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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.

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(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*.

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(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

.....

.....

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(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

.....

.....

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(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.

.....

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(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.

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.....

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(2 marks)

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

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(1 mark)

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

.....

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(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*.

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(2 marks)

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

Trend .....

Explanation .....

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(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 .....

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(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 .....

.....

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(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

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(1 mark)

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

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(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

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)

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)

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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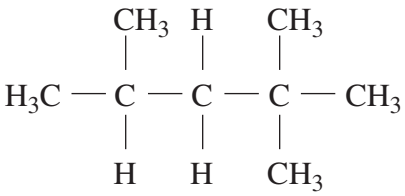
(2 marks)

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

Answer **all** the questions.

1 Carbon occurs in a wide range of compounds and is essential to living systems.

(a) Two isotopes of carbon are ^{12}C and ^{13}C.

(i) State what is meant by the term *isotopes*.

.....

..... **[1]**

(ii) Isotopes of carbon have the same chemical properties.

Explain why.

.....

..... **[1]**

(iii) The ^{12}C isotope is used as the standard measurement of relative masses.

Define the term *relative isotopic mass*.

.....

.....

.....

..... **[2]**

(b) One form of naturally occurring carbon is graphite.

The table below lists some properties of graphite.

electrical conductivity	good conductor
hardness	soft
melting point	very high

- Describe the bonding and structure in graphite.
- Explain, in terms of bonding and structure, the properties of graphite shown above.

In your answer, you should use appropriate technical terms, spelt correctly.

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..... **[5]**

(c) In the sixteenth century, a large deposit of graphite was discovered in the Lake District.

People at the time thought that the graphite was a form of lead.

Nowadays, graphite is used in pencils but it is still referred to as 'pencil lead'.

A student decided to investigate the number of carbon atoms in a 'pencil lead'. He found that the mass of the 'pencil lead' was 0.321 g.

(i) Calculate the amount, in mol, of carbon atoms in the student's pencil lead.

Assume that the 'pencil lead' is pure graphite.

answer = ... mol **[1]**

(ii) Using the Avogadro constant, N_A, calculate the number of carbon atoms in the student's 'pencil lead'.

number of carbon atoms = ... **[1]**

[Total: 11]

2 Chemists have developed models for bonding and structure which are used to explain different properties.

(a) Ammonia, NH_3, is a covalent compound.

(i) Explain what is meant by a *covalent bond*.

..... **[1]**

(ii) Draw a '*dot-and-cross*' diagram to show the bonding in NH_3.

Show **outer** electrons only.

[1]

(iii) Name the shape of the ammonia molecule.

Explain, using your '*dot-and-cross*' diagram, why ammonia has this shape and has a bond angle of 107°.

shape: .....

explanation: .....

.....

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.....

..... **[3]**

(b) Ammonia reacts with hydrogen chloride, HC*l*, to form ammonium chloride, NH_4Cl.

NH_4Cl is an ionic compound containing NH_4^+ and Cl^- ions.

(i) Complete the electron configuration of the Cl^- ion.

$1s^2$ ..... **[1]**

(ii) Draw a '*dot-and-cross*' diagram to show the bonding in NH_4^+.

Show **outer** electrons only.

[1]

(iii) State the shape of, and bond angle in, an NH_4^+ ion.

shape: .....

bond angle: ..... **[2]**

(iv) A student investigated the conductivity of ammonium chloride.

She noticed that when the ammonium chloride was solid it did **not** conduct electricity. However, when ammonium chloride was dissolved in water, the resulting solution did conduct electricity.

Explain these observations.

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..... **[2]**

(c) Ammonium compounds such as ammonium sulfate, $(NH_4)_2SO_4$, can be used as fertilisers.

(i) Write a balanced equation to show how ammonium sulfate could be formed by the reaction between aqueous ammonia and sulfuric acid.

..... **[1]**

(ii) Ammonium sulfate is an example of a salt formed when an acid is neutralised by a base.

Explain what is meant by the term *salt*.

.....

..... **[1]**

(iii) Why is ammonia acting as a base in this neutralisation?

.....

..... **[1]**

(iv) What is the relative formula mass of $(NH_4)_2SO_4$?

Give your answer to **one** decimal place.

..... **[1]**

[Total: 15]

3 A student used the internet to research chlorine and some of its compounds.

(a) He discovered that sea water contains chloride ions. The student added aqueous silver nitrate to a sample of sea water.

(i) What would the student see?

..... **[1]**

(ii) Write an ionic equation, including state symbols, for the reaction that would occur.

..... **[2]**

(iii) After carrying out the test in **(i)**, the student added dilute aqueous ammonia to the mixture.

What would the student see?

..... **[1]**

(b) The student also discovered that chlorine, Cl_2, is used in the large-scale treatment of water.

(i) State **one** benefit of adding chlorine to water.

.....

..... **[1]**

(ii) Not everyone agrees that chlorine should be added to drinking water.

Suggest **one** possible hazard of adding chlorine to drinking water.

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..... **[1]**

(c) The equation for the reaction of chlorine with water is shown below.

$$Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HClO(aq)$$

(i) State the oxidation number of chlorine in:

Cl_2 ..... HCl ..... HClO ..... **[1]**

(ii) The reaction of chlorine with water is a *disproportionation* reaction.

Use the oxidation numbers in **(i)** to explain why.

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..... **[2]**

(iii) Chlorine reacts with sodium hydroxide to form bleach in another disproportionation reaction.

Write an equation for this reaction.

..... **[1]**

(d) Two other chlorine compounds of chlorine are chlorine dioxide and chloric(V) acid.

(i) Chlorine dioxide, ClO_2, is used as a bleaching agent in both the paper and the flour industry. When dry, ClO_2 decomposes explosively to form oxygen and chlorine.

Construct an equation for the decomposition of ClO_2.

..... **[1]**

(ii) Chloric(V) acid has the following percentage composition by mass:

H, 1.20%; Cl, 42.0%; O, 56.8%.

Using this information, calculate the empirical formula of chloric(V) acid.

Show **all** of your working.

empirical formula = ... **[2]**

(iii) What does (V) represent in chloric(V) acid?

.....

..... **[1]**

[Total: 14]

4 The table below shows the melting points and atomic radii of the elements in Period 3, Na to C*l*.

element	Na	Mg	A*l*	Si	P	S	C*l*
melting point/°C	98	639	660	1410	44	113	–101
atomic radius/pm	186	160	143	118	110	102	99

$1\,pm = 1 \times 10^{-12}\,m$

(a) (i) Explain the difference in melting point for the elements Na and Mg.

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..... **[3]**

(ii) Sulfur exists as S_8 molecules and chlorine as Cl_2 molecules. Use this information to explain the difference in their melting points.

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..... **[2]**

(b) Explain the decrease in the atomic radii across the period from Na to C*l*.

In your answer, you should use appropriate technical terms, spelt correctly.

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..... **[3]**

[Total: 8]

5 The Group 2 element barium, Ba, is silvery white when pure but blackens when exposed to air. The blackening is due to the formation of both barium oxide and barium nitride. The nitride ion is N^{3-}.

(a) Predict the formula of:

barium oxide …… barium nitride …… **[2]**

(b) A 0.11 g sample of pure barium was added to 100 cm^3 of water.

$$Ba(s) + 2H_2O(l) \longrightarrow Ba(OH)_2(aq) + H_2(g)$$

(i) Show that 8.0×10^{-4} mol of Ba were added to the water.

[1]

(ii) Calculate the volume of hydrogen, in cm^3, produced at room temperature and pressure.

volume = ... cm^3 **[1]**

(iii) Calculate the concentration, in mol dm^{-3}, of the $Ba(OH)_2(aq)$ solution formed.

concentration = ... mol dm^{-3} **[1]**

(iv) State the approximate pH of the $Ba(OH)_2(aq)$ solution.

..... **[1]**

TURN OVER FOR QUESTION 5(c) AND 5(d)

(c) A student repeated the experiment in **(b)** using a 0.11 g sample of barium that had blackened following exposure to the air.

Suggest why the volume of hydrogen produced would be slightly less than the volume collected using pure barium.

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..... **[1]**

(d) Describe and explain the trend, down the group, in the reactivity of the Group 2 elements with water.

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..... **[5]**

[Total: 12]

END OF QUESTION PAPER

Answer **all** the questions.

1 Hydrogen, H_2, reacts with nitrogen monoxide, NO, as shown in the equation below.

$$2H_2(g) + 2NO(g) \rightarrow N_2(g) + 2H_2O(g)$$

A chemist carries out a series of experiments and determines the rate equation for this reaction:

$$\text{rate} = k[H_2(g)][NO(g)]^2$$

(a) In one of the experiments, the chemist reacts together:

- 1.2×10^{-2} mol dm^{-3} $H_2(g)$
- 6.0×10^{-3} mol dm^{-3} NO(g)

The initial rate of this reaction is 3.6×10^{-2} mol dm^{-3} s^{-1}.

Calculate the rate constant, *k*, for this reaction. State the units, if any.

k = ... units ..... **[3]**

(b) Predict what would happen to the initial rate of reaction for the following changes in concentrations.

(i) The concentration of $H_2(g)$ is doubled.

..... **[1]**

(ii) The concentration of NO(g) is halved.

..... **[1]**

(iii) The concentrations of $H_2(g)$ and NO(g) are **both** increased by four times.

.....

..... **[1]**

(c) The chemist carries out the reaction between hydrogen and nitrogen monoxide at a higher pressure.

(i) Explain, with a reason, what happens to the initial rate of reaction.

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.....

.....

..... **[1]**

(ii) State what happens to the rate constant.

..... **[1]**

(d) This overall reaction between hydrogen and nitrogen monoxide takes place by a two-step mechanism. The first step is much slower than the second step.

Suggest a possible two-step mechanism for the overall reaction.

step 1: .....

step 2: ..... **[2]**

[Total: 10]

2 Iron and platinum are transition elements. They both form ions that combine with ligands to form complex ions. Some of these complexes are important in biological systems.

(a) Complete the electron structures of:

an atom of Fe: $1s^2 2s^2 2p^6$ .....

an ion of Fe^{2+}: $1s^2 2s^2 2p^6$ ..... **[2]**

(b) State **one** property of Fe^{2+}, other than the ability to form complex ions, which is typical of an ion of a transition element.

.....

..... **[1]**

(c) Aqueous iron(II) sulfate takes part in redox reactions.

Using oxidation numbers, show that both reduction and oxidation have taken place in the redox reaction of aqueous iron(II) sulfate shown below.

$$6FeSO_4 + 7H_2SO_4 + Na_2Cr_2O_7 \longrightarrow 3Fe_2(SO_4)_3 + Cr_2(SO_4)_3 + Na_2SO_4 + 7H_2O$$

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..... **[2]**

(d) Hexaaquairon(II) ions, $[Fe(H_2O)_6]^{2+}$, take part in a ligand substitution reaction with ammonia.

$$[Fe(H_2O)_6]^{2+}(aq) + 6NH_3(aq) \rightleftharpoons [Fe(NH_3)_6]^{2+}(aq) + 6H_2O(l)$$

Write an expression for the stability constant, K_{stab}, for this equilibrium.

[2]

(e) Haemoglobin is a complex of iron(II).

(i) Explain how ligand substitutions allow haemoglobin to transport oxygen in the blood.

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..... **[2]**

(ii) In the presence of carbon monoxide, less oxygen is transported in the blood.

In terms of stability constants, suggest why.

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..... **[2]**

(f) Platin, $Pt(NH_3)_2Cl_2$, is a complex of platinum(II) that has two stereoisomers. One of these stereoisomers is used in medicine.

(i) Platin is a neutral complex.

Explain why platin is neutral.

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..... **[1]**

(ii) Draw diagrams of the two stereoisomers of platin and describe its bonding.

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..... **[3]**

(iii) Describe the action of platin in the treatment of cancer patients.

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..... **[1]**

(g) The use of platin in medicine can cause unpleasant side effects for patients.

In the search for alternatives, chemists often start with the current drug and modify its properties by chemically changing some of the groups.

A recent discovery is a drug called carboplatin. The structure of carboplatin is similar to platin except that a single 1,1-cyclobutanedicarboxylate ion replaces the two chloride ligands in the structure of platin.

Draw the structures of,

- the 1,1-cyclobutanedicarboxylate ion
- carboplatin.

1,1-cyclobutanedicarboxylate ion

carboplatin

[2]

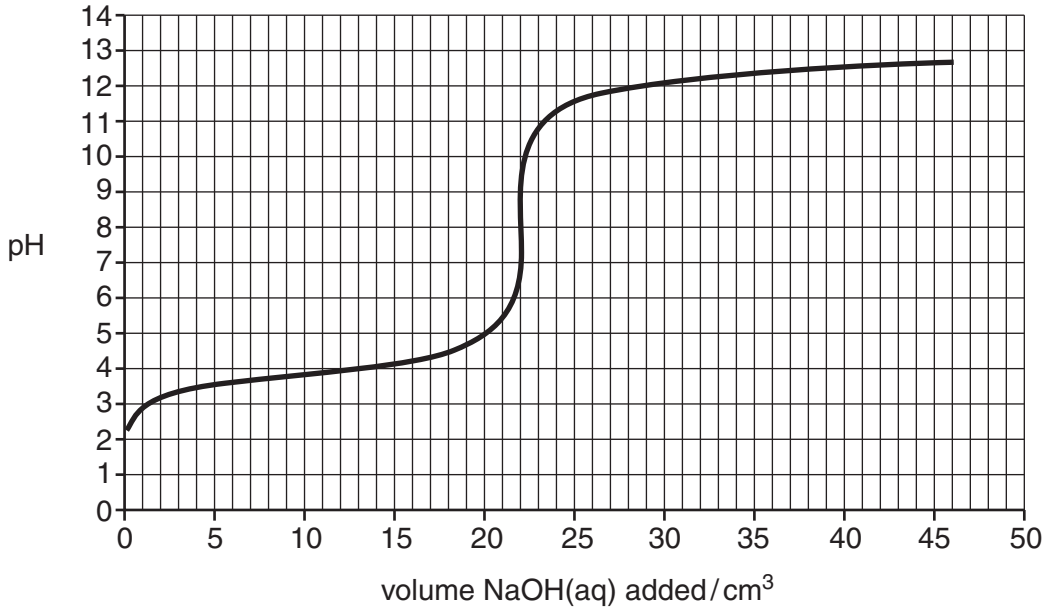
[Total: 18]

3 Glycolic acid, $HOCH_2COOH$, and thioglycolic acid, $HSCH_2COOH$, are weak acids.

(a) Glycolic acid reacts with bases, such as aqueous sodium hydroxide, NaOH(aq), to form salts.

A student pipetted 25.0 cm^3 of 0.125 mol dm^{-3} glycolic acid into a conical flask. The student added NaOH(aq) from a burette. A pH meter and data logger were used to measure continuously the pH of the contents of the conical flask.

The pH curve that the student obtained is shown below.



1 mol of glycolic acid reacts with 1 mol of sodium hydroxide.

(i) Write the equation for the reaction that takes place in the titration.

..... **[1]**

(ii) Determine the concentration, in mol dm^{-3}, of the NaOH.

concentration of NaOH = ... mol dm^{-3} **[2]**

(iii) The student decided to carry out this titration using an acid–base indicator.

What important factor does the student need to consider when deciding on the most suitable indicator to use for this titration?

.....

.....

..... **[1]**

(b) The 0.125 mol dm^{-3} glycolic acid had a pH of 2.37.

(i) What is the expression for the acid dissociation constant, K_a, of glycolic acid?

[1]

(ii) Calculate K_a for glycolic acid.

K_a = …… units …… **[3]**

(iii) Calculate the percentage molar dissociation of the glycolic acid.

percentage dissociation = ... % **[1]**

(c) A buffer of glycolic acid and ammonium glycolate is used in a facial cleanser.

Explain, using equations,

- how a solution containing glycolic acid and glycolate ions can act as a buffer
- how this buffer could be prepared from ammonia and glycolic acid.

In your answer you should explain how the equilibrium system allows the buffer solution to control the pH.

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.... **[7]**

(d) Ammonium thioglycolate, $HSCH_2COONH_4$, is the ammonium salt of thioglycolic acid, $HSCH_2COOH$.

When ammonium thioglycolate is dissolved in water, an acid–base equilibrium is set up. The equilibrium lies well to the left-hand side.

$HSCH_2COO^-(aq)$ + $NH_4^+(aq)$ $\rightleftharpoons$ $HSCH_2COOH(aq)$ + $NH_3(aq)$

…… …… …… ……

In the spaces above,

- label one conjugate acid–base pair as '**Acid 1**' and '**Base 1**'
- label the other conjugate acid–base pair as '**Acid 2**' and '**Base 2**'. **[2]**

(e) Ammonium thioglycolate is used by hairdressers to perm hair.

Hair is a protein and its shape is largely the result of cross-linked disulfide bonds, –S–S–. The formula of the protein in hair can be represented as R–S–S–R.

Perming of hair involves two stages.

Stage 1

- Hair is first wound around curlers and a solution of ammonium thioglycolate is applied to the hair.
- In this process, each disulfide bond is broken by two thioglycolate ions to form two molecules containing thiol groups, –S–H, and one other product.

Stage 2

- After 15–30 minutes, the hair is rinsed with a weak solution of hydrogen peroxide, H_2O_2.
- The hydrogen peroxide reforms disulfide bonds that lock the hair in the shape of the curlers. The hair is now 'permed'.

Suggest equations for the two processes that take place during perming.
In your equations, use R–S–S–R to represent the protein in hair.

Stage 1

Stage 2

[2]

[Total: 20]

4 Redox reactions are used to generate electrical energy from electrochemical cells.

(a) **Table 4.1** shows three redox systems, and their standard redox potentials.

redox system	$E^{\ominus}$/V
$Cu^{+}(aq) + e^{-} \rightleftharpoons Cu(s)$	+0.52
$Cr^{3+}(aq) + 3e^{-} \rightleftharpoons Cr(s)$	–0.74
$Sn^{4+}(aq) + 2e^{-} \rightleftharpoons Sn^{2+}(aq)$	+0.15

Table 4.1

(i) Draw a labelled diagram to show how the standard electrode potential of a Sn^{4+}/Sn^{2+} redox system could be measured.

[3]

(ii) Using the information in **Table 4.1**, write equations for the reactions that are feasible.

Suggest **two** reasons why these reactions may **not** actually take place.

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..... **[5]**

(b) Modern fuel cells are being developed as an alternative to the direct use of fossil fuels. The 'fuel' can be hydrogen but many other substances are being considered.
In a methanol fuel cell, the overall reaction is the combustion of methanol.

As with all fuel cells, the fuel (methanol) is supplied at one electrode and the oxidant (oxygen) at the other electrode.

Oxygen reacts at the positive electrode of a methanol fuel cell:

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

(i) Write an equation for the complete combustion of methanol.

..... **[1]**

(ii) Deduce the half-equation for the reaction that takes place at the negative electrode in a methanol fuel cell.

..... **[1]**

(iii) State **two** advantages of vehicles using fuel cells compared with the combustion of conventional fossil fuels.

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..... **[2]**

(iv) Suggest **one** advantage of using methanol, rather than hydrogen, in a fuel cell for vehicles. Justify your answer.

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..... **[1]**

[Total: 13]

5 Entropy changes are an important factor in determining the feasibility of reactions.

(a) You are provided with equations for four processes.

A $2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$
B $H_2O(l) \longrightarrow H_2O(g)$
C $H_2(g) + ½O_2(g) \longrightarrow H_2O(l)$
D $2C(s) + O_2(g) \longrightarrow 2CO(g)$

For each process, explain why ΔS has the sign shown below.

A: sign of ΔS: negative

reason for sign: .....

.....

B: sign of ΔS: positive

reason for sign: .....

.....

C: sign of ΔS: negative

reason for sign: .....

.....

D: sign of ΔS: positive

reason for sign: .....

..... **[4]**

(b) Calcium oxide, CaO, is used to make cement. Calcium oxide is manufactured by the thermal decomposition of calcium carbonate.

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g) \qquad \Delta H = +178\,kJ\,mol^{-1}$$

Standard entropies of $CaCO_3(s)$, CaO(s) and $CO_2(g)$ are given in the table below.

substance	$CaCO_3(s)$	CaO(s)	$CO_2(g)$
S **/ J K^{-1}mol^{-1}**	89	40	214

- Using the information in the table, show that the entropy change, ΔS, for the decomposition of calcium carbonate is $0.165\,kJ\,K^{-1}\,mol^{-1}$.
- Show that calcium carbonate is stable at room temperature (25 °C).
- Calculate the minimum temperature needed to decompose calcium carbonate.

Show all your working.

[7]

[Total: 11]

6 The dissociation of water is a reversible reaction.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The ionic product of water, K_w, measures the extent of dissociation of water.

K_w varies with temperature. Therefore, it is always important to quote the temperature at which measurements are being taken.

Fig. 6.1 shows the variation of K_w between 0 °C and 60 °C.

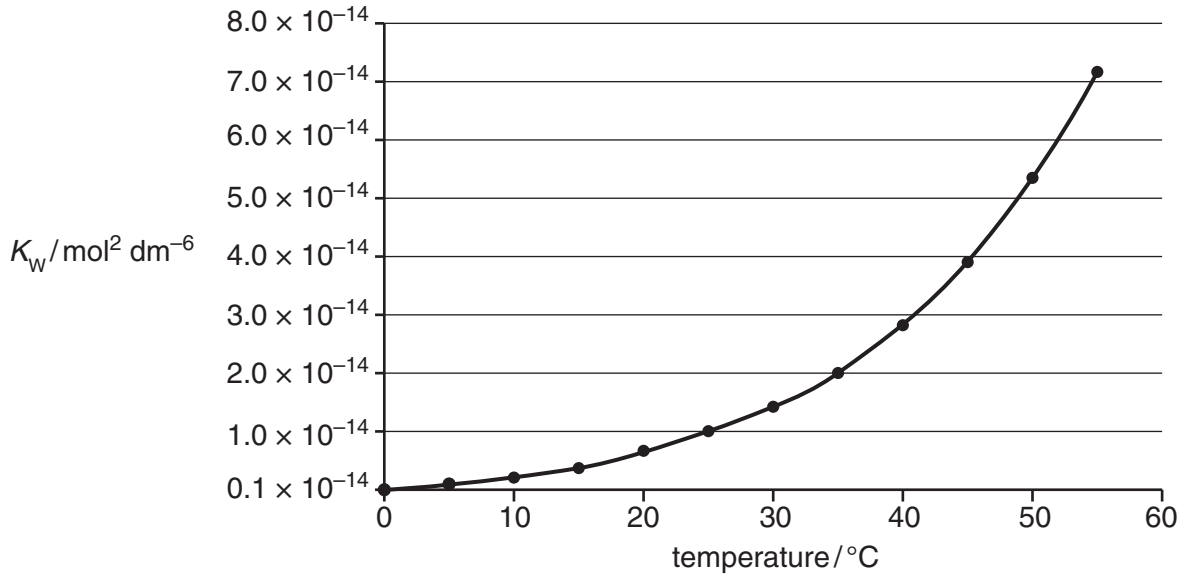

Fig. 6.1

(a) (i) Write the expression for K_w.

..... **[1]**

(ii) Calculate the $OH^-(aq)$ concentration in an aqueous solution of hydrochloric acid with a pH of 4.37 at 25 °C.

Give your answer to **two** significant figures.

OH^- concentration = ... mol dm^{-3} **[2]**

(b) (i) Using **Fig. 6.1**, explain whether the dissociation of water is an exothermic or endothermic process.

.....

.....

.....

..... **[1]**

(ii) Determine the pH of pure water at body temperature, 37 °C.

pH = ... **[3]**

(iii) Many experimental measurements use published data, such as K_w, measured at 25 °C. Often these measurements have been taken at different temperatures, especially in experimental work carried out at body temperature.

What is the consequence of this for published scientific work?

.....

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.....

..... **[1]**

(c) The reverse reaction of the dissociation of water is called neutralisation.

Plan an experiment that a student could carry out to measure the enthalpy change of neutralisation.

In your answer you should explain how the enthalpy change of neutralisation could be calculated from the experimental results.

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..... **[6]**

(d) When dissolved in water, the enthalpy change of solution of the salt potassium fluoride, KF, is $-15\,kJ\,mol^{-1}$.

The salt rubidium fluoride, RbF, has an enthalpy change of solution in water of $-24\,kJ\,mol^{-1}$.

Suggest reasons for the difference between the enthalpy changes of solution of KF and RbF.

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..... **[4]**

(e) A student hurt his ankle whilst playing football. The physiotherapist applied a cold pack to soothe the pain.

The cold pack is made of two separated compartments, one containing ammonium nitrate crystals, NH_4NO_3, the other containing water. The pack is activated by breaking the barrier between the two compartments. The crystals dissolve spontaneously in the water causing the temperature of the pack to drop.

Explain why ammonium nitrate in the cold pack dissolves spontaneously in water even though this process is endothermic.

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.....

..... **[2]**

[Total: 20]

7 The Dissolved Oxygen Concentration (DOC) in rivers and lakes is important for aquatic life. If the DOC falls below 5 mg dm^{-3}, most species of fish cannot survive.

Environmental chemists can determine the DOC in water using the procedure below.

- A sample of river water is shaken with aqueous Mn^{2+} and aqueous alkali.
  The dissolved oxygen oxidises the Mn^{2+} to Mn^{3+}, forming a pale brown precipitate of $Mn(OH)_3$.

$$O_2(aq) + 4Mn^{2+}(aq) + 8OH^-(aq) + 2H_2O(l) \longrightarrow 4Mn(OH)_3(s)$$

- The $Mn(OH)_3$ precipitate is then reacted with an excess of aqueous potassium iodide, which is oxidised to iodine, I_2.

$$2Mn(OH)_3(s) + 2I^-(aq) \longrightarrow I_2(aq) + 2Mn(OH)_2(s) + 2OH^-(aq)$$

- The iodine formed is then determined by titration with aqueous sodium thiosulfate, $Na_2S_2O_3(aq)$.

$$2S_2O_3^{2-}(aq) + I_2(aq) \longrightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

A 25.0 cm^3 sample of river water was analysed using the procedure above.

The titration required 24.6 cm^3 of 0.00100 mol dm^{-3} $Na_2S_2O_3(aq)$.

(a) (i) Calculate the DOC of the sample of river water, in mg dm^{-3}.

DOC = ... mg dm^{-3} **[4]**

(ii) Comment on whether there is enough dissolved oxygen in the river water for fish to survive.

.....

.....

..... **[1]**

(b) The presence of nitrate(III) ions, NO_2^-, interferes with this method because NO_2^- ions can also oxidise iodide ions to iodine.

During the reaction, a colourless gas is produced with a molar mass of $30\,g\,mol^{-1}$.

(i) Predict the formula of the colourless gas.

..... **[1]**

(ii) Write an equation for the oxidation of aqueous iodide ions by aqueous nitrate(III) ions. Hydroxide ions are produced in this reaction.

..... **[2]**

[Total: 8]

END OF QUESTION PAPER

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.

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(2 marks)

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

.....

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(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*.

.....

.....

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.....

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(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)

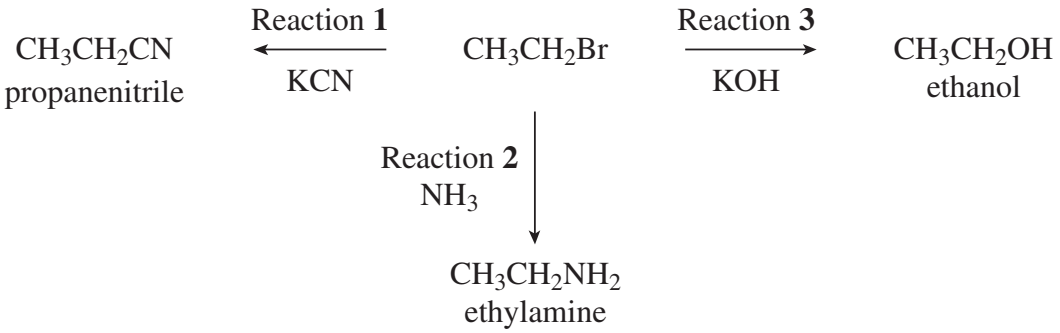
7 (c) (ii) Draw the structure of (*E*)-but-2-ene.

.....

(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.

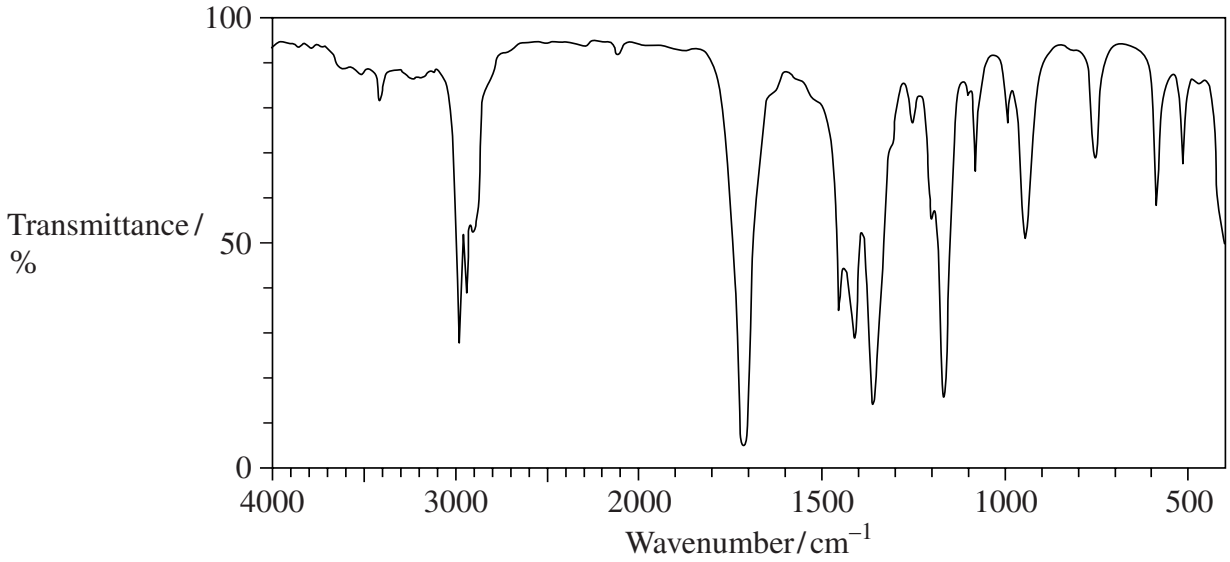
$$CH_3CH_2CH(OH)CH_3 + [O] \longrightarrow CH_3CH_2COCH_3 + H_2O$$

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

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.

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(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

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.

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(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.

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(1 mark)

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

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(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 $R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$)

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

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.....

.....

(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.

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(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.

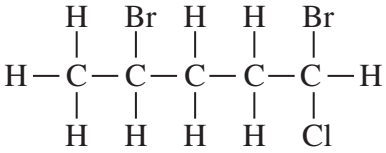
.....

.....

(1 mark)

Question 4 continues on the next page

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

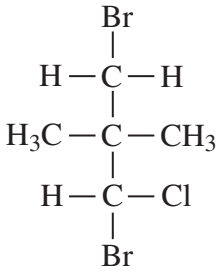


4 (e) (i) Name **Q**.

.....

(1 mark)

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



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(1 mark)

11

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.

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(2 marks)

(Extra space) .....

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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

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(3 marks)

(Extra space) .....

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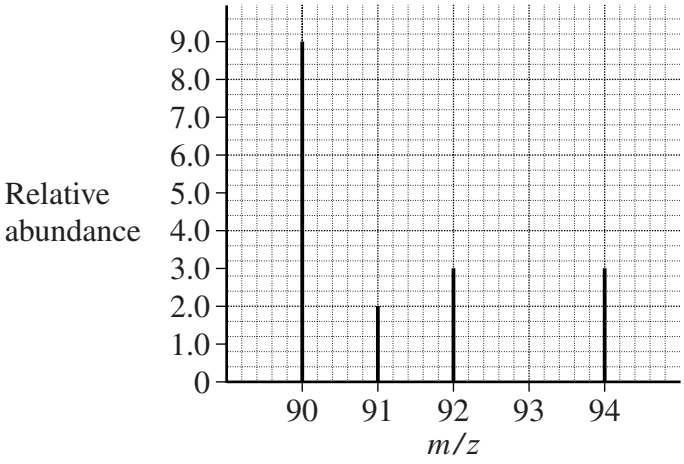
Question 5 continues on the next page

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