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SECTION A

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

1 (a) Complete the electronic configuration for the sodium ion, Na^+

ls^2 .....

(1 mark)

1 (b) (i) Write an equation, including state symbols, to represent the process for which the energy change is the second ionisation energy of sodium.

.....

(2 marks)

1 (b) (ii) Explain why the second ionisation energy of sodium is greater than the second ionisation energy of magnesium.

.....

.....

.....

.....

(3 marks)

1 (b) (iii) An element **X** in Period 3 of the Periodic Table has the following successive ionisation energies.

	First	Second	Third	Fourth
Ionisation energies / kJ mol^{-1}	577	1820	2740	11600

Deduce the identity of element **X**.

.....

(1 mark)

1 (c) State and explain the trend in atomic radius of the Period 3 elements from sodium to chlorine.

Trend .....

Explanation .....

.....

.....

(3 marks)

1 (d) Explain why sodium has a lower melting point than magnesium.

.....

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.....

.....

(3 marks)

1 (e) Sodium reacts with ammonia to form the compound $NaNH_2$ which contains the NH_2^- ion. Draw the shape of the NH_2^- ion, including any lone pairs of electrons. Name the shape made by the three atoms in the NH_2^- ion.

Shape of NH_2^-

Name of shape .....

(2 marks)

1 (f) In terms of its electronic configuration, give **one** reason why neon does not form compounds with sodium.

.....

(1 mark)

16

2 Under suitable conditions magnesium will react with dilute nitric acid according to the following equation.

$$Mg(s) + 2HNO_3(aq) \longrightarrow Mg(NO_3)_2(aq) + H_2(g)$$

A 0.0732 g sample of magnesium was added to 36.4 cm^3 of 0.265 mol dm^{-3} nitric acid. The acid was in excess.

2 (a) (i) Calculate the amount, in moles, of magnesium in the 0.0732 g sample.

.....

.....

(1 mark)

2 (a) (ii) Hence calculate the amount, in moles, of nitric acid needed to react completely with this sample of magnesium.

.....

.....

(1 mark)

2 (a) (iii) Calculate the amount, in moles, of nitric acid originally added to this sample of magnesium.

.....

.....

(1 mark)

2 (a) (iv) Hence calculate the amount, in moles, of nitric acid that remains unreacted.

.....

.....

(1 mark)

2 (b) In a second experiment, 0.512 mol of hydrogen gas was produced when another sample of magnesium reacted with dilute nitric acid. Calculate the volume that this gas would occupy at 298 K and 96 kPa. Include units in your final answer.
(The gas constant $R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$)

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(3 marks)

2 (c) Concentrated nitric acid reacts with magnesium to form an oxide of nitrogen which contains 30.4% by mass of nitrogen.

Calculate the empirical formula of this oxide of nitrogen. Show your working.

.....

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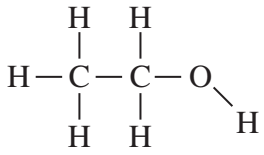
.....

(3 marks)

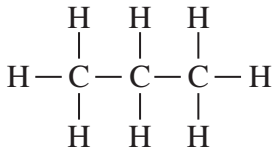
10

Turn over for the next question

3 (a) Two organic compounds with similar relative molecular masses are shown below.



Ethanol



Propane

3 (a) (i) State the type of bond present between the C and H atoms in both of these molecules. Explain how this type of bond is formed.

Type of bond .....

Explanation .....

.....

(2 marks)

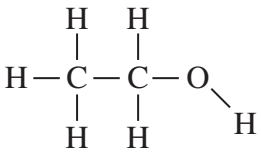
3 (a) (ii) State the strongest type of intermolecular force present in each compound.

Liquid ethanol .....

Liquid propane .....

(2 marks)

3 (b) Ethanol dissolves in water. Draw a diagram to show how one molecule of ethanol interacts with one molecule of water in the solution. Include partial charges and all lone pairs. The ethanol molecule has been drawn for you.



(3 marks)

3 (c) Ethanol was the fuel used in the first mass-produced car, the Model T Ford.

3 (c) (i) Write an equation which shows how ethanol burns completely in air to form carbon dioxide and water as the only products.

.....

(1 mark)

3 (c) (ii) Suggest **one** environmental problem caused by incomplete combustion of ethanol in a car engine.

.....

.....

(1 mark)

3 (c) (iii) Suggest **one** economic problem for the car user caused by incomplete combustion of ethanol in the car engine.

.....

.....

(1 mark)

3 (d) Propane is also used as a fuel, although sometimes it can be contaminated with sulfur-containing impurities. When this propane burns, these impurities form sulfur dioxide.

3 (d) (i) State how the sulfur dioxide can be removed from the waste gases produced when this propane is burned on a large scale in industry. Suggest a reason why the method you have stated may not be 100% efficient.

How removed .....

.....

Reason for less than 100% efficiency .....

.....

(2 marks)

3 (d) (ii) Although propane has a boiling point of –42 °C, it is usually supplied as a liquid for use in camping stoves. Suggest why it is supplied as a liquid.

.....

.....

(1 mark)

13

4 Hexane is a member of the homologous series of alkanes.

4 (a) State **two** characteristics of a *homologous series*.

Characteristic 1 .....

.....

Characteristic 2 .....

.....

(2 marks)

4 (b) (i) Hexane can be converted into 2,2-dichlorohexane.

Draw the displayed formula of 2,2-dichlorohexane and deduce its empirical formula.

Displayed formula

Empirical formula .....

.....

(2 marks)

4 (b) (ii) Explain why 2,2-dichloro-3-methylpentane is a structural isomer of 2,2-dichlorohexane.

.....

.....

(2 marks)

4 (c) A reaction of hexane with chlorine is shown by the equation below.

$$C_6H_{14} + 2Cl_2 \longrightarrow C_6H_{12}Cl_2 + 2HCl$$

Calculate the percentage atom economy for the formation of $C_6H_{12}Cl_2$ in this reaction.

.....

.....

.....

(2 marks)

4 (d) The boiling points of some straight-chain alkanes are shown below.

Alkane	C_4H_{10}	C_5H_{12}	C_6H_{14}
Boiling point / °C	–0.5	36.3	68.7

4 (d) (i) Explain the trend in these boiling points.

.....

.....

.....

(2 marks)

4 (d) (ii) Name a process which can be used to separate C_5H_{12} from C_6H_{14}

.....

(1 mark)

11

SECTION B

Answer Question **5** in the spaces provided.

5 (a) (i) Define the term *relative atomic mass* (A_r) of an element.

.....

.....

.....

.....

(2 marks)

5 (a) (ii) A sample of the metal silver has the relative atomic mass of 107.9 and exists as two isotopes. In this sample, 54.0% of the silver atoms are one isotope with a relative mass of 107.1

Calculate the relative mass of the other silver isotope.

State why the isotopes of silver have identical chemical properties.

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(4 marks)

5 (b) The isotopes of silver, when vaporised, can be separated in a mass spectrometer.

Name the **three** processes that occur in a mass spectrometer before the vaporised isotopes can be detected.

State how each process is achieved.

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(6 marks)

Question 5 continues on the next page

5 (c) State the type of bonding involved in silver.

Draw a diagram to show how the particles are arranged in a silver lattice and show the charges on the particles.

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(3 marks)

5 (d) Silver reacts with fluorine to form silver fluoride (AgF).

Silver fluoride has a high melting point and has a structure similar to that of sodium chloride.

State the type of bonding involved in silver fluoride.

Draw a diagram to show how the particles are arranged in a silver fluoride lattice and show the charges on the particles.

Explain why the melting point of silver fluoride is high.

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(5 marks)

20

END OF QUESTIONS

Areas outside the box will not be scanned for marking

Section A

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

1 Sodium thiosulfate solution ($Na_2S_2O_3$) reacts slowly with dilute hydrochloric acid to form a precipitate. The rate of this reaction can be studied by measuring the time (t) that it takes for a small fixed amount of precipitate to form under different conditions. The fixed amount of precipitate is taken as the amount needed to obscure a cross on paper.

The equation for this reaction is shown below.

$$Na_2S_2O_3 + 2HCl \longrightarrow 2NaCl + S + SO_2 + H_2O$$

1 (a) Identify the insoluble product of this reaction which forms the precipitate.

.....

(1 mark)

1 (b) When this reaction takes place, the collision between the reacting particles requires an activation energy. State what is meant by the term *activation energy*.

.....

.....

(2 marks)

1 (c) In terms of particles, explain why, at a fixed temperature, you might expect the rate of this reaction to double when the concentration of sodium thiosulfate is doubled and the concentration of hydrochloric acid remains the same.

.....

.....

.....

.....

(2 marks)

1 (d) (i) State what is meant by the term *rate of reaction*.

.....

.....

(1 mark)

1 (d) (ii) Consider the description of the way in which this experiment is carried out. Use your understanding of the term *rate of reaction* to explain why it is possible to use a simplified formula $\frac{1}{t}$ as a measure of the rate of **this** reaction.

.....

.....

(1 mark)

7

Turn over for the next question

2 Barium can be extracted from barium oxide (BaO) in a process using aluminium. A mixture of powdered barium oxide and powdered aluminium is heated strongly. The equation for this extraction process is shown below.

$$3BaO(s) + 2Al(s) \longrightarrow 3Ba(s) + Al_2O_3(s)$$

Some standard enthalpies of formation are given in the table below.

Substance	BaO(s)	$Al_2O_3(s)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–558	–1669

2 (a) (i) State what is meant by the term *standard enthalpy of formation*.

.....

.....

.....

.....

.....

(3 marks)

2 (a) (ii) State why the standard enthalpy of formation of barium and that of aluminium are both zero.

.....

(1 mark)

2 (a) (iii) Use the data to calculate the standard enthalpy change for the reaction shown by the equation above.

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.....

(3 marks)

2 (b) (i) Suggest the major reason why this method of extracting barium is expensive.

.....

(1 mark)

2 (b) (ii) Using barium oxide and aluminium powders increases the surface area of the reactants. Suggest **one** reason why this increases the rate of reaction.

.....

(1 mark)

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

.....

(1 mark)

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

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

Simplest ionic equation

.....

Observation .....

(2 marks)

2 (c) (iii) State how barium sulfate can be used in medicine. Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .....

Explanation .....

.....

(2 marks)

14

3 A group of students devised an experiment which they believed would enable them to investigate the strength of the intermolecular forces between ethyl ethanoate molecules ($CH_3COOCH_2CH_3$) and trichloromethane molecules ($CHCl_3$).

They mixed exactly 0.10 mol of each of the two liquids in a copper calorimeter and recorded the following results. The starting temperature of both liquids was the same.

Mass of 0.10 mol of ethyl ethanoate / g	8.80
Mass of 0.10 mol of trichloromethane / g	11.95
Increase in temperature (ΔT) on mixing / K	9.5

3 (a) (i) Write an expression for the heat change (q) which relates mass (m), specific heat capacity (c) and change in temperature (ΔT).

.....

(1 mark)

3 (a) (ii) Calculate the amount of heat required to increase the temperature of 8.80 g of ethyl ethanoate by 9.5 K during the mixing process. (You should assume that c for ethyl ethanoate = 1.92 J $g^{-1}K^{-1}$)

.....

(1 mark)

3 (a) (iii) Calculate the amount of heat required to increase the temperature of 11.95 g of trichloromethane by 9.5 K during the mixing process. (You should assume that c for trichloromethane = 0.96 J $g^{-1}K^{-1}$)

.....

(1 mark)

3 (a) (iv) Using the values from parts (a) (ii) and (a) (iii), calculate the molar enthalpy change in kJ mol^{-1} for the mixing process.

.....

.....

(2 marks)

3 (b) The students deduced that the heat change was due only to the formation of intermolecular forces between ethyl ethanoate molecules and trichloromethane molecules.

Ignoring all experimental errors, give **one** reason why the students may have made an incorrect deduction.

.....

.....

(1 mark)

6

Turn over for the next question

4 Carbon monoxide and hydrogen are used in the manufacture of methanol. An equilibrium is established according to the following equation.

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

4 (a) Give **two** features of a reaction at equilibrium.

Feature 1 .....

.....

Feature 2 .....

.....

(2 marks)

4 (b) Explain why an increase in temperature causes a decrease in the equilibrium yield of methanol.

.....

.....

.....

(2 marks)

4 (c) (i) State what is meant by the term *catalyst*.

.....

.....

(1 mark)

4 (c) (ii) State the effect, if any, of the copper catalyst on the position of this equilibrium at a fixed temperature.

.....

(1 mark)

4 (d) Two methods are used to produce carbon monoxide from natural gas. Equations for these two methods are shown below.

Method 1 $CH_4 + H_2O \longrightarrow CO + 3H_2$

Method 2 $CH_4 + CO_2 \longrightarrow 2CO + 2H_2$

The manufacture of methanol from these sources of carbon monoxide has been described as carbon neutral.

4 (d) (i) State what is meant by the term *carbon neutral*.

.....

.....

.....

(1 mark)

4 (d) (ii) Show how combining the equations from these two methods can lead to the 1:2 mol ratio of carbon monoxide to hydrogen required for this synthesis of methanol.

.....

.....

.....

(1 mark)

8

Turn over for the next question

5 This question is about the extraction of metals.

5 (a) Coke is mainly carbon and is a raw material used in the extraction of iron from iron(III) oxide.

5 (a) (i) Write an equation for the formation of carbon monoxide from carbon.

.....

(1 mark)

5 (a) (ii) Write an equation for the reduction of iron(III) oxide to iron by carbon monoxide.

.....

(1 mark)

5 (a) (iii) The Earth's resources of iron(III) oxide are very large and commercial ores have a high iron content. Give **one** economic and **one** environmental reason for recycling scrap iron and steel.

Economic reason .....

.....

Environmental reason .....

.....

(2 marks)

5 (b) Pure titanium is extracted by the reduction of titanium(IV) chloride, but not by the direct reduction of titanium(IV) oxide using carbon.

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

.....

(2 marks)

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

.....

(2 marks)

5 (b) (iii) State why titanium is not extracted directly from titanium(IV) oxide using carbon.

.....

(1 mark)

5 (c) Aluminium is extracted by the electrolysis of a molten mixture containing aluminium oxide.

5 (c) (i) State why the electrolysis needs to be of a *molten* mixture.

.....

(1 mark)

5 (c) (ii) Write an equation for the reaction of oxide ions at the positive electrode during the electrolysis.

.....

(1 mark)

5 (c) (iii) State why the positive electrodes need frequent replacement.

.....

(1 mark)

5 (c) (iv) Give the major reason why it is less expensive to recycle aluminium than to extract it from aluminium oxide by electrolysis.

.....

(1 mark)

13

Turn over for the next question

6 Acidified silver nitrate solution can be used to identify and distinguish between halide ions in solution.

6 (a) Explain why hydrochloric acid should **not** be used to acidify the silver nitrate.

.....

.....

(1 mark)

6 (b) State and explain what would be observed when acidified silver nitrate solution is added to a solution of sodium fluoride.

Observation .....

Explanation .....

(2 marks)

6 (c) State what would be observed when acidified silver nitrate solution is added to a solution containing iodide ions. Write the **simplest ionic** equation for the reaction that occurs.

Observation .....

Equation .....

(2 marks)

5

7 The reaction of bromine with an alkene is used in a test to show that the alkene is unsaturated.

7 (a) State what is meant by the term *unsaturated* as applied to an alkene.

.....

(1 mark)

7 (b) Name and outline a mechanism for the reaction of bromine with but-2-ene.

Name of mechanism .....

Mechanism

(5 marks)

7 (c) But-2-ene can exist as a pair of stereoisomers.

7 (c) (i) State what is meant by the term *stereoisomers*.

.....

.....

.....

(2 marks)

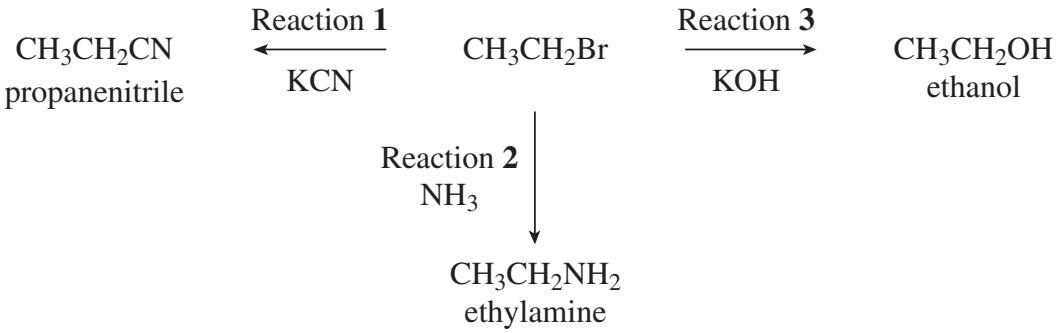
7 (c) (ii) Draw the structure of (*E*)-but-2-ene.

.....

(1 mark)

9

8 Nucleophiles react with bromoethane in substitution reactions. This type of reaction is illustrated in the following scheme.



8 (a) State what is meant by the term *nucleophile*.

.....

(1 mark)

8 (b) Outline a mechanism for the reaction of potassium cyanide with bromoethane (Reaction **1**).

(2 marks)

8 (c) Explain why an excess of ammonia is needed in Reaction **2** to produce a high yield of ethylamine.

.....

.....

(1 mark)

8 (d) When potassium hydroxide reacts with bromoethane, ethene can also be formed. Name and outline a mechanism for this reaction.

Name of mechanism .....

Mechanism

(4 marks)

8

Turn over for the next question

9 Butan-2-ol can be oxidised by acidified potassium dichromate(VI) to form butanone as shown by the following equation.

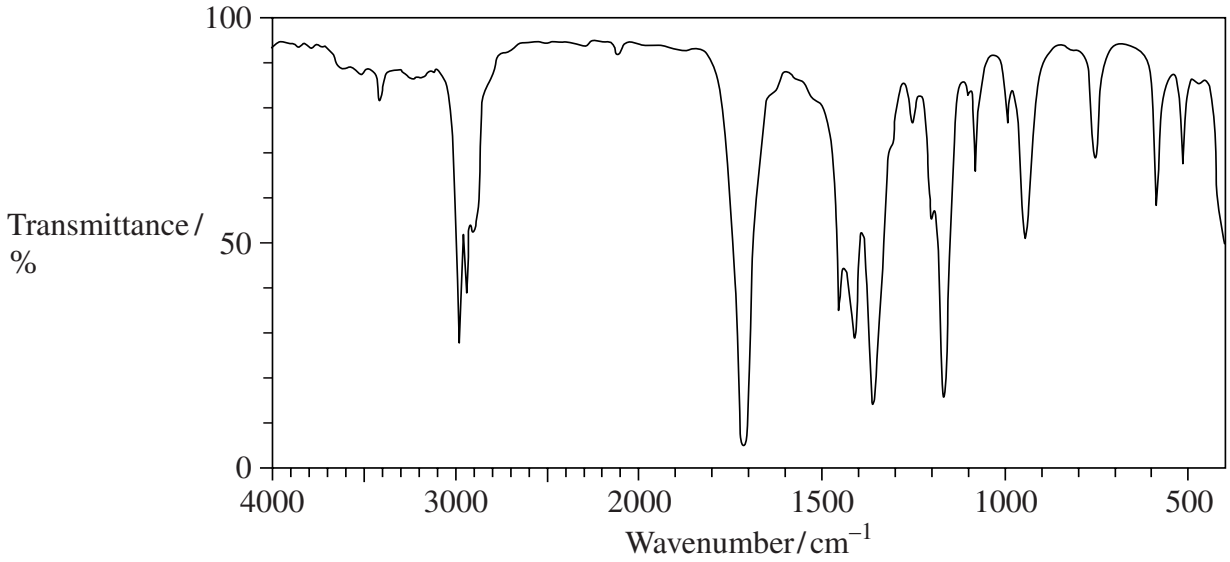
$$CH_3CH_2CH(OH)CH_3 + [O] \longrightarrow CH_3CH_2COCH_3 + H_2O$$

9 (a) State the class of alcohol to which butan-2-ol belongs.

.....

(1 mark)

9 (b) The infrared spectrum shown below is either that of butan-2-ol or that of butanone.



Identify the compound to which this infrared spectrum refers.

Explain your answer.

You may find it helpful to refer to the table of infrared absorption data on the back of the Periodic Table (**Table 1**).

Identity of the compound .....

Explanation .....

.....

.....

(3 marks)

9 (c) Draw the displayed formula of the alcohol C_4H_9OH which is resistant to oxidation by acidified potassium dichromate(VI).

.....

(1 mark)

5

Turn over for the next question

Section B

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

10 In the past 150 years, three different processes have been used to extract bromine from potassium bromide. These processes are illustrated below.

Extraction Process **1**

$$2KBr + MnO_2 + 2H_2SO_4 \longrightarrow MnSO_4 + K_2SO_4 + 2H_2O + Br_2$$

Extraction Process **2**

The reaction of solid potassium bromide with concentrated sulfuric acid.

Extraction Process **3**

The reaction of aqueous potassium bromide with chlorine gas.

10 (a) Write a half-equation for the conversion of MnO_2 in acid solution into Mn^{2+} ions and water. In terms of electrons, state what is meant by the term *oxidising agent* and identify the oxidising agent in the overall reaction.

.....

.....

.....

.....

.....

.....

(3 marks)

10 (b) Write an equation for Extraction Process **2** and an equation for Extraction Process **3**. Calculate the percentage atom economy for the extraction of bromine from potassium bromide by Extraction Process **3**. Suggest why Extraction Process **3** is the method in large-scale use today.

.....

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(5 marks)

Question 10 continues on the next page

10 (c) Bromine has been used for more than 70 years to treat the water in swimming pools. The following equilibrium is established when bromine is added to water.

$$Br_2 + H_2O \rightleftharpoons HBrO + HBr$$

Give the oxidation state of bromine in HBr and in HBrO

Deduce what will happen to this equilibrium as the HBrO reacts with micro-organisms in the swimming pool water. Explain your answer.

.....

.....

.....

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(4 marks)

12

11 One of the first substances used as an anaesthetic in medicine was chloroform (trichloromethane, $CHCl_3$). By 1950, *halothane* was in common use but by 1990 this had been replaced by more acceptable anaesthetics such as *desflurane*.

$CF_3CHBrCl$	$CF_3CHFOCHF_2$
halothane	*desflurane*

One reason for replacing *halothane* was that it is an organic compound that contains chlorine. Chlorine-containing organic compounds are thought to cause damage to the ozone layer in the upper atmosphere.

11 (a) Name and outline a mechanism for the reaction of chlorine with methane to form chloromethane (CH_3Cl).

Write an overall equation for the reaction of chlorine with methane to form trichloromethane ($CHCl_3$).

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(5 marks)

Question 11 continues on the next page

11 (b) Explain how chlorine atoms are formed from chlorine-containing organic compounds in the upper atmosphere.

Explain, with the aid of equations, how chlorine atoms act as a catalyst in the decomposition of ozone into oxygen.

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(6 marks)

11 (c) Use the formulae of the two anaesthetics, *halothane* and *desflurane*, to help to explain why *desflurane* is considered to be a more **environmentally** acceptable anaesthetic than *halothane*.

.....

.....

.....

.....

(2 marks)

13

END OF QUESTIONS

Practice 3

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 nucleus of a $^{23}_{11}Na$ atom contains

☒ **A** 11 protons and 12 neutrons.

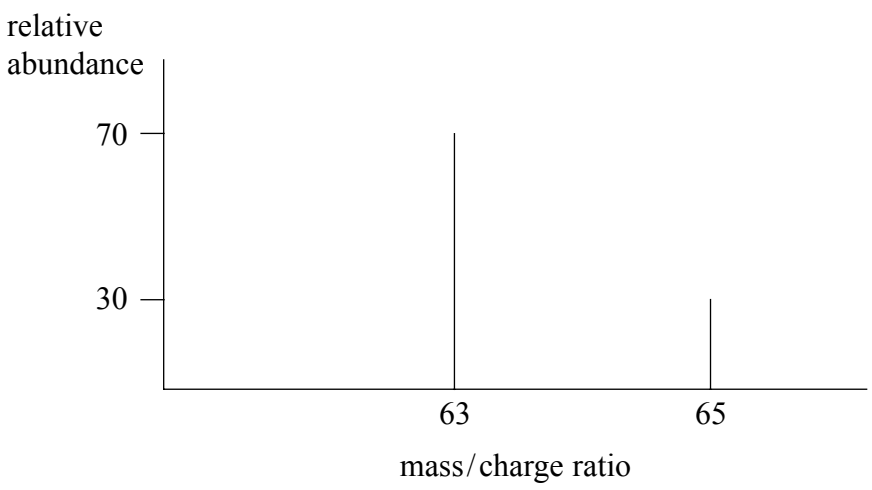
☒ **B** 11 protons and 12 electrons.

☒ **C** 23 protons and 11 neutrons.

☒ **D** 23 protons and 11 electrons.

(Total for Question 1 = 1 mark)

2 The mass spectrum for a sample of a metal is shown below.



The relative atomic mass of the metal is

☒ **A** 63.2

☒ **B** 63.4

☒ **C** 63.6

☒ **D** 64.0

(Total for Question 2 = 1 mark)

3 Some mean bond enthalpy values are given in the table below.

Bond	Mean bond enthalpy / kJ mol^{-1}
H—H	+436
I—I	+151
H—I	+299

What is the enthalpy change for the reaction shown below in kJ mol^{-1}?

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

☒ **A** +436 + 151 – 299 = +288

☒ **B** –436 – 151 + 299 = –288

☒ **C** +436 +151 – (2 × 299) = –11

☒ **D** –436 – 151 + (2 × 299) = +11

(Total for Question 3 = 1 mark)

4 A compound was analysed and found to contain

1.45 g carbon 0.482 g hydrogen 1.69 g nitrogen

[Relative atomic masses: C = 12; H = 1; N = 14]

The empirical formula of the compound is

☒ **A** CH_3N

☒ **B** CH_4N

☒ **C** CH_5N

☒ **D** C_2H_4N

(Total for Question 4 = 1 mark)

5 17.1 g of aluminium sulfate, $Al_2(SO_4)_3$, was dissolved in water.

Calculate the number of sulfate ions, SO_4^{2-}, present in the solution formed.

[Assume the molar mass of $Al_2(SO_4)_3$ is 342 g mol^{-1} and the Avogadro Constant is 6×10^{23} mol^{-1}.]

☒ **A** 3×10^{21}

☒ **B** 1×10^{22}

☒ **C** 3×10^{22}

☒ **D** 9×10^{22}

(Total for Question 5 = 1 mark)

6 Calculate the mass of calcium hydroxide, $Ca(OH)_2$, present in 100 cm^3 of a 0.100 mol dm^{-3} solution.

[Assume the molar mass of $Ca(OH)_2$ is 74.0 g mol^{-1}.]

☒ **A** 0.570 g

☒ **B** 0.740 g

☒ **C** 1.85 g

☒ **D** 3.70 g

(Total for Question 6 = 1 mark)

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

7 The first five successive ionization energies of an element, **X**, are shown in the table below.

Ionization energy	first	second	third	fourth	fifth
Value / kJ mol^{-1}	590	1100	4900	6500	8100

Which ion is **X** most likely to form when it reacts with chlorine?

☒ **A** X^+

☒ **B** X^{2+}

☒ **C** X^{3+}

☒ **D** X^{4+}

(Total for Question 7 = 1 mark)

8 Which of the following alkenes exhibits **E-Z** isomerism?

☒ **A** $H_3CCH{=}C(CH_3)_2$

☒ **B** $(CH_3)_2C{=}CH_2$

☒ **C** $H_2C{=}CHCH_2CH_3$

☒ **D** $H_3CCH{=}CHCH_3$

(Total for Question 8 = 1 mark)

9 Which of the following covalent bonds is the shortest?

☒ **A** H—F

☒ **B** H—Cl

☒ **C** H—Br

☒ **D** H—I

(Total for Question 9 = 1 mark)

10 Which of the following substances, obtained from the fractional distillation of crude oil, has the lowest boiling temperature?

☒ **A** refinery gas

☒ **B** kerosene

☒ **C** diesel oil

☒ **D** lubricating oil

(Total for Question 10 = 1 mark)

11 Sodium hydrogensulfate, $NaHSO_4$, reacts with sodium hydroxide, NaOH, as shown below.

$$NaHSO_4(aq) + NaOH(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$$

0.0100 mol of sodium hydrogensulfate is neutralized with dilute sodium hydroxide, concentration 0.200 mol dm^{-3}.

Calculate the volume of sodium hydroxide required.

☒ **A** 20.0 cm^3

☒ **B** 50.0 cm^3

☒ **C** 100 cm^3

☒ **D** 500 cm^3

(Total for Question 11 = 1 mark)

12 Which of the following ions would undergo the greatest deflection in a mass spectrometer?

☒ **A** $^{35}Cl^{2+}$

☒ **B** $^{35}Cl^{+}$

☒ **C** $^{37}Cl^{+}$

☒ **D** $^{35}Cl^{37}Cl^{+}$

(Total for Question 12 = 1 mark)

13 Which pair of atomic numbers represents elements which are both in the p-block of the Periodic Table?

☒ **A** 4, 8

☒ **B** 6, 12

☒ **C** 8, 16

☒ **D** 10, 20

(Total for Question 13 = 1 mark)

14 The electronic structure of an atom of an element in Group 6 of the Periodic Table could be

☒ **A** $1s^2\ 2s^2\ 2p^2$

☒ **B** $1s^2\ 2s^2\ 2p^4$

☒ **C** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$

☒ **D** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6$

(Total for Question 14 = 1 mark)

15 Which of the following formulae for compounds of germanium, Ge, is unlikely to be correct, given the position of germanium in the Periodic Table?

☒ **A** GeF_3

☒ **B** GeS_2

☒ **C** GeO_2

☒ **D** GeH_4

(Total for Question 15 = 1 mark)

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

16 The electronic configurations of the atoms of four different elements are given below. For which element would you expect the value of the first ionization energy to be the largest?

☒ **A** $1s^1$

☒ **B** $1s^2$

☒ **C** $1s^2\ 2s^1$

☒ **D** $1s^2\ 2s^2$

(Total for Question 16 = 1 mark)

17 Which of the following gas samples occupies the greatest volume at the same temperature and pressure?

[Relative atomic masses: H = 1; C = 12; O = 16; F = 19; Ne = 20]

☒ **A** 1 gram of ethane

☒ **B** 1 gram of oxygen

☒ **C** 1 gram of fluorine

☒ **D** 1 gram of neon

(Total for Question 17 = 1 mark)

18 Which of the following has the smallest ionic radius?

☒ **A** F^-

☒ **B** Na^+

☒ **C** Mg^{2+}

☒ **D** O^{2-}

(Total for Question 18 = 1 mark)

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

19 Which of the following does **not** have exactly 10 electrons?

☒ **A** An ion of fluorine, F^-

☒ **B** A molecule of methane, CH_4

☒ **C** A molecule of nitrogen, N_2

☒ **D** An ion of sodium, Na^+

(Total for Question 19 = 1 mark)

20 Which of the following statements correctly describes an environmental problem caused by the burning of hydrocarbon fuels?

☒ **A** The carbon dioxide is toxic and kills plants.

☒ **B** The smoke produced reflects sunlight and leads to global warming.

☒ **C** The water produced results in a damaging increase in rainfall.

☒ **D** The carbon dioxide produced absorbs heat radiated from the Earth and leads to global warming.

(Total for Question 20 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

21 This question is about hydrocarbons.

(a) Liquefied petroleum gas (LPG) is a fuel sold as an alternative to petrol. It is a mixture of liquefied C_3 and C_4 alkanes.

(i) Suggest a reason why the alkanes are liquefied.

(1)

.....

.....

(ii) There are two C_4 alkanes.

Draw **skeletal** formulae of each of the C_4 alkanes in the spaces provided.

Name each alkane.

(4)

First skeletal formula	Second skeletal formula
Name:	Name: .....

(iii) Complete the following sentence.

(1)

Compounds with the same molecular formula but different structural formula are called .....

(b) Propane, C_3H_8, reacts with chlorine, Cl_2, in a substitution reaction.

$$C_3H_8 + Cl_2 \rightarrow C_3H_7Cl + HCl$$

The mechanism for this reaction is described in three stages.

(i) Give the **initiation step** for this reaction and state the condition necessary for this step to occur.

(2)

Initiation step

Condition .....

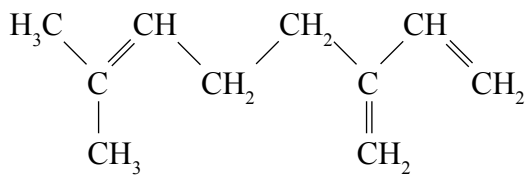
(ii) Give the TWO **propagation steps** for this reaction.

(2)

(iii) Give a possible **termination step** for this reaction.

(1)

(c) Myrcene, $C_{10}H_{16}$, is a naturally occurring compound which is used in perfumes.



Myrcene

(i) Name the functional group in myrcene.

(1)

.....

(ii) What colour change would you observe when bromine, dissolved in an organic solvent, is added to myrcene?

(1)

From ..... **To** .....

(iii) Classify the type and mechanism of the reaction that occurs when myrcene reacts with bromine, Br_2.

(2)

.....

.....

(iv) In an experiment, 1.36 g of myrcene (molar mass: 136 g mol^{-1}) was found to react with 0.72 dm^3 of hydrogen, H_2, in the presence of a nickel catalyst.

Use this information to draw the structural formula of the product of the reaction between myrcene and hydrogen.

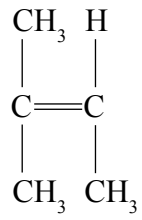
[Assume the molar volume of H_2 under the conditions of the experiment is 24 dm^3 mol^{-1}.]

(2)

Calculation

Hence structural formula of the product

(d) Myrcene is one of a group of compounds related to 2-methylbut-2-ene shown below.



2-methylbut-2-ene undergoes addition polymerization in a similar way to ethene.

Draw the structural formula of the repeat unit of the polymer formed.

(2)

(Total for Question 21 = 19 marks)

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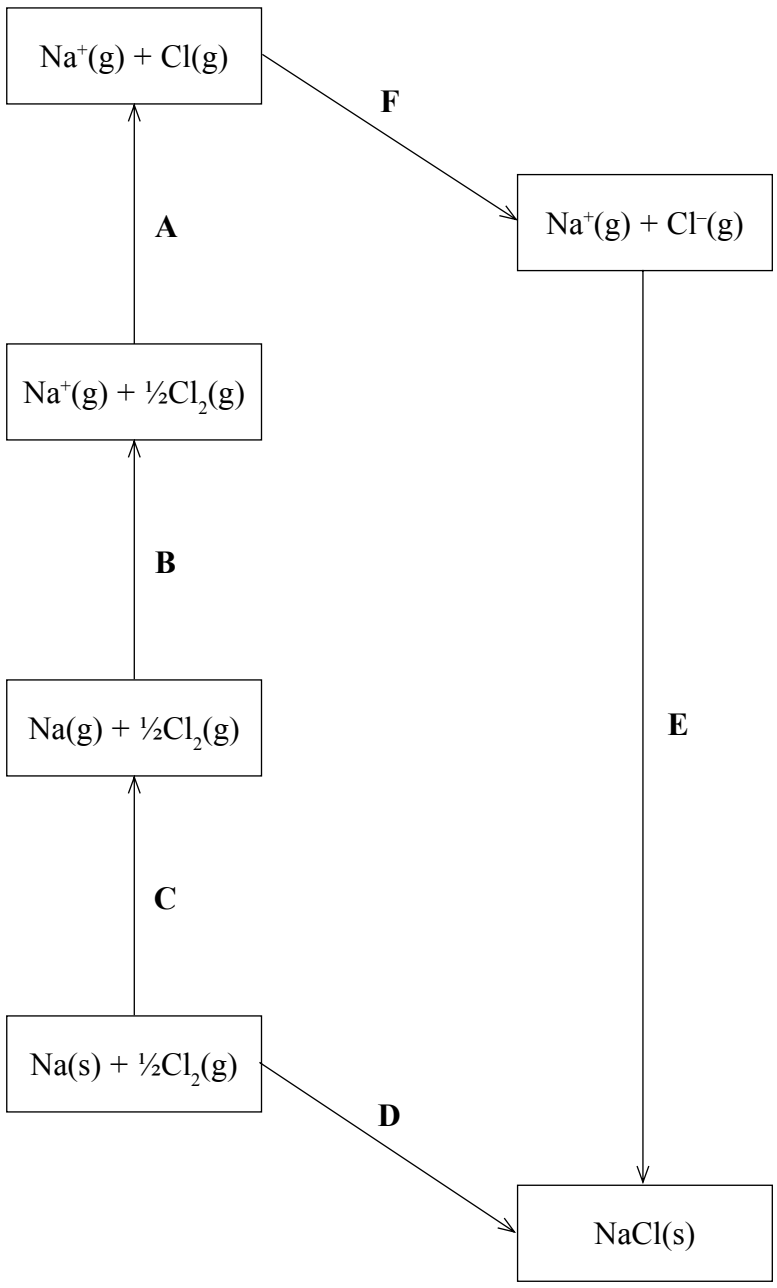
22 The Born-Haber cycle for the formation of sodium chloride from sodium and chlorine may be represented by a series of steps labelled **A** to **F** as shown.



(a) (i) Complete the table below by adding the letters **A** to **F** next to the corresponding energy changes.

(3)

Energy change	Letter	ΔH /kJ mol^{-1}
Lattice energy for sodium chloride		–775
Enthalpy change of atomization of sodium		+109
Enthalpy change of atomization of chlorine		+121
First ionization energy of sodium		+494
First electron affinity of chlorine		
Enthalpy change of formation of sodium chloride		–411

(ii) Calculate the first electron affinity of chlorine, in kJ mol^{-1}, from the data given.

(2)

(b) Lattice energies can be calculated from electrostatic theory (theoretical values) as well as by Born-Haber cycles (experimental values).

Compound	Experimental lattice energy / kJ mol^{-1}	Theoretical lattice energy / kJ mol^{-1}
NaCl	–770	–766
AgI	–889	–778

(i) Comment on the fact that there is close agreement between the values for sodium chloride, NaCl.

(1)

*(ii) Explain, in terms of chemical bonding, why the experimental value for silver iodide, AgI, is more exothermic than the value calculated theoretically for the same compound.

(2)

*(c) Suggest why the first ionization energies of the Group 1 elements decrease down the group.

(2)

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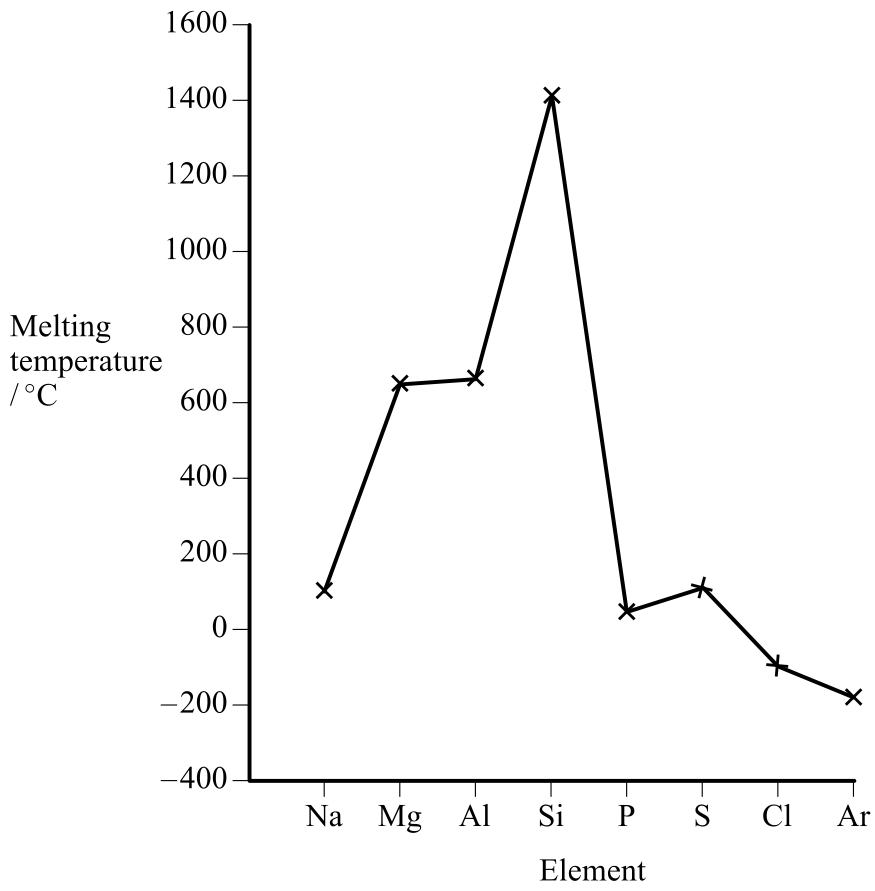
(Total for Question 22 = 10 marks)

Turn over ▶

23 The graph shows the variation in melting temperatures of the elements across Period 3 (Na to Ar) of the Periodic Table.



(a) Complete the table below to show the type of structure and bonding for the elements shown.

(3)

Element	Structure	Bonding
sodium		
silicon		
sulfur		

(b) Explain why silicon has a much higher melting temperature than sulfur.

(2)

*(c) Explain why the melting temperature increases from sodium to aluminium.

(2)

(d) Magnesium forms the basic oxide magnesium oxide, MgO. This oxide is almost insoluble in water. On gentle warming with dilute sulfuric acid, magnesium oxide reacts to form aqueous magnesium sulfate solution.

*(i) Describe how you would use the above reaction to prepare a pure sample of magnesium sulfate.

(5)

(ii) Suggest what action should be taken if a pupil spilt a small quantity of dilute sulfuric acid on a laboratory bench.

(1)

(e) The data in the table below will be useful when answering this question.

Soluble in water	Insoluble in water
$MgSO_4$	$MgCO_3$ $SrCO_3$ $SrSO_4$

Magnesium carbonate reacts with dilute sulfuric acid.

$$MgCO_3(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + CO_2(g) + H_2O(l)$$

(i) Explain why the reaction between strontium carbonate and dilute sulfuric acid stops after a few seconds.

(1)

.....

.....

.....

(ii) Strontium sulfate is produced when aqueous sodium sulfate is added to aqueous strontium chloride.

Give the **ionic** equation for the reaction, including state symbols.

(2)

(Total for Question 23 = 16 marks)

24 Propanone, C_3H_6O, undergoes complete combustion to form carbon dioxide and water.

$$C_3H_6O(l) + 4O_2(g) \rightarrow 3CO_2(g) + 3H_2O(l)$$

(a) In an experiment to calculate the enthalpy change of combustion for propanone, 2.90 g of propanone was burned completely in oxygen.

The heat energy from this combustion raised the temperature of 200 g of water from 20.2 °C to 78.4 °C.

The specific heat capacity of water is 4.18 J g^{-1} $°C^{-1}$.

(i) Calculate the number of moles of propanone present in 2.90 g.

[The molar mass of propanone is 58 g mol^{-1}.]

(1)

(ii) Use the expression

$$\text{energy transferred (J)} = \text{mass} \times \text{specific heat capacity} \times \text{temperature change}$$

to calculate the heat energy transferred to raise the temperature of 200 g of water from 20.2 °C to 78.4 °C.

(2)

(iii) Use your answers to (a)(i) and (ii) to calculate a value for the enthalpy change of combustion of propanone. Give your answer to **three** significant figures and include a sign and units.

(3)

(b) In another experiment, the enthalpy change of combustion for butanone, C_4H_8O, was found to be –1300 kJ mol^{-1}.

A Data Book value for the standard enthalpy change of combustion for butanone is –2440 kJ mol^{-1}.

(i) Suggest a reason why the value obtained in the experiment is so different from the Data Book value.

(1)

.....

(ii) This Data Book value (–2440 kJ mol^{-1}) refers to the following equation.

$$C_4H_8O(l) + 6½O_2(g) \rightarrow 4CO_2(g) + 4H_2O(l)$$

How would the value be different if it referred to the formation of water in the **gaseous** state? Justify your answer.

(2)

Difference .....

Justification .....

.....

.....

.....

(c) Standard enthalpy changes of combustion can be used to calculate the standard enthalpy change of formation of a compound.

(i) Define the term **standard enthalpy change of formation**, making clear the meaning of **standard** in this context.

(3)

.....

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.....

(ii) Use the standard enthalpy changes of combustion, $\Delta H_c^{\ominus}$, given in the table below to find the standard enthalpy change of formation for ethanoic acid, CH_3COOH, in kJ mol^{-1}.

Substance	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
C(s, graphite)	–394
$H_2(g)$	–286
$CH_3COOH(l)$	–870

$$2C(s, \text{graphite}) + 2H_2(g) + O_2(g) \rightarrow CH_3COOH(l)$$

(3)

(Total for Question 24 = 15 marks)

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

Practice 4

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 What is the oxidation number of chlorine in the ClO_3^- ion?

☒ **A** –1

☒ **B** +4

☒ **C** +5

☒ **D** +6

(Total for Question 1 = 1 mark)

2 Which of these reactions is **not** a redox reaction?

☒ **A** $Mg(NO_3)_2(s) \rightarrow MgO(s) + 2NO_2(g) + ½O_2(g)$

☒ **B** $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

☒ **C** $Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

☒ **D** $Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$

(Total for Question 2 = 1 mark)

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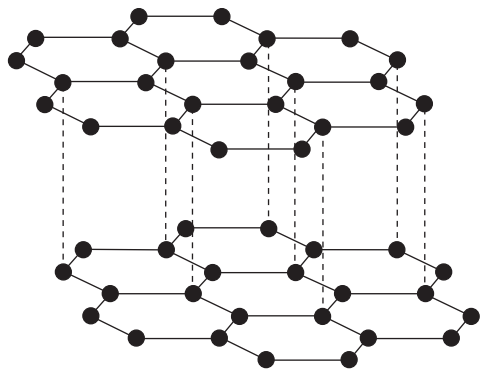
3 Which of these carbon structures is represented by the diagram below?



☒ **A** Graphite

☒ **B** Diamond

☒ **C** A fullerene

☒ **D** A carbon nanotube

(Total for Question 3 = 1 mark)

4 What colour precipitate would you expect to see if 1-bromopropane was heated with a solution of silver nitrate?

☒ **A** Orange

☒ **B** White

☒ **C** Yellow

☒ **D** Cream

(Total for Question 4 = 1 mark)

5 Which of these bond angles is the smallest?

☒ **A** HNH in NH_3

☒ **B** HCH in CH_4

☒ **C** HOH in H_2O

☒ **D** OCO in CO_2

(Total for Question 5 = 1 mark)

6 Which statement best describes the shape and bond angles in the molecule SF_6?

☒ **A** Octahedral, 90° and 180°

☒ **B** Trigonal bipyramidal, 90° and 180°

☒ **C** Octahedral, 90° and 120°

☒ **D** Trigonal bipyramidal, 90° and 120°

(Total for Question 6 = 1 mark)

7 Which of the following values for the mass/charge ratio for singly charged ions would be present in the mass spectrum of propanal, CH_3CH_2CHO, but not of propanone, CH_3COCH_3?

☒ **A** 15

☒ **B** 29

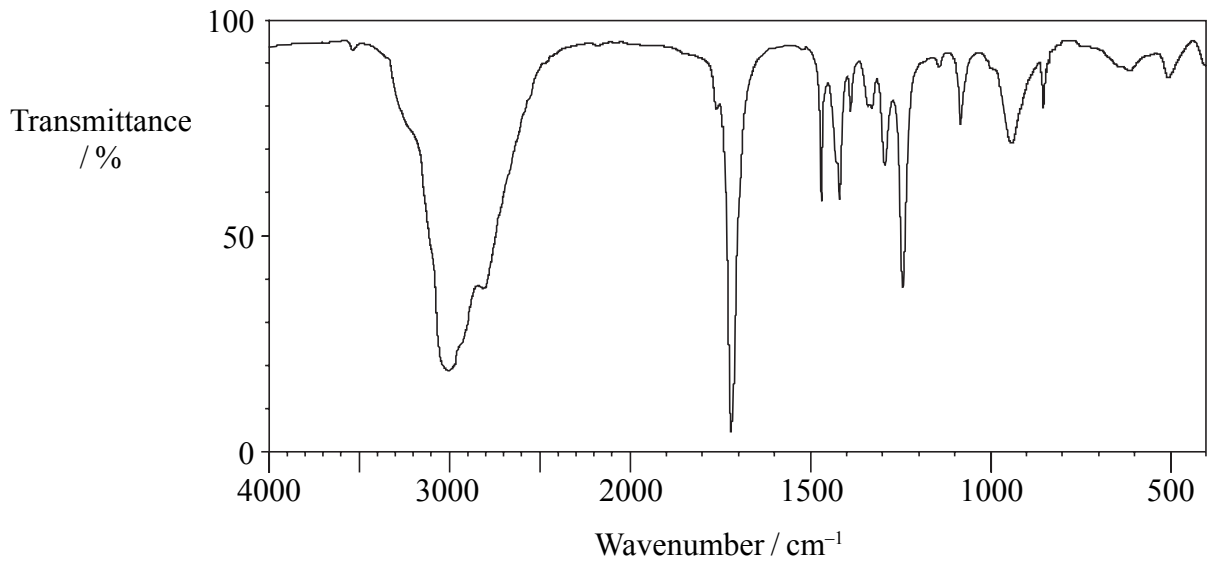
☒ **C** 43

☒ **D** 58

(Total for Question 7 = 1 mark)

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

8 The infrared spectrum below is most likely to be that of a member of which homologous series?



C—Cl stretching vibrations 600 – 800 cm^{-1}
O—H stretching vibrations 2500 – 3300 cm^{-1}
C═O stretching vibrations 1680 – 1740 cm^{-1}

☒ **A** Alcohol

☒ **B** Chloroalkane

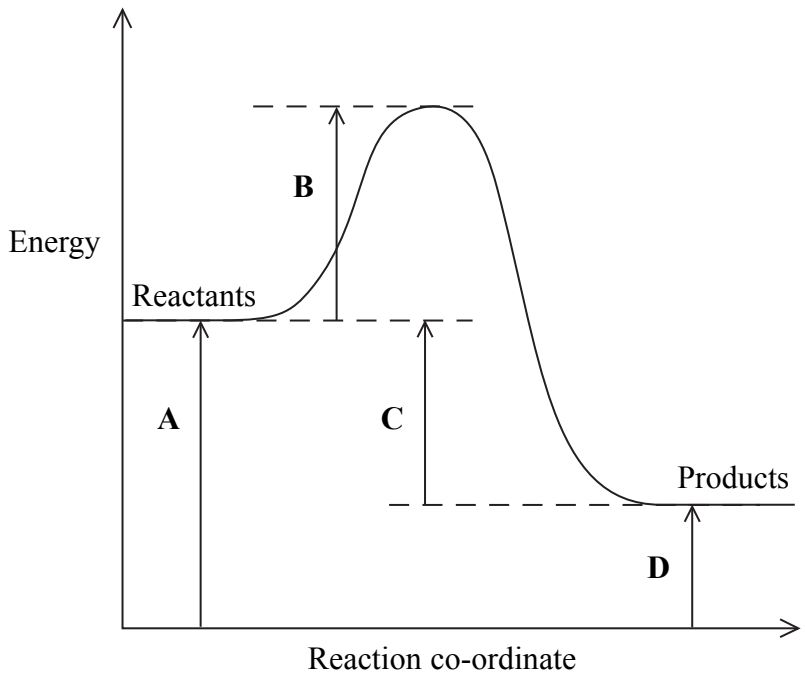
☒ **C** Aldehyde

☒ **D** Carboxylic acid

(Total for Question 8 = 1 mark)

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

9 In the reaction profile below, which energy change would alter if a catalyst was added to the reaction?



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 9 = 1 mark)

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

10 In the equilibrium below, what effect would the changes described have on the system?

$$2H_2S(g) + SO_2(g) \rightleftharpoons 3S(s) + 2H_2O(g) \qquad \Delta H \text{ is negative}$$

(a) Increase in temperature

(1)

☒ **A** increase rate, decrease yield

☒ **B** increase rate, increase yield

☒ **C** decrease rate, decrease yield

☒ **D** decrease rate, increase yield

(b) Decrease in pressure

(1)

☒ **A** increase rate, decrease yield

☒ **B** increase rate, increase yield

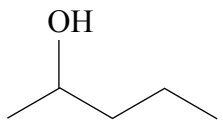
☒ **C** decrease rate, decrease yield

☒ **D** decrease rate, increase yield

(Total for Question 10 = 2 marks)

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

11 What is the correct systematic name for the alcohol shown below?



- ☒ **A** hexan-4-ol
- ☒ **B** hexan-2-ol
- ☒ **C** pentan-4-ol
- ☒ **D** pentan-2-ol

(Total for Question 11 = 1 mark)

12 Which of these compounds is a secondary halogenoalkane?

- ☒ **A** $CH_3CH(OH)CH_3$
- ☒ **B** $CH_3CCl(CH_3)CH_3$
- ☒ **C** $CH_3CHClCH_3$
- ☒ **D** $CH_3CH_2CH_2Cl$

(Total for Question 12 = 1 mark)

13 The bonding in **gaseous** hydrogen halides is best described as

- ☒ **A** mainly covalent with an increasing tendency towards ionic as you go down the group.
- ☒ **B** mainly covalent with an increasing tendency towards ionic as you go up the group.
- ☒ **C** mainly ionic with an increasing tendency towards covalent as you go down the group.
- ☒ **D** mainly ionic with an increasing tendency towards covalent as you go up the group.

(Total for Question 13 = 1 mark)

14 What would be the colour of the solution when iodine is dissolved in a hydrocarbon solvent?

☒ **A** Grey

☒ **B** Brown

☒ **C** Yellow

☒ **D** Purple

(Total for Question 14 = 1 mark)

15 Starch is often used as an indicator in titrations between sodium thiosulfate and iodine solutions. What colour change would you see at the end-point as sodium thiosulfate is added to iodine solution in the presence of starch?

☒ **A** Yellow to colourless

☒ **B** Colourless to yellow

☒ **C** Blue-black to colourless

☒ **D** Colourless to blue-black

(Total for Question 15 = 1 mark)

16 An electric field can affect the direction of a stream of some liquids. Which of these liquids would be affected by an electric field?

☒ **A** 1-chloropropane

☒ **B** Pentane

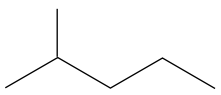
☒ **C** Tetrachloromethane

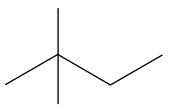
☒ **D** Cyclopentane

(Total for Question 16 = 1 mark)

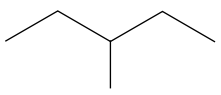
Use this space for any rough working. Anything you write in this space will gain no credit.

17 Which of these isomers has the highest boiling temperature?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for Question 17 = 1 mark)

18 Which of the following statements is **true**?

☒ **A** Calcium hydroxide is more soluble in water than magnesium hydroxide.

☒ **B** Chlorine is more electronegative than fluorine.

☒ **C** Iodine is a stronger oxidizing agent than bromine.

☒ **D** The first ionization energy of barium is greater than that of strontium.

(Total for Question 18 = 1 mark)

19 Iodine can react with sodium hydroxide solution to form $NaIO_3(aq)$, according to the equation below.

$$3I_2(aq) + 6NaOH(aq) \rightarrow 5NaI(aq) + NaIO_3(aq) + 3H_2O(l)$$

Which of the statements about the reaction is **false**?

☒ **A** The oxidation number of some iodine atoms goes up.

☒ **B** At high temperatures NaIO(aq) also forms.

☒ **C** Sodium ions are spectator ions.

☒ **D** The oxidation number of some iodine atoms goes down.

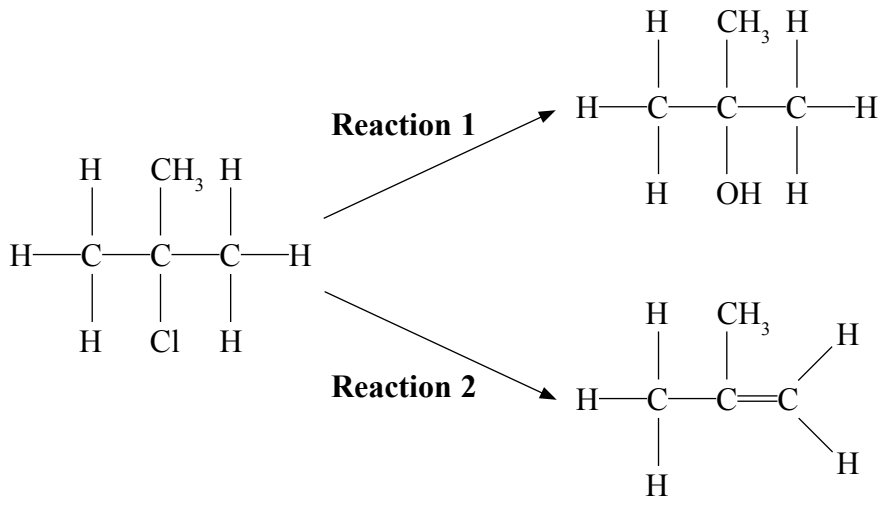
(Total for Question 19 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

20 When 2-chloro-2-methylpropane is heated in a mixture of water and ethanol at 65 °C, two types of reaction occur. A mixture of two organic products, 2-methylpropan-2-ol and 2-methylpropene, is formed.



(a) (i) Name the two reaction types that are taking place.

(2)

Reaction 1 .....

Reaction 2 .....

*(ii) Explain how the two products form, by describing the role of the water in each case.

(4)

Reaction 1 .....

.....

.....

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Reaction 2 .....

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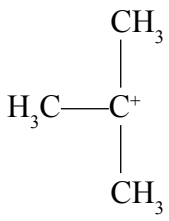
Turn over ▶

(b) A proposed mechanism for **Reaction 1** involved the formation of the carbocation,



(i) What type of bond breaking must have occurred during the carbocation formation?

(1)

(ii) Suggest why 1-chlorobutane reacts with water via a different mechanism.

(2)

(c) Another halogenoalkane, 2-chlorobutane, behaves in a similar way to 2-chloro-2-methylpropane but in **Reaction 2** can form three different alkenes. Suggest how **three** different alkenes can form and give their displayed formulae.

(4)

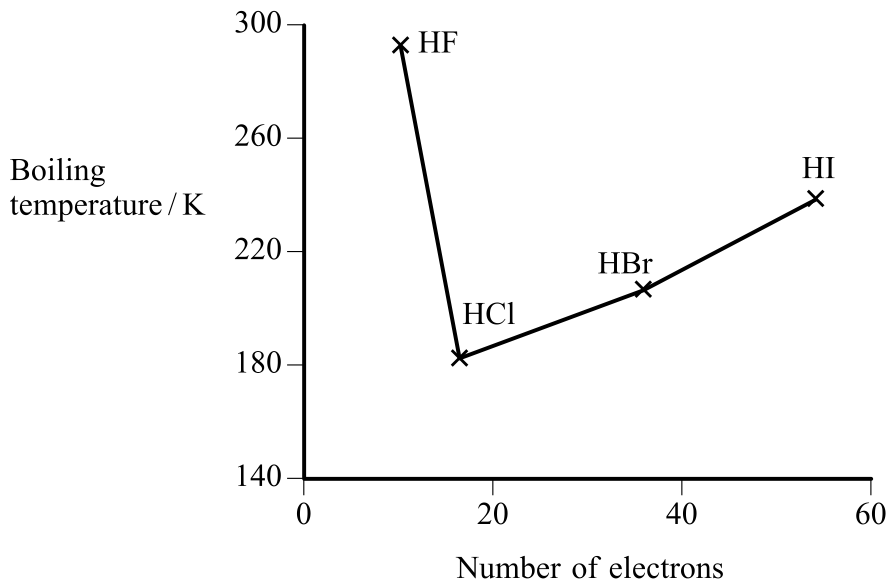
(d) Suggest why 2-fluoro-2-methylpropane would react more slowly than 2-chloro-2-methylpropane in **Reaction 1**.

What reagent could you use instead of water to increase the rate of this reaction involving 2-fluoro-2-methylpropane? Explain why the reagent would have this effect.

(3)

(Total for Question 20 = 16 marks)

21 The graph below shows the boiling temperatures of the hydrides of Group 7.



(a) (i) Identify the type of intermolecular force that gives rise to the unusually high boiling temperature of hydrogen fluoride.

(1)

(ii) State and explain whether the electronegativity of fluorine is greater than, similar to or less than, that of bromine.

Hence explain why hydrogen fluoride can form the type of intermolecular force named in (a)(i) but hydrogen bromide cannot.

(3)

(iii) Use the graph to predict what the boiling temperature of hydrogen fluoride would be without the presence of the type of intermolecular force named in (a)(i).

(1)

(b) Propanone, CH_3COCH_3, is a useful solvent for cleaning glassware in laboratories.

(i) Why is propanone able to dissolve a wide range of substances?

(1)

(ii) Propanone can be used to remove both water and octane from glassware.

For each of these substances, identify the strongest intermolecular force formed with propanone and the feature of the propanone molecule involved.

(2)

Water

Octane

(Total for Question 21 = 8 marks)

22 Calcium oxide, known as quicklime, is produced by the thermal decomposition of calcium carbonate, found naturally in limestone.

(a) (i) Explain what is meant by the term **thermal decomposition**.

(2)

(ii) Write an equation for the thermal decomposition of calcium carbonate, including state symbols.

(1)

(iii) Other Group 2 carbonates can also undergo thermal decomposition. Describe and explain the trend in thermal stability of carbonates down Group 2.

(3)

(b) 0.121 g of an impure sample of quicklime was dissolved in 50.0 cm^3 of hydrochloric acid, concentration 0.100 mol dm^{-3}. The excess hydrochloric acid was titrated with sodium hydroxide solution, concentration 0.100 mol dm^{-3}, and 18.0 cm^3 was needed to just neutralize the acid. The indicator used was methyl orange.

The equations for the reactions involved are shown below.

$$CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$$

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

(i) What colour would the indicator be at the end-point?

(1)

(ii) Calculate the number of moles of hydrochloric acid that reacted with the sodium hydroxide solution.

(1)

(iii) Calculate the number of moles of hydrochloric acid originally added to the quicklime. Use this answer and your answer to (b)(ii) to calculate the number of moles of quicklime that reacted with the hydrochloric acid.

(2)

(iv) Calculate the percentage purity of the sample of quicklime. Give your answer to **three** significant figures.

(2)

(c) (i) Describe how to carry out a flame test on the impure sample of quicklime to confirm that it contains calcium ions.

(3)

(ii) If the flame test gave a green colour, in addition to the expected brick red flame, which Group 2 metal is also likely to be present?

(1)

(Total for Question 22 = 16 marks)

TOTAL FOR SECTION B = 40 MARKS

SECTION C

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

23 As levels of fossil fuel resources are getting lower, society is increasingly looking at the use of biofuels as alternatives to coal, oil and gas. Biofuels are derived from plants and examples include bioethanol, biodiesel and *Miscanthus*, a plant more commonly known as elephant grass. These fuels have the advantage of being renewable and the plants take in carbon dioxide as they grow.

Bioethanol is produced from crops such as sugar cane or corn. The raw plant material is treated to produce a sugary solution which is then fermented to produce ethanol, water and carbon dioxide gas. The ethanol is removed by distillation. The resulting solution contains about 96 % ethanol. The remaining water has to be removed by absorption using a suitable drying agent so that the ethanol can burn efficiently. The bioethanol can then be burnt alone or mixed with petrol in vehicle engines.

Biodiesel is formed by the hydrolysis of vegetable oils using sodium hydroxide solution, followed by esterification with methanol and a sodium hydroxide catalyst. Biodiesel can then be used on its own in diesel-engined vehicles or mixed with diesel derived from crude oil. Plants which are used to produce the vegetable oils include rapeseed in the UK, soya bean in the USA and palm oil in Asia.

Miscanthus, or elephant grass, is a quick growing, high-yield plant that grows up to four metres in height. After harvesting, the grass is left to dry and then burnt in power stations designed to run on solid fuels such as coal. In the United Kingdom, farms that produce elephant grass are normally situated within 50 miles of such a power station.

In an experiment to simulate the production of bioethanol, a student produced a water/ethanol mixture by fermentation of sucrose solution using yeast. It was then proposed to separate the ethanol from water by carrying out a distillation on the mixture. The mixture would then be dried using a suitable drying agent.

(a) Draw a diagram to show the most significant intermolecular force between an ethanol molecule and a water molecule. Label the bond angle between the molecules and state its value.

(2)

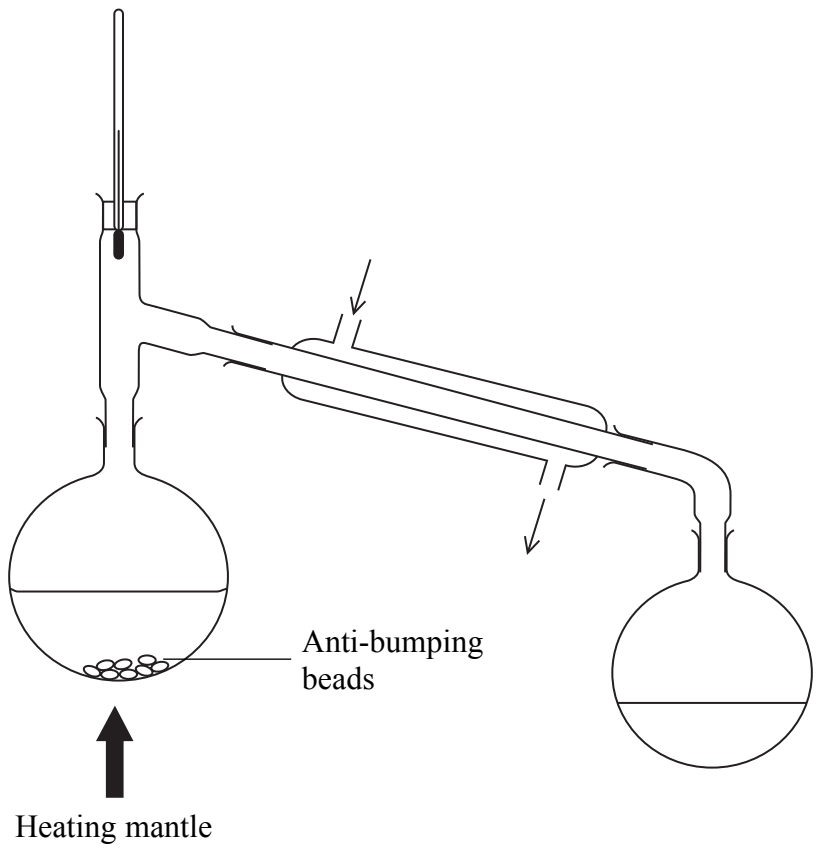
(b) The student proposed to set up the apparatus as shown below to carry out the distillation to try to separate the ethanol from water.

There are **three** errors with the set-up. Draw a circle around each error.

Describe what effect these errors would have if the student attempted to carry out the separation as shown.

[Clamps are not shown in the diagram but you can assume the apparatus is supported adequately.]

(6)



(c) If a balance accurate to two decimal places was used to record the mass of ethanol collected, what would be the percentage error due to the balance readings if the total mass of ethanol collected was 20.10 g?

(1)

(d) Suggest a suitable drying agent to absorb the water remaining with the ethanol after distillation. Describe how you would use it to produce a dry sample of ethanol.

(2)

(e) Describe a chemical test you could carry out to confirm the presence of the –OH group in ethanol. What result would you expect to see?

(2)

Test .....

.....

Result .....

(f) *(i) Explain what is meant by a **carbon neutral fuel**.

(2)

*(ii) Suggest TWO reasons why these biofuels may **not** be carbon neutral and describe TWO effects that large scale production of biofuels may have on society. Which of the three biofuels do you think is the most sustainable? Justify your choice.

(5)

(Total for Question 23 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 80 MARKS

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Section A

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

1 A reaction mechanism is a series of steps by which an overall reaction may proceed. The reactions occurring in these steps may be deduced from a study of reaction rates. Experimental evidence about initial rates leads to a rate equation. A mechanism is then proposed which agrees with this rate equation.

Ethanal dimerises in dilute alkaline solution to form compound **X** as shown in the following equation.

$$2CH_3CHO \longrightarrow \underset{\mathbf{X}}{CH_3CH(OH)CH_2CHO}$$

A chemist studied the kinetics of the reaction at 298 K and then proposed the following rate equation.

$$\text{Rate} = k[CH_3CHO][OH^-]$$

1 (a) Give the IUPAC name of compound **X**.

.....

(1 mark)

1 (b) The initial rate of the reaction at 298 K was found to be 2.2×10^{-3} mol dm^{-3} s^{-1} when the initial concentration of ethanal was 0.10 mol dm^{-3} and the initial concentration of sodium hydroxide was 0.020 mol dm^{-3}.
Calculate a value for the rate constant at this temperature and give its units.

Calculation .....

.....

.....

Units .....

(3 marks)

1 (c) The sample of **X** produced consists of a racemic mixture (racemate). Explain how this racemic mixture is formed.

.....

.....

.....

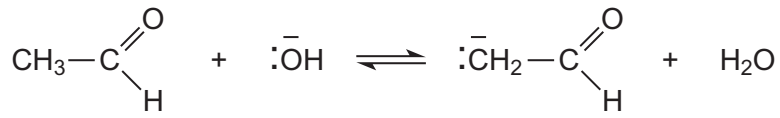
(2 marks)

Question 1 continues on the next page

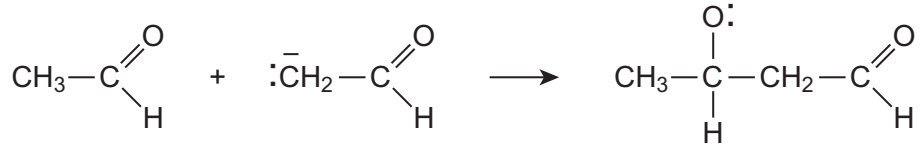
Do not write outside the box

1 (d) A three-step mechanism has been proposed for this reaction according to the following equations.

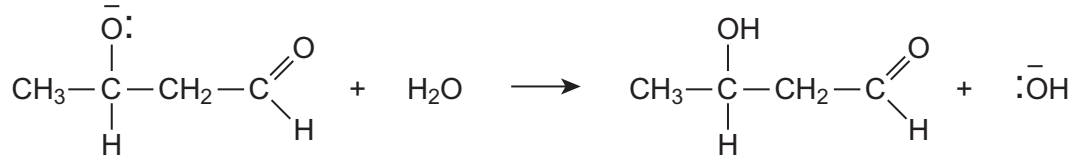
Step **1**



Step **2**



Step **3**



1 (d) (i) Using the rate equation, predict which of the three steps is the rate-determining step. Explain your answer.

Rate-determining step .....

Explanation .....

.....

(2 marks)

1 (d) (ii) Deduce the role of ethanal in Step **1**.

.....

(1 mark)

Do not write outside the box

1 (d) (iii) Use your knowledge of reaction mechanisms to deduce the type of reaction occurring in Step **2**.

.....

(1 mark)

1 (d) (iv) In the space below draw out the mechanism of Step **2** showing the relevant curly arrows.

(2 marks)

1 (e) In a similar three-step mechanism, one molecule of **X** reacts further with one molecule of ethanal. The product is a trimer containing six carbon atoms.

Deduce the structure of this trimer.

(1 mark)

13

2 The reaction of methane with steam produces hydrogen for use in many industrial processes. Under certain conditions the following reaction occurs.

$$CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g) \qquad \Delta H^{\ominus} = +165\ kJ\,mol^{-1}$$

2 (a) Initially, 1.0 mol of methane and 2.0 mol of steam were placed in a flask and heated with a catalyst until equilibrium was established. The equilibrium mixture contained 0.25 mol of carbon dioxide.

2 (a) (i) Calculate the amounts, in moles, of methane, steam and hydrogen in the equilibrium mixture.

Moles of methane .....

Moles of steam .....

Moles of hydrogen .....

(3 marks)

2 (a) (ii) The volume of the flask was 5.0 dm^3. Calculate the concentration, in mol dm^{-3}, of methane in the equilibrium mixture.

.....

.....

(1 mark)

2 (b) The table below shows the equilibrium concentration of each gas in a different equilibrium mixture in the same flask and at temperature *T*.

gas	$CH_4(g)$	$H_2O(g)$	$CO_2(g)$	$H_2(g)$
concentration / mol dm^{-3}	0.10	0.48	0.15	0.25

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

.....

.....

.....

(1 mark)

Do not write outside the box

2 (b) (ii) Calculate a value for K_c at temperature T and give its units.

Calculation .....

.....

.....

.....

Units of K_c .....

(3 marks)

2 (c) The mixture in part (b) was placed in a flask of volume greater than 5.0 dm^3 and allowed to reach equilibrium at temperature T.
State and explain the effect on the amount of hydrogen.

Effect on amount of hydrogen .....

Explanation .....

.....

.....

.....

(3 marks)

2 (d) Explain why the amount of hydrogen decreases when the mixture in part **(b)** reaches equilibrium at a lower temperature.

.....

.....

.....

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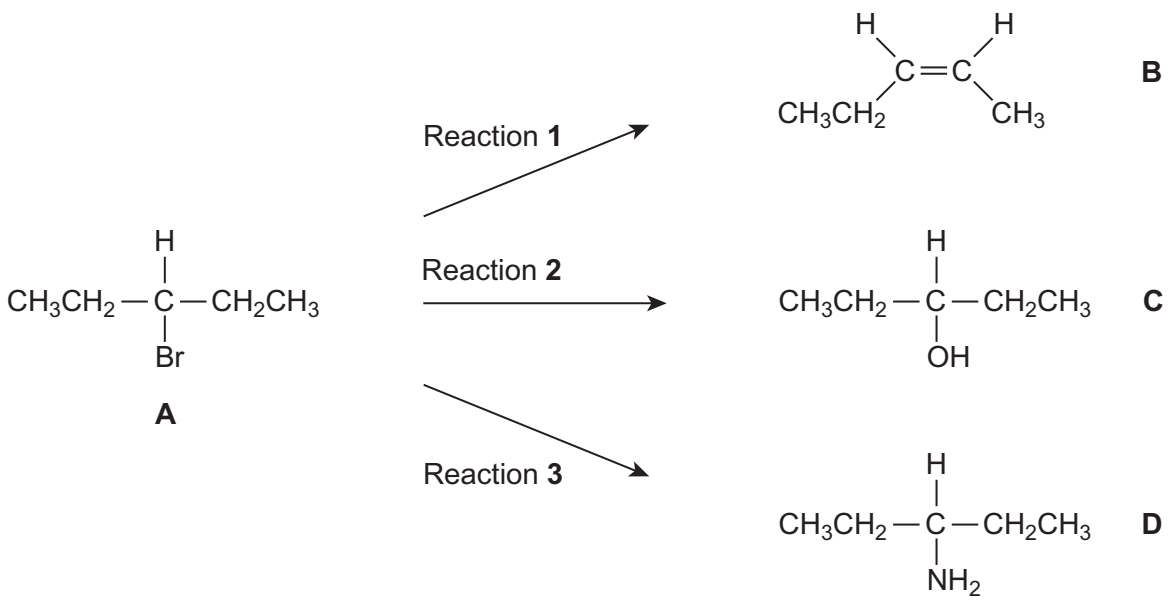
(2 marks)

13

Turn over for the next question

3 Haloalkanes are useful compounds in synthesis.
Consider the three reactions of the haloalkane **A** shown below.



3 (a) (i) Draw a **branched-chain** isomer of **A** that exists as optical isomers.

(1 mark)

3 (a) (ii) Name the type of mechanism in Reaction **1**.

.....

(1 mark)

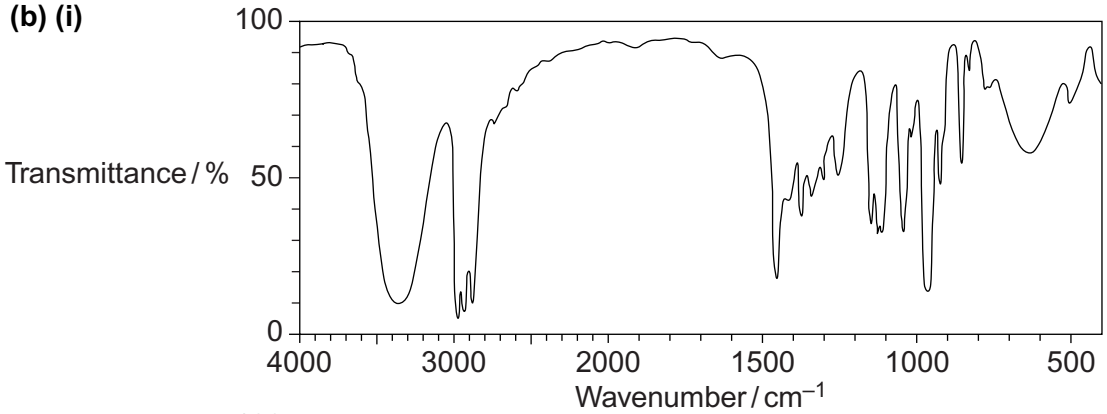
3 (a) (iii) Give the full IUPAC name of compound **B**.

.....

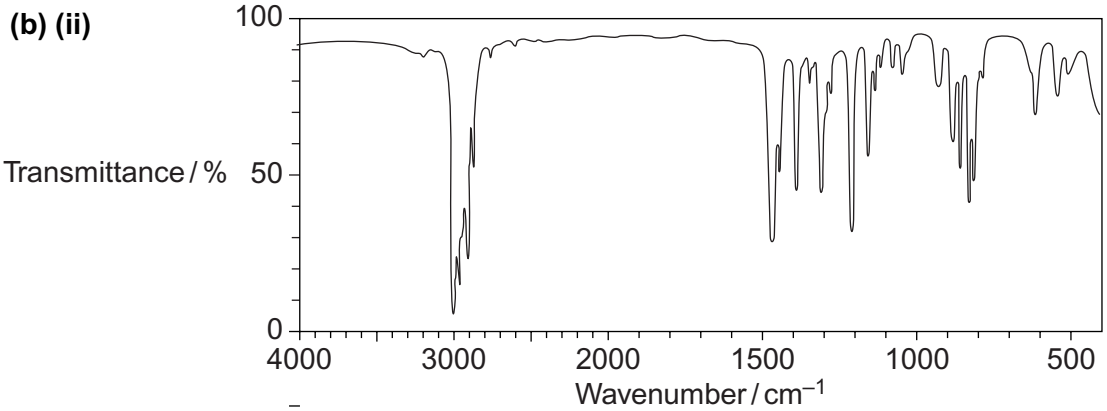
(1 mark)

3 (b) The infrared spectra shown below are those of the four compounds, **A**, **B**, **C** and **D**. Using **Table 1** on the Data Sheet, write the correct letter in the box next to each spectrum.

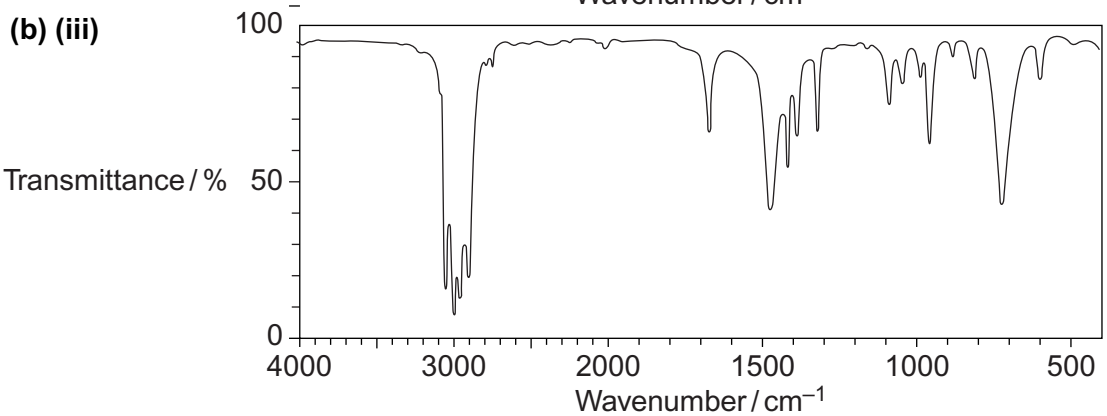
3 (b) (i)



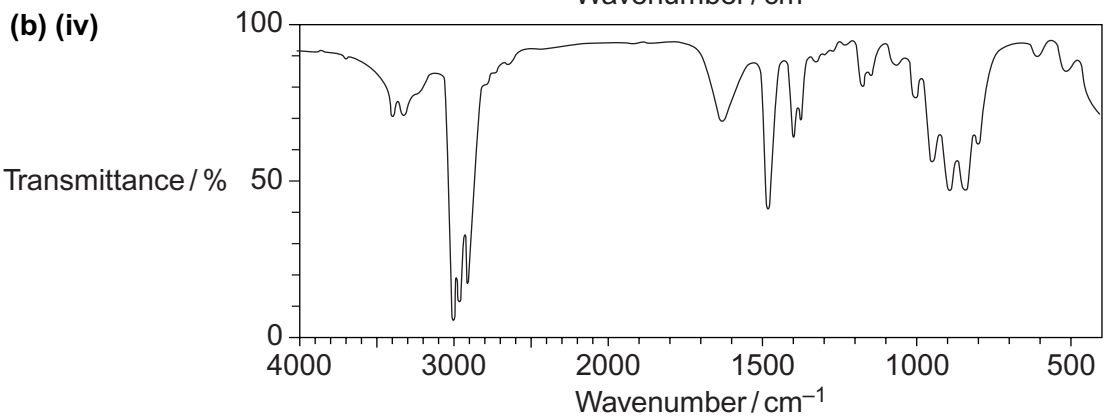
3 (b) (ii)



3 (b) (iii)



3 (b) (iv)



(4 marks)

Question 3 continues on the next page

Do not write outside the box

3 (c) Draw the repeating unit of the polymer formed by **B** and name the type of polymerisation involved.

Repeating unit

Type of polymerisation .....

(2 marks)

3 (d) (i) Outline a mechanism for Reaction **3**.

(4 marks)

3 (d) (ii) State the conditions used in Reaction **3** to form the maximum amount of the primary amine, **D**.

.....

(1 mark)

Do not write outside the box

3 (d) (iii) Draw the structure of the secondary amine formed as a by-product in Reaction **3**.

(1 mark)

3 (e) **D** is a primary amine which has three peaks in its ^{13}C n.m.r. spectrum.

3 (e) (i) An isomer of **D** is also a primary amine and also has three peaks in its ^{13}C n.m.r. spectrum. Draw the structure of this isomer of **D**.

(1 mark)

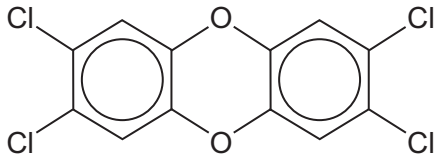
3 (e) (ii) Another isomer of **D** is a tertiary amine. Its ^{1}H n.m.r. spectrum has three peaks. One of the peaks is a doublet. Draw the structure of this isomer of **D**.

(1 mark)

17

Do not write outside the box

4 In 2008, some food products containing pork were withdrawn from sale because tests showed that they contained amounts of compounds called dioxins many times greater than the recommended safe levels.
Dioxins can be formed during the combustion of chlorine-containing compounds in waste incinerators. Dioxins are very unreactive compounds and can therefore remain in the environment and enter the food chain.
Many dioxins are polychlorinated compounds such as tetrachlorodibenzodioxin (TCDD) shown below.



In a study of the properties of dioxins, TCDD and other similar compounds were synthesised. The mixture of chlorinated compounds was then separated before each compound was identified by mass spectrometry.

4 (a) Fractional distillation is **not** a suitable method to separate the mixture of chlorinated compounds before identification by mass spectrometry.
Suggest how the mixture could be separated.

.....

(1 mark)

4 (b) The molecular formula of TCDD is $C_{12}H_4O_2Cl_4$
Chlorine exists as two isotopes ^{35}Cl (75%) and ^{37}Cl (25%).
Deduce the number of molecular ion peaks in the mass spectrum of TCDD and calculate the *m*/*z* value of the most abundant molecular ion peak.

Number of molecular ion peaks .....

.....

m/*z* value of the most abundant molecular ion peak .....

.....

(2 marks)

4 (c) Suggest **one** operating condition in an incinerator that would minimise the formation of dioxins.

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(1 mark)

Do not write outside the box

4 (d) TCDD can also be analysed using ^{13}C n.m.r.

4 (d) (i) Give the formula of the compound used as the standard when recording a ^{13}C spectrum.

.....

(1 mark)

4 (d) (ii) Deduce the number of peaks in the ^{13}C n.m.r. spectrum of TCDD.

.....

(1 mark)

6

Turn over for the next question

Do not write outside the box

5 In this question, give all values of pH to two decimal places.

Calculating the pH of aqueous solutions can involve the use of equilibrium constants such as K_w and K_a

K_w is the ionic product of water. The value of K_w is $5.48 \times 10^{-14}\,mol^2\,dm^{-6}$ at 50 °C.

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

.....

(1 mark)

5 (a) (ii) Write an expression for K_w

.....

(1 mark)

5 (b) (i) Calculate the pH of pure water at 50 °C.

.....

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(2 marks)

5 (b) (ii) Suggest why this pure water is **not** acidic.

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(1 mark)

5 (b) (iii) Calculate the pH of $0.140\,mol\,dm^{-3}$ aqueous sodium hydroxide at 50 °C.

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(3 marks)

5 (c) Calculate the pH of the solution formed when 25.0 cm^3 of 0.150 mol dm^{-3} aqueous sulfuric acid are added to 30.0 cm^3 of 0.200 mol dm^{-3} aqueous potassium hydroxide at 25 °C. Assume that the sulfuric acid is fully dissociated.

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(6 marks)

5 (d) (i) Write an expression for the acid dissociation constant, K_a, for ethanoic acid.

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(1 mark)

5 (d) (ii) The value of K_a for ethanoic acid is 1.74×10^{-5} mol dm^{-3} at 25 °C.
Calculate the pH of a 0.136 mol dm^{-3} aqueous solution of ethanoic acid at this temperature.

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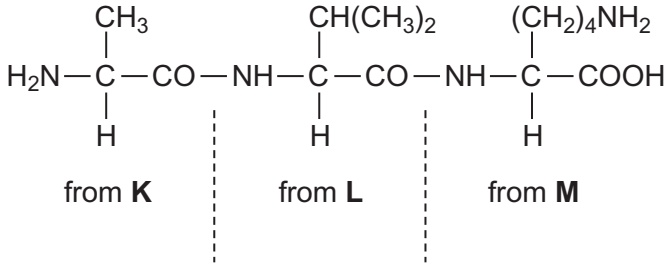
(3 marks)

18

Do not write outside the box

6 (a) Consider the tripeptide shown below that is formed from three amino acids, **K**, **L** and **M**.



6 (a) (i) Name the process by which the tripeptide is split into three amino acids.

.....

(1 mark)

6 (a) (ii) Give the IUPAC name for the amino acid **K**.

.....

(1 mark)

6 (a) (iii) Draw the structure of the zwitterion of amino acid **L**.

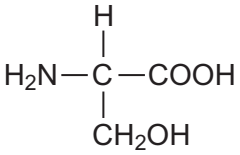
(1 mark)

6 (a) (iv) Draw the structure of the species formed by amino acid **M** at low pH.

(1 mark)

Do not write outside the box

6 (b) Consider the amino acid serine.



6 (b) (i) Draw the structure of the product formed when serine reacts with an excess of CH_3Br

(1 mark)

6 (b) (ii) Draw the structure of the dipeptide formed by two molecules of serine.

(1 mark)

6

Turn over for the next question

Section B

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

7 Esters have many important commercial uses such as solvents and artificial flavourings in foods.

Esters can be prepared in several ways including the reactions of alcohols with carboxylic acids, acid anhydrides, acyl chlorides and other esters.

7 (a) Ethyl butanoate is used as a pineapple flavouring in sweets and cakes.

Write an equation for the preparation of ethyl butanoate from an acid and an alcohol.

Give a catalyst used for the reaction.

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(4 marks)

7 (b) Butyl ethanoate is used as a solvent in the pharmaceutical industry.

Write an equation for the preparation of butyl ethanoate from an acid anhydride and an alcohol.

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(3 marks)

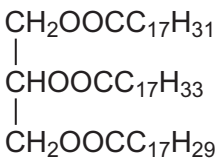
7 (c) Name and outline a mechanism for the reaction of CH_3COCl with CH_3OH to form an ester.

(5 marks)

Question 7 continues on the next page

Do not write outside the box

7 (d) The ester shown below occurs in vegetable oils. Write an equation to show the formation of biodiesel from this ester.



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(3 marks)

Do not write outside the box

7 (e) Draw the repeating unit of the polyester Terylene that is made from benzene-1,4-dicarboxylic acid and ethane-1,2-diol.

Although Terylene is biodegradeable, it is preferable to recycle objects made from Terylene.

Give **one** advantage and **one** disadvantage of recycling objects made from Terylene.

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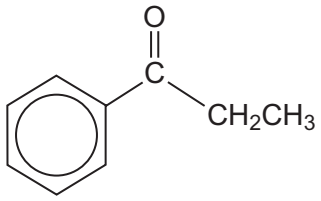
(4 marks)

19

Turn over for the next question

Do not write outside the box

8 Consider compound **P** shown below that is formed by the reaction of benzene with an electrophile.



P

8 (a) Give the **two** substances that react together to form the electrophile and write an equation to show the formation of this electrophile.

.....

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(3 marks)

8 (b) Outline a mechanism for the reaction of this electrophile with benzene to form **P**.

(3 marks)

Do not write outside the box

8 (c) Compound **Q** is an isomer of **P** that shows optical isomerism. **Q** forms a silver mirror when added to a suitable reagent.

Identify this reagent and suggest a structure for **Q**.

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.....

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(2 marks)

8

END OF QUESTIONS