide from hydrogen and iodine is exothermic or endothermic.

.....

(1 mark)

1 (a) (iii) State what the diagram suggests about the sum of the bond enthalpies for the reactant molecules compared with the product molecules.

.....

.....

(1 mark)

1 (a) (iv) In terms of *p* and *q*, identify the following for this equilibrium without a catalyst.

A value for the activation energy for the forward reaction .....

A value for the overall enthalpy change for the forward reaction .....

(2 marks)

1 (b) A mixture of $H_2(g)$ and $I_2(g)$ was allowed to reach equilibrium.

1 (b) (i) State the effect of a catalyst on the rate of attainment of this equilibrium.

.....

(1 mark)

1 (b) (ii) State and explain the effect of an increase in total pressure on the rate of attainment of this equilibrium.

Effect of an increase in pressure on rate .....

Explanation .....

.....

.....

.....

(3 marks)

10

Turn over for the next question

2 A student carried out an experiment to study the rates of hydrolysis of some haloalkanes.

2 (a) In the experiment, two different haloalkanes were placed in separate test tubes containing silver nitrate solution. The haloalkanes reacted with the water in the silver nitrate solution. The student timed how long it took for the first appearance of the silver halide precipitate in each tube at a constant temperature. This time was used to provide a measure of the initial rate of reaction.
The student obtained the following results.

	1-bromobutane	1-iodobutane
Time to form a precipitate / s	480	15

2 (a) (i) State the meaning of the term *hydrolysis.*

.....

.....

(1 mark)

2 (a) (ii) State the colour of the precipitate formed when iodide ions react with silver nitrate and write the **simplest** ionic equation for this reaction.

Colour of precipitate.....

Simplest ionic equation

.....

(2 marks)

2 (a) (iii) Use your knowledge of the reactions of halide ions with silver nitrate to suggest why the student did **not** include 1-fluorobutane in this experiment.

.....

.....

(2 marks)

2 (b) The student used the following enthalpy data to try to account for the different initial rates of hydrolysis of the haloalkanes used in part **(a)**. The student deduced that the rate of hydrolysis of a haloalkane is influenced by the strength of the carbon–halogen bond in the haloalkane.

	C–Br	C–I
Bond enthalpy / kJ mol^{-1}	276	238

State how the experimental evidence enabled the student to make this deduction.

.....

.....

(1 mark)

2 (c) The student had read that the reaction of water with haloalkanes was similar to the reaction of aqueous sodium hydroxide with haloalkanes and was an example of a nucleophilic substitution reaction.

2 (c) (i) State the meaning of the term *nucleophile*.

.....

(1 mark)

2 (c) (ii) When a hydroxide ion collides with a molecule of 1-bromobutane, the following reaction occurs.

$$CH_3CH_2CH_2CH_2Br + OH^- \longrightarrow CH_3CH_2CH_2CH_2OH + Br^-$$

Outline the nucleophilic substitution mechanism for this reaction.

(2 marks)

Question 2 continues on the next page

2 (d) The reaction of hydroxide ions with 2-bromo-2-methylpropane may occur by a different mechanism from the one in part **(c)**. This different mechanism involves the formation of a carbocation.

2 (d) (i) Complete the following equation by drawing the structure of the carbocation formed when the C–Br bond in 2-bromo-2-methylpropane is broken.

.....

(1 mark)

2 (d) (ii) Suggest **one** reason why this reaction occurs by a mechanism involving a carbocation, but the reaction in part **(c) (ii)** does not.

.....

.....

(1 mark)

11

3 Sulfuric acid is made from SO_3 which can be manufactured in a series of stages from iron(II) disulfide (FeS_2), found in the mineral iron pyrites.

3 (a) In the first stage, FeS_2 is roasted in air to form iron(III) oxide and sulfur dioxide.

3 (a) (i) Balance the following equation for this reaction.

$$.....FeS_2 + ...O_2 \longrightarrow .....Fe_2O_3 + ...SO_2$$

(1 mark)

3 (a) (ii) Deduce the oxidation state of sulfur in each of the following compounds.

SO_2 .....

FeS_2 .....

(2 marks)

3 (b) In the second stage of the manufacture of sulfuric acid, sulfur dioxide reacts with oxygen. The equation for the equilibrium that is established is shown below.

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad \Delta H = -98\,kJ\,mol^{-1}$$

State and explain the effect of an increase in temperature on the equilibrium yield of SO_3

Effect of increase in temperature on yield .....

Explanation .....

.....

.....

(3 marks)

(Extra space) .....

.....

3 (c) In the extraction of iron, carbon monoxide reacts with iron(III) oxide. Write an equation for this reaction and state the role of the carbon monoxide.

Equation .....

Role of the carbon monoxide .....

(2 marks)

8

Turn over ▶

4 A scientist used mass spectrometry to analyse a sample of the air near a fertiliser factory. The sample of air included traces of a gas which was shown by its molecular ion to have a precise M_r = 44.00105

4 (a) State the meaning of the term *molecular ion*.

.....

.....

(1 mark)

4 (b) (i) Use the following data to show that the trace gas was dinitrogen oxide (N_2O). Show your working.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{14}N	14.00307
^{16}O	15.99491

.....

.....

(1 mark)

4 (b) (ii) Propane is used as a fuel in the fertiliser factory. State why both propane and its combustion product, carbon dioxide, might have been identified as the trace gas if the scientist had used relative molecular masses calculated to one decimal place.

.....

.....

(1 mark)

4 (b) (iii) State why the precise relative atomic mass for the ^{12}C isotope is exactly 12.00000

.....

(1 mark)

4 (c) Dinitrogen oxide is formed when ammonia is oxidised according to the following equation.

$$2NH_3(g) + 2O_2(g) \longrightarrow N_2O(g) + 3H_2O(l)$$

4 (c) (i) Use the standard enthalpies of formation in the table below to calculate a value for the standard enthalpy change of this reaction.

	$NH_3(g)$	$O_2(g)$	$N_2O(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–46	0	+82	–286

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(3 marks)

(Extra space) .....

.....

4 (c) (ii) State **one** condition necessary for enthalpies of formation to be quoted as standard values at a specified temperature of 298 K.

.....

(1 mark)

8

Turn over for the next question

5 Sulfuric acid is an important chemical in many industrial and laboratory reactions. Consider the following three reactions involving sulfuric acid.

Reaction **1** $Mg(OH)_2 + H_2SO_4 \longrightarrow MgSO_4 + 2H_2O$

Reaction **2** The reaction of solid sodium bromide with concentrated sulfuric acid

Reaction **3** $H_2C{=}CH_2 + H_2O \xrightarrow{\text{conc. } H_2SO_4} CH_3CH_2OH$

5 (a) Give a use for magnesium hydroxide in medicine.

.....

(1 mark)

5 (b) Sulfuric acid behaves as an oxidising agent in Reaction **2**.

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

.....

(1 mark)

5 (b) (ii) Give the formula of the oxidation product that is formed from sodium bromide in Reaction **2**.

.....

(1 mark)

5 (b) (iii) Deduce the half-equation for the reduction of H_2SO_4 to SO_2 in Reaction **2**.

.....

(1 mark)

5 (c) The formation of ethanol in Reaction **3** uses concentrated sulfuric acid and proceeds in two stages according to the following equations.

Stage **1** $H_2C{=}CH_2 + H_2SO_4 \longrightarrow CH_3CH_2OSO_2OH$

Stage **2** $CH_3CH_2OSO_2OH + H_2O \longrightarrow CH_3CH_2OH + H_2SO_4$

5 (c) (i) State the overall role of sulfuric acid in Reaction **3**.

.....

(1 mark)

5 (c) (ii) Outline a mechanism for Stage **1** of this reaction.

(4 marks)

5 (c) (iii) State the class of alcohols to which ethanol belongs.

.....

(1 mark)

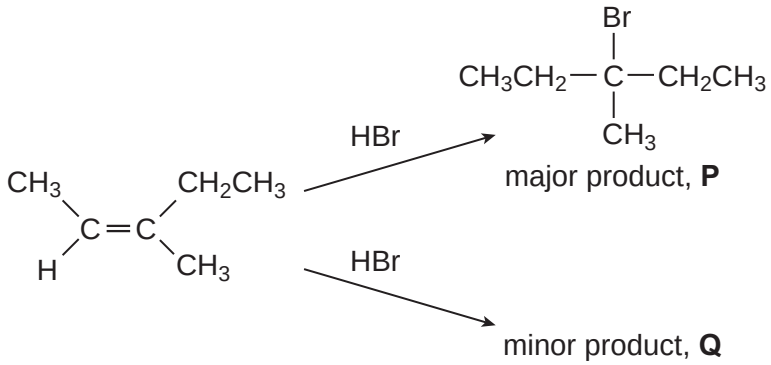
5 (c) (iv) Draw the displayed formula of the carboxylic acid formed when ethanol is oxidised by an excess of acidified potassium dichromate(VI) solution.

(1 mark)

11

Turn over ▶

6 The alkene (Z)-3-methylpent-2-ene reacts with hydrogen bromide as shown below.



6 (a) (i) Name the major product **P**.

.....

(1 mark)

6 (a) (ii) Name the mechanism for these reactions.

.....

(1 mark)

6 (a) (iii) Draw the displayed formula for the minor product **Q** and state the type of structural isomerism shown by **P** and **Q**.

Displayed formula for **Q**

Type of structural isomerism .....

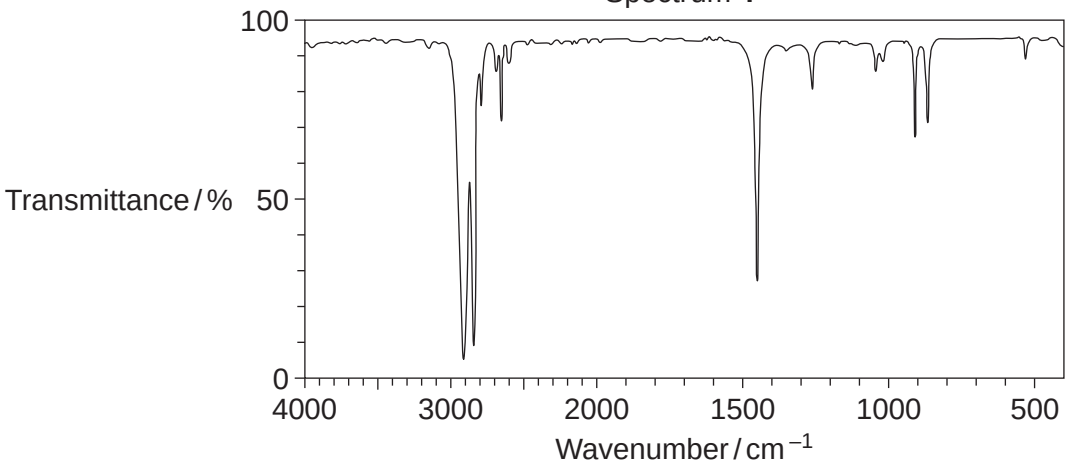
(2 marks)

6 (a) (iv) Draw the structure of the (E)-stereoisomer of 3-methylpent-2-ene.

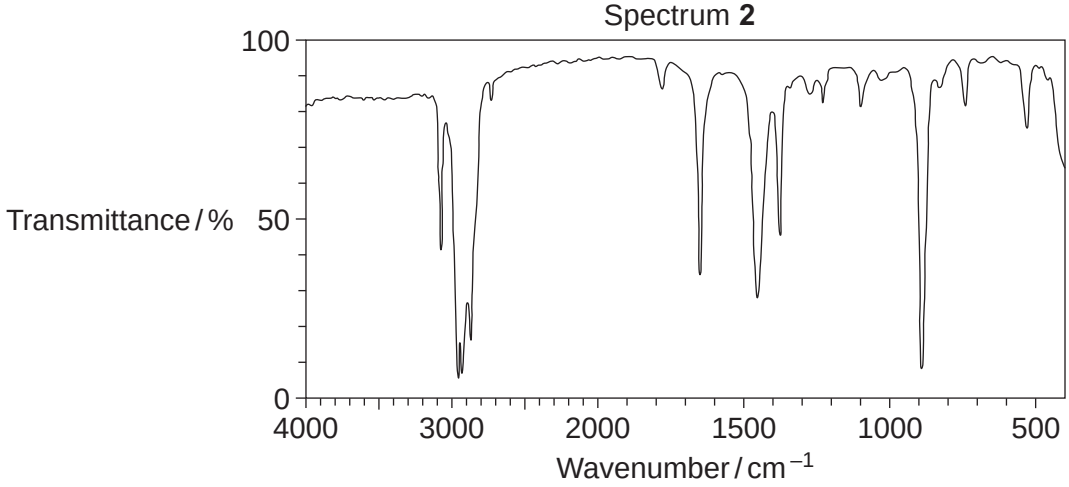
(1 mark)

6 (b) The infrared spectra of two compounds **R** and **S** are shown below. **R** and **S** have the molecular formula C_6H_{12} and are structural isomers of 3-methylpent-2-ene. **R** is an unsaturated hydrocarbon and **S** is a saturated hydrocarbon.

Spectrum **1**



Spectrum **2**



6 (b) (i) Identify the infrared Spectrum **1** or **2** that represents compound **R**.
Use information from the infrared spectra to give **one** reason for your answer.
You may find it helpful to refer to **Table 1** on the Data Sheet.

R is represented by Spectrum .....

Reason .....

.....

(2 marks)

6 (b) (ii) State the type of structural isomerism shown by **R** and **S**.

.....

(1 mark)

6 (b) (iii) Name **one** possible compound which could be **S**.

.....

(1 mark)

9

Turn over ▶

7 Chlorine is a useful industrial chemical.

7 (a) Chlorine gas is used in the manufacture of chlorine-containing organic compounds.

7 (a) (i) Write equations for the following steps in the mechanism for the reaction of chlorine with ethane to form chloroethane (CH_3CH_2Cl).

Initiation step

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First propagation step

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Second propagation step

.....

A termination step producing butane.

.....

(4 marks)

7 (a) (ii) Give **one** essential condition and name the type of mechanism in this reaction of chlorine with ethane.

Essential condition .....

Type of mechanism .....

(2 marks)

7 (b) Chlorine reacts with cold water.

7 (b) (i) Write an equation for this reaction.

.....

(1 mark)

7 (b) (ii) Give **one** large-scale application of the use of chlorine in water. Explain why it is used in this application even though chlorine is very toxic. Do **not** include cost.

Example of application.....

Explanation of use .....

.....

(2 marks)

7 (b) (iii) Two different chlorine-containing compounds are formed when chlorine reacts with cold, dilute sodium hydroxide solution. One of these compounds is sodium chloride. Name the other chlorine-containing compound formed.

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(1 mark)

7 (c) Chlorine is used in the extraction of bromine from seawater.

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

.....

(1 mark)

7 (c) (ii) Explain why bromine has a higher boiling point than chlorine.

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(2 marks)

13

Section B

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

8 Glucose, produced during photosynthesis in green plants, is a renewable source from which ethanol can be made. Ethanol is a liquid fuel used as a substitute for petrol. The processes involved can be summarised as follows.

Process **1** Photosynthesis in green plants

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Process **2** Fermentation of glucose to form ethanol

Process **3** Complete combustion of ethanol

$$CH_3CH_2OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

8 (a) State **three** essential conditions for the fermentation of aqueous glucose in Process **2**.

Write an equation for the reaction that takes place during this fermentation.

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(4 marks)

(Extra space) .....

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8 (b) It has been claimed that there is no net carbon (greenhouse gas) emission to the atmosphere when ethanol made by Process **2** is used as a fuel.

State the term that is used to describe fuels of this type.

Use the equations for Processes **1**, **2** and **3** to show why it can be claimed that there is no net emission of carbon-containing greenhouse gases.

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(3 marks)

(Extra space) .....

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Question 8 continues on the next page

8 (c) Use the information from the equation for Process **3** on page 16 and the mean bond enthalpies from the table below to calculate a value for the enthalpy change for this process.

	C–H	C–C	C–O	O–H	C=O	O=O
Mean bond enthalpy / kJ mol^{-1}	+412	+348	+360	+463	+743	+496

Give **one** reason why the value calculated from mean bond enthalpies is different from the value given in a data book.

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(4 marks)

(Extra space) .....

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8 (d) A student carried out a simple laboratory experiment to measure the enthalpy change for Process **3**. The student showed that the temperature of 200 g of water increased by 8.0 °C when 0.46 g of pure ethanol was burned in air and the heat produced was used to warm the water.

Use these results to calculate the value, in $kJ\,mol^{-1}$, obtained by the student for this enthalpy change. (The specific heat capacity of water is $4.18\,J\,K^{-1}\,g^{-1}$)

Give **one** reason, other than heat loss, why the value obtained from the student's results is less exothermic than a data book value.

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(4 marks)

(Extra space) .....

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15

Turn over for the next question

9 The method of extraction of zinc has changed as different ores containing the element have been discovered and as technology has improved.

Extraction process 1
In the earliest process, calamine (impure zinc carbonate) was heated with charcoal in earthenware pots. This two-stage process gave a low yield of zinc.

$$ZnCO_3(s) \longrightarrow ZnO(s) + CO_2(g)$$
$$ZnO(s) + C(s) \longrightarrow Zn(s) + CO(g)$$

Extraction process 2
Deposits of calamine were being used up and a new two-stage process was developed using zinc sulfide ores. All of the waste gases from this process were released into the atmosphere.

$$2ZnS(s) + 3O_2(g) \longrightarrow 2ZnO(s) + 2SO_2(g)$$
$$ZnO(s) + C(s) \longrightarrow Zn(s) + CO(g)$$

Extraction process 3
The modern process uses the electrolysis of aqueous solutions of very pure zinc sulfate. The first step in this process is the same as the first step in Extraction process **2**. The second step uses sulfuric acid made from the SO_2 collected in the first step. The third step involves the electrolysis of zinc sulfate solution to form pure zinc.

$$2ZnS(s) + 3O_2(g) \longrightarrow 2ZnO(s) + 2SO_2(g)$$
$$ZnO(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2O(l)$$
$$ZnSO_4(aq) \xrightarrow{\text{electrolysis}} Zn(s)$$

9 (a) In the first stage of Extraction process **1** the following equilibrium is established when zinc carbonate is heated in a closed container.

$$ZnCO_3(s) \rightleftharpoons ZnO(s) + CO_2(g)$$

Use Le Chatelier's principle to suggest and explain the effect on the yield of zinc oxide of allowing the carbon dioxide to escape from the container.

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(3 marks)

(Extra space) .....

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9 (b) State and explain **one** environmental reason why Extraction process **3** is an improvement over Extraction process **2**.

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(3 marks)

(Extra space) .....

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9 (c) Give **one** reason why Extraction process **3** is an expensive method of making zinc but one which is justified in terms of the product formed.

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(2 marks)

(Extra space) .....

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Question 9 continues on the next page

9 (d) Deduce the half-equation for the formation of zinc from zinc ions during the electrolysis of zinc sulfate solution and identify the electrode at which this reaction occurs.

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(2 marks)

(Extra space) .....

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9 (e) Identify **one** reaction from the three extraction processes that is **not** a redox reaction and state the type of reaction that it is. In terms of redox, state what happens to the carbon in Extraction process **2**.

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(3 marks)

(Extra space) .....

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9 (f) Zinc and magnesium both react with steam in a similar way. Write an equation for the reaction of zinc with steam and name the products of this reaction.

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(2 marks)

(Extra space) .....

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15

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED