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Section A

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

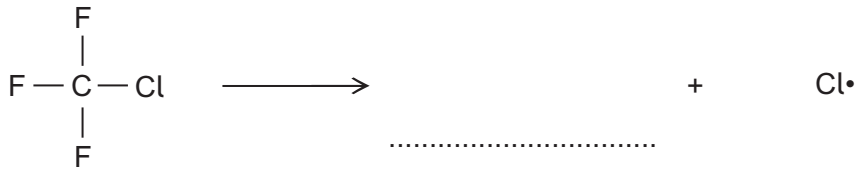
1 Oxygen and ozone (O_3) both occur as gases in the upper atmosphere.
Chlorine atoms catalyse the decomposition of ozone and contribute to the formation of a hole in the ozone layer.
These chlorine atoms are formed from chlorofluorocarbons (CFCs) such as CF_3Cl

1 (a) (i) Give the IUPAC name of CF_3Cl

.....

(1 mark)

1 (a) (ii) Complete the following equation that shows the formation of a chlorine atom from a molecule of CF_3Cl



(1 mark)

1 (a) (iii) State what the • represents in Cl•

.....

(1 mark)

1 (b) Write two equations that show how chlorine atoms catalyse the decomposition of ozone into oxygen.

Equation 1 .....

Equation 2 .....

(2 marks)

Do not write outside the box

1 (c) An equilibrium is established between oxygen and ozone molecules as shown below.

$$3O_2(g) \rightleftharpoons 2O_3(g) \qquad \Delta H = +284\,\text{kJ mol}^{-1}$$

1 (c) (i) State Le Chatelier's principle.

.....

.....

.....

(1 mark)

(Extra space) .....

.....

1 (c) (ii) Use Le Chatelier's principle to explain how an increase in temperature causes an increase in the equilibrium yield of ozone.

.....

.....

.....

.....

(2 marks)

(Extra space) .....

.....

1 (d) Chemists supported the legislation to ban the use of CFCs. Modern refrigerators use pentane rather than CFCs as refrigerants.
With reference to its formula, state why pentane is a more environmentally acceptable refrigerant.

.....

.....

(1 mark)

(Extra space) .....

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9

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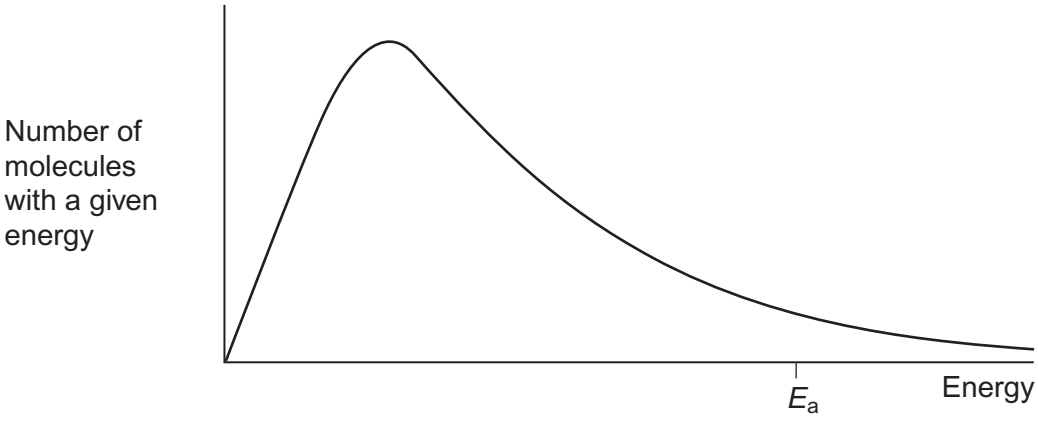
2 The diagram below shows a Maxwell–Boltzmann distribution for a sample of gas at a fixed temperature.
E_a is the activation energy for the decomposition of this gas.



2 (a) (i) On this diagram, sketch the distribution for the same sample of gas at a higher temperature. *(2 marks)*

2 (a) (ii) With reference to the Maxwell–Boltzmann distribution, explain why an increase in temperature increases the rate of a chemical reaction.

.....

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(2 marks)

(Extra space) .....

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2 (b) Dinitrogen oxide (N_2O) is used as a rocket fuel. The data in the table below show how the activation energy for the decomposition of dinitrogen oxide differs with different catalysts.

$$2N_2O(g) \longrightarrow 2N_2(g) + O_2(g)$$

	E_a / kJ mol^{-1}
Without a catalyst	245
With a gold catalyst	121
With an iron catalyst	116
With a platinum catalyst	136

2 (b) (i) Use the data in the table to deduce which is the most effective catalyst for this decomposition.

.....

(1 mark)

2 (b) (ii) Explain how a catalyst increases the rate of a reaction.

.....

.....

.....

.....

(2 marks)

(Extra space) .....

.....

7

Do not write outside the box

3 The following pairs of compounds can be distinguished by observing what happens in test-tube reactions.
For each pair, give a suitable aqueous reagent that could be added separately to each compound.
Describe what you would observe in each case.

3 (a) NaF(aq) and NaCl(aq)

Reagent .....

Observation with NaF(aq) .....

Observation with NaCl(aq) .....

(3 marks)

3 (b) $BaCl_2(aq)$ and $MgCl_2(aq)$

Reagent .....

Observation with $BaCl_2(aq)$.....

Observation with $MgCl_2(aq)$ .....

(3 marks)

3 (c) AgCl(s) and AgI(s)

Reagent .....

Observation with AgCl(s) .....

Observation with AgI(s) .....

(3 marks)

3 (d) Butan-2-ol(l) and 2-methylpropan-2-ol(l)

Reagent .....

Observation with butan-2-ol(l) .....

Observation with 2-methylpropan-2-ol(l) .....

(3 marks)

12

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4 (a) Pure manganese is extracted from the ore pyrolusite (MnO_2) by reduction using carbon monoxide.
Write an equation for the reduction of MnO_2 to manganese using carbon monoxide.

.....

(1 mark)

4 (b) Impure manganese is extracted by reduction of Mn_3O_4 using powdered aluminium according to the following equation.

$$3Mn_3O_4 + 8Al \longrightarrow 9Mn + 4Al_2O_3$$

Deduce the redox half-equation for aluminium in this extraction process.

.....

(1 mark)

4 (c) Copper can be extracted by the high-temperature carbon reduction of copper(II) oxide. Write an equation for this reaction.

.....

(1 mark)

4 (d) Scrap iron is used in a low-cost process to extract copper from aqueous solutions containing copper(II) ions.

4 (d) (i) Give **one** reason, other than the cost of scrap iron, why this method is low-cost.

.....

.....

(1 mark)

4 (d) (ii) Write the **simplest ionic** equation for the reaction of iron with copper(II) ions in aqueous solution.

.....

(1 mark)

5

5 Sea water contains large amounts of dissolved magnesium compounds. Approximately 1 kg of magnesium can be extracted from 1000 dm^3 of sea water.

5 (a) The first step in the extraction process is to react the magnesium ions in sea water with hydroxide ions to produce a precipitate of magnesium hydroxide. Write the **simplest ionic** equation for this reaction.

.....

(1 mark)

5 (b) The second step in the extraction process is to react magnesium hydroxide with hydrochloric acid to give magnesium chloride. Write an equation for this reaction.

.....

(1 mark)

5 (c) In the final step, molten magnesium chloride is electrolysed to form magnesium and chlorine. This is similar to the method used to extract aluminium. Deduce an equation for the reaction that occurs at the negative electrode in the electrolysis of magnesium chloride.

.....

(1 mark)

5 (d) Magnesium is used in the extraction of titanium.

5 (d) (i) Write an equation for the conversion of titanium(IV) oxide into titanium(IV) chloride.

.....

(2 marks)

5 (d) (ii) Write an equation for the extraction of titanium from titanium(IV) chloride using magnesium.

.....

(1 mark)

5 (d) (iii) State the role of magnesium in this extraction.

.....

(1 mark)

Do not write outside the box

5 (e) Use your knowledge of the reactions of Group 2 metals with water to explain why water should **not** be used to put out a fire in which magnesium metal is burning.

.....

.....

.....

(2 marks)

(Extra space) .....

.....

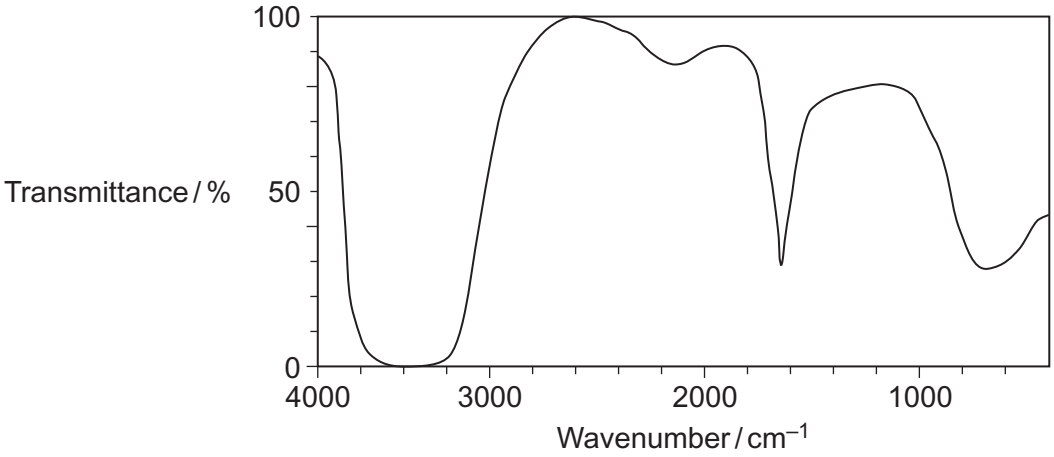
9

Turn over for the next question

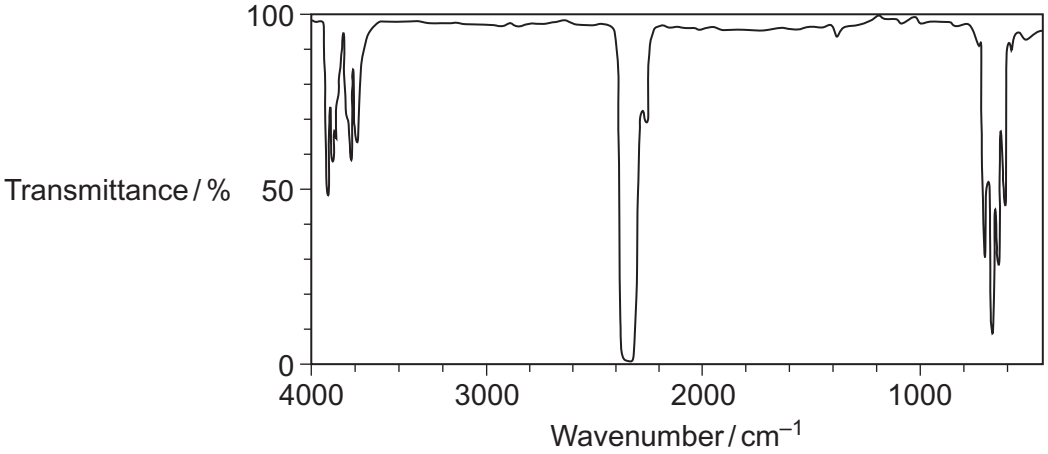
Do not write outside the box

6 (a) A student used the infrared spectra of water vapour and of carbon dioxide to try to find a link between infrared radiation and global warming.

Infrared spectrum of water vapour



Infrared spectrum of carbon dioxide



6 (a) (i) Use information from the infrared spectra to deduce **one** reason why the student concluded that water vapour is a more effective greenhouse gas than carbon dioxide.

.....

.....

(1 mark)

6 (a) (ii) Use your knowledge of the bonds in CO_2 to state why the infrared spectrum of carbon dioxide is **not** as might be predicted from the data provided in **Table 1** on the Data Sheet.

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(2 marks)

Do not write outside the box

6 (b) The initiatives to decrease the carbon dioxide in the atmosphere include the use of carbon-neutral fuels and the development of carbon capture.
The mineral serpentine, $Mg_3Si_2O_5(OH)_4$, has been proposed as a solid for the capture of carbon dioxide gas.

6 (b) (i) Give the meaning of the term *carbon-neutral*, as applied to a fuel.

.....

.....

(1 mark)

(Extra space) .....

.....

6 (b) (ii) Balance the following equation for the reaction of serpentine with carbon dioxide.

$Mg_3Si_2O_5(OH)_4$ + ...CO_2 ⟶ .....$MgCO_3$ + ...SiO_2 + ...H_2O

(1 mark)

5

Turn over for the next question

Do not write outside the box

7 (a) The reaction of bromine with propane is similar to that of chlorine with methane.
Three steps in the mechanism for the bromination of propane to form 1-bromopropane are shown below.

Step **1** $Br_2 \longrightarrow 2Br\bullet$

Step **2** $Br\bullet + CH_3CH_2CH_3 \longrightarrow CH_3CH_2CH_2\bullet + HBr$

Step **3** $CH_3CH_2CH_2\bullet + Br_2 \longrightarrow CH_3CH_2CH_2Br + Br\bullet$

7 (a) (i) Name the type of mechanism in this reaction.

.....

(1 mark)

7 (a) (ii) Give an essential condition for Step **1** to occur.

.....

(1 mark)

7 (a) (iii) Name the type of step illustrated by Steps **2** and **3**.

.....

(1 mark)

7 (a) (iv) In this mechanism, a different type of step occurs in which free radicals combine.
Name this type of step.
Write an equation to show how hexane could be formed from two free radicals in the mechanism of this reaction.

Type of step .....

Equation .....

(2 marks)

7 (a) (v) Write an overall equation for the reaction between bromine and propane by the same mechanism to produce octabromopropane (C_3Br_8).

.....

(1 mark)

7 (b) Bromine reacts with alkenes, even though bromine is a non-polar molecule.

7 (b) (i) Explain why bromine molecules react with the double bonds in alkenes.

.....

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.....

.....

(2 marks)

(Extra space) .....

.....

7 (b) (ii) Name the type of mechanism involved in this reaction.

.....

(1 mark)

7 (b) (iii) Draw the structure of the compound with M_r = 387.6 formed when penta-1,4-diene ($H_2C{=}CHCH_2CH{=}CH_2$) reacts with an excess of bromine.

(1 mark)

7 (c) Two products are formed when propene reacts with hydrogen bromide.
Draw the structure of the intermediate that leads to the formation of the major product in the reaction of propene with hydrogen bromide.
Give the name of this type of intermediate.

Structure of intermediate

Type of intermediate .....

(2 marks)

12

There are no questions printed on this page

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8 A student read the following passage on the Internet.

> Haloalkanes contain a polar covalent bond. The carbon atom of the polar covalent bond can be attacked by nucleophiles. Nucleophilic attack enables haloalkanes to undergo substitution reactions.
> A nucleophilic substitution reaction occurs when a haloalkane undergoes hydrolysis; the rate of hydrolysis of the haloalkane is influenced by the carbon–halogen bond enthalpy.

8 (a) Explain the meaning of each of the following terms in the information given above.

8 (a) (i) *nucleophile*

.....

.....

.....

(1 mark)

8 (a) (ii) *substitution,* as applied to nucleophilic substitution in a haloalkane

.....

.....

.....

(1 mark)

8 (a) (iii) *hydrolysis*

.....

.....

.....

(1 mark)

8 (a) (iv) *bond enthalpy,* as applied to a carbon–halogen bond.

.....

.....

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(1 mark)

Question 8 continues on the next page

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8 (b) Outline a mechanism for the nucleophilic substitution reaction in which 2-bromopropane ($CH_3CHBrCH_3$) reacts with potassium hydroxide to form propan-2-ol.

(2 marks)

8 (c) Haloalkanes also undergo elimination reactions to produce alkenes.

8 (c) (i) Outline a mechanism for the elimination reaction in which 2-bromopropane reacts with potassium hydroxide to form propene.

(3 marks)

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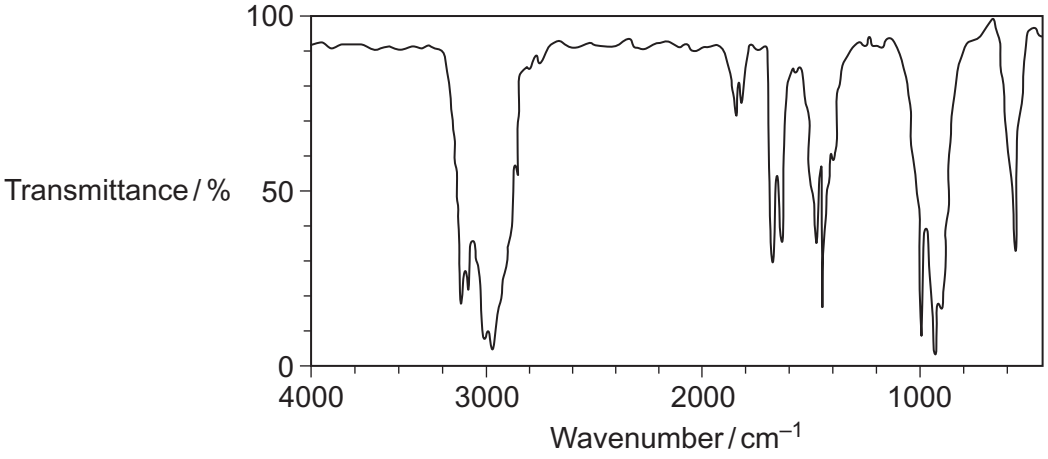
8 (c) (ii) A student obtained the following infrared spectrum for the product from this elimination reaction.



Use information from the infrared spectrum to state and explain how the student deduced that the product was an alkene.
You may find it helpful to refer to **Table 1** on the Data Sheet.

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(2 marks)

(Extra space) .....

.....

11

Turn over for the next question

Section B

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

9 A student devised an experiment to investigate the enthalpies of combustion of some alcohols. The student chose the following series of primary alcohols.

Name	Formula
Methanol	CH_3OH
Ethanol	CH_3CH_2OH
Propan-1-ol	$CH_3CH_2CH_2OH$
Butan-1-ol	$CH_3CH_2CH_2CH_2OH$
Pentan-1-ol	$CH_3CH_2CH_2CH_2CH_2OH$
Alcohol **X**	$CH_3CH_2CH_2CH_2CH_2CH_2OH$
Heptan-1-ol	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2OH$

9 (a) (i) Name alcohol **X**.

.....

(1 mark)

9 (a) (ii) State the general name of the type of series shown by these primary alcohols.

.....

(1 mark)

9 (a) (iii) Draw the displayed formula of the position isomer of butan-1-ol.

(1 mark)

9 (a) (iv) Using [O] to represent the oxidising agent, write an equation for the oxidation of butan-1-ol to form an aldehyde.

.....

(1 mark)

9 (a) (v) Draw the displayed formula of a functional group isomer of this aldehyde.

(1 mark)

9 (b) The student carried out a laboratory experiment to determine the enthalpy change when a sample of butan-1-ol was burned.
The student found that the temperature of 175 g of water increased by 8.0 °C when 5.00×10^{-3} mol of pure butan-1-ol was burned in air and the heat produced was used to warm the water.

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

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(3 marks)

(Extra space) .....

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Question 9 continues on the next page

9 (c) (i) Give the meaning of the term *standard enthalpy of combustion*.

.....

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.....

(3 marks)

(Extra space) .....

.....

.....

9 (c) (ii) Use the standard enthalpy of formation data from the table and the equation for the combustion of butan-1-ol to calculate a value for the standard enthalpy of combustion of butan-1-ol.

	$CH_3CH_2CH_2CH_2OH(l)$	$O_2(g)$	$CO_2(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 327	0	– 394	– 286

$$CH_3CH_2CH_2CH_2OH(l) + 6O_2(g) \longrightarrow 4CO_2(g) + 5H_2O(l)$$

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(3 marks)

(Extra space) .....

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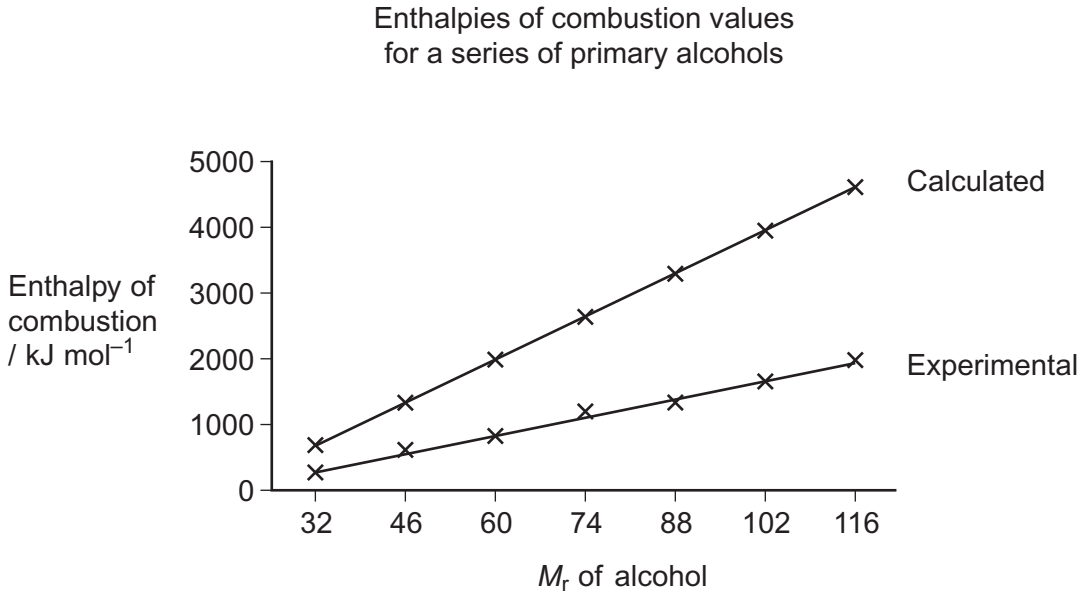
Do not write outside the box

9 (d) The student repeated the experiment described in part **9 (b)** and obtained an experimental value for the enthalpy of combustion for each alcohol in this series. These experimental values were then compared with calculated values from standard enthalpies of formation, as shown in the graph below.



9 (d) (i) In terms of bonds broken and bonds formed, explain why the calculated values of enthalpies of combustion of these alcohols, when plotted against M_r, follow a straight line.

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(2 marks)

(Extra space) .....

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9 (d) (ii) Give **two** reasons why the experimental values obtained by the student are lower than the calculated values using the enthalpy of formation data.

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(2 marks)

18

Do not write outside the box

10 Reactions that involve oxidation and reduction are used in a number of important industrial processes.

10 (a) Iodine can be extracted from seaweed by the oxidation of iodide ions.
In this extraction, seaweed is heated with MnO_2 and concentrated sulfuric acid.

10 (a) (i) Give the oxidation state of manganese in MnO_2

.....

(1 mark)

10 (a) (ii) Write a half-equation for the reaction of MnO_2 in acid to form Mn^{2+} ions and water as the only products.

.....

(1 mark)

10 (a) (iii) In terms of electrons, state what happens to the iodide ions when they are oxidised.

.....

.....

(1 mark)

10 (b) Chlorine is used in water treatment. When chlorine is added to cold water it reacts to form the acids HCl and HClO
The following equilibrium is established.

$$Cl_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + Cl^-(aq) + HClO(aq)$$

10 (b) (i) Give the oxidation state of chlorine in Cl_2 and in HClO

Cl_2 .....

HClO .....

(2 marks)

Do not write outside the box

10 (b) (ii) Deduce what happens to this equilibrium as the HClO reacts with bacteria in the water supply. Explain your answer.

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(2 marks)

(Extra space) .....

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10 (c) Concentrated sulfuric acid is reduced when it reacts with solid potassium bromide. Concentrated sulfuric acid is **not** reduced when it reacts with solid potassium chloride.

10 (c) (i) Write the two half-equations for the following redox reaction.

$$2H^+ + 2Br^- + H_2SO_4 \longrightarrow Br_2 + SO_2 + 2H_2O$$

Half-equation 1

.....

Half-equation 2

.....

(2 marks)

10 (c) (ii) Write an equation for the reaction of solid potassium chloride with concentrated sulfuric acid.

.....

(1 mark)

Question 10 continues on the next page

Do not write outside the box

10 (c) (iii) Explain why chloride ions are weaker reducing agents than bromide ions.

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(2 marks)

(Extra space) .....

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12

END OF QUESTIONS

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Section A

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

1 The rate of hydrolysis of an ester **X** ($HCOOCH_2CH_2CH_3$) was studied in alkaline conditions at a given temperature. The rate was found to be first order with respect to the ester and first order with respect to hydroxide ions.

1 (a) (i) Name ester **X**.

.....

(1 mark)

1 (a) (ii) Using **X** to represent the ester, write a rate equation for this hydrolysis reaction.

.....

(1 mark)

1 (a) (iii) When the initial concentration of **X** was 0.024 mol dm^{-3} and the initial concentration of hydroxide ions was 0.035 mol dm^{-3}, the initial rate of the reaction was 8.5×10^{-5} mol dm^{-3} s^{-1}.
Calculate a value for the rate constant at this temperature and give its units.

Calculation .....

.....

.....

.....

Units .....

.....

(3 marks)

1 (a) (iv) In a second experiment at the same temperature, water was added to the original reaction mixture so that the total volume was doubled.
Calculate the initial rate of reaction in this second experiment.

.....

.....

(1 mark)

Do not write outside the box

1 (a) (v) In a third experiment at the same temperature, the concentration of **X** was half that used in the experiment in part **1 (a) (iii)** and the concentration of hydroxide ions was three times the original value.
Calculate the initial rate of reaction in this third experiment.

.....

.....

(1 mark)

1 (a) (vi) State the effect, if any, on the value of the rate constant *k* when the temperature is lowered but all other conditions are kept constant. Explain your answer.

Effect .....

Explanation .....

.....

(2 marks)

1 (b) Compound **A** reacts with compound **B** as shown by the overall equation

$$A + 3B \rightarrow AB_3$$

The rate equation for the reaction is

$$\text{rate} = k[A][B]^2$$

A suggested mechanism for the reaction is

Step **1** $A + B \rightarrow AB$

Step **2** $AB + B \rightarrow AB_2$

Step **3** $AB_2 + B \rightarrow AB_3$

Deduce which one of the three steps is the rate-determining step.

Explain your answer.

Rate-determining step .....

Explanation .....

.....

(2 marks)

11

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2 This question is about the pH of several solutions.

Give all values of pH to 2 decimal places.

2 (a) (i) Write an expression for pH.

.....

(1 mark)

2 (a) (ii) Calculate the pH of 0.154 mol dm^{-3} hydrochloric acid.

.....

.....

(1 mark)

2 (a) (iii) Calculate the pH of the solution formed when 10.0 cm^3 of 0.154 mol dm^{-3} hydrochloric acid are added to 990 cm^3 of water.

.....

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.....

(2 marks)

2 (b) The acid dissociation constant, K_a, for the weak acid HX has the value 4.83×10^{-5} mol dm^{-3} at 25 °C.
A solution of HX has a pH of 2.48

Calculate the concentration of HX in the solution.

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(4 marks)

Question 2 continues on the next page

Do not write outside the box

2 (c) Explain why the pH of an acidic buffer solution remains almost constant despite the addition of a small amount of sodium hydroxide.

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(2 marks)

2 (d) The acid dissociation constant, K_a, for the weak acid HY has the value 1.35×10^{-5} mol dm^{-3} at 25 °C.

A buffer solution was prepared by dissolving 0.0236 mol of the salt NaY in 50.0 cm^3 of a 0.428 mol dm^{-3} solution of the weak acid HY

2 (d) (i) Calculate the pH of this buffer solution.

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(4 marks)

2 (d) (ii) A 5.00×10^{-4} mol sample of sodium hydroxide was added to this buffer solution.

Calculate the pH of the buffer solution after the sodium hydroxide was added.

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(4 marks)

18

Turn over for the next question

Do not write outside the box

3 Synthesis gas is a mixture of carbon monoxide and hydrogen. Methanol can be manufactured from synthesis gas in a reversible reaction as shown by the following equation.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H^{\ominus} = -91 \text{ kJ mol}^{-1}$$

3 (a) A sample of synthesis gas containing 0.240 mol of carbon monoxide and 0.380 mol of hydrogen was sealed together with a catalyst in a container of volume 1.50 dm^3. When equilibrium was established at temperature T_1 the equilibrium mixture contained 0.170 mol of carbon monoxide.

Calculate the amount, in moles, of methanol and the amount, in moles, of hydrogen in the equilibrium mixture.

Methanol .....

Hydrogen .....

(2 marks)

3 (b) A different sample of synthesis gas was allowed to reach equilibrium in a similar container of volume 1.50 dm^3 at temperature T_1

At equilibrium, the mixture contained 0.210 mol of carbon monoxide, 0.275 mol of hydrogen and 0.0820 mol of methanol.

3 (b) (i) Write an expression for the equilibrium constant K_c for this reaction.

.....

.....

(1 mark)

3 (b) (ii) Calculate a value for K_c for the reaction at temperature T_1 and state its units.

Calculation .....

.....

.....

.....

.....

Units .....

.....

(4 marks)

3 (b) (iii) State the effect, if any, on the value of K_c of adding more hydrogen to the equilibrium mixture.

.....

(1 mark)

3 (c) The temperature of the mixture in part **3 (b)** was changed to T_2 and the mixture was left to reach a new equilibrium position. At this new temperature the equilibrium concentration of methanol had increased.
Deduce which of T_1 or T_2 is the higher temperature and explain your answer.

Higher temperature .....

Explanation .....

.....

.....

(3 marks)

3 (d) The following reaction has been suggested as an alternative method for the production of methanol.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

The hydrogen used in this method is obtained from the electrolysis of water.

Suggest **one** possible environmental disadvantage of the production of hydrogen by electrolysis.

.....

.....

(1 mark)

3 (e) One industrial use of methanol is in the production of biodiesel from vegetable oils such as

$$\begin{array}{l} CH_2OOCC_{17}H_{35} \\ | \\ CHOOCC_{17}H_{31} \\ | \\ CH_2OOCC_{17}H_{29} \end{array}$$

Give the formula of **one** compound in biodiesel that is formed by the reaction of methanol with the vegetable oil shown above.

.....

(1 mark)

13

4 (a) Name compound **Y**, $HOCH_2CH_2COOH$

.....

(1 mark)

4 (b) Under suitable conditions, molecules of **Y** can react with each other to form a polymer.

4 (b) (i) Draw a section of the polymer showing **two** repeating units.

(1 mark)

4 (b) (ii) Name the type of polymerisation involved.

.....

(1 mark)

4 (c) When **Y** is heated, an elimination reaction occurs in which one molecule of **Y** loses one molecule of water. The organic product formed by this reaction has an absorption at $1637\ cm^{-1}$ in its infrared spectrum.

4 (c) (i) Identify the bond that causes the absorption at $1637\ cm^{-1}$ in its infrared spectrum.

.....

(1 mark)

4 (c) (ii) Write the displayed formula for the organic product of this elimination reaction.

(1 mark)

4 (c) (iii) The organic product from part **4 (c) (ii)** can also be polymerised.
Draw the repeating unit of the polymer formed from this organic product.

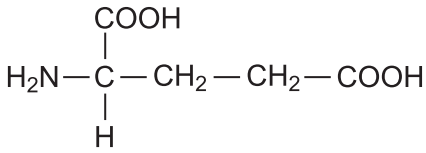
(1 mark)

Do not write outside the box

4 (d) At room temperature, 2-aminobutanoic acid exists as a solid.
Draw the structure of the species present in the solid form.

(1 mark)

4 (e) The amino acid, glutamic acid, is shown below.



Draw the structure of the organic species formed when glutamic acid reacts with each of the following.

4 (e) (i) an excess of sodium hydroxide

(1 mark)

4 (e) (ii) an excess of methanol in the presence of concentrated sulfuric acid

(1 mark)

4 (e) (iii) ethanoyl chloride

(1 mark)

Question 4 continues on the next page

Do not write outside the box

4 (f) A tripeptide was heated with hydrochloric acid and a mixture of amino acids was formed. This mixture was separated by column chromatography.
Outline briefly why chromatography is able to separate a mixture of compounds.
Practical details are **not** required.

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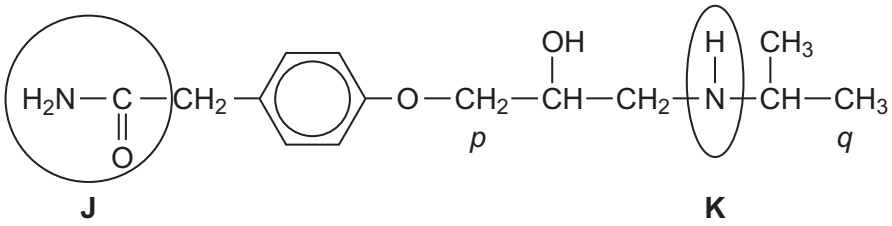
(3 marks)

13

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

5 Atenolol is an example of the type of medicine called a beta blocker. These medicines are used to lower blood pressure by slowing the heart rate. The structure of atenolol is shown below.



J **K**

5 (a) Give the name of each of the circled functional groups labelled **J** and **K** on the structure of atenolol shown above.

Functional group labelled **J** .....

Functional group labelled **K** .....

(2 marks)

5 (b) The ^{1}H n.m.r. spectrum of atenolol was recorded.

One of the peaks in the ^{1}H n.m.r. spectrum is produced by the CH_2 group labelled *p* in the structure of atenolol.
Use **Table 2** on the Data Sheet to suggest a range of δ values for this peak.
Name the splitting pattern of this peak.

Range of δ values .....

Name of splitting pattern .....

(2 marks)

5 (c) N.m.r. spectra are recorded using samples in solution.
The ^{1}H n.m.r. spectrum was recorded using a solution of atenolol in $CDCl_3$

5 (c) (i) Suggest why $CDCl_3$ and **not** $CHCl_3$ was used as the solvent.

.....

.....

(1 mark)

5 (c) (ii) Suggest why $CDCl_3$ is a more effective solvent than CCl_4 for polar molecules such as atenolol.

.....

.....

(1 mark)

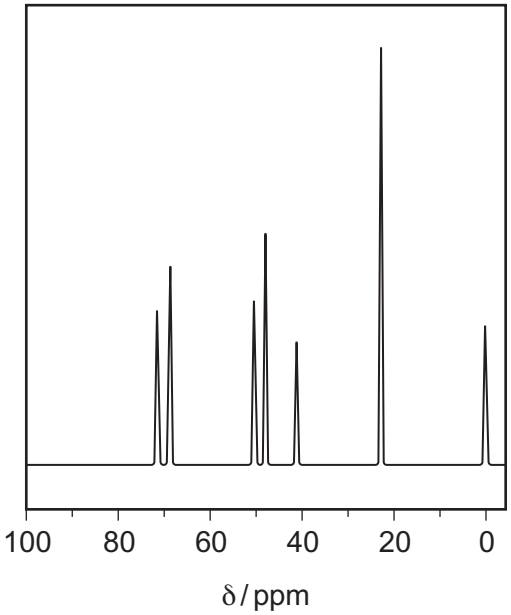
5 (d) The ^{13}C n.m.r. spectrum of atenolol was also recorded.

Use the structure of atenolol given to deduce the total number of peaks in the ^{13}C n.m.r. spectrum of atenolol.

.....

(1 mark)

5 (e) Part of the ^{13}C n.m.r. spectrum of atenolol is shown below. Use this spectrum and **Table 3** on the Data Sheet, where appropriate, to answer the questions which follow.



5 (e) (i) Give the formula of the compound that is used as a standard and produces the peak at $\delta = 0$ ppm in the spectrum.

.....

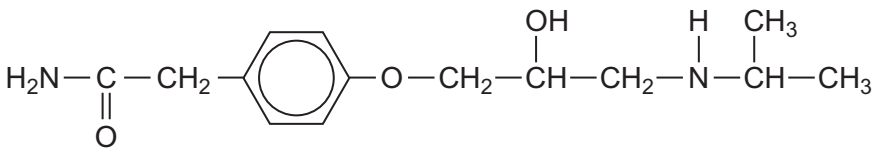
(1 mark)

5 (e) (ii) One of the peaks in the ^{13}C n.m.r. spectrum above is produced by the CH_3 group labelled *q* in the structure of atenolol.
Identify this peak in the spectrum by stating its δ value.

.....

(1 mark)

5 (e) (iii) There are three CH_2 groups in the structure of atenolol. One of these CH_2 groups produces the peak at $\delta = 71$ in the ^{13}C n.m.r. spectrum above.
Draw a circle around this CH_2 group in the structure of atenolol shown below.



(1 mark)

Question 5 continues on the next page

Do not write outside the box

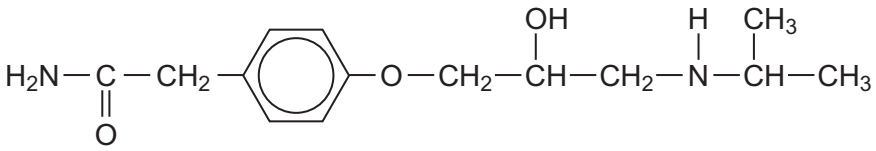
5 (f) Atenolol is produced industrially as a racemate (an equimolar mixture of two enantiomers) by reduction of a ketone. Both enantiomers are able to lower blood pressure. However, recent research has shown that one enantiomer is preferred in medicines.

5 (f) (i) Suggest a reducing agent that could reduce a ketone to form atenolol.

.....

(1 mark)

5 (f) (ii) Draw a circle around the asymmetric carbon atom in the structure of atenolol shown below.



(1 mark)

5 (f) (iii) Suggest how you could show that the atenolol produced by reduction of a ketone was a racemate and **not** a single enantiomer.

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(2 marks)

5 (f) (iv) Suggest **one** advantage and **one** disadvantage of using a racemate rather than a single enantiomer in medicines.

Advantage .....

.....

Disadvantage .....

.....

(2 marks)

16

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Section B

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

6 Many synthetic routes need chemists to increase the number of carbon atoms in a molecule by forming new carbon–carbon bonds. This can be achieved in several ways including

- reaction of an aromatic compound with an acyl chloride
- reaction of an aldehyde with hydrogen cyanide.

6 (a) Consider the reaction of benzene with CH_3CH_2COCl

6 (a) (i) Write an equation for this reaction and name the organic product.
Identify the catalyst required in this reaction.
Write equations to show how the catalyst is used to form a reactive intermediate and how the catalyst is reformed at the end of the reaction.

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(5 marks)

(*Extra space)* .....

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6 (a) (ii) Name and outline a mechanism for the reaction of benzene with this reactive intermediate.

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(4 marks)

(Extra space) .....

.....

Question 6 continues on the next page

6 (b) Consider the reaction of propanal with HCN

6 (b) (i) Write an equation for the reaction of propanal with HCN and name the product.

.....

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(2 marks)

(*Extra space)* .....

.....

6 (b) (ii) Name and outline a mechanism for the reaction of propanal with HCN

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(5 marks)

(Extra space) .....

.....

6 (b) (iii) The rate-determining step in the mechanism in part **6 (b) (ii)** involves attack by the nucleophile.
Suggest how the rate of reaction of propanone with HCN would compare with the rate of reaction of propanal with HCN
Explain your answer.

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(2 marks)

(Extra space) .....

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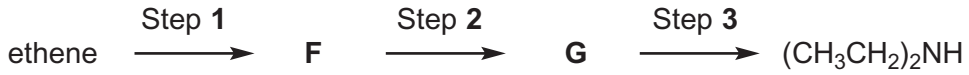
18

Turn over for the next question

Do not write outside the box

7 The compound $(CH_3CH_2)_2NH$ can be made from ethene in a three-step synthesis as shown below.



7 (a) Name the compound $(CH_3CH_2)_2NH$

.....

(1 mark)

7 (b) Identify compounds **F** and **G**.

Compound **F** .....

Compound **G** .....

(2 marks)

7 (c) For the reactions in Steps **1**, **2** and **3**,

- give a reagent or reagents
- name the mechanism.

Balanced equations and mechanisms using curly arrows are **not** required.

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(6 marks)

(*Extra space)* .....

.....

Do not write outside the box

7 (d) Identify **one** organic impurity in the product of Step **3** and give a reason for its formation.

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.....

(2 marks)

(Extra space) .....

.....

11

END OF QUESTIONS

SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The compound butane has

☒ **A** the empirical formula C_4H_{10} and the molecular formula C_2H_5.

☒ **B** the empirical formula C_2H_5 and the molecular formula C_4H_{10}.

☒ **C** the empirical formula C_2H_5 and the molecular formula C_nH_{2n+2}.

☒ **D** the empirical formula C_nH_{2n+2} and the molecular formula C_4H_{10}.

(Total for Question 1 = 1 mark)

---

2 For the oxidation of ammonia

$$a\ NH_3 + b\ O_2 \rightarrow c\ NO + d\ H_2O$$

the values of the coefficients in the balanced equation are

☒ **A** a = 2, b = 3, c = 2 and d = 3

☒ **B** a = 4, b = 7, c = 4 and d = 4

☒ **C** a = 4, b = 5, c = 4 and d = 6

☒ **D** a = 6, b = 7, c = 6 and d = 9

(Total for Question 2 = 1 mark)

---

3 The Avogadro constant is 6.0×10^{23} mol^{-1}. Therefore the number of **atoms** in 1 mol of carbon dioxide is

☒ **A** 2.0×10^{23}

☒ **B** 6.0×10^{23}

☒ **C** 1.2×10^{24}

☒ **D** 1.8×10^{24}

(Total for Question 3 = 1 mark)

---

4 The equation for the complete combustion of octane is

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$$

(a) The mass of 10 mol of octane is

(1)

☒ **A** 0.66 kg

☒ **B** 1.14 kg

☒ **C** 2.10 kg

☒ **D** 2.28 kg

(b) The volume of 1 mol of any gas (measured at room temperature and pressure) is 24 dm^3. Hence the volume of oxygen (measured at room temperature and pressure) required for the complete combustion of 10 mol of octane is

(1)

☒ **A** 240 dm^3

☒ **B** 300 dm^3

☒ **C** 3000 dm^3

☒ **D** 6000 dm^3

(Total for Question 4 = 2 marks)

5 The enthalpy change for the reaction

$$CH_4(g) \rightarrow C(g) + 4H(g)$$

is +1648 kJ mol^{-1}. Hence the mean bond enthalpy for the C–H bond is

☒ **A** +329.6 kJ mol^{-1}

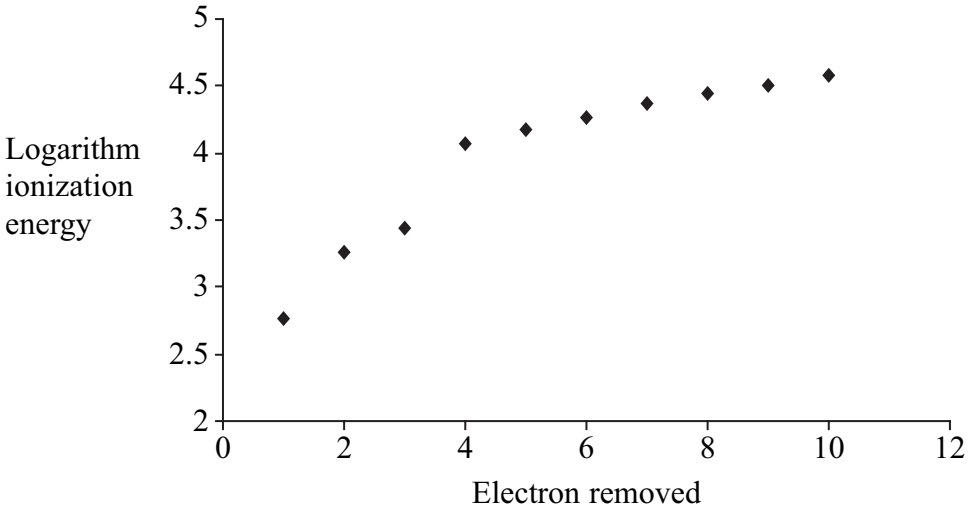
☒ **B** +412.0 kJ mol^{-1}

☒ **C** +1648 kJ mol^{-1}

☒ **D** +6592 kJ mol^{-1}

(Total for Question 5 = 1 mark)

6 The graph below represents the successive ionization energies of an element **X** plotted against the number of the electron removed. **X** is not the symbol for the element.



(a) From this graph it is possible to deduce the group in the Periodic Table to which **X** belongs. **X** is in

(1)

☒ **A** Group 1

☒ **B** Group 3

☒ **C** Group 5

☒ **D** Group 7

(b) From the graph it is possible to deduce that the most stable ion of **X** will be

(1)

☒ **A** X^{3+}

☒ **B** X^{+}

☒ **C** X^{-}

☒ **D** X^{3-}

(Total for Question 6 = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

7 Element **R** is in Group 1 of the Periodic Table and element **T** is in Group 6. **R** and **T** are not the symbols for the elements.

(a) The compound of **R** and **T** will have the formula

(1)

☒ **A** RT

☒ **B** RT_6

☒ **C** RT_2

☒ **D** R_2T

(b) The compound of **R** and **T** will have bonding which is predominantly

(1)

☒ **A** ionic.

☒ **B** covalent.

☒ **C** dative covalent.

☒ **D** metallic.

(c) In terms of its electrical conductivity, the compound of **R** and **T** will

(1)

☒ **A** conduct when solid and liquid.

☒ **B** conduct when solid but not when liquid.

☒ **C** conduct when liquid but not when solid.

☒ **D** not conduct when solid or liquid.

(Total for Question 7 = 3 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

8 Ethane reacts with chlorine when the substances are exposed to UV radiation.

(a) The equation for this reaction is

(1)

☒ **A** $C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$

☒ **B** $C_2H_6 + Cl_2 \rightarrow C_2H_4Cl_2 + H_2$

☒ **C** $C_2H_6 + Cl_2 \rightarrow 2CH_3Cl$

☒ **D** $C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2$

(b) The role of the UV radiation in the reaction is to

(1)

☒ **A** break the Cl—Cl bond forming Cl• free radicals.

☒ **B** break the Cl—Cl bond forming Cl^+ and Cl^- ions.

☒ **C** break the C—C bond in ethane forming CH_3• free radicals.

☒ **D** break a C—H bond in ethane forming C_2H_5• free radicals.

(c) The overall reaction between ethane and chlorine is best described as

(1)

☒ **A** addition.

☒ **B** homolytic fission.

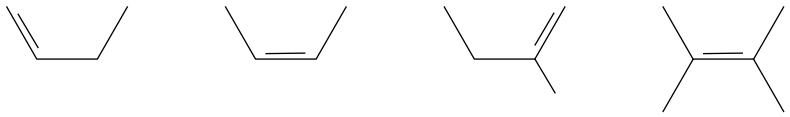
☒ **C** heterolytic fission.

☒ **D** substitution.

(Total for Question 8 = 3 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

9 This question concerns the following compounds



A **B** **C** **D**

Which of these compounds will show geometric (*E–Z* or *cis/trans*) isomerism?

☒ **A**

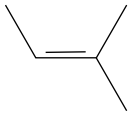
☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 1 mark)

10 The correct name for the compound shown below is



☒ **A** 2-methylbut-3-ene

☒ **B** 3-methylbut-2-ene

☒ **C** 3-methylbut-3-ene

☒ **D** 2-methylbut-2-ene

(Total for Question 10 = 1 mark)

11 Most compounds of lead are insoluble, an exception being lead(II) nitrate. Therefore a good method of preparing lead(II) sulfate is

☒ **A** adding dilute sulfuric acid to lead metal.

☒ **B** adding concentrated sulfuric acid to lead metal.

☒ **C** adding dilute sulfuric acid to lead(II) nitrate solution.

☒ **D** adding dilute sulfuric acid to solid lead(II) oxide.

(Total for Question 11 = 1 mark)

12 Metals usually have high melting temperatures and boiling temperatures because there are

- ☒ **A** strong attractions between the ions.
- ☒ **B** strong attractions between the delocalised electrons.
- ☒ **C** strong attractions between the ions and the delocalised electrons.
- ☒ **D** strong intermolecular forces.

(Total for Question 12 = 1 mark)

13 In 2006, the concentration of carbon dioxide in the atmosphere was 382 ppm. This is equivalent to

- ☒ **A** 0.00382%
- ☒ **B** 0.0382%
- ☒ **C** 0.382%
- ☒ **D** 3.82%

(Total for Question 13 = 1 mark)

14 A hazard that is particularly associated with alkanes is that they are

- ☒ **A** corrosive.
- ☒ **B** flammable.
- ☒ **C** toxic by inhalation.
- ☒ **D** toxic by skin absorption.

(Total for Question 14 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

15 The relative atomic mass of an element is determined using a mass spectrometer.

(a) Define the term **relative atomic mass**.

(2)

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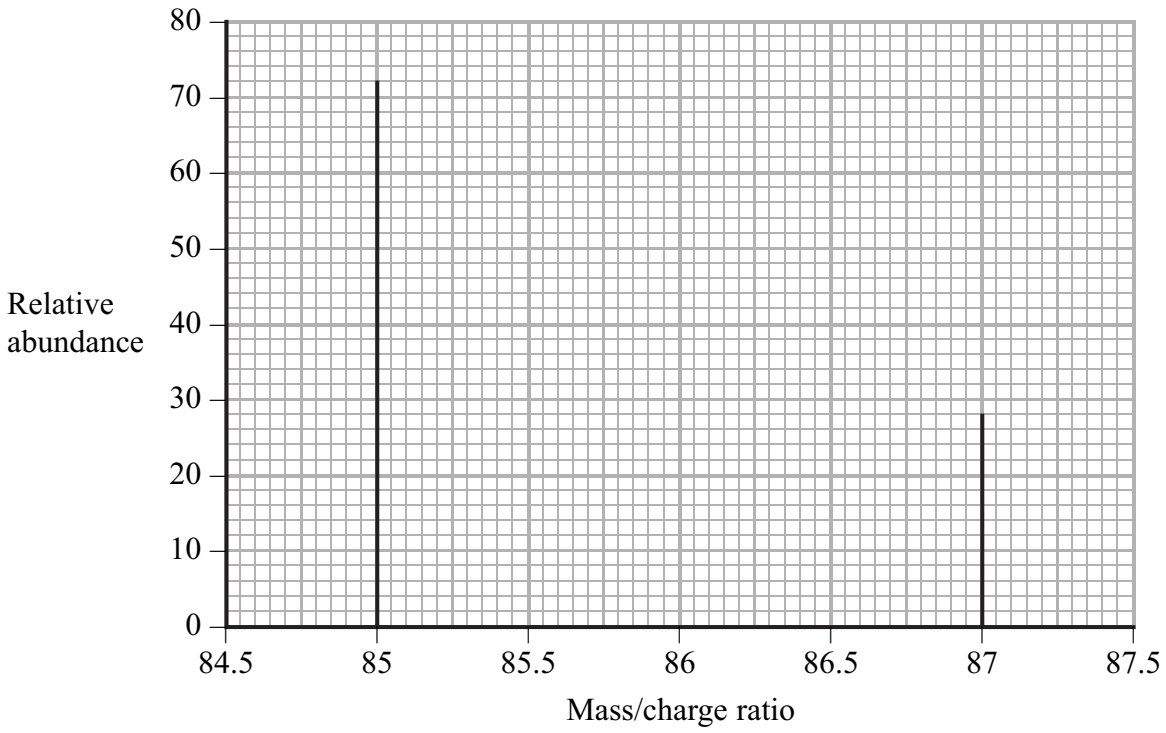
(b) The mass spectrum of rubidium is shown below.



(i) Explain why there are two peaks in the spectrum.

(1)

.....

.....

(ii) Use the spectrum to calculate the relative atomic mass of rubidium.

(2)

(Total for Question 15 = 5 marks)

16 (a) Coral reefs are produced by living organisms and predominantly made up of calcium carbonate. It has been suggested that coral reefs will be damaged by global warming because of the increased acidity of the oceans due to higher concentrations of carbon dioxide.

(i) Write a chemical equation to show how the presence of carbon dioxide in water results in the formation of carbonic acid. State symbols are **not** required.

(1)

(ii) Write the **ionic** equation to show how acids react with carbonates. State symbols are **not** required.

(2)

(b) One method of determining the proportion of calcium carbonate in a coral is to dissolve a known mass of the coral in excess acid and measure the volume of carbon dioxide formed.

In such an experiment, 1.13 g of coral was dissolved in 25 cm^3 of hydrochloric acid (an excess) in a conical flask. When the reaction was complete, 224 cm^3 of carbon dioxide had been collected over water using a 250 cm^3 measuring cylinder.

(i) Draw a labelled diagram of the apparatus that could be used to carry out this experiment.

(2)

(ii) Suggest how you would mix the acid and the coral to ensure that no carbon dioxide escaped from the apparatus.

(1)

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.....

.....

(iii) Calculate the number of moles of carbon dioxide collected in the experiment.

[The molar volume of any gas is 24 000 $cm^3\ mol^{-1}$ at room temperature and pressure.]

(1)

(iv) Complete the equation below for the reaction between calcium carbonate and hydrochloric acid by inserting the missing state symbols.

(1)

$$CaCO_3(.....) + 2HCl(.....) \rightarrow CaCl_2(.....) + H_2O(l) + CO_2(.....)$$

(v) Calculate the mass of 1 mol of calcium carbonate.

[Assume relative atomic masses: Ca = 40, C = 12, O = 16.]

(1)

(vi) Use your data and the equation in (iv) to calculate the mass of calcium carbonate in the sample and the percentage by mass of calcium carbonate in the coral. Give your final answer to **three** significant figures.

(2)

(vii) When this experiment is repeated, the results are inconsistent. Suggest a reason for this other than errors in the procedure, measurements or calculations.

(1)

.....

.....

(Total for Question 16 = 12 marks)

17 This question is about the element chlorine (atomic number = 17).

(a) Complete the electronic structure of chlorine.

(1)

$1s^2\ 2s^2$ .....

(b) Chlorine forms compounds with magnesium and with carbon.

(i) Draw a dot and cross diagram to show the electronic structure of the compound magnesium chloride (only the outer electrons need be shown).
Include the charges present.

(2)

(ii) Draw a dot and cross diagram to show the electronic structure of the compound tetrachloromethane (only the outer electrons need be shown).

(2)

*(iii) Suggest why the melting temperature of magnesium oxide is higher than that of magnesium chloride, even though both are almost 100% ionic.

(3)

(c) Magnesium chloride may be prepared from magnesium by reaction with chlorine or with hydrochloric acid. Compare these two preparations in terms of the atom economies of the reactions. No calculation is required.

(2)

(Total for Question 17 = 10 marks)

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18 Alkenes are unsaturated hydrocarbons which, because of their reactivity, are important industrial starting materials. Alkenes for industrial use are obtained by cracking alkanes.

(a) Write the equation for the cracking of decane ($C_{10}H_{22}$) to form 1 molecule of propene as the only alkene.

(1)

(b) The carbon–carbon double bond in alkenes consists of a σ and a π bond.

(i) Explain, using diagrams, the difference between the σ and the π bond in the carbon–carbon double bond of an alkene.

(4)

Diagrams

Explanation

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.....

(ii) State the type and mechanism involved in the typical reaction of alkenes.

(1)

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*(iii) By considering the strength and structure of the π bond, explain why alkenes are more reactive than alkanes.

(2)

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(c) When propene reacts with hydrogen bromide, there are two possible products.

(i) Draw a displayed formula of each of these products and label the major product.

(2)

(ii) Give the mechanism for the reaction of propene with hydrogen bromide which forms the major product.

(3)

(iii) Explain, by referring to the mechanism, why the major product is formed.

(2)

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.....

(d) The polymer poly(propene) is manufactured from propene.

(i) Write an equation for the polymerization, drawing the displayed formula of the repeat unit of poly(propene).

(3)

(ii) UV radiation causes poly(propene) to degrade. Suggest one advantage and one disadvantage of this.

(2)

Advantage .....

.....

Disadvantage .....

.....

(Total for Question 18 = 20 marks)

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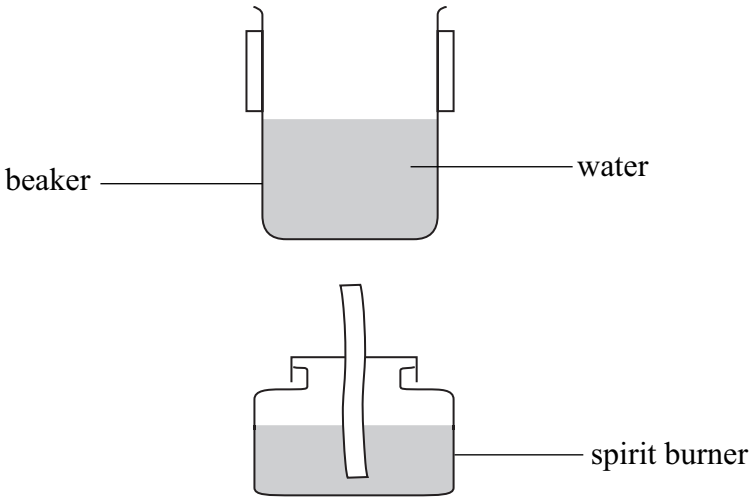
19 The enthalpy change of combustion of ethanol was determined using the apparatus shown in the diagram below. In the experiment, the temperature increase of the water in the beaker is measured when a known mass of the ethanol is burned.



(a) The results of the experiment are summarised in the table below.

Mass of water in the beaker	250.00 g
Mass of spirit burner + contents (initial)	63.21 g
Mass of spirit burner + contents (final)	62.47 g
Temperature of water (initial)	21.0 °C
Temperature of water (final)	31.5 °C

(i) Calculate the heat energy produced by the combustion of the alcohol using the equation

heat energy produced (J) = mass of water × 4.18 × temperature change

(1)

(ii) Calculate the number of moles of ethanol burned in this experiment (the formula of ethanol is C_2H_5OH).

(3)

(iii) Use the equation below to calculate the enthalpy change of combustion of ethanol in kJ mol^{-1}. Give the value an appropriate sign.

$$\Delta H = \text{heat energy produced} \div \text{number of moles}$$

(2)

(b) The data book value for the enthalpy change of combustion of ethanol is –1370 kJ mol^{-1}.

(i) Calculate the percentage error in the value calculated in (a)(iii) in comparison with the data book value.

(1)

(ii) List **three** ways in which the design of the experiment causes the results to be so different from the data book value. (You should be specific but detailed explanations are not required.)

(3)

1 .....

.....

2 .....

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3 .....

.....

(iii) Use the data book values for enthalpy changes of combustion given in the table below to calculate the enthalpy change of formation of ethanol.

(3)

Substance	Enthalpy change of combustion / kJ mol^{-1}
C(s, graphite)	–394
$H_2(g)$	–286
$C_2H_5OH(l)$	–1370

(Total for Question 19 = 13 marks)

TOTAL FOR SECTION B = 60 MARKS
TOTAL FOR PAPER = 80 MARKS

SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The equation for the reaction between limewater and hydrochloric acid, including state symbols, is

☒ **A** $CaOH(s) + HCl(aq) \rightarrow CaCl(aq) + H_2O(l)$

☒ **B** $Ca(OH)_2(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(aq)$

☒ **C** $CaOH(aq) + HCl(aq) \rightarrow CaCl(aq) + H_2O(aq)$

☒ **D** $Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$

(Total for Question 1 = 1 mark)

---

2 As you go down Group 2 of the Periodic Table, which of the following decreases?

☒ **A** The reactivity of the elements.

☒ **B** The solubility of the hydroxides of the elements.

☒ **C** The solubility of the sulfates of the elements.

☒ **D** The thermal stability of the carbonates of the elements.

(Total for Question 2 = 1 mark)

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3 Which concentrated acid would be best for mixing with a salt to carry out a flame test?

☒ **A** Hydrochloric acid

☒ **B** Nitric acid

☒ **C** Phosphoric(V) acid

☒ **D** Sulfuric acid

(Total for Question 3 = 1 mark)

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4 The flame produced by a compound containing barium in a flame test is

☒ **A** colourless.

☒ **B** green.

☒ **C** red.

☒ **D** yellow.

(Total for Question 4 = 1 mark)

---

5 Which of the following is a greenhouse gas?

☒ **A** Argon

☒ **B** Nitrogen

☒ **C** Oxygen

☒ **D** Water vapour

(Total for Question 5 = 1 mark)

---

6 For parts (a) and (b), use your knowledge of intermolecular forces to predict the compound with the highest boiling temperature.

(a) ☒ **A** HF

☒ **B** H_2O

☒ **C** NH_3

☒ **D** CH_4

(1)

(b) ☒ **A** 1-iodobutane

☒ **B** 1-chlorobutane

☒ **C** 2-methyl-2-iodopropane

☒ **D** 2-methyl-2-chloropropane

(1)

(Total for Question 6 = 2 marks)

Use this space for any rough working. Anything you write in this space will gain no credit.

7 Consider the following organic liquids:

A ethanal

B ethanol

C tetrachloromethane

D trichloromethane

(a) Each liquid is run from a burette. Which liquid would **not** be deflected significantly by a charged rod?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which liquid would react with phosphorus(V) chloride to give a gas which fumes in moist air?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which liquid would you expect to have the peak at the greatest mass/charge ratio in its mass spectrum?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(d) Which liquid has an infrared spectrum with a broad absorption due to hydrogen bonding?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 7 = 4 marks)

8 Which of the following best defines the meaning of the term **anthropogenic** change?

It is a change caused by

☒ **A** nature.

☒ **B** plants.

☒ **C** animals.

☒ **D** humans.

(Total for Question 8 = 1 mark)

9 Which of the following equations represents the change when concentrated sulfuric acid is added to solid potassium chloride at room temperature?

☒ **A** $8KCl + 5H_2SO_4 \rightarrow 4K_2SO_4 + H_2S + 4Cl_2 + 4H_2O$

☒ **B** $2KCl + 3H_2SO_4 \rightarrow 2KHSO_4 + SO_2 + Cl_2 + 2H_2O$

☒ **C** $6KCl + 4H_2SO_4 \rightarrow 3K_2SO_4 + S + 3Cl_2 + 4H_2O$

☒ **D** $KCl + H_2SO_4 \rightarrow KHSO_4 + HCl$

(Total for Question 9 = 1 mark)

10 The Maxwell-Boltzmann distribution of molecular energies is useful for explaining why increasing temperature affects the rate of a chemical reaction.

(a) Which of the following statements describes how the shape of the Maxwell-Boltzmann distribution curve changes as temperature increases?

(1)

☒ **A** The peak decreases in height and moves to the left.

☒ **B** The peak increases in height and moves to the left.

☒ **C** The peak decreases in height and moves to the right.

☒ **D** The peak increases in height and moves to the right.

(b) The **main** reason that reaction rates increase with temperature is that

(1)

☒ **A** all the molecules move faster.

☒ **B** all the molecules collide more frequently.

☒ **C** more molecules collide with the correct orientation.

☒ **D** a larger proportion of molecules have high energies.

(Total for Question 10 = 2 marks)

11 Four organic reactions are given below:

A $CH_3CH_3 \rightarrow CH_2{=}CH_2 + H_2$

B $nCH_2{=}CH_2 \rightarrow -(-CH_2{-}CH_2-)_n-$

C $CH_2{=}CH_2 + HBr \rightarrow CH_3CH_2Br$

D $CH_3CH_2Br + H_2O \rightarrow CH_3CH_2OH + HBr$

(a) Which reaction is a substitution reaction?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which reaction is an electrophilic addition reaction?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which reaction involves initial attack by a nucleophile?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(d) Which reaction requires an initiator?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 11 = 4 marks)

12 Which of the following statements is true?

☒ **A** CFCs and nitrogen monoxide, NO, are involved in the depletion of the ozone layer.

☒ **B** CFCs act as catalysts for the depletion of the ozone layer, while nitrogen monoxide, NO, does not.

☒ **C** CFCs and ozone are free radicals.

☒ **D** CFCs and nitrogen monoxide, NO, are decomposed by UV radiation.

(Total for Question 12 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

13 This question is about iodine and its compounds.

(a) (i) The element iodine can be obtained from seaweed. One step in the procedure is to extract the iodine from aqueous solution by shaking with a hydrocarbon solvent in a separating funnel.

Draw a diagram of a separating funnel containing the separated layers. Label the hydrocarbon layer, and state its colour.

[Density of hydrocarbon layer 0.660 g cm^{-3}]

(3)

Diagram

Colour of hydrocarbon layer .....

(ii) Iodine is also formed when an aqueous solution containing iodide ions reacts with an aqueous solution of iron(III) ions.

Write the ionic equation for this reaction. State symbols are **not** required.

(1)

(b) Hydrogen iodide gas is usually prepared by adding phosphoric(V) acid to solid potassium iodide.

(i) Suggest why phosphoric(V) acid is used in this preparation rather than concentrated sulfuric acid.

(1)

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.....

.....

(ii) Describe what you would see if a test tube of hydrogen iodide gas was inverted in a beaker of water.

(1)

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.....

(iii) When hydrogen iodide gas reacts with ammonia, dense white fumes form. Write the equation for this reaction, including state symbols.

(2)

(c) 1-iodobutane can be made by reacting butan-1-ol with phosphorus(III) iodide, PI_3, formed by reacting moist red phosphorus with iodine.

(i) Complete the following equation for the formation of 1-iodobutane.

(1)

PI_3 + ... $C_4H_9OH \rightarrow$

(ii) Identify the intermolecular forces present between molecules of 1-iodobutane.

(1)

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.....

.....

(iii) 1-iodobutane reacts with hot aqueous silver nitrate solution. Describe what you would see when this reaction takes place.

(1)

.....

(iv) Give the structural formula for the organic product of the reaction between 1-iodobutane and ammonia.

(1)

(Total for Question 13 = 12 marks)

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14 This question is about methanol, CH_3OH, and ethanol, CH_3CH_2OH.

(a) (i) Draw a dot and cross diagram for **methanol**, showing outer electrons only.

(1)

(ii) Give the approximate values for the HCH and COH bond angles in methanol. Justify your answers.

(4)

HCH angle .....

Justification .....

.....

.....

COH angle .....

Justification .....

.....

.....

(iii) Using displayed formulae, draw a diagram to show a hydrogen bond between two methanol molecules. On your diagram, show the bond angle around the hydrogen atom of the hydrogen bond and give its value.

(2)

(b) Methanol reacts with sodium.

(i) State what you would observe in this reaction.

(2)

.....

.....

(ii) Write the equation for this reaction. State symbols are **not** required.

(1)

(c) **Ethanol** can be used to make ethanal.

(i) Identify, by name or formula, the two chemicals you would use to make ethanal from ethanol in the laboratory.

(2)

.....

.....

(ii) Draw a diagram of the apparatus you would use to prepare ethanal from ethanol in the laboratory and collect the product.

(2)

(iii) Both ethanal and propane have a molar mass of 44 g mol^{-1}, but their boiling temperatures are different.

Suggest which substance has the higher boiling temperature. Justify your answer by comparing the intermolecular forces in each compound.

(2)

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(Total for Question 14 = 16 marks)

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15 The ingredients list on the label of a commercial indigestion remedy states that each tablet contains 680 mg of calcium carbonate.

To check this, the following experiment was carried out.

One tablet was crushed. 50.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid, an excess, was then added and the mixture was transferred to a volumetric flask. The volume was made up to exactly 100 cm^3 with distilled water. 10.0 cm^3 of this solution was titrated with 0.300 mol dm^{-3} sodium hydroxide solution. The following results were obtained.

Run	Rough	1	2
Final burette reading / cm^3	21.80	33.20	44.40
Initial burette reading / cm^3	10.00	21.80	33.20
Volume added / cm^3	11.80	11.40	11.20

(a) (i) What should be used to crush the tablet?

(1)

.....

(ii) Name a suitable indicator for the titration. State the colour change you would expect to see.

(2)

Indicator .....

Colour change from ..... to .....

(b) (i) Select appropriate readings and calculate the mean titre.

(1)

(ii) Calculate the number of moles of sodium hydroxide used.

(1)

(iii) Use your answer to (ii) to write down the number of moles of hydrochloric acid left in 10.0 cm^3 of the solution used in the titration.

(1)

(iv) Calculate the number of moles of hydrochloric acid left in 100 cm^3 of solution.

(1)

(v) 50.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid contains 0.0500 mol of hydrochloric acid.

Use this and your answer to (iv) to calculate the number of moles of hydrochloric acid that reacted with the indigestion tablet.

(1)

(vi) The equation for the reaction between hydrochloric acid and calcium carbonate is:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

Use this, and your answer to (v), to calculate the number of moles of calcium carbonate in one tablet.

(1)

(vii) Calculate the mass of calcium carbonate in one tablet.

[Assume that the molar mass of $CaCO_3$ is 100 g mol^{-1}]

(1)

(viii) Suggest a reason, other than experimental error, why your value differs from the value given on the label.

(1)

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.....

(Total for Question 15 = 11 marks)

TOTAL FOR SECTION B = 39 MARKS

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SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

16 This question is about some reactions which can be used in the manufacture of hydrogen.

Reaction 1 uses two naturally occurring chemicals, water and natural gas. Steam is reacted with methane to form carbon monoxide and hydrogen in an equilibrium reaction.

Reaction 1 $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +210 \text{ kJ mol}^{-1}$

In reaction 2, carbon monoxide and steam are passed over copper at high temperature. This forms carbon dioxide and hydrogen.

Reaction 2 $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$

The carbon dioxide formed is removed by passing it through potassium carbonate solution in reaction 3.

Reaction 3 $K_2CO_3(aq) + CO_2(g) + H_2O(l) \rightarrow 2KHCO_3(aq)$

The potassium carbonate is regenerated by heating the potassium hydrogencarbonate solution in reaction 4. The carbon dioxide gas produced is released into the atmosphere.

Reaction 4 $2KHCO_3(aq) \rightarrow K_2CO_3(aq) + CO_2(g) + H_2O(l)$

(a) For each of the first three reactions, state the initial and final oxidation numbers of any elements that change their oxidation numbers. Hence decide which are redox reactions.

(5)

Reaction 1 .....

.....

.....

Reaction 2 .....

.....

.....

Reaction 3 .....

.....

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*(b) (i) Discuss, with reasons, the conditions of temperature and pressure that would favour the production of hydrogen in **reaction 1**. You should consider the effect of the conditions on both yield and rate.

(7)

(ii) Excess steam is used in **reaction 1**. State why an excess of a reagent is used and suggest why steam, rather than methane, is chosen.

(2)

(c) Copper is a catalyst in **reaction 2**. Explain how a catalyst increases the rate of a reaction.

(2)

(d) (i) State **one** economic advantage of **reaction 4**.

(1)

*(ii) **Reaction 4** contributes to global warming. Identify the substance formed in this reaction which is likely to be responsible and explain the processes that lead to an increase in global temperatures.

Suggest **two** effects an increase in global temperatures might have on the environment.

(4)

(Total for Question 16 = 21 marks)

TOTAL FOR SECTION C = 21 MARKS
TOTAL FOR PAPER = 80 MARKS