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National
Qualifications
2022

Mark

X813/76/01

Chemistry
Paper 2

FRIDAY, 29 APRIL
10:10 AM – 12:30 PM

X81376 01

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth
Day Month Year

Scottish candidate number

Total marks — 95

Attempt ALL questions.

You may use a calculator.

You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. Score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

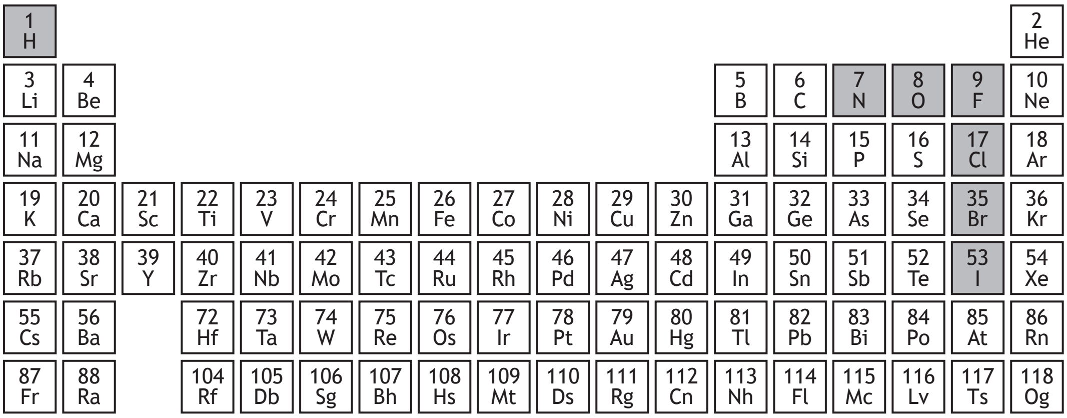
Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

Total marks — 95

Attempt ALL questions

1. Elements and compounds can exist as diatomic molecules.

(a) The seven elements that exist as diatomic molecules are shown in the periodic table below.



1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

(i) Explain why diatomic elements form non-polar molecules. **1**

(ii) Nitrogen, oxygen and fluorine are found in the second period of the periodic table.

Explain the decrease in covalent radius going from nitrogen to fluorine. **1**

(b) First ionisation energies decrease going down a group.

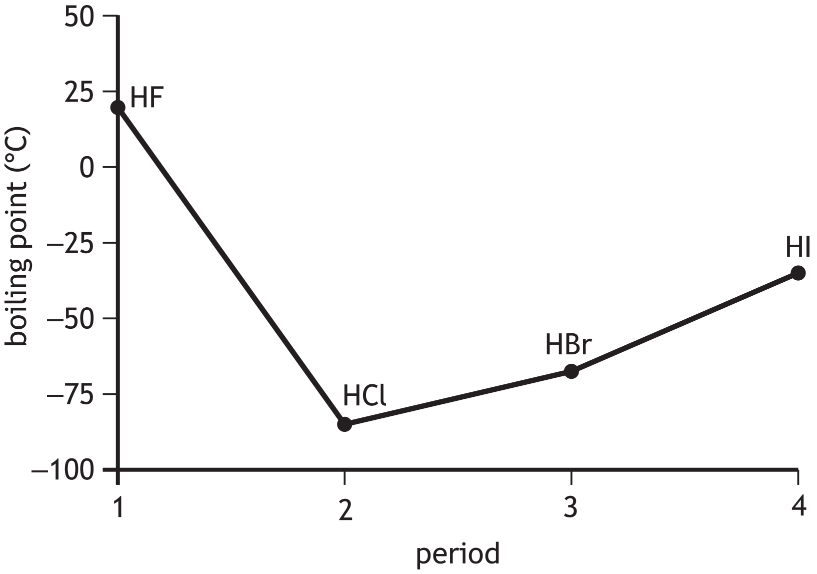
(i) State what is meant by the term *first ionisation energy*. **1**

1. (b) (continued)

(ii) Explain why the first ionisation energy of the group 7 elements decreases going down the group. **1**

(c) Hydrogen halides are diatomic molecules formed between hydrogen and the elements fluorine, chlorine, bromine and iodine.

The boiling points of the hydrogen halides are shown on the graph below.



(i) Hydrogen fluoride, HF, has the highest boiling point of the hydrogen halides.

State the name of the strongest type of intermolecular force found between hydrogen fluoride molecules and explain how this type of intermolecular force arises. **2**

[Turn over

1. (c) (continued)

(ii) The table shows the boiling points of hydrogen chloride, hydrogen bromide and hydrogen iodide.

Hydrogen halide	**Boiling point (°C)**
Hydrogen chloride	–85
Hydrogen bromide	–66
Hydrogen iodide	–35

Explain **fully** why the boiling point increases from hydrogen chloride to hydrogen iodide. **2**

2. Fireworks contain a range of chemicals including a fuel, oxidising agents and metal salts.

(a) One oxidising agent used in fireworks is potassium perchlorate, $KClO_4$. This reacts with aluminium metal and produces a bright flash.

The equation for the reaction is

$$KClO_4 \quad + \quad Al \quad \rightarrow \quad KCl \quad + \quad Al_2O_3$$

Balance this equation. **1**

(b) Fireworks were traditionally made using compounds containing the chlorate ion, ClO_3^-, as an oxidising agent.

(i) Chlorate ions release oxygen when they decompose.

Potassium chlorate, $KClO_3$, ($GFM = 122.6$ g) reacts as shown.

$$2KClO_3(s) \quad \rightarrow \quad 3O_2(g) \quad + \quad 2KCl(s)$$

Calculate the volume of oxygen produced, in litres, when 4.6 g of potassium chlorate decomposes. **2**

Take the volume of 1 mole of oxygen gas to be 24 litres.

[Turn over

2. (b) (continued)

(ii) The decomposition of potassium chlorate can be speeded up by the addition of a catalyst.

State the effect of adding a catalyst on the enthalpy change for this reaction. **1**

(iii) A firework containing 5.5 g of potassium perchlorate ($GFM = 138.6$ g) releases 103 kJ of energy.

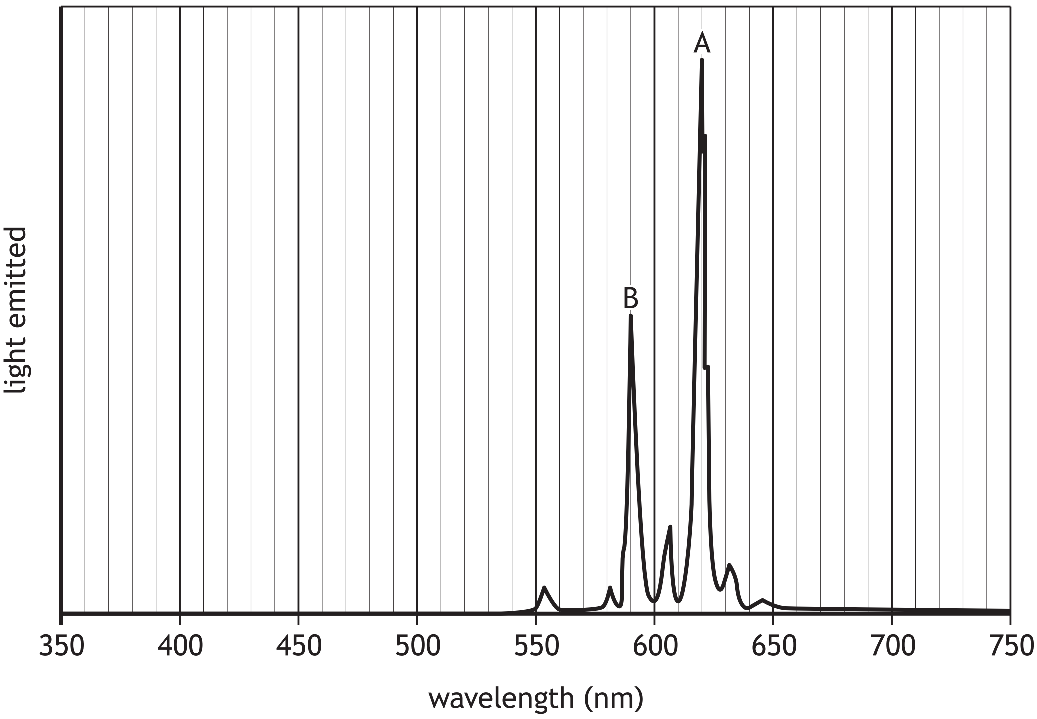
Calculate the energy, in kJ, released per mole of potassium perchlorate. **1**

2. (b) (continued)

(iv) Explain **fully** why increasing temperature increases the rate of a chemical reaction. **2**

(c) The different flame colours produced by metal salts are caused by different wavelengths of light being emitted. The flame colours associated with different wavelengths are given in the data booklet.

The following profile shows the colours emitted by one particular firework. Each peak represents a different colour of light.



Peak A has a wavelength of 620 nm, corresponding to red light.

Suggest the **metal** responsible for peak B on the spectrum. **1**

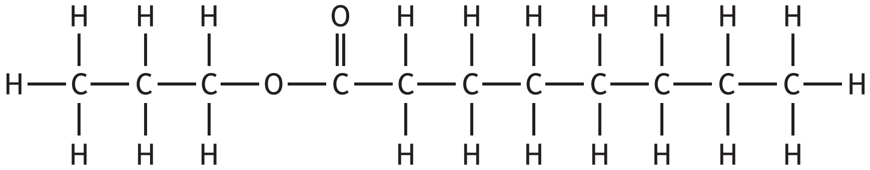
[Turn over

3. Atoms of different elements have different attractions for bonding electrons. Electronegativity is a measure of the attraction an atom involved in a bond has for the electrons in the bond.

Using your knowledge of chemistry, discuss the importance of electronegativity in bonding, structure and properties of compounds. **3**

4. Coconut oil contains a mixture of compounds.

(a) Propyl octanoate is a compound found in coconut oil.



(i) Name the functional group in propyl octanoate. **1**

(ii) Draw a structural formula for the carboxylic acid formed by hydrolysis of propyl octanoate. **1**

(iii) An isomer of propyl octanoate with the same functional group was hydrolysed. One of the products of this hydrolysis was butanoic acid.

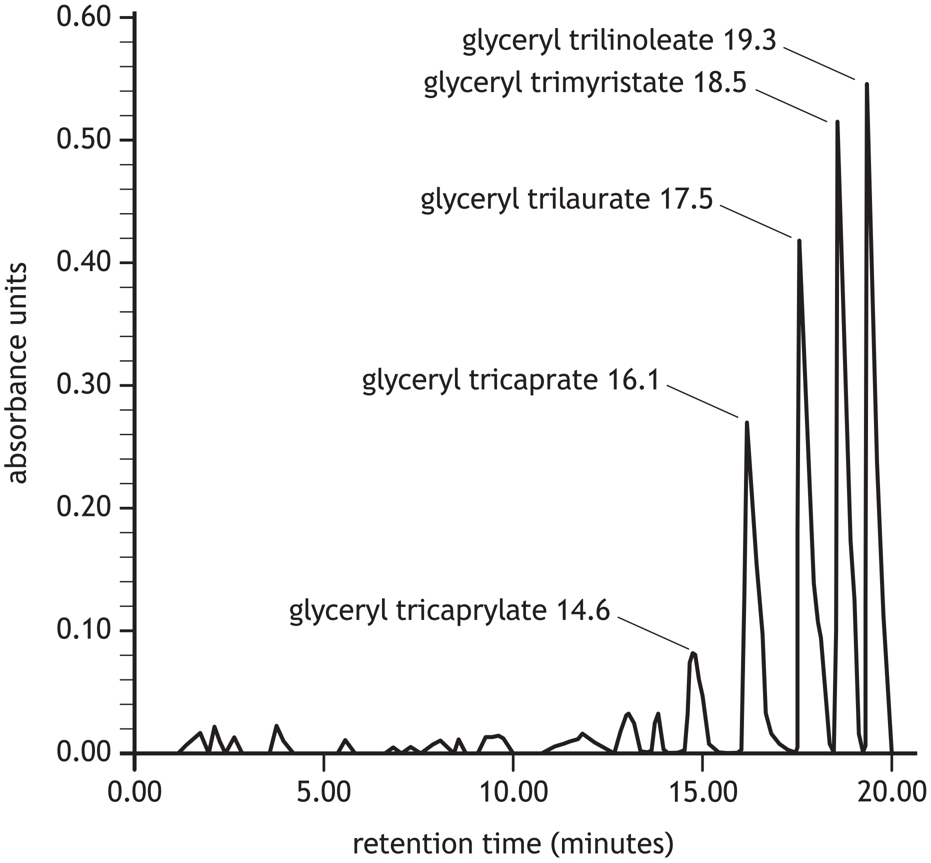
Suggest a name for the other product. **1**

[Turn over

4. (continued)

(b) Chromatography can be used to separate the fats and oils in coconut oil.

The result of a chromatography experiment is shown.



(i) Using the graph **and** the information in the table, predict the number of carbons in glyceryl trilaurate. **1**

Name	Molecular formula	Melting point (°C)
Glyceryl tricaprylate	$C_{27}H_{50}O_6$	10
Glyceryl tricaprate	$C_{33}H_{62}O_6$	31
Glyceryl trilinoleate	$C_{57}H_{98}O_6$	–5

4. (b) (continued)

(ii) Identify the compound listed in the table which is the most unsaturated. **1**

(c) Edible oils such as coconut oil can be used to make emulsifiers.

(i) State how emulsifiers are made from edible oils. **1**

(ii) Explain **fully** how emulsifiers prevent non-polar and polar liquids from separating into layers. **2**

[Turn over

5. Fusel oil is formed as a by-product during the production of bioethanol for fuel. It is a mixture of several alcohols.

(a) The shortened structural formula of one of the alcohols contained in fusel oil is shown.

$$CH_3CH(CH_3)CH_2CH_2OH$$

State the name of this alcohol. **1**

(b) Propan-1-ol is also found in fusel oil.

Propan-1-ol is reacted with an oxidising agent to produce propanal.

(i) Complete the ion-electron equation for the oxidation reaction. **1**

$$C_3H_7OH \qquad \rightarrow \qquad C_3H_6O$$

(ii) Acidified potassium dichromate can be used as the oxidising agent and reacts as shown below.

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(\ell)$$

Suggest why the potassium dichromate must be acidified. **1**

5. (b) (continued)

(iii) State the colour change that would be observed when propan-1-ol reacts with acidified potassium dichromate. **1**

(iv) The equation for the reduction of another oxidising agent that could be used to oxidise propan-1-ol is shown below.

$$Ag^{+}(aq) \quad + \quad e^{-} \quad \rightarrow \quad Ag(s)$$

Name the reagent that provides this oxidising agent. **1**

(v) State why 2-methylbutan-2-ol cannot be oxidised using these oxidising agents. **1**

(vi) In the reaction of butan-1-ol to butanal, oxidation can be identified by an increase in the oxygen to hydrogen ratio.

Complete the table to show the oxygen to hydrogen ratios in butan-1-ol and butanal. **1**

	Oxygen to hydrogen ratio
Butan-1-ol	
Butanal	

[Turn over

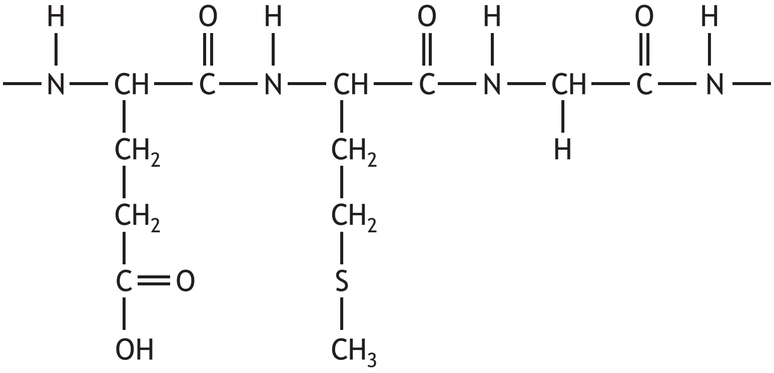
6. Sweet potatoes contain nutrients, including starch, vitamin C and proteins.

(a) Catalase is an enzyme contained in sweet potatoes that speeds up the breakdown of hydrogen peroxide.

(i) State what is meant by the term enzyme. **1**

(ii) Enzymes are a type of protein. Proteins are formed from smaller molecules called amino acids.

(A) A section of a protein is shown.



Circle a peptide link in the above structure. **1**

(An additional diagram can be found on *page 33*.)

(B) Draw a structural formula for one of the amino acids used to form this section of protein. **1**

6. (a) (ii) (continued)

(C) State what is meant by the term **essential** amino acid. 1

(D) Name the type of reaction that takes place when amino acids join to form proteins. 1

(iii) As sweet potatoes are cooked, the ability of catalase to break down hydrogen peroxide decreases.

Explain **fully** what happens to the enzyme structure to cause this reduction in activity. 2

[Turn over

6. (a) (continued)

(iv) Hydrogen peroxide is broken down by catalase to produce water and oxygen.

An experiment was carried out to determine how much oxygen was produced from the breakdown of hydrogen peroxide by a sample of sweet potato.

Draw a diagram showing assembled apparatus that could be used to react hydrogen peroxide solution with sweet potato and measure the volume of oxygen produced.

Your diagram should include labels showing the names and positions of the reactants and the collected product. **3**

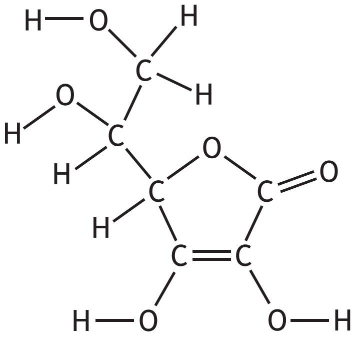
(b) Sweet potatoes are a good source of the antioxidant vitamin C.

(i) Antioxidants like vitamin C are added to food.

Explain why antioxidants are added to food. **1**

6. (b) (continued)

(ii) The structure of vitamin C is shown.



Explain **fully** why vitamin C is soluble in water. **2**

(c) Unlike sweet potatoes, white potatoes contain the chemical solanine, that can be toxic to humans in large doses. A dose of 3 mg per kg of body weight can cause toxic symptoms.

A typical white potato can contain 0.2 mg per g of solanine.

Calculate the mass of white potato that could produce a toxic dose to an adult weighing 65 kg. **3**

[Turn over

7. Natural gas is a source of methane.

(a) Methane, CH_4, can be used as a fuel.

In an experiment, methane was burned to raise the temperature of 100 cm^3 of water by 27 °C.

Using the enthalpy of combustion of methane (891 $kJ\,mol^{-1}$), calculate the mass of methane, in g, burned in this experiment. **3**

(b) The equation for the combustion of methane is shown.

$$CH_4(g) \quad + \quad 2O_2(g) \quad \rightarrow \quad CO_2(g) \quad + \quad 2H_2O(g)$$

Bond enthalpies can be used to calculate a theoretical enthalpy change for this reaction.

Using bond enthalpies from the data booklet, calculate the enthalpy change, in $kJ\,mol^{-1}$, for the combustion of methane. **2**

7. (continued)

(c) Methane reacts with steam to produce hydrogen.

$$\underset{GFM = 16\text{ g}}{CH_4(g)} + \underset{GFM = 18\text{ g}}{H_2O(g)} \rightarrow \underset{GFM = 28\text{ g}}{CO(g)} + \underset{GFM = 2\text{ g}}{3H_2(g)}$$

Calculate the atom economy for the formation of hydrogen. **2**

(d) Another naturally occurring gas is nitrogen dioxide, NO_2.

Nitrogen dioxide exists in equilibrium with dinitrogen tetroxide, N_2O_4.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58\text{ kJ mol}^{-1}$$

Complete the table to show the conditions that would maximise the yield of **nitrogen dioxide**. **1**

Condition	High/Low
Temperature	
Pressure	

[Turn over

7. (continued)

(e) (i) In the United States Space Shuttle, dinitrogen tetroxide was reacted with methylhydrazine.

$$4CH_3NHNH_2(\ell) + 5N_2O_4(\ell) \rightarrow 4CO_2(g) + 12H_2O(g) + 9N_2(g)$$

Calculate the enthalpy of this reaction, in kJ, by using the data shown below. **2**

$$C(s) + 3H_2(g) + N_2(g) \rightarrow CH_3NHNH_2(\ell) \quad \Delta H = +54\ \text{kJ mol}^{-1}$$

$$N_2(g) + 2O_2(g) \rightarrow N_2O_4(\ell) \quad \Delta H = -20\ \text{kJ mol}^{-1}$$

$$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -394\ \text{kJ mol}^{-1}$$

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(\ell) \quad \Delta H = -286\ \text{kJ mol}^{-1}$$

$$H_2O(l) \rightarrow H_2O(g) \quad \Delta H = +41\ \text{kJ mol}^{-1}$$

(ii) Draw the full structural formula for methylhydrazine, CH_3NHNH_2. **1**

8. Fizzy drinks are made by adding carbon dioxide gas, preservative, colouring and flavouring to water.

(a) Carbon dioxide for fizzy drinks can be produced using the water-gas shift reaction.

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

(i) A catalyst for this reaction is copper(II) oxide.

Complete the table by circling one option on each line to show the effect of copper(II) oxide on the reaction. **2**

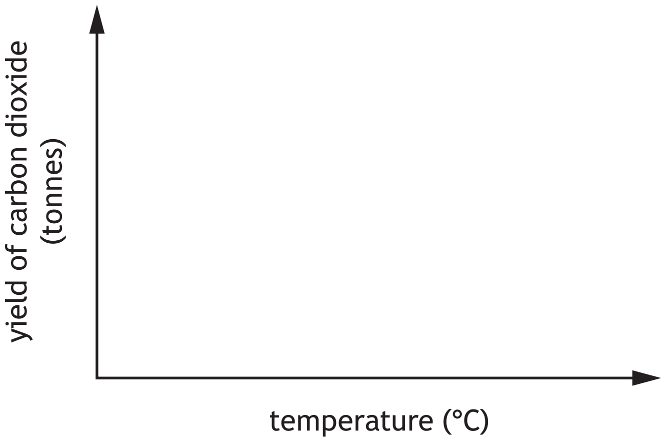
(An additional table can be found on *page 33*.)

Feature of reaction	**Effect of catalyst**
Rate of forward reaction	increase/decrease/no effect
Rate of reverse reaction	increase/decrease/no effect
Position of equilibrium	moves to right/moves to left/no effect

(ii) The water-gas shift reaction is exothermic.

Draw a line on the axes below to show how the yield of carbon dioxide would vary with increasing temperature. **1**

(An additional diagram can be found on *page 33*.)



[Turn over

8. (continued)

(b) A preservative added to some fizzy drinks is made by reacting sorbic acid and potassium hydroxide.

In an experiment, 7 g of sorbic acid, $C_6H_8O_2$, is reacted with 250 cm^3 of potassium hydroxide solution, concentration 0.5 mol l^{-1}.

$$C_6H_8O_2(s) \quad + \quad KOH(aq) \quad \rightarrow \quad H_2O(\ell) \quad + \quad C_6H_7O_2K(aq)$$

$GFM = 112$ g

Show, by calculation, that sorbic acid is the limiting reactant. **2**

8. (continued)

(c) Ammonium ferric citrate ($GFM = 261.8$ g) gives some drinks a characteristic orange colour. A typical drink contains 0.002% of ammonium ferric citrate.

A 1% solution contains 1 g made up to 100 cm^3 of solution.

Calculate the number of moles of ammonium ferric citrate required to make 330 cm^3 of this fizzy drink. **2**

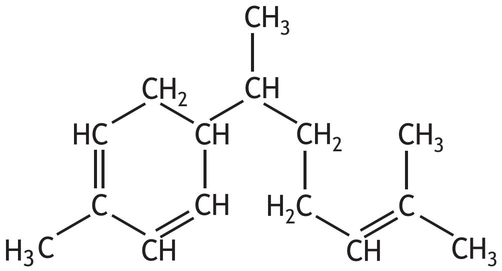
[Turn over

8. (continued)

(d) Ginger root is used as a flavouring for some fizzy drinks.

(i) Ginger oil is an essential oil obtained from ginger root.

Zingiberene is one of the main components in this essential oil.



zingiberene

(A) State one property of an essential oil. **1**

(B) Zingiberene is formed from isoprene units.

(I) Name the type of compound formed when isoprene units join together. **1**

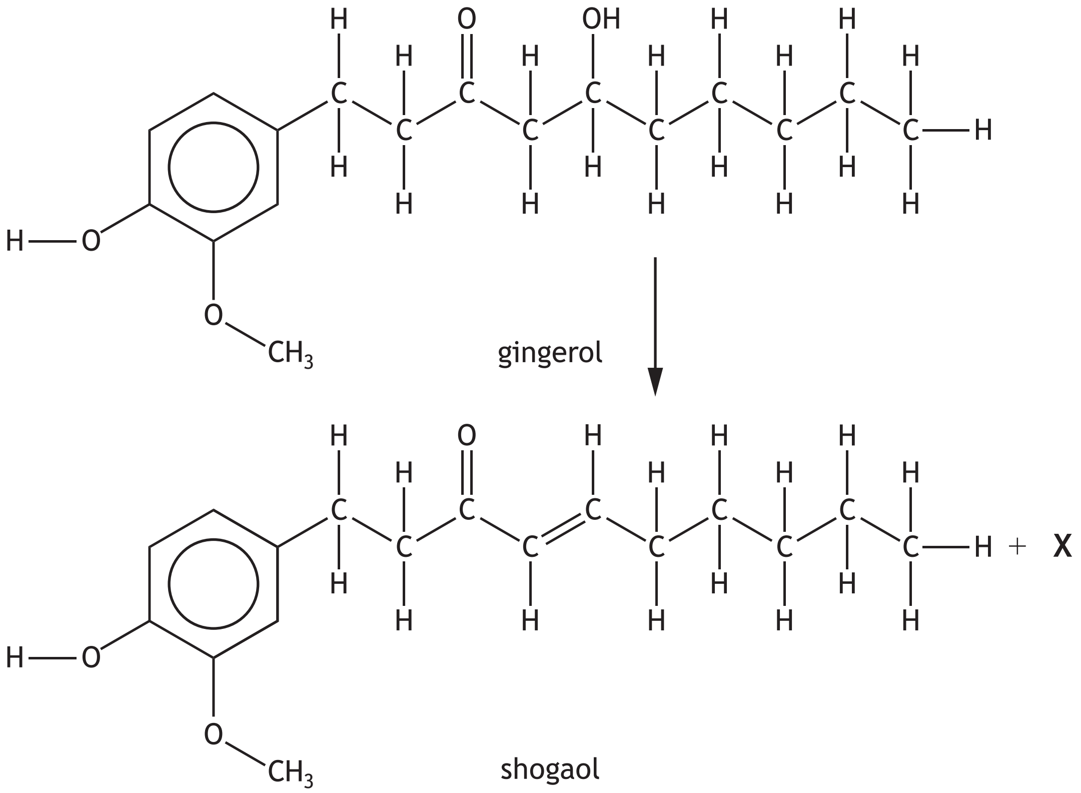
(II) Isoprene is also called 2-methyl-1,3-butadiene.

Draw a structural formula for isoprene. **1**

(III) State the number of isoprene units in a zingiberene molecule. **1**

8. (d) (continued)

(ii) Gingerol is another compound found in ginger root. Gingerol can form the compound shogaol as shown.



(A) Name product **X**. 1

(B) Name two functional groups present in gingerol and shogaol that are **not** present in zingiberene. 1

9. For a particular set of reaction conditions, the actual yield is the quantity of desired product made in a reaction.

Some examples of reactions with their desired products are shown.

Equation	Desired product
$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$	$BaSO_4(s)$
$CH_3OH(\ell) + C_2H_5COOH(\ell) \rightleftharpoons C_2H_5COOCH_3(\ell) + H_2O(\ell)$	$C_2H_5COOCH_3(\ell)$
$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$	$H_2(g)$

Using your knowledge of chemistry, describe how the actual yield in a reaction could be determined.

Your answer should include experimental procedures that could be used to determine the quantity of product made in reactions such as the examples shown in the table. **3**

9. (continued)

[Turn over

10. A refrigerant is a chemical used in cooling processes. Some refrigerant compounds can damage the ozone layer.

(a) The ozone depletion potential (ODP) of a refrigerant compound is the relative amount of damage that it can cause to the ozone layer. The higher the number, the greater the damage.

	Refrigerant compound	**Ozone depletion potential**
1	$C_2F_4Br_2$	6.00
2	CF_2ClBr	3.00
3	C_2FCl_5	1.00
4	$C_2F_3Cl_3$	0.85
5	$C_2F_4Cl_2$	0.58
6	$C_2H_3Cl_3$	0.16

(i) Describe a relationship between the formulae of refrigerant compounds 3, 4 and 5 and their ODP. **1**

(ii) Identify which pair of compounds should be used to show the effect of replacing chlorine atoms with bromine atoms in refrigerant compounds. **1**

(iii) The refrigerants carbon dioxide, CO_2, and ammonia, NH_3, have ODP values of 0.00.

Suggest why this is the case. **1**

10. (continued)

(b) The compound difluoromethane, CH_2F_2, is also used as a refrigerant. It is made by reacting fluorine gas with fluoromethane, CH_3F, in a free radical chain reaction.

(i) State what is meant by a free radical. **1**

(ii) The first step in the reaction involves splitting a fluorine molecule to produce two fluorine radicals.

$$F_2 \rightarrow 2F\bullet$$

(A) State the name given to this step. **1**

(B) Write an equation for a possible propagation step in this reaction. **1**

(c) Household fridges use coolants made from refrigerant compounds. A common coolant is made from 50% difluoromethane, CH_2F_2, ($GFM = 52$ g) and 50% pentafluoroethane, CF_3CHF_2, ($GFM = 120$ g).

A typical fridge contains 0.05 kg of coolant.

Calculate the number of moles of pentafluoroethane required to make this mass of coolant. **1**

[Turn over

11. Spinach is a leafy green vegetable.

(a) Fertilisers containing copper(II) ethanoate are used to supply spinach with copper ions.

Copper(II) ethanoate can be made by reacting copper(II) carbonate with ethanoic acid.

(i) Name the other products of this reaction. **1**

(ii) Write the ionic formula of copper(II) ethanoate. **1**

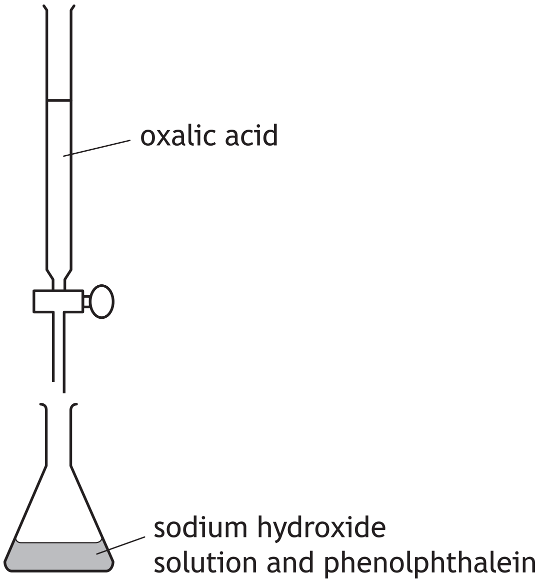
(b) Spinach is a source of oxalic acid.

A standard solution of oxalic acid can be used to determine the accurate concentration of a sodium hydroxide solution.

Given an accurately known mass of oxalic acid, describe **fully** how 250 cm^3 of a standard solution of oxalic acid could be prepared. **3**

11. (continued)

(c) The concentration of sodium hydroxide can be determined by titration with oxalic acid.



An accurate volume of sodium hydroxide solution is measured into a conical flask using a pipette.

(i) Draw a diagram of a pipette suitable for measuring an accurate volume. **1**

(ii) The indicator used in this titration is phenolphthalein. Phenolphthalein is colourless in acidic and neutral solutions but is pink in alkaline conditions.

State the colour change that would be observed at the end point in this titration. **1**

[Turn over

11. (c) (continued)

(iii) The titration was repeated until results were obtained that were within 0.2 cm^3 of each other.

State the term used to describe titre volumes within 0.2 cm^3 of each other. **1**

(d) The equation for the reaction of oxalic acid and sodium hydroxide is shown.

$$H_2C_2O_4(aq) + 2NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2H_2O(\ell)$$

The concentration of sodium hydroxide solution was determined by titrating 25.0 cm^3 samples with 0.126 mol l^{-1} oxalic acid solution.

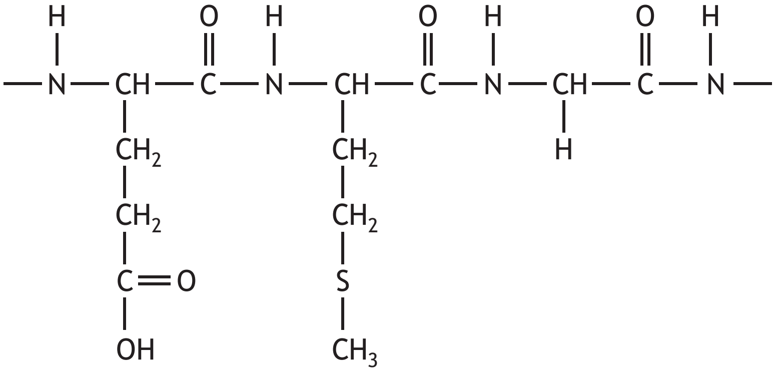
The average volume of oxalic acid solution required in the titration was 26.75 cm^3.

Calculate the concentration, in mol l^{-1}, of the sodium hydroxide. **3**

[END OF QUESTION PAPER]

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

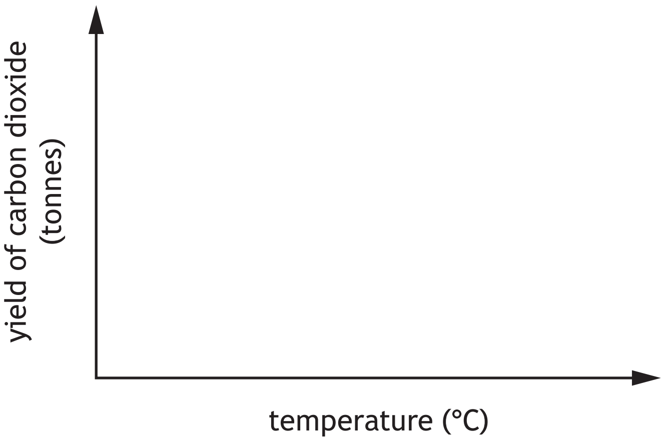
Additional diagram for question 6 (a) (ii) (A)



Additional table for question 8 (a) (i)

Feature of reaction	Effect of catalyst
Rate of forward reaction	increase/decrease/no effect
Rate of reverse reaction	increase/decrease/no effect
Position of equilibrium	moves to right/moves to left/no effect

Additional diagram for question 8 (a) (ii)



ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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