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SECTION A

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

1 In 1913 Niels Bohr proposed a model of the atom with a central nucleus, made up of protons and neutrons, around which electrons moved in orbits. After further research, the model was refined when the existence of energy levels and sub-levels was recognised.

1 (a) Complete the following table for the particles in the nucleus.

Particle	Relative charge	Relative mass
proton		
neutron		

(2 marks)

1 (b) State the block in the Periodic Table to which the element tungsten, W, belongs.

.....

(1 mark)

1 (c) Isotopes of tungsten include ^{182}W and ^{186}W

1 (c) (i) Deduce the number of protons in ^{182}W

.....

(1 mark)

1 (c) (ii) Deduce the number of neutrons in ^{186}W

.....

(1 mark)

1 (d) In order to detect the isotopes of tungsten using a mass spectrometer, a sample containing the isotopes must be vaporised and then ionised.

1 (d) (i) Give **two** reasons why the sample must be ionised.

1 .....

2 .....

(2 marks)

1 (d) (ii) State what can be adjusted in the mass spectrometer to enable ions formed by the different isotopes to be directed onto the detector.

.....

(1 mark)

1 (e) State and explain the difference, if any, between the chemical properties of the isotopes ^{182}W and ^{186}W

Difference .....

Explanation .....

.....

(2 marks)

1 (f) The table below gives the relative abundance of each isotope in the mass spectrum of a sample of tungsten.

m/z	182	183	184	186
Relative abundance / %	26.4	14.3	30.7	28.6

Use the data above to calculate a value for the relative atomic mass of this sample of tungsten. Give your answer to 2 decimal places.

.....

.....

.....

(2 marks)

12

2 The table below shows the electronegativity values of some elements.

	H	C	N	O
Electronegativity	2.1	2.5	3.0	3.5

2 (a) State the meaning of the term *electronegativity*.

.....

.....

.....

(2 marks)

2 (b) State the strongest type of intermolecular force in the following compounds.

Methane (CH_4) .....

Ammonia (NH_3) .....

(2 marks)

2 (c) Use the values in the table to explain how the strongest type of intermolecular force arises between two molecules of ammonia.

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(3 marks)

2 (d) Phosphorus is in the same group of the Periodic Table as nitrogen.
A molecule of PH_3 reacts with an H^+ ion to form a PH_4^+ ion.
Name the type of bond formed when PH_3 reacts with H^+ and explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

(3 marks)

2 (e) Arsenic is in the same group as nitrogen. It forms the compound AsH_3
Draw the shape of an AsH_3 molecule, including any lone pairs of electrons. Name the shape made by its atoms.

Shape

Name of shape .....

(2 marks)

2 (f) The boiling point of AsH_3 is $-62.5\,°C$ and the boiling point of NH_3 is $-33.0\,°C$.
Suggest why the boiling point of AsH_3 is lower than that of NH_3

.....

.....

.....

(1 mark)

2 (g) Balance the following equation which shows how AsH_3 can be made.

..... $AsCl_3$ + ... $NaBH_4$ $\longrightarrow$ ..... AsH_3 + ... NaCl + ... BCl_3

(1 mark)

14

Turn over for the next question

3 Titanium(IV) oxide (TiO_2, M_r = 79.9) is used as a white pigment in some paints. The pigment can be made as shown in the following equation.

$$TiCl_4(l) + 2H_2O(l) \longrightarrow TiO_2(s) + 4HCl(aq)$$

3 (a) (i) Calculate the percentage atom economy for the formation of TiO_2

.....

.....

.....

(2 marks)

3 (a) (ii) In view of the low atom economy of this reaction, suggest how a company can maximise its profits without changing the reaction conditions or the production costs.

.....

.....

(1 mark)

3 (b) In an experiment 165 g of $TiCl_4$ were added to an excess of water.

3 (b) (i) Calculate the amount, in moles, of $TiCl_4$ in 165 g.

.....

.....

.....

(2 marks)

3 (b) (ii) Calculate the maximum amount, in moles, of TiO_2 which can be formed in this experiment.

.....

.....

(1 mark)

3 (b) (iii) Calculate the maximum mass of TiO_2 formed in this experiment.

.....

.....

(1 mark)

3 (b) (iv) In this experiment only 63.0 g of TiO_2 were produced. Calculate the percentage yield of TiO_2

.....

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(1 mark)

8

Turn over for the next question

4 This question is about the elements in Period 3 from Na to P

4 (a) (i) Explain the meaning of the term *first ionisation energy*.

.....

.....

.....

(2 marks)

4 (a) (ii) State and explain the general trend in first ionisation energies for the elements Na to P

Trend .....

Explanation .....

.....

.....

(3 marks)

4 (a) (iii) State which one of the elements from Na to P deviates from this general trend and explain why this occurs.

Element .....

Explanation .....

.....

.....

(3 marks)

4 (b) State which one of the elements from Na to P has the highest melting point and explain your answer.

Element .....

Explanation .....

.....

.....

(3 marks)

11

5 A metal carbonate MCO_3 reacts with hydrochloric acid as shown in the following equation.

$$MCO_3 + 2HCl \longrightarrow MCl_2 + H_2O + CO_2$$

A 0.548 g sample of MCO_3 reacted completely with 30.7 cm^3 of 0.424 mol dm^{-3} hydrochloric acid.

5 (a) (i) Calculate the amount, in moles, of HCl which reacted with 0.548 g MCO_3

.....

.....

(1 mark)

5 (a) (ii) Calculate the amount, in moles, of MCO_3 in 0.548 g.

.....

.....

(1 mark)

5 (a) (iii) Calculate the relative formula mass of MCO_3

.....

.....

(1 mark)

5 (b) Use your answer from part (a) (iii) to deduce the relative atomic mass of metal M and suggest its identity.
(If you have been unable to calculate a value for the relative formula mass of MCO_3 you should assume it to be 147.6 but this is not the correct answer.)

Relative atomic mass .....

.....

.....

Identity of M .....

(2 marks)

5

SECTION B

Answer Question 6 in the spaces provided on pages 10 to 15.

6 Petrol contains saturated hydrocarbons. Some of the molecules in petrol have the molecular formula C_8H_{18} and are referred to as octanes. These octanes can be obtained from crude oil by fractional distillation and by cracking suitable heavier fractions.

Petrol burns completely in a plentiful supply of air but can undergo incomplete combustion in a car engine.

6 (a) State the meaning of both the words *saturated* and *hydrocarbon* as applied to the term *saturated hydrocarbon*.

Name the homologous series to which C_8H_{18} belongs.

.....

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(3 marks)

6 (b) Outline the essential features of the fractional distillation of crude oil that enable the crude oil to be separated into fractions.

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(4 marks)

Question 6 continues on the next page

6 (c) C_8H_{18} is obtained by the catalytic cracking of suitable heavy fractions.
State what is meant by the term *cracking* and name the catalyst used in catalytic cracking.

Write an equation to show how one molecule of $C_{14}H_{30}$ is cracked to form one molecule of C_8H_{18} and one molecule of another hydrocarbon.

Explain why oil companies need to crack 'suitable heavy fractions'.

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(4 marks)

6 (d) Write an equation for the incomplete combustion of C_8H_{18} to form carbon monoxide and water only.

A catalytic converter is used to remove carbon monoxide from the exhaust gases in a car. Identify a catalyst used in the catalytic converter.

Write an equation to show how carbon monoxide is removed in a catalytic converter.

State why the water produced in the exhaust gases may contribute to global warming.

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(4 marks)

Question 6 continues on the next page

6 (e) When some petrol was accidentally contaminated in 2007, the sensors in the affected cars caused a decrease in the supply of petrol to the engine.

Suggest the effect that the contaminated fuel would have on the performance of the cars.

State how the oil company might have recognised the problem before the petrol was sold.

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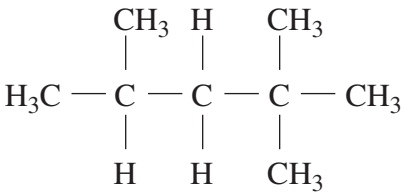
.....

(2 marks)

6 (f) The molecular formula C_8H_{18} represents several structural isomers.

State what is meant by the term *structural isomers*.

Name the following structural isomer of C_8H_{18}



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(3 marks)

20

END OF QUESTIONS

Practice 2

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 Which equation represents the reaction for which the enthalpy change is the lattice energy of sodium fluoride, NaF?

☒ **A** $Na(s) + \frac{1}{2}F_2(g) \rightarrow NaF(s)$

☒ **B** $Na(g) + F(g) \rightarrow NaF(s)$

☒ **C** $Na^+(g) + F^-(g) \rightarrow NaF(s)$

☒ **D** $Na(g) + \frac{1}{2}F_2(g) \rightarrow NaF(s)$

(Total for Question 1 = 1 mark)

2 **Theoretical** lattice energies can be calculated from electrostatic theory. Which of the following affects the magnitude of the theoretical lattice energy of an alkali metal halide, M^+X^-?

☒ **A** The first electron affinity of X.

☒ **B** The first ionization energy of M.

☒ **C** The enthalpy of atomization of M.

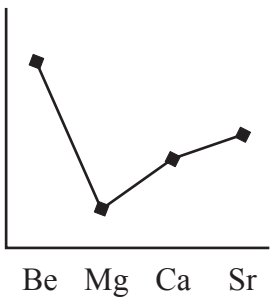
☒ **D** The radius of the X^- ion.

(Total for Question 2 = 1 mark)

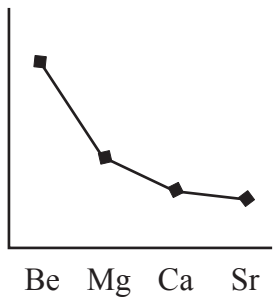
Use this space for any rough working. Anything you write in this space will gain no credit.

3 Which of the following graphs shows the variation in the ionic radius of the Group 2 elements?

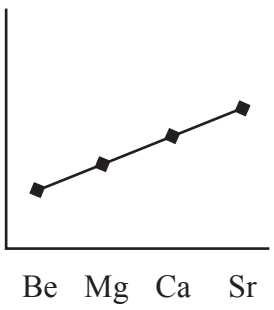
☒ **A**



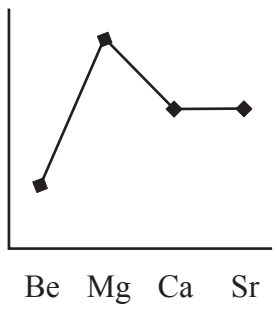
☒ **B**



☒ **C**



☒ **D**



(Total for Question 3 = 1 mark)

4 The first five ionization energies of an element, **Z**, are:

790, 1600, 3200, 4400, 16100 kJ mol^{-1}

In which group of the Periodic Table is **Z** found?

☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 5

(Total for Question 4 = 1 mark)

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

5 The standard enthalpy changes of combustion of carbon, hydrogen and methane are shown in the table below.

Substance	Standard enthalpy change of combustion / kJ mol^{-1}
carbon, C(s)	–394
hydrogen, $H_2(g)$	–286
methane, $CH_4(g)$	–891

Which one of the following expressions gives the correct value for the standard enthalpy change of formation of methane in kJ mol^{-1}?

$$C(s) + 2H_2(g) \rightarrow CH_4(g)$$

☒ **A** 394 + (2 × 286) – 891

☒ **B** –394 – (2 × 286) + 891

☒ **C** 394 + 286 – 891

☒ **D** –394 – 286 + 891

(Total for Question 5 = 1 mark)

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

6 This question is about some standard enthalpy changes, $\Delta H^{\ominus}$

A enthalpy of reaction

B enthalpy of combustion

C mean bond enthalpy

D bond enthalpy

(a) Which enthalpy change is represented by **p**?

$CH_4(g) \rightarrow CH_3(g) + H(g)$ $\Delta H^{\ominus} = p$

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which enthalpy change is represented by **q**?

$CH_4(g) \rightarrow C(g) + 4H(g)$ $\Delta H^{\ominus} = 4q$

(1)

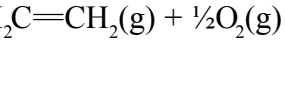
☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which enthalpy change is represented by **r**?

$H_2C{=}CH_2(g) + \frac{1}{2}O_2(g) \rightarrow$  $\Delta H^{\ominus} = r$

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 6 = 3 marks)

Turn over ▶

7 Given the following data:

$\Delta H_f^{\ominus}[FeO(s)] = -270\ kJ\ mol^{-1}$

$\Delta H_f^{\ominus}[Fe_2O_3(s)] = -820\ kJ\ mol^{-1}$

select the expression which gives the enthalpy change, in kJ mol^{-1}, for the reaction:

$$2FeO(s) + \tfrac{1}{2}O_2(g) \rightarrow Fe_2O_3(s)$$

☒ **A** $(-820 \times \frac{1}{2}) + 270 = -140$

☒ **B** $(+820 \times \frac{1}{2}) - 270 = +140$

☒ **C** $-820 + (270 \times 2) = -280$

☒ **D** $+820 - (270 \times 2) = +280$

(Total for Question 7 = 1 mark)

8 An organic compound contains 38.4 % carbon, 4.80 % hydrogen and 56.8 % chlorine by mass. What is the empirical formula of the compound?

☒ **A** C_2H_3Cl

☒ **B** CH_3Cl

☒ **C** C_2H_5Cl

☒ **D** $C_3H_5Cl_3$

(Total for Question 8 = 1 mark)

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

9 Which of the following contains the greatest number of hydrogen atoms?

☒ **A** 2 moles of water, H_2O

☒ **B** 1.5 moles of ammonia, NH_3

☒ **C** 1 mole of hydrogen gas, H_2

☒ **D** 0.5 moles of methane, CH_4

(Total for Question 9 = 1 mark)

10 Magnesium oxide reacts with dilute hydrochloric acid according to the following equation.

$$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$$

How many **moles** of magnesium oxide, MgO, are required to neutralize 20 cm^3 of 0.50 mol dm^{-3} hydrochloric acid, HCl?

☒ **A** 0.0010

☒ **B** 0.0050

☒ **C** 0.010

☒ **D** 0.020

(Total for Question 10 = 1 mark)

11 Hydrogen and oxygen react according to the following equation.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

If all volumes are measured at 110 °C and one atmosphere pressure, the volume of steam produced after 50 cm^3 of hydrogen react completely with 25 cm^3 of oxygen is

☒ **A** 25 cm^3

☒ **B** 50 cm^3

☒ **C** 75 cm^3

☒ **D** 100 cm^3

(Total for Question 11 = 1 mark)

12 Hydrogen peroxide decomposes on heating as follows:

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

What mass of hydrogen peroxide is required to give 16 g of oxygen gas?

☒ **A** 8.5 g

☒ **B** 17 g

☒ **C** 34 g

☒ **D** 68 g

(Total for Question 12 = 1 mark)

13 The equation for the dehydration of cyclohexanol, $C_6H_{11}OH$, to cyclohexene, C_6H_{10} is:

$$C_6H_{11}OH \rightarrow C_6H_{10} + H_2O$$

50.0 g of cyclohexanol produced 32.8 g of cyclohexene.

[Molar masses / g mol^{-1} : cyclohexanol = 100; cyclohexene = 82]

Calculate the percentage yield of cyclohexene.

☒ **A** 32.8 %

☒ **B** 40.0 %

☒ **C** 65.6 %

☒ **D** 80.0 %

(Total for Question 13 = 1 mark)

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

14 How many isomers are there of C_5H_{12}?

☒ **A** Two

☒ **B** Three

☒ **C** Four

☒ **D** Five

(Total for Question 14 = 1 mark)

15 In a molecule of ethene, C_2H_4, how many π (pi) bonds are present?

☒ **A** One

☒ **B** Two

☒ **C** Three

☒ **D** Four

(Total for Question 15 = 1 mark)

16 The mechanism of the reaction represented by the equation

$$C_2H_4 + Br_2 \rightarrow CH_2BrCH_2Br$$

is an example of

☒ **A** Free radical substitution

☒ **B** Free radical addition

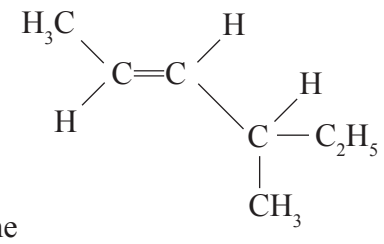
☒ **C** Electrophilic substitution

☒ **D** Electrophilic addition

(Total for Question 16 = 1 mark)

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

17 What is the systematic name for the following compound?



- ☒ **A** *Z*-4-methylhex-2-ene
- ☒ **B** *E*-2-ethylpent-3-ene
- ☒ **C** *Z*-4-ethylpent-2-ene
- ☒ **D** *E*-4-methylhex-2-ene

(Total for Question 17 = 1 mark)

18 Propene reacts with hydrogen chloride gas to give mainly

- ☒ **A** 1-chloropropane ($CH_3CH_2CH_2Cl$)
- ☒ **B** 2-chloropropane ($CH_3CHClCH_3$)
- ☒ **C** 3-chloroprop-1-ene ($CH_2{=}CHCH_2Cl$)
- ☒ **D** 1,2-dichloropropane ($CH_3CHClCH_2Cl$)

(Total for Question 18 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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

SECTION B

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

19 (a) (i) Complete the electronic configuration of the magnesium atom.

(1)

$1s^2$ .....

(ii) Complete the electronic configuration of the chlorine atom.

(1)

$1s^2$ .....

(b) (i) Write the equation, including state symbols, for the reaction of magnesium with chlorine.

(2)

(ii) Name the type of bonding present in magnesium chloride.

(1)

.....

(iii) Draw a diagram (using dots or crosses) to show the bonding in magnesium chloride. Include **ALL** the electrons in each species and the charges present.

(3)

(c) State the type of bonding that exists in solid magnesium.

(1)

Type .....

*(d) Explain fully why the melting temperature of magnesium is higher than that of sodium.

(3)

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(Total for Question 19 = 12 marks)

20 (a) A gaseous sample of an element can be analysed using a mass spectrometer.

(i) Describe briefly how positive ions are formed from gaseous atoms in a mass spectrometer.

(2)

(ii) What is used to accelerate the positive ions in a mass spectrometer?

(1)

(iii) What is used to deflect the positive ions in a mass spectrometer?

(1)

(b) The following data were obtained from the mass spectrum of a sample of chromium.

Mass/charge ratio	% abundance
50.0	4.3
52.0	83.8
53.0	9.5
54.0	2.4

Calculate the relative atomic mass of chromium in this sample. Give your answer to **three** significant figures.

(2)

(c) Explain why the four isotopes of chromium behave identically in chemical reactions.

(1)

(d) In which block of the Periodic Table is chromium found?

(1)

(Total for Question 20 = 8 marks)

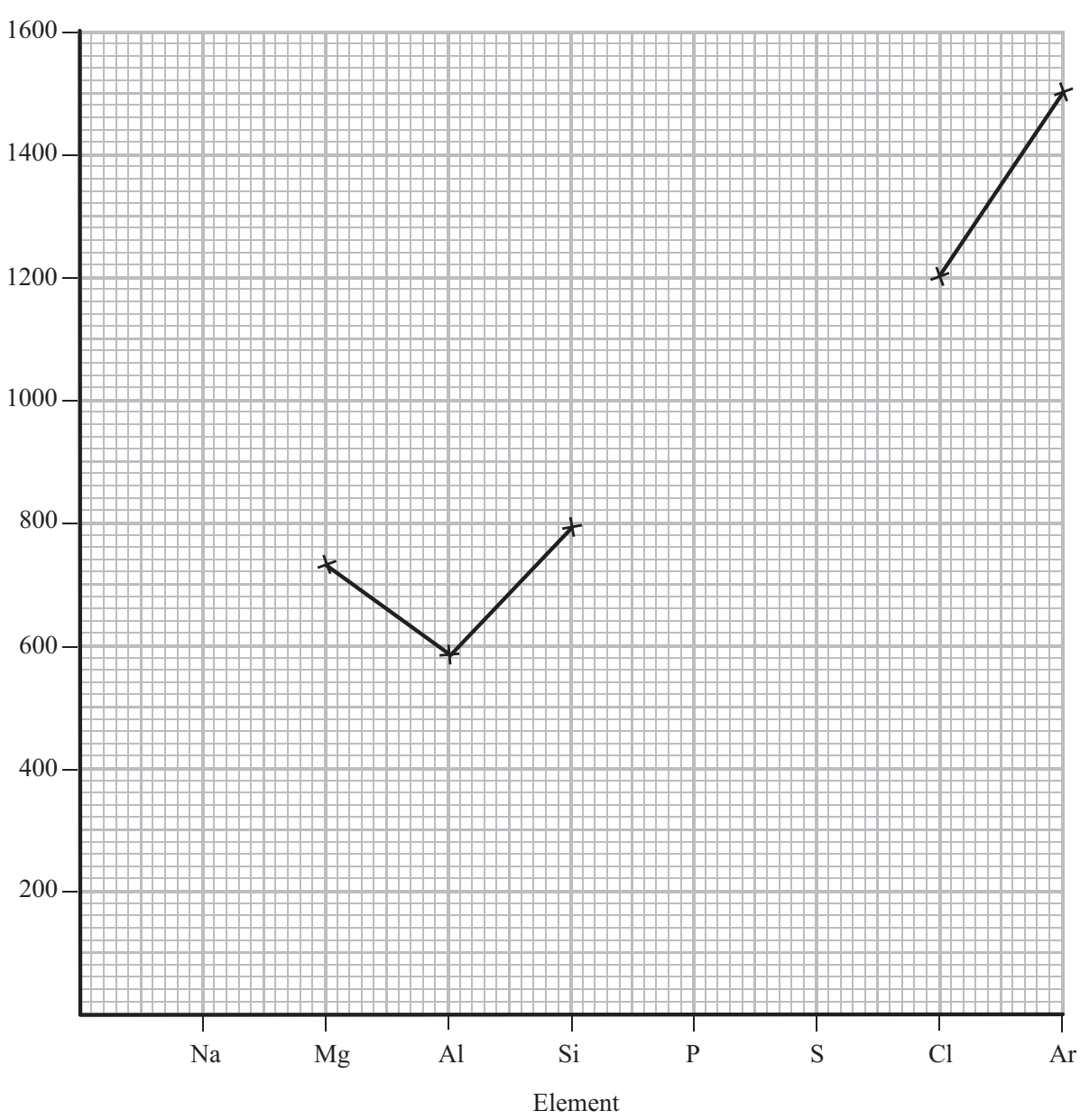
21 (a) Define the term **first ionization energy**.

(3)

(b) Write an equation, with state symbols, to illustrate the process occurring when the **second** ionization energy of sodium is measured.

(2)

(c) The graph below shows the variation in the **first** ionization energies of some of the elements in Period 3.



(i) On the graph, use crosses to show the approximate values of the first ionization energies for the elements Na, P and S.

Join the crosses to complete your graph.

(3)

Turn over ▶

*(ii) Explain why the first ionization energies generally increase across the period sodium to argon (Na to Ar).

(3)

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*(iii) Explain why the first ionization energy of aluminium is less than that of magnesium.

(2)

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(d) Place the following species

S^+ S S^-

in order of increasing first ionization energy, starting with the lowest.

(1)

Lowest first ionization energy		Highest first ionization energy
.....	.....	.....

(Total for Question 21 = 14 marks)

22 (a) Define the term **covalent bond**.

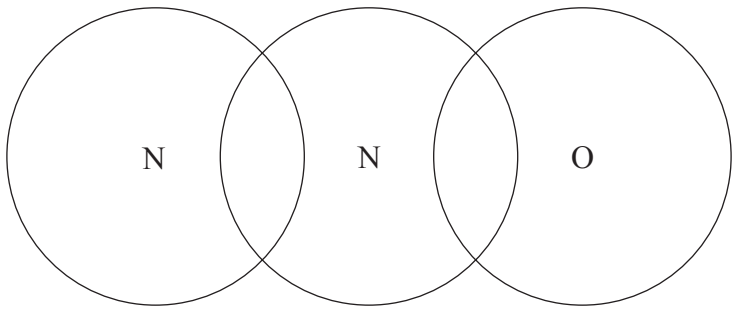
(2)

(b) Nitrogen forms an oxide called nitrous oxide, N_2O. The bonding in nitrous oxide can be represented as:

$$N \equiv N \rightarrow O$$

Complete the diagram below for the N_2O molecule using dots or crosses to represent electrons. Just show all of the outer shell electrons.

(3)



(Total for Question 22 = 5 marks)

Turn over ▶

23 The standard enthalpy change, $\Delta H_1^{\ominus}$, for the decomposition of potassium hydrogencarbonate, $KHCO_3$, is impossible to determine directly.

$$2KHCO_3(s) \rightarrow K_2CO_3(s) + CO_2(g) + H_2O(l)$$

The value of $\Delta H_1^{\ominus}$ can be calculated from the standard enthalpy changes which accompany the reactions below:

$KHCO_3(s) + HCl(aq) \rightarrow KCl(aq) + CO_2(g) + H_2O(l)$ $\Delta H_2^{\ominus}$

$K_2CO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + CO_2(g) + H_2O(l)$ $\Delta H_3^{\ominus}$

Procedure:

- The solids were added to separate 30 cm^3 portions of dilute hydrochloric acid. The acid was in excess for both solids.
- The maximum temperature change for each experiment was noted.

Results:

- The following results were obtained **with $KHCO_3(s)$**.

  Mass of $KHCO_3$ used = 2.00 g

  Temperature change = −4.9 °C

- The experiment with $K_2CO_3(s)$ gave a $\Delta H_3^{\ominus}$ value of −34 kJ mol^{-1}.

Assumption:

- The dilute hydrochloric acid solution has a density of 1 g cm^{-3}.

(a) (i) Calculate the heat energy absorbed, in joules, by the reaction of the $KHCO_3(s)$ with the solution of dilute hydrochloric acid.

Use the expression

energy absorbed (J) = mass of solution × 4.18 × temperature change

(1)

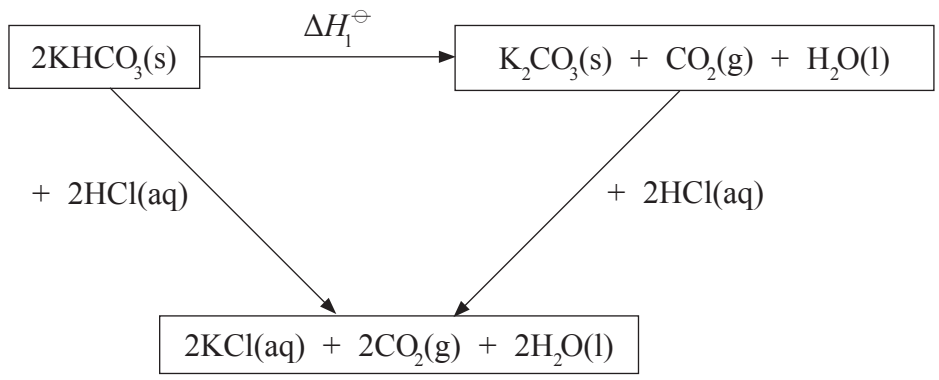
(ii) Calculate the number of moles of $KHCO_3(s)$ used. Assume that the molar mass of $KHCO_3(s)$ is 100 g mol^{-1}.

(1)

(iii) Use your answers to (a)(i) and (ii) to calculate, in **kJ mol^{-1}**, the enthalpy change when one mole of $KHCO_3(s)$ reacts completely with the acid (i.e. $\Delta H_2^{\ominus}$). Include a sign in your answer.

(2)

(b) A Hess Cycle based on these reactions is shown below.



(i) Apply Hess's Law to obtain an expression for $\Delta H_1^{\ominus}$ in terms of $\Delta H_2^{\ominus}$ and $\Delta H_3^{\ominus}$.

(1)

$\Delta H_1^{\ominus}$ =

(ii) Use your answers to (a)(iii) and (b)(i), and the $\Delta H_3^{\ominus}$ value of –34 kJ mol^{-1}, to calculate a value for $\Delta H_1^{\ominus}$ in kJ mol^{-1}. Include a sign in your answer.

(2)

(c) The maximum errors for the apparatus used in the experiment with the $KHCO_3(s)$ were as follows:

Balance	± 0.01 g
Measuring cylinder	± 0.5 cm^3

(i) Calculate the maximum percentage error in using each of the following pieces of apparatus in the $KHCO_3(s)$ experiment:

(2)

Balance

Measuring cylinder

(ii) Suggest a piece of apparatus that could have been used to measure the volume of dilute hydrochloric acid more accurately in this experiment.

(1)

(Total for Question 23 = 10 marks)

24 (a) State the general formula of the alkanes, using the letter ***n*** to denote the number of carbon atoms in each molecule.

(1)

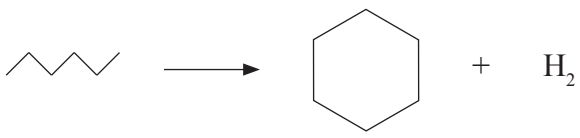
(b) Alkanes are used as fuels. In the petrochemical industry, useful hydrocarbons are often produced from longer chain molecules.

Name the type of reaction shown below.

(i) 

(1)

Type of reaction .....

(ii) 

(1)

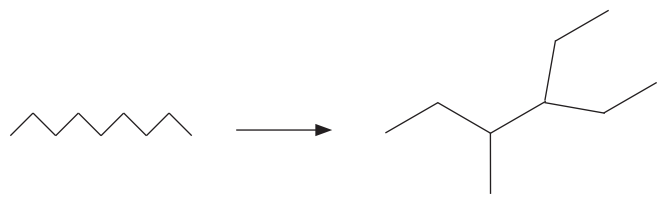
Type of reaction .....

(c) By what **type** of formula are the **organic** molecules in (b) represented?

(1)

.....

(d) Another reaction carried out in industry can be represented as shown below.



compound 1 **compound 2**

(i) Give the molecular formula of **compound 2**.

(1)

.....

(ii) Give the name of **compound 2**.

(1)

.....

(e) An equation for the reaction between methane and chlorine is:

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

The reaction occurs in the presence of ultraviolet (UV) light via a free-radical chain mechanism.

The initiation step is $Cl_2 \rightarrow 2Cl\bullet$

The next step could be

EITHER $CH_4 + Cl\bullet \rightarrow \bullet CH_3 + HCl$ (Step **A**)

OR $CH_4 + Cl\bullet \rightarrow CH_3Cl + H\bullet$ (Step **B**)

(i) Use the following data to calculate a value for the enthalpy change for each of the Steps, **A** and **B**.

(3)

Bond	Mean bond enthalpy / kJ mol^{-1}
C – H	+ 413
C – Cl	+ 346
H – Cl	+ 432

Enthalpy change for Step A $CH_4 + Cl\bullet \rightarrow \bullet CH_3 + HCl$

Answer ..... kJ mol^{-1}

Enthalpy change for Step B $CH_4 + Cl\bullet \rightarrow CH_3Cl + H\bullet$

Answer ..... kJ mol^{-1}

Answer ..... kJ mol^{-1}

(ii) Use your answer to (i) to justify which of the Steps, **A** or **B**, is the more likely.

(1)

.....

.....

QUESTION 24 CONTINUES ON THE NEXT PAGE.

(f) Another halogenoalkane, bromomethane, CH_3Br, is a toxic gas used to protect plants against insects.

Health and Safety advice states that concentrations above 5 parts per million (ppm) by volume of this gas are harmful.

A research laboratory contains 2.5×10^5 dm^3 of air. Calculate the maximum volume of bromomethane, in dm^3, allowed in the laboratory to comply with the advice given.

(1)

(Total for Question 24 = 11 marks)

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

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 10.0 cm^3 of 0.250 mol dm^{-3} potassium hydroxide solution was placed in a conical flask and titrated with 0.200 mol dm^{-3} hydrochloric acid solution, using phenolphthalein as an indicator.

(a) What colour would phenolphthalein turn at the end-point in this titration?

(1)

☒ **A** Colourless

☒ **B** Pink

☒ **C** Yellow

☒ **D** Orange

(b) The best piece of apparatus to accurately measure out 10.0 cm^3 is a

(1)

☒ **A** pipette.

☒ **B** burette.

☒ **C** syringe.

☒ **D** measuring cylinder.

(c) What volume of 0.200 mol dm^{-3} hydrochloric acid solution was added by the end-point?

(1)

☒ **A** 8.00 cm^3

☒ **B** 10.00 cm^3

☒ **C** 12.50 cm^3

☒ **D** 25.00 cm^3

(Total for Question 1 = 3 marks)

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

2 Which of these metal hydroxides is the most soluble in water?

- ☒ **A** Barium hydroxide
- ☒ **B** Calcium hydroxide
- ☒ **C** Magnesium hydroxide
- ☒ **D** Strontium hydroxide

(Total for Question 2 = 1 mark)

3 Which of these metals will give a lilac flame colour?

- ☒ **A** Sodium
- ☒ **B** Calcium
- ☒ **C** Potassium
- ☒ **D** Magnesium

(Total for Question 3 = 1 mark)

4 Which of these is a tertiary alcohol?

- ☒ **A** 3-methylpentan-2-ol
- ☒ **B** Pentan-2-ol
- ☒ **C** Pentan-3-ol
- ☒ **D** 2-methylpentan-2-ol

(Total for Question 4 = 1 mark)

5 Which of these statements about fluorine is **not** correct?

- ☒ **A** It is a gaseous element at room temperature and pressure.
- ☒ **B** It can react with chloride ions to form chlorine.
- ☒ **C** It forms salts with Group 1 metals.
- ☒ **D** It is less electronegative than chlorine.

(Total for Question 5 = 1 mark)

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

6 What is the oxidation number of oxygen in dioxygen difluoride, O_2F_2?

- ☒ **A** –1
- ☒ **B** –2
- ☒ **C** +1
- ☒ **D** +2

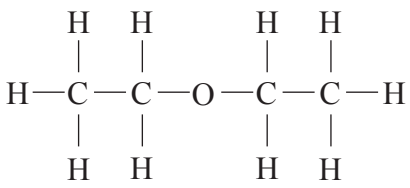
(Total for Question 6 = 1 mark)

7 Which of these four molecules, PCl_3, CO, CO_2 and CCl_4, are polar?

- ☒ **A** All four
- ☒ **B** PCl_3 and CO
- ☒ **C** CO and CCl_4
- ☒ **D** PCl_3 and CO_2

(Total for Question 7 = 1 mark)

8 Which intermolecular forces exist between molecules of ethoxyethane?



- ☒ **A** Instantaneous dipole – induced dipole only
- ☒ **B** Permanent dipole – permanent dipole only
- ☒ **C** Instantaneous dipole – induced dipole and hydrogen bonds
- ☒ **D** Instantaneous dipole – induced dipole and permanent dipole – permanent dipole

(Total for Question 8 = 1 mark)

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

9 The following liquids all have the same number of electrons in each molecule. Which one is likely to have the lowest boiling point?

- ☒ **A** $CH_3CH_2CH_2CH_2OH$
- ☒ **B** $CH_3CH_2CH_2CH_2CH_3$
- ☒ **C** $CH_3C(CH_3)_2CH_3$
- ☒ **D** $CH_3CH(CH_3)CH_2CH_3$

(Total for Question 9 = 1 mark)

10 Which of these is likely to be the best solvent for cyclohexanol?

- ☒ **A** $H_2O(l)$
- ☒ **B** $CH_3COCH_3(l)$
- ☒ **C** NaCl(aq)
- ☒ **D** $CH_3CH_2CH_2CH_2CH_2CH_3(l)$

(Total for Question 10 = 1 mark)

11 The ability of a liquid to flow is linked to the strength of its intermolecular forces. Suggest which of these liquids flows the slowest when poured.

- ☒ **A** Propane-1,2,3-triol
- ☒ **B** Propane-1,2-diol
- ☒ **C** Pentane
- ☒ **D** Butane

(Total for Question 11 = 1 mark)

12 What type of species forms when a bond breaks homolytically?

- ☒ **A** Nucleophile
- ☒ **B** Electron
- ☒ **C** Electrophile
- ☒ **D** Free radical

(Total for Question 12 = 1 mark)

13 In the reaction between $Ag^+(aq)$ ions and $Fe^{2+}(aq)$ ions, what would be the effect of increasing the concentration of $Ag^+(aq)$ ions?

$$Ag^+(aq) + Fe^{2+}(aq) \rightleftharpoons Fe^{3+}(aq) + Ag(s)$$

☒ **A** Rate of reaction increases, yield of $Fe^{3+}(aq)$ stays the same.

☒ **B** Rate of reaction increases, yield of $Fe^{3+}(aq)$ decreases.

☒ **C** Rate of reaction decreases, yield of $Fe^{3+}(aq)$ stays the same.

☒ **D** Rate of reaction increases, yield of $Fe^{3+}(aq)$ increases.

(Total for Question 13 = 1 mark)

14 Which one of these reactions is **not** a disproportionation reaction?

☒ **A** $2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(l)$

☒ **B** $S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow SO_2(g) + S(s) + H_2O(l)$

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

☒ **D** $2Cu^+(aq) \rightarrow Cu(s) + Cu^{2+}(aq)$

(Total for Question 14 = 1 mark)

15 Molecules absorb IR radiation because

☒ **A** they change their polarity when they vibrate.

☒ **B** they change their velocity when they vibrate.

☒ **C** they change their magnetic field when they vibrate.

☒ **D** they change their direction of rotation when they vibrate.

(Total for Question 15 = 1 mark)

16 How many of the following molecules will absorb IR radiation?

H_2O N_2 CH_4 O_2 CO_2

☒ **A** Two

☒ **B** Three

☒ **C** Four

☒ **D** Five

(Total for Question 16 = 1 mark)

17 Infrared (IR) spectra can be used to follow the progress of reactions involving propan-1-ol and propan-2-ol. Some absorption ranges by chemical bonds in the IR spectrum are given below.

1 O—H stretching in alcohols at 3750 − 3200 cm^{-1}

2 C═O stretching in aldehydes at 1740 − 1720 cm^{-1}

3 C═O stretching in ketones at 1700 − 1680 cm^{-1}

4 C═O stretching in carboxylic acids at 1725 − 1700 cm^{-1}

(a) To identify the formation of the product when propan-1-ol has been partially oxidized, you can look for absorptions in the IR spectrum at absorption range

(1)

☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

(b) To monitor whether all of the sample of propan-2-ol has been oxidized, you can look for

(1)

☒ **A** a lack of absorptions in the IR spectrum at 1.

☒ **B** a lack of absorptions in the IR spectrum at 2.

☒ **C** absorptions in the IR spectrum at 3.

☒ **D** absorptions in the IR spectrum at 4.

(Total for Question 17 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

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

SECTION B

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

18 This question is about the reactions and properties of some halogenoalkanes.

(a) State the reagents and conditions needed to convert the following halogenoalkanes into the named product.

(i) 1-bromobutane into butan-1-ol

(2)

(ii) 1-iodobutane into butylamine

(2)

(iii) 2-chloropropane into propene

(2)

(b) Chloroethane can be prepared by reacting ethanol with potassium chloride in the presence of concentrated sulfuric acid.

Explain why a similar reaction using potassium iodide and concentrated sulfuric acid should **not** be used to prepare iodoethane.

(2)

(c) Two gaseous halogenoalkanes that could be used as fire retardants have the structural formulae CF_2ClBr and CF_3CHF_2.

(i) Give the systematic name of CF_2ClBr.

(1)

(ii) Draw the **skeletal** formula of CF_3CHF_2.

(1)

(iii) Suggest TWO reasons to explain how these compounds can help put out fires.

(2)

*(iv) Explain why fire retardants containing some halogenoalkanes, such as CF_2ClBr, are being phased out.

Suggest a reason why the scientific community still supports the use of fire retardants containing CF_3CHF_2.

(4)

(Total for Question 18 = 16 marks)

19 10.0 cm^3 of a solution containing $Cu^{2+}(aq)$ ions was added to excess potassium iodide solution and the following reaction occurred.

$$2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$$

(a) What happens to the $Cu^{2+}(aq)$ during this reaction? Justify your answer.

(2)

(b) All of the mixture containing iodine was titrated using sodium thiosulfate solution of concentration 0.200 mol dm^{-3}. The volume of sodium thiosulfate solution added at the end-point was 12.75 cm^3.

The equation for the reaction is

$$I_2(aq) + 2Na_2S_2O_3(aq) \rightarrow Na_2S_4O_6(aq) + 2NaI(aq)$$

(i) The end-point is shown most effectively using an indicator. State a suitable indicator and the colour change you would expect to see at the end-point.

(2)

Indicator

Colour change at end-point

(ii) Calculate the number of moles of iodine in the solution.

(2)

*(iii) Use your answer from (ii), and the equation for the reaction between $Cu^{2+}(aq)$ and $I^{-}(aq)$, to calculate the concentration of the $Cu^{2+}(aq)$ in the original sample of solution.

Give your answer to **three** significant figures and justify why this is an appropriate level of accuracy.

(3)

(iv) The whole of the solution containing iodine was used in one titration. Explain how this affects the reliability of your answer to (iii).

(1)

(Total for Question 19 = 10 marks)

20 This question is about boron and nitrogen compounds.

(a) Draw and name the shape of a boron trifluoride, BF_3, molecule. Suggest the FBF bond angle.

(3)

Name of shape

FBF bond angle

(b) Ammonia has the formula NH_3. Its HNH bond angle is less than the FBF bond angle in boron trifluoride.

(i) Estimate the HNH bond angle in NH_3.

(1)

(ii) Explain why the HNH bond angle is less than that for FBF.

(1)

(iii) Name the strongest intermolecular force between BF_3 molecules.

(1)

(iv) Name the strongest intermolecular force between NH_3 molecules.

(1)

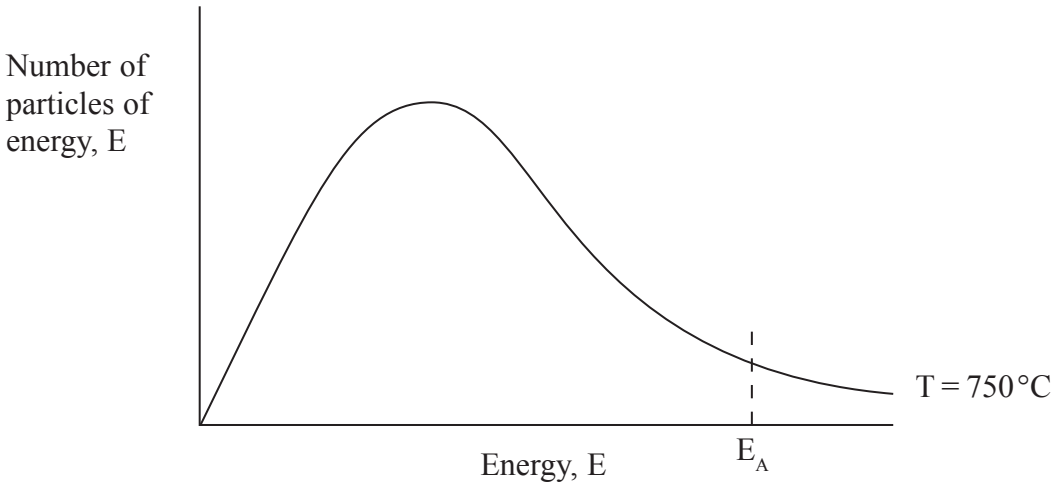
(c) Ammonia will react with oxygen in the presence of a platinum catalyst at 750 °C forming water and nitrogen(II) oxide, NO.

(i) What is the oxidation number of nitrogen in ammonia, NH_3?

(1)

(ii) The diagram below shows the distribution of molecular energies in the reaction at 750 °C. On the same diagram, draw a curve to show the distribution at 500 °C and explain what effect this change in temperature would have on the rate of the reaction.

(3)



*(d) Explain how a catalyst speeds up the rate of a reaction.

(3)

(Total for Question 20 = 14 marks)

TOTAL FOR SECTION B = 40 MARKS

SECTION C

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

21 Ethanoic acid is used industrially in the manufacture of polymers and glues and also in the food industry as an acidity regulator.

It can be synthesized in the laboratory by the reaction of ethanol with excess sodium dichromate(VI) solution, acidified with concentrated sulfuric acid. Ethanol is placed in a suitable flask along with some anti-bumping beads. The concentrated sulfuric acid is then added a drop at a time. The sodium dichromate(VI) solution is then added a drop at a time causing the mixture to boil spontaneously. When the addition of the sodium dichromate(VI) solution is complete, the mixture is heated under reflux for approximately 15 minutes. The ethanoic acid formed can then be separated from the reaction mixture.

$$CH_3CH_2OH \xrightarrow[\text{heat, 1 atm}]{\substack{Na_2Cr_2O_7 \\ H_2SO_4}} CH_3COOH$$

Ethanoic acid can be produced industrially by the Cativa™ process. Methanol, which can be obtained from wood, is reacted with carbon monoxide in the presence of an iridium catalyst.

$$CH_3OH(g) + CO(g) \underset{\text{190 °C}}{\overset{\text{Iridium catalyst, 20–30 atm}}{\rightleftharpoons}} CH_3COOH(g)$$

(a) (i) Balance the half-equation for the reduction of dichromate(VI) ions.

(1)

$Cr_2O_7^{2-}$ + ... H^+ + ... e^- → ..... Cr^{3+} + ... H_2O

(ii) The half-equation for the oxidation of ethanol is

$$CH_3CH_2OH + H_2O \rightarrow CH_3COOH + 4H^+ + 4e^-$$

Use this and your answer to (a)(i) to write a full equation for the overall reaction between acidified dichromate(VI) ions and ethanol. State symbols are **not** required.

(2)

Turn over ▶

(b) (i) Why are the concentrated sulfuric acid and sodium dichromate(VI) added a drop at a time in the laboratory process?

(1)

.....

.....

(ii) Draw a labelled diagram of the apparatus that could be used to heat the mixture under reflux.

(3)

(iii) What colour would the mixture be after it was heated under reflux?

(1)

.....

(c) A solution containing both water and ethanoic acid is produced by distillation of the final reaction mixture.

(i) Explain why the other products and any excess reactants are left behind in the distillation flask.

(1)

(ii) Suggest a method to separate pure ethanoic acid, boiling temperature 118 °C, from the water.

(1)

(d) (i) In the Cativa™ process what effect, if any, would increasing the pressure have on the yield of ethanoic acid? Justify your answer.

(2)

(ii) Suggest TWO reasons why it might be difficult, or undesirable, to produce ethanoic acid in industry by scaling up the laboratory process.

(2)

Turn over ▶

*(e) An alternative industrial process for the production of ethanoic acid is the oxidation of butane using a transition metal catalyst at 150 °C and 55–60 atm.

$$2C_4H_{10}(l) + 5O_2(g) \rightarrow 4CH_3COOH(aq) + 2H_2O(l)$$

Evaluate the 'greenness' and sustainability of the two industrial processes.

Suggest TWO additional pieces of information that would help you make a more informed decision.

(6)

(Total for Question 21 = 20 marks)

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

Areas outside the box will not be scanned for marking

SECTION A

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

1 Ionisation energies provide evidence for the arrangement of electrons in atoms.

1 (a) Complete the electron configuration of the Mg^+ ion.

$1s^2$ .....

(1 mark)

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

.....

.....

.....

(2 marks)

1 (b) (ii) Write an equation, including state symbols, to show the reaction that occurs when the **second** ionisation energy of magnesium is measured.

.....

(1 mark)

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

.....

.....

.....

(1 mark)

1 (b) (iv) Use your understanding of electron arrangement to complete the table by suggesting a value for the third ionisation energy of magnesium.

	First	Second	Third	Fourth	Fifth
Ionisation energies of magnesium / kJ mol^{-1}	736	1450		10 500	13 629

(1 mark)

1 (c) State and explain the general trend in the first ionisation energies of the Period 3 elements sodium to chlorine.

Trend .....

Explanation .....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

1 (d) State how the element sulfur deviates from the general trend in first ionisation energies across Period 3. Explain your answer.

How sulfur deviates from the trend .....

.....

Explanation .....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

1 (e) A general trend exists in the first ionisation energies of the Period 2 elements lithium to fluorine. Identify **one** element which deviates from this general trend.

.....

(1 mark)

13

2 Ammonium sulfate reacts with sodium hydroxide to form ammonia, sodium sulfate and water as shown in the equation below.

$$(NH_4)_2SO_4(s) + 2NaOH(aq) \longrightarrow 2NH_3(g) + Na_2SO_4(aq) + 2H_2O(l)$$

2 (a) A 3.14 g sample of ammonium sulfate reacted completely with 39.30 cm^3 of a sodium hydroxide solution.

2 (a) (i) Calculate the amount, in moles, of $(NH_4)_2SO_4$ in 3.14 g of ammonium sulfate.

.....

.....

.....

(2 marks)

2 (a) (ii) Hence calculate the amount, in moles, of sodium hydroxide which reacted.

.....

(1 mark)

2 (a) (iii) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution used.

.....

.....

(1 mark)

2 (b) Calculate the percentage atom economy for the production of ammonia in the reaction between ammonium sulfate and sodium hydroxide.

.....

.....

.....

(2 marks)

2 (c) Ammonia is manufactured by the Haber Process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Calculate the percentage atom economy for the production of ammonia in this process.

.....

.....

(1 mark)

2 (d) A sample of ammonia gas occupied a volume of 1.53×10^{-2} m^3 at 37 °C and a pressure of 100 kPa.
(The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$)

Calculate the amount, in moles, of ammonia in this sample.

.....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

2 (e) Glauber's salt is a form of hydrated sodium sulfate that contains 44.1% by mass of sodium sulfate. Hydrated sodium sulfate can be represented by the formula $Na_2SO_4.xH_2O$ where x is an integer. Calculate the value of x.

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

13

3 The table below shows the boiling points of some hydrogen compounds formed by Group 6 elements.

	H_2O	H_2S	H_2Se	H_2Te
Boiling point / K	373	212	232	271

3 (a) State the strongest type of intermolecular force in water and in hydrogen sulfide (H_2S).

Water .....

Hydrogen sulfide .....

(2 marks)

3 (b) Draw a diagram to show how two molecules of water are attracted to each other by the type of intermolecular force you stated in part (a). Include partial charges and all lone pairs of electrons in your diagram.

(3 marks)

3 (c) Explain why the boiling point of water is much higher than the boiling point of hydrogen sulfide.

.....

.....

(1 mark)

3 (d) Explain why the boiling points increase from H_2S to H_2Te

.....

.....

(2 marks)

3 (e) When H^+ ions react with H_2O molecules, H_3O^+ ions are formed.

Name the type of bond formed when H^+ ions react with H_2O molecules.
Explain how this type of bond is formed in the H_3O^+ ion.

Type of bond .....

Explanation .....

.....

(2 marks)

3 (f) Sodium sulfide (Na_2S) has a melting point of 1223 K.
Predict the type of bonding in sodium sulfide and explain why its melting point is high.

Type of bonding .....

Explanation .....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

13

Turn over for the next question

4 Alkanes are saturated hydrocarbons which can be obtained from crude oil.
Pentane is an example of an alkane. A molecule of pentane contains five carbon atoms.

4 (a) (i) State the meaning of the term *saturated* and of the term *hydrocarbon* as applied to alkanes.

Saturated .....

.....

Hydrocarbon .....

.....

(2 marks)

4 (a) (ii) Give the general formula for the alkanes.

.....

(1 mark)

4 (b) Pentane burns completely in oxygen.

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

.....

(1 mark)

4 (b) (ii) State how the products of this reaction may affect the environment.

.....

.....

(1 mark)

4 (c) Give the name of a solid pollutant which may form when pentane burns incompletely in air.

.....

(1 mark)

4 (d) One molecule of C_9H_{20} can be cracked to form one molecule of pentane and one other product.

4 (d) (i) Write an equation for this cracking reaction.

.....

(1 mark)

4 (d) (ii) Suggest a type of compound that can be manufactured from the other product of this cracking reaction.

.....

.....

(1 mark)

4 (d) (iii) State why a high temperature is needed for cracking reactions to occur.

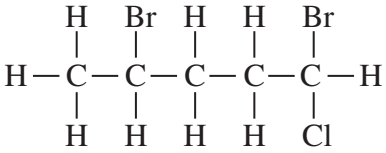
.....

.....

(1 mark)

Question 4 continues on the next page

4 (e) Pentane can react to form the following haloalkane **Q**.

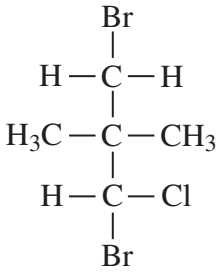


4 (e) (i) Name **Q**.

.....

(1 mark)

4 (e) (ii) State the type of structural isomerism shown by **Q** and the haloalkane shown below.



.....

(1 mark)

11

SECTION B

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

5 A mass spectrometer can be used to investigate the isotopes in an element.

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

.....

.....

.....

.....

(2 marks)

(Extra space) .....

.....

5 (b) Element **X** has a relative atomic mass of 47.9

Identify the block in the Periodic Table to which element **X** belongs and give the electron configuration of an atom of element **X**.

Calculate the number of neutrons in the isotope of **X** which has a mass number 49

.....

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

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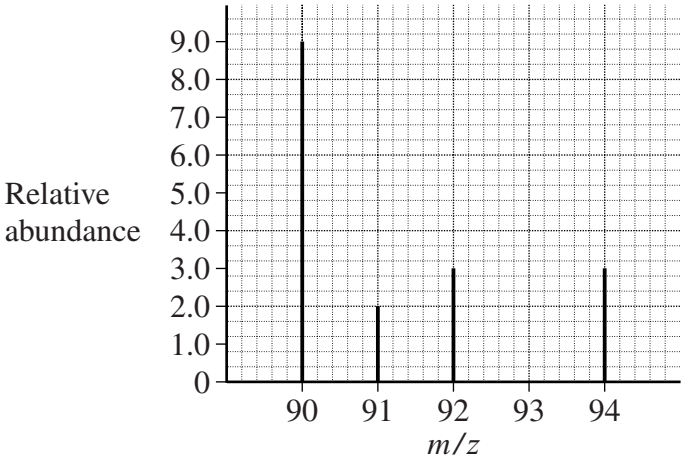
Question 5 continues on the next page

5 (c) The mass spectrum of element **Z** is shown below.

Use this spectrum to calculate the relative atomic mass of **Z**, giving your answer to one decimal place.

Identify element **Z**.



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(4 marks)

(Extra space) .....

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5 (d) State how vaporised atoms of **Z** are converted into $\mathbf{Z}^+$ ions in a mass spectrometer.

State and explain which of the $\mathbf{Z}^+$ ions formed from the isotopes of **Z** in part (c) will be deflected the most in a mass spectrometer.

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(4 marks)

(Extra space) .....

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5 (e) Explain briefly how the relative abundance of an ion is measured in a mass spectrometer.

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(2 marks)

(Extra space) .....

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15

6 A molecule of ClF_3 reacts with a molecule of AsF_5 as shown in the following equation.

$$ClF_3 + AsF_5 \longrightarrow ClF_2^+ + AsF_6^-$$

Use your understanding of electron pair repulsion to draw the shape of the AsF_5 molecule and the shape of the ClF_2^+ ion. Include any lone pairs of electrons.

Name the shape made by the atoms in the AsF_5 molecule and in the ClF_2^+ ion.

Predict the bond angle in the ClF_2^+ ion.

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(5 marks)

(Extra space) .....

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5

END OF QUESTIONS

Areas outside the box will not be scanned for marking

SECTION A

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

1 Hydrogen gas is used in the chemical industry.

1 (a) Tungsten is extracted by passing hydrogen over heated tungsten oxide (WO_3).

1 (a) (i) State the role of the hydrogen in this reaction.

.....

(1 mark)

1 (a) (ii) Write an equation for this reaction.

.....

(1 mark)

1 (a) (iii) State **one** risk of using hydrogen gas in metal extractions.

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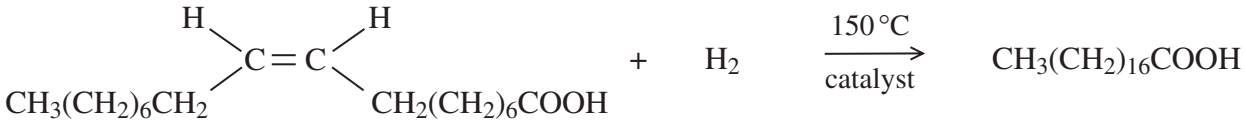
(1 mark)

1 (b) Hydrogen is used to convert oleic acid into stearic acid as shown by the following equation.



oleic acid stearic acid

1 (b) (i) Use your knowledge of the chemistry of alkenes to deduce the type of reaction that has occurred in this conversion.

.....

(1 mark)

1 (b) (ii) State the type of stereoisomerism shown by oleic acid.

.....

(1 mark)

1 (c) Hydrogen reacts with nitrogen in the Haber Process. The equation for the equilibrium that is established is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

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

.....

.....

(1 mark)

1 (c) (ii) Use Le Chatelier's principle to explain why an increase in the total pressure of this equilibrium results in an increase in the equilibrium yield of ammonia.

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(2 marks)

1 (d) Hydrogen reacts with oxygen in an exothermic reaction as shown by the following equation.

$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(g) \qquad \Delta H = -242\,\text{kJ mol}^{-1}$$

Use the information in the equation and the data in the following table to calculate a value for the bond enthalpy of the H–H bond.

	O–H	O=O
Mean bond enthalpy / kJ mol^{-1}	+463	+496

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(3 marks)

(Extra space) .....

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11

2 Hess's Law is used to calculate the enthalpy change in reactions for which it is difficult to determine a value experimentally.

2 (a) State the meaning of the term *enthalpy change*.

.....

(1 mark)

2 (b) State Hess's Law.

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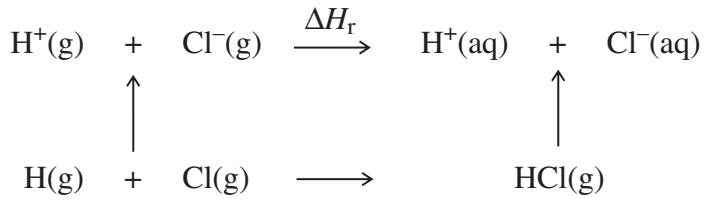
(1 mark)

2 (c) Consider the following table of data and the scheme of reactions.

Reaction	Enthalpy change / kJ mol^{-1}
$HCl(g) \longrightarrow H^+(aq) + Cl^-(aq)$	–75
$H(g) + Cl(g) \longrightarrow HCl(g)$	–432
$H(g) + Cl(g) \longrightarrow H^+(g) + Cl^-(g)$	+963



Use the data in the table, the scheme of reactions and Hess's Law to calculate a value for ΔH_r

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(3 marks)

5

3 For each of the following reactions, select from the list below, the **formula** of a sodium halide that would react as described.

NaF NaCl NaBr NaI

Each **formula** may be selected once, more than once or not at all.

3 (a) This sodium halide is a white solid that reacts with concentrated sulfuric acid to give a brown gas.

Formula of sodium halide .....

(1 mark)

3 (b) When a solution of this sodium halide is mixed with silver nitrate solution, no precipitate is formed.

Formula of sodium halide .....

(1 mark)

3 (c) When this solid sodium halide reacts with concentrated sulfuric acid, the reaction mixture remains white and steamy fumes are given off.

Formula of sodium halide .....

(1 mark)

3 (d) A colourless aqueous solution of this sodium halide reacts with orange bromine water to give a dark brown solution.

Formula of sodium halide .....

(1 mark)

4

Turn over for the next question

4 Group 2 metals and their compounds are used commercially in a variety of processes and applications.

4 (a) State a use of magnesium hydroxide in medicine.

.....

(1 mark)

4 (b) Calcium carbonate is an insoluble solid that can be used in a reaction to lower the acidity of the water in a lake.

Explain why the rate of this reaction decreases when the temperature of the water in the lake falls.

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(3 marks)

(Extra space) .....

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4 (c) Strontium metal is used in the manufacture of alloys.

4 (c) (i) Explain why strontium has a higher melting point than barium.

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(2 marks)

(Extra space) .....

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4 (c) (ii) Write an equation for the reaction of strontium with water.

.....

(1 mark)

4 (d) Magnesium can be used in the extraction of titanium.

4 (d) (i) Write an equation for the reaction of magnesium with titanium(IV) chloride.

.....

(1 mark)

4 (d) (ii) The excess of magnesium used in this extraction can be removed by reacting it with dilute sulfuric acid to form magnesium sulfate.

Use your knowledge of Group 2 sulfates to explain why the magnesium sulfate formed is easy to separate from the titanium.

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(1 mark)

9

Turn over for the next question

5 Nitric acid is manufactured from ammonia in a process that involves several stages.

5 (a) In the first stage, ammonia is converted into nitrogen monoxide and the following equilibrium is established.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -905\,kJ\,mol^{-1}$$

The catalyst for this equilibrium reaction is a platinum–rhodium alloy in the form of a gauze. This catalyst gauze is heated initially but then remains hot during the reaction.

5 (a) (i) In terms of redox, state what happens to the ammonia in the forward reaction.

.....

(1 mark)

5 (a) (ii) Suggest a reason why the catalyst must be hot.

.....

(1 mark)

5 (a) (iii) Suggest a reason why the catalyst remains hot during the reaction.

.....

(1 mark)

5 (a) (iv) State how a catalyst increases the rate of a reaction.

.....

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(2 marks)

5 (b) In the second stage, nitrogen monoxide is converted into nitrogen dioxide. The equation for the equilibrium that is established is shown below.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = -113\,kJ\,mol^{-1}$$

Explain why the equilibrium mixture is cooled during this stage of the process.

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(2 marks)

5 (c) In the final stage, nitrogen dioxide reacts with water as shown by the following equation.

$$2NO_2(g) + H_2O(l) \longrightarrow H^+(aq) + NO_3^-(aq) + HNO_2(aq)$$

Give the oxidation state of nitrogen in each of the following.

NO_2 .....

NO_3^- .....

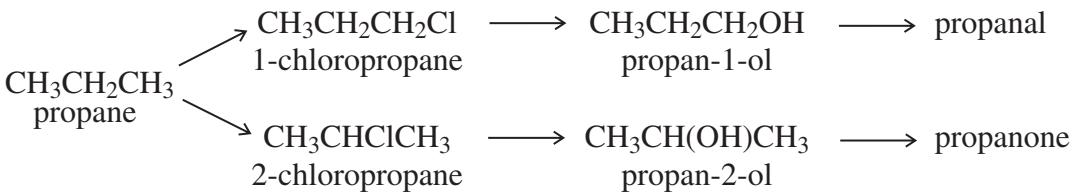
HNO_2 .....

(3 marks)

10

Turn over for the next question

6 Consider the following scheme of reactions.



6 (a) State the type of structural isomerism shown by propanal and propanone.

.....

(1 mark)

6 (b) A chemical test can be used to distinguish between separate samples of propanal and propanone.

Identify a suitable reagent for the test.
State what you would observe with propanal and with propanone.

Test reagent .....

Observation with propanal .....

Observation with propanone .....

(3 marks)

6 (c) State the structural feature of propanal and propanone which can be identified from their infrared spectra by absorptions at approximately $1720\,cm^{-1}$.
You may find it helpful to refer to **Table 1** on the Data Sheet.

.....

(1 mark)

6 (d) The reaction of chlorine with propane is similar to the reaction of chlorine with methane.

6 (d) (i) Name the type of mechanism in the reaction of chlorine with methane.

.....

(1 mark)

6 (d) (ii) Write an equation for each of the following steps in the mechanism for the reaction of chlorine with propane to form l-chloropropane ($CH_3CH_2CH_2Cl$).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step to form a molecule with the empirical formula C_3H_7

.....

(4 marks)

6 (e) High resolution mass spectrometry of a sample of propane indicated that it was contaminated with traces of carbon dioxide.

Use the data in the table to show how precise M_r values can be used to prove that the sample contains both of these gases.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{1}H	1.00794
^{16}O	15.99491

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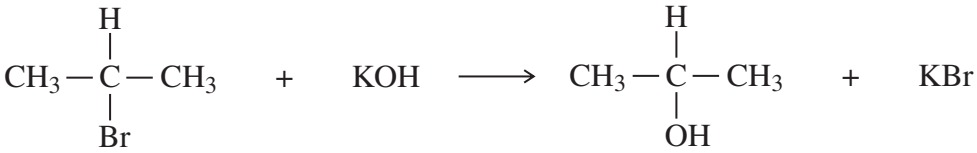
(2 marks)

12

7 (a) Consider the following reaction.



7 (a) (i) Name and outline a mechanism for this reaction.

Name of mechanism .....

Mechanism

(3 marks)

7 (a) (ii) Name the haloalkane in this reaction.

.....

(1 mark)

7 (a) (iii) Identify the characteristic of the haloalkane molecule that enables it to undergo this type of reaction.

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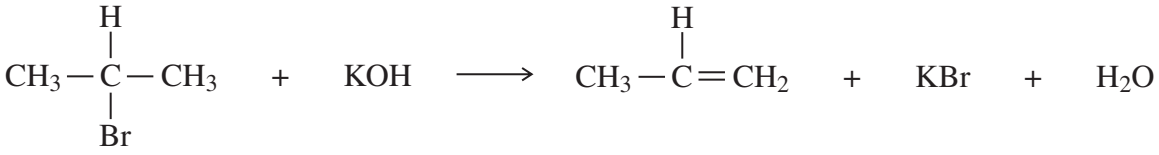
(1 mark)

7 (b) An alternative reaction can occur between this haloalkane and potassium hydroxide as shown by the following equation.



Name and outline a mechanism for this reaction.

Name of mechanism .....

Mechanism

(4 marks)

7 (c) Give **one** condition needed to favour the reaction shown in part (b) rather than that shown in part (a).

.....

(1 mark)

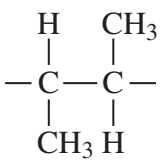
7 (d) Alkenes can be polymerised to produce poly(alkenes).

7 (d) (i) State the type of polymerisation that alkenes undergo.

.....

(1 mark)

7 (d) (ii) Name the alkene that gives a polymer with the repeating unit shown below.



Name of alkene .....

(1 mark)

12

8 Copper is extracted from the ore chalcopyrite ($CuFeS_2$) in a three-stage process.

8 (a) In the first stage of this extraction, the chalcopyrite is heated with silicon dioxide and oxygen.

8 (a) (i) Balance the following equation for this first stage in which copper(I) sulfide is formed.

……$CuFeS_2$ + ……SiO_2 + ……O_2 ⟶ Cu_2S + ……$FeSiO_3$ + ……SO_2

(1 mark)

8 (a) (ii) Give **one** environmental reason why the SO_2 gas formed in this reaction is not allowed to escape into the atmosphere.

.....

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(1 mark)

8 (a) (iii) State **one** use for the sulfur dioxide formed in this reaction.

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(1 mark)

8 (b) In the second stage of this extraction, the copper(I) sulfide is converted into copper(II) oxide. This occurs by roasting the sulfide with oxygen at high temperature. Write an equation for this reaction.

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(1 mark)

8 (c) In the third stage of this extraction, copper(II) oxide is reduced to copper by its reaction with carbon. Write an equation for this reaction.

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(1 mark)

8 (d) Scrap iron can be used to extract copper from dilute aqueous solutions containing copper(II) ions.

8 (d) (i) Explain why this is a low-cost method of extracting copper.

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(1 mark)

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

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(1 mark)

7

Turn over for the next question

SECTION B

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

9 There are **four** isomeric alcohols with the molecular formula $C_4H_{10}O$

9 (a) Two of these are butan-l-ol ($CH_3CH_2CH_2CH_2OH$) and butan-2-ol.
The other two isomers are alcohol **X** and alcohol **Y**.

Draw the displayed formula for butan-2-ol.

Alcohol **X** does not react with acidified potassium dichromate(VI) solution.
Give the structure of alcohol **X**.

Name the fourth isomer, alcohol **Y**.

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(3 marks)

(Extra space) .....

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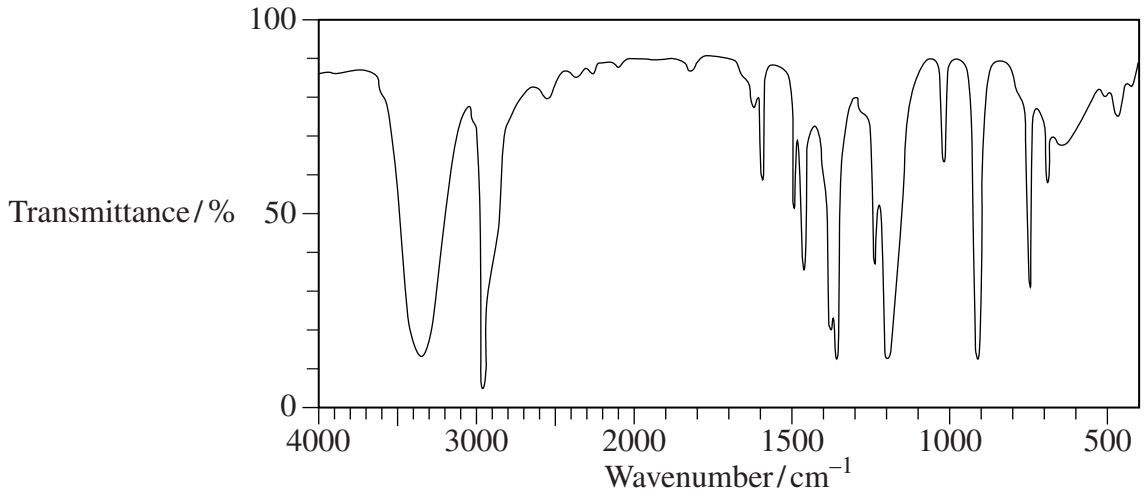
9 (b) The infrared spectrum of one of these isomeric alcohols is given below.



Identify **one** feature of the infrared spectrum which supports the fact that this is an alcohol. You may find it helpful to refer to **Table 1** on the Data Sheet.

Explain how infrared spectroscopy can be used to identify this isomeric alcohol.

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(3 marks)

(Extra space) .....

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Question 9 continues on the next page

9 (c) British scientists have used bacteria to ferment glucose and produce the biofuel butan-l-ol.

Write an equation for the fermentation of glucose ($C_6H_{12}O_6$) to form butan-l-ol, carbon dioxide and water only.

State **one** condition necessary to ensure the complete combustion of a fuel in air.

Write an equation for the complete combustion of butan-l-ol and state why it can be described as a *biofuel*.

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(4 marks)

(Extra space) .....

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9 (d) Butan-l-ol reacts with acidified potassium dichromate(VI) solution to produce two organic compounds.

State the class of alcohols to which butan-l-ol belongs.

Draw the displayed formula for **both** of the organic products.

State the type of reaction that occurs and the change in colour of the potassium dichromate(VI) solution.

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(5 marks)

(Extra space) .....

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15

Turn over for the next question

10 (a) When chlorine gas dissolves in cold water, a pale green solution is formed. In this solution, the following equilibrium is established.

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

Give the formula of the species responsible for the pale green colour in the solution of chlorine in water.

Use Le Chatelier's principle to explain why the green colour disappears when sodium hydroxide solution is added to this solution.

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(3 marks)

(Extra space) .....

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10 (b) Consider the following reaction in which iodide ions behave as reducing agents.

$$Cl_2(aq) + 2I^-(aq) \longrightarrow I_2(aq) + 2Cl^-(aq)$$

In terms of electrons, state the meaning of the term *reducing agent*.

Deduce the half-equation for the conversion of chlorine into chloride ions.

Explain why iodide ions are stronger reducing agents than chloride ions.

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(4 marks)

(Extra space) .....

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Question 10 continues on the next page

10 (c) When chlorine reacts with water in bright sunlight, only two products are formed. One of these products is a colourless, odourless gas and the other is an acidic solution that reacts with silver nitrate solution to give a white precipitate.

Write an equation for the reaction of chlorine with water in bright sunlight.

Name the white precipitate and state what you would observe when an excess of aqueous ammonia is added to it.

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(3 marks)

(Extra space) .....

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10 (d) The reaction of chlorine with ethene is similar to that of bromine with ethene.

Name and outline a mechanism for the reaction of chlorine with ethene to form 1,2-dichloroethane, as shown by the following equation.

$$H_2C{=}CH_2 + Cl_2 \longrightarrow ClCH_2CH_2Cl$$

(5 marks)

15

END OF QUESTIONS