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National Qualifications 2019

Mark

X813/76/01

Chemistry Paper 2

FRIDAY, 10 MAY

10:10 AM – 12:30 PM

X8137601

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.

SQA ©

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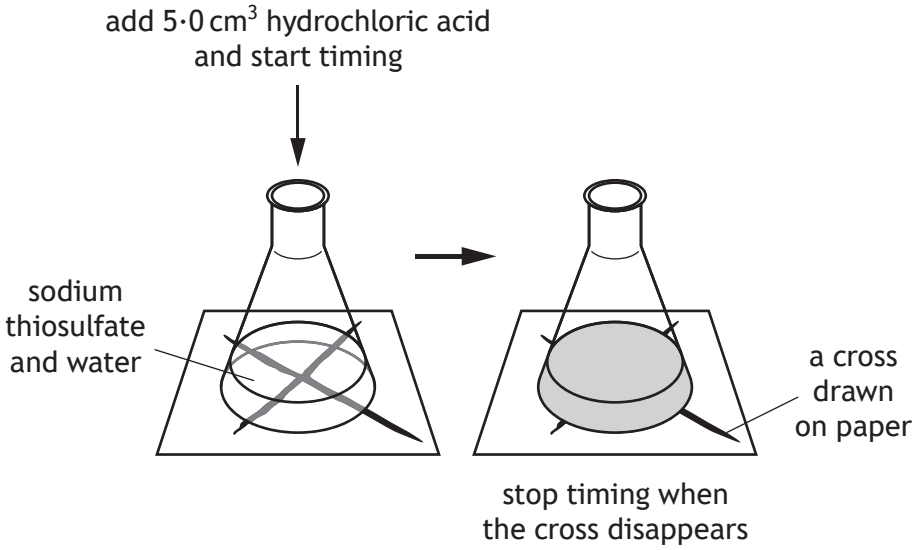
Total marks — 95

Attempt ALL questions

1. Sodium thiosulfate, $Na_2S_2O_3$, can be used to investigate the effect of reaction conditions on the rate of reaction.

(a) Sodium thiosulfate solution reacts with hydrochloric acid to form a precipitate of solid sulfur. By placing the reaction mixture in a conical flask over a cross and recording the time taken for the cross to disappear, the effect of changing the reaction conditions can be investigated.



(i) The equation for the reaction is

$$Na_2S_2O_3(aq) + HCl(aq) \rightarrow S(s) + SO_2(g) + NaCl(aq) + H_2O(\ell)$$

Balance the equation. **1**

1. (a) (continued)

(ii) In one set of experiments, the effect of varying the concentration of sodium thiosulfate was investigated.

Experiment	Volume of 0·15 mol l^{-1} $Na_2S_2O_3$ (cm^3)	Volume of water (cm^3)	Rate (s^{-1})
A	50	0	0·0454
B	40		0·0370
C	30		0·0285
D	20		0·0169
E	10	40	0·0063

(A) Complete the table to show the volumes of water that would have been used to vary the concentration of sodium thiosulfate. **1**

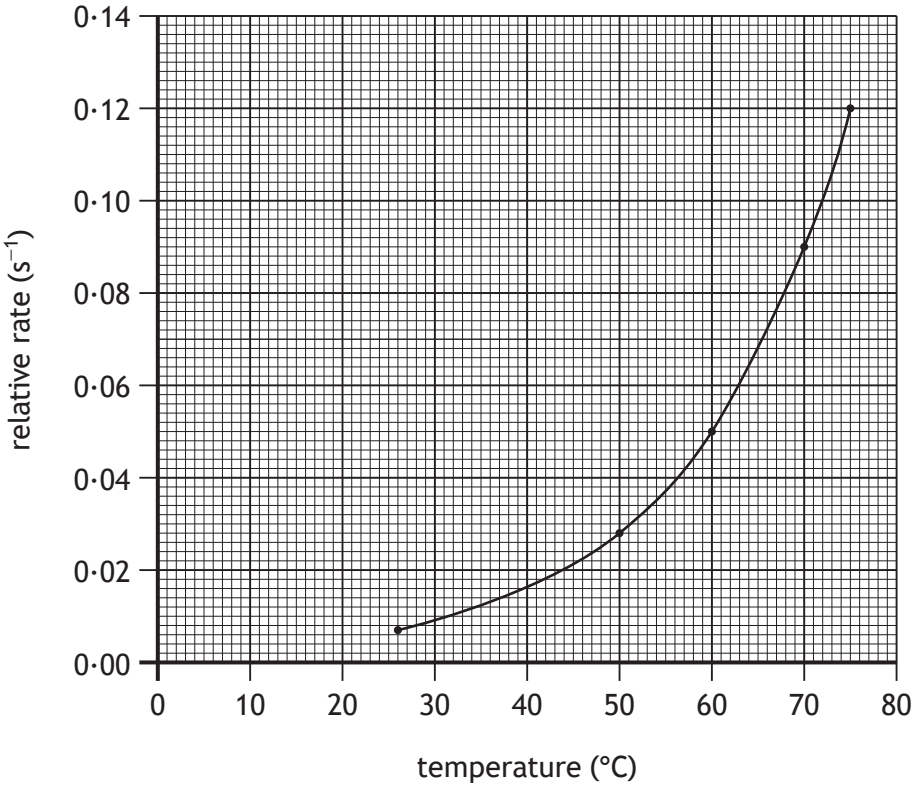
(B) Calculate the time, in seconds, for the cross to disappear in experiment C. **1**

[Turn over

1. (a) (continued)

(iii) The reaction can also be used to investigate the effect of changing temperature on the rate of reaction.

The results from an investigation are shown in the graph below.



Use the graph to determine the temperature rise, in °C, required to double the rate of the reaction. **1**

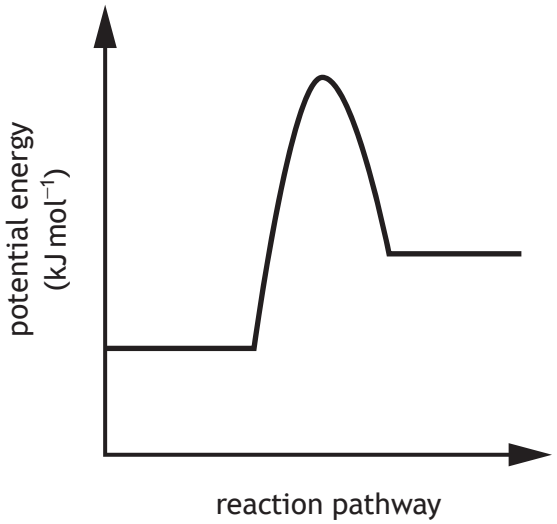
(b) Collision theory states that for particles to react they must first collide with each other.

State **two** conditions necessary for the collisions to result in the formation of products. **2**

1. (continued)

(c) Sodium thiosulfate also reacts with iron(III) nitrate.

The potential energy diagram below shows the change in potential energy during the reaction carried out without a catalyst.



(i) Draw an **X** on the potential energy diagram above to show where the activated complex is formed. **1**

(An additional diagram, if required, can be found on *page 41*).

(ii) Cu^{2+} ions catalyse the reaction.

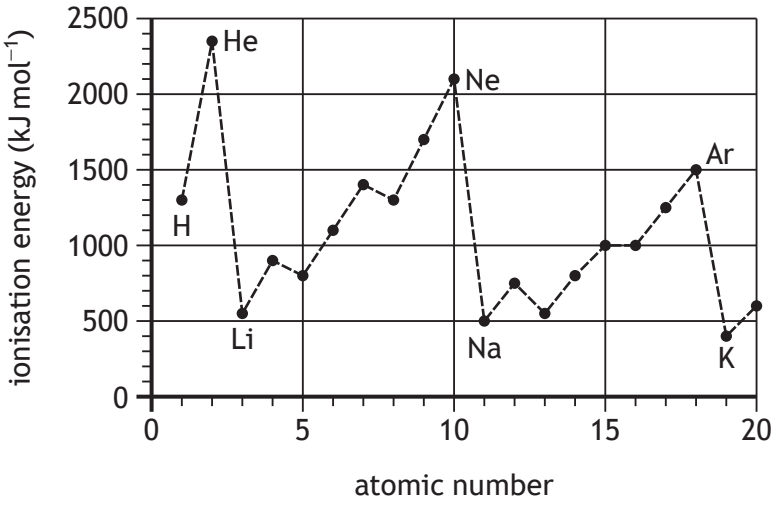
Add a dotted line to the diagram to show the change in potential energy with the catalyst. **1**

(An additional diagram, if required, can be found on *page 41*).

[Turn over

2. 2019 is the 150th anniversary of the periodic table's creation by Dmitri Mendeleev. The patterns identified by Mendeleev form the basis of the modern periodic table. The major periodic trends include ionisation energy and covalent radius.

(a) The first ionisation energies of elements with atomic number 1 to 20 are shown in the graph.

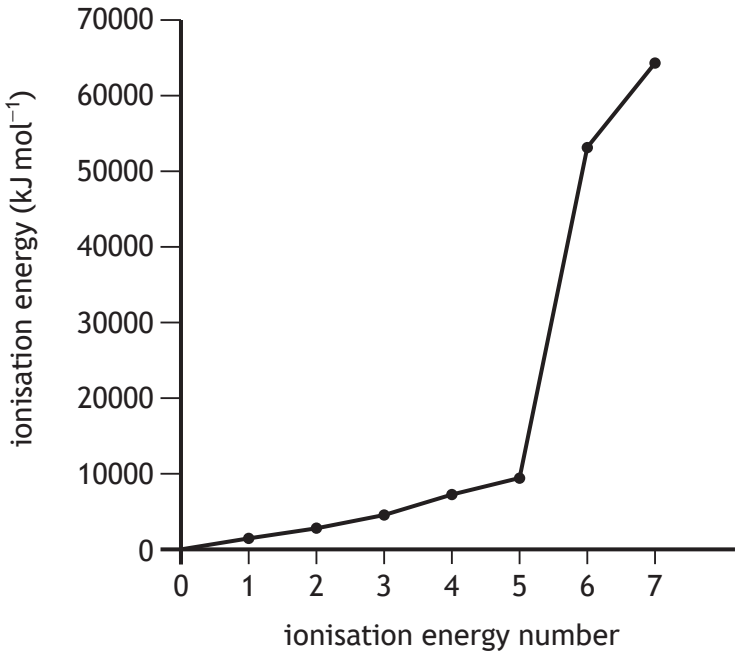


(i) Explain why the first ionisation energy shows an increase going from lithium to neon. **1**

(ii) Explain why the first ionisation energy of potassium is less than the first ionisation energy of lithium. **1**

2. (continued)

(b) A graph showing the ionisation energies for nitrogen is shown.



(i) Write the equation for the second ionisation energy of nitrogen. **1**

(ii) Explain **fully** the increase between the 5th and 6th ionisation energies of nitrogen. **2**

[Turn over

2. (continued)

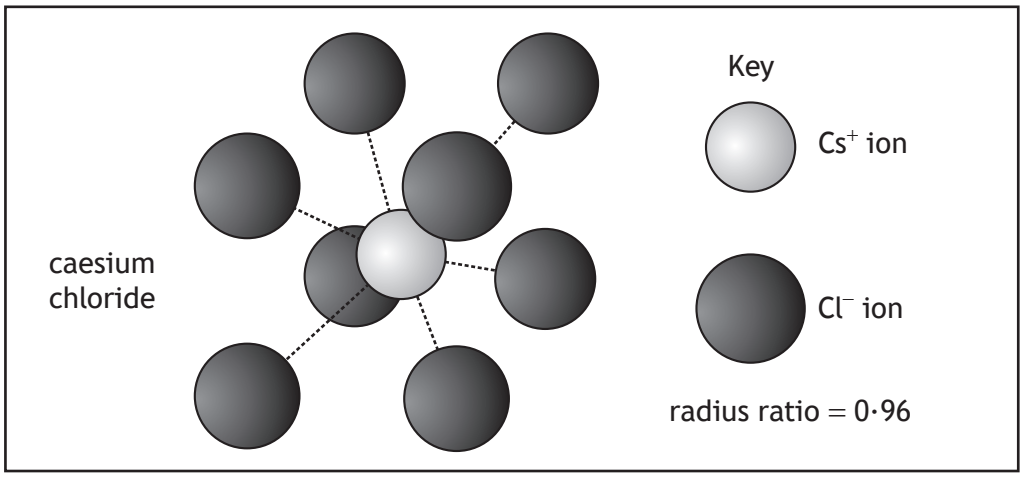
(c) Ionic radius is a measure of the size of an ion.

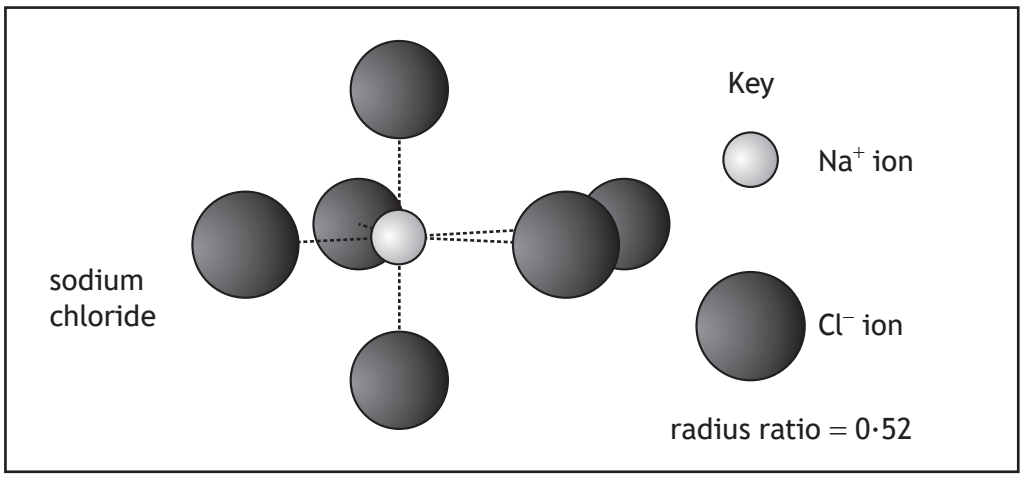
Explain **fully** why the ionic radius of phosphorus is greater than the ionic radius of aluminium. **2**

2. (continued)

(d) The structure of an ionic compound consists of a giant lattice of oppositely charged ions. The arrangement of ions is determined by the 'radius ratio' of the ions involved.

$$\text{radius ratio} = \frac{\text{radius of positive ion}}{\text{radius of negative ion}}$$





By using the table of ionic radii on *page 17* of the data booklet, predict whether the structure of barium oxide, BaO, is similar to caesium chloride or sodium chloride.

Your answer **must** include a calculated radius ratio. **1**

3. The melting point of **non-metal elements** depends on structure and bonding.
Using your knowledge of chemistry, comment on this statement. **3**

4. Cider is made from apples in a process that involves crushing and pressing the apples, converting the sugars into alcohol, maturing and bottling.

(a) Brewers add yeast, which contains a mixture of enzymes to convert the sugars in the apples into alcohol and carbon dioxide.

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

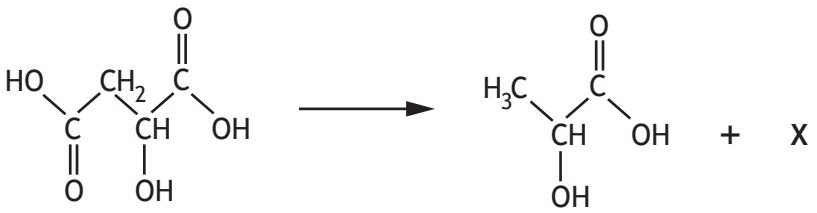
(ii) The % mass of alcohol in the cider can be calculated using the formula

$$\%\,\text{mass of alcohol} = \frac{\text{mass of alcohol}}{\text{mass of cider}} \times 100$$

A 50·0 cm^3 sample of cider was found to contain 3·05 g of alcohol. 1·0 cm^3 of the cider weighed 1·36 g.

Calculate the % mass of alcohol in the cider. **1**

(b) During the maturing process malic acid is converted to lactic acid and another product.



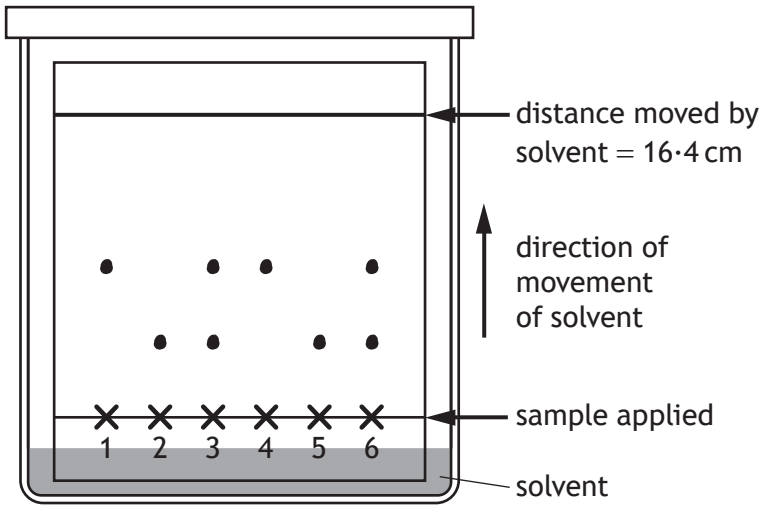
malic acid lactic acid

(i) Name compound **X**. **1**

4. (b) (continued)

(ii) The maturing process in cider samples can be monitored using thin layer chromatography.

Samples of lactic acid, malic acid and ciders A, B, C, and D are spotted on a silica plate and the solvent allowed to travel up the plate. The chromatogram obtained is shown below.



Number	Sample applied	Distance moved by spot(s) (cm)
1	lactic acid	8·2
2	malic acid	4·1
3	cider A	4·1, 8·2
4	cider B	8·2
5	cider C	4·1
6	cider D	4·1, 8·2

4. (b) (ii) (continued)

The retention factor, R_f, for a substance can be a useful method of identifying the substance.

$$R_f = \frac{\text{distance moved by the substance}}{\text{distance moved by the solvent}}$$

(A) Calculate the R_f value of malic acid. **1**

(B) The maturing process is complete when all of the malic acid has been converted to lactic acid. The cider is now ready to be bottled.

Use the chromatogram to determine which cider is ready to be bottled. **1**

[Turn over

MARKS

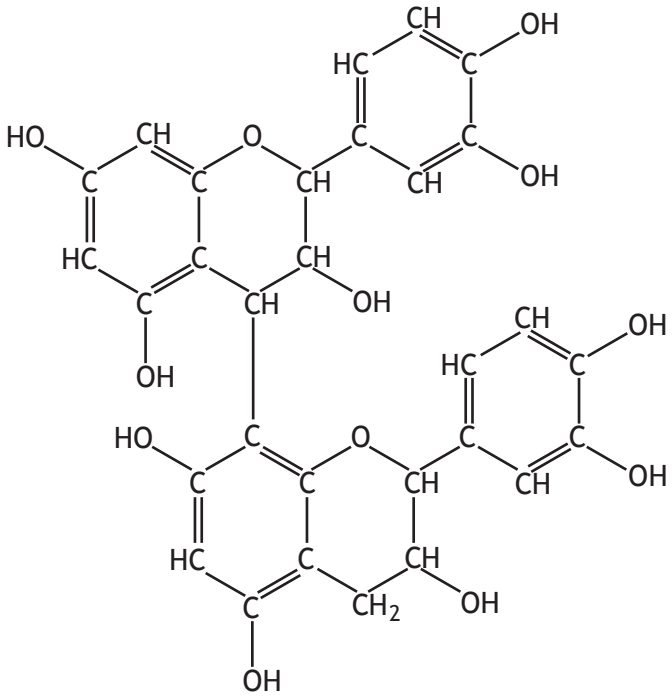
DO NOT WRITE IN THIS MARGIN

(c) Glycerol can be added to cider before bottling to produce a sweeter tasting cider.

State the systematic name for glycerol. **1**

(d) Cider contains many naturally occurring compounds that affect taste and aroma.

(i) Procyanidin B2 provides a bitter taste to cider.



procyanidin B2

Explain **fully** why procyanidin B2 is water soluble. **2**

MARKS

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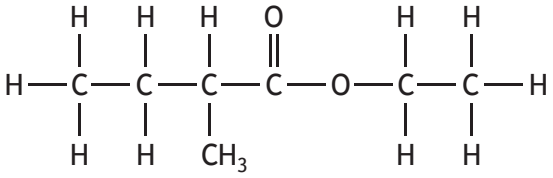
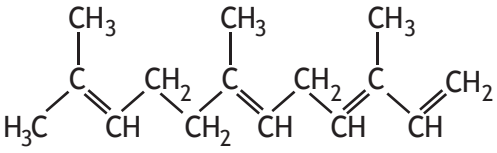
(ii) Cider smells of apples because it contains ethyl 2-methylbutanoate.



ethyl 2-methylbutanoate

Name the carboxylic acid used to make ethyl 2-methylbutanoate. **1**

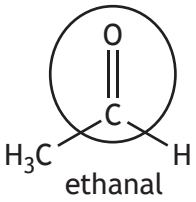
(iii) Farnesene is a terpene responsible for the ripe apple aroma of cider.



farnesene

Name the molecule on which terpenes are based. **1**

(e) Ethanol in cider can be oxidised to ethanal, spoiling the aroma.



ethanal

(i) Name the functional group circled in the ethanal molecule. **1**

(ii) Further oxidation of ethanal can produce another product that spoils the flavour of cider.

Name this product. **1**

5. The combustion reactions of methane and heptane can be studied in different ways.

(a) The combustion of methane produces carbon dioxide and water vapour when carried out at temperatures above 100 °C.

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

(i) Using bond enthalpies and mean bond enthalpies from the data booklet, calculate the enthalpy change, in kJ mol^{-1}, for this reaction. **2**

(ii) Explain the difference between bond enthalpy and mean bond enthalpy. **1**

5. (a) (continued)

(iii) Calculate the mass, in g, of carbon dioxide produced by combustion of 200 cm^3 methane in excess oxygen. **2**

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

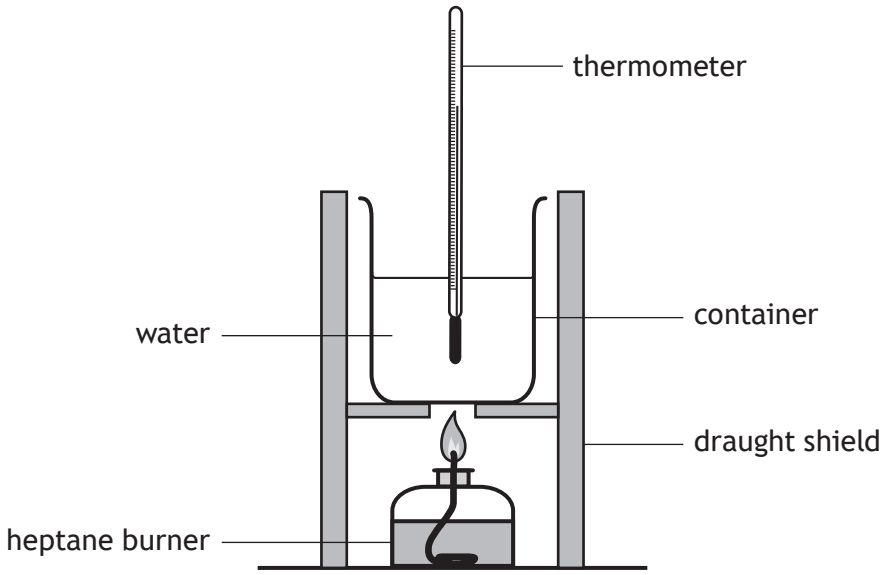
$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

GFM = 44·0 g

[Turn over

5. (continued)

(b) The enthalpy of combustion of heptane, C_7H_{16}, can be determined using a calorimeter.



The following results were obtained.

Mass of heptane burned (g)	1·1
Mass of 1 mole of heptane (g)	100·0
Volume of water used (cm^3)	400
Initial temperature of water (°C)	26
Final temperature of water (°C)	49

(i) State the measurements required to calculate the mass of heptane burned in this experiment. **1**

5. (b) (continued)

(ii) Calculate the enthalpy of combustion, in kJ mol^{-1}, for heptane from the experimental results given. **3**

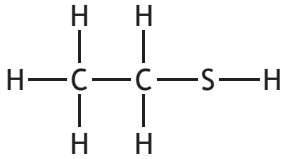
(iii) The theoretical value for the enthalpy of combustion of heptane is significantly higher than the experimental value.

Suggest why the experimental value is different to the theoretical value. **1**

[Turn over

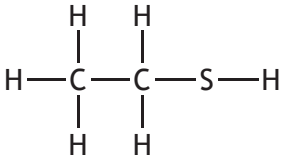
6. Thiols are compounds that contain an –SH functional group. They often have very strong, unpleasant odours.

(a) Ethanethiol is used to add a smell to gaseous fuels in order to give warnings of gas leaks.

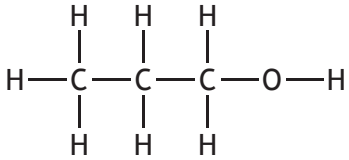


ethanethiol

(i) A student used the boiling points of ethanethiol and propan-1-ol to compare the strength of intermolecular forces.



ethanethiol
boiling point = 35 °C



propan-1-ol
boiling point = 97 °C

(A) State the reason why propan-1-ol was a suitable alcohol to compare with ethanethiol. **1**

(B) Explain why propan-1-ol has a higher boiling point than ethanethiol. Your answer should include the names of the intermolecular forces broken when each liquid boils. **2**

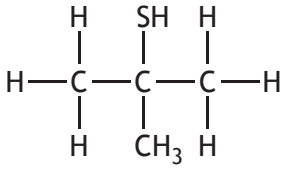
6. (a) (continued)

(ii) Name the thiol that contains only one carbon atom. **1**

(iii) The minimum concentration of ethanethiol in air that can be detected by humans is $2{\cdot}7 \times 10^{-7}$ mg per cm^3 of air.

Calculate the minimum mass of ethanethiol that needs to be present in a room containing 43 900 litres of air in order for it to be detected. **2**

(b) 2-methyl-2-propanethiol is also used to add a smell to gaseous fuels.



2-methyl-2-propanethiol

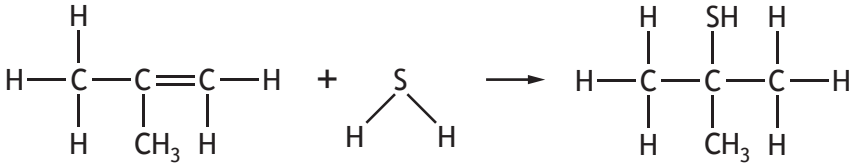
(i) Suggest why 2-methyl-2-propanethiol is classified as a tertiary thiol. **1**

[Turn over

6. (b) (continued)

(ii) Thiols can be made by the addition of hydrogen sulfide to alkenes.

2-methyl-2-propanethiol can be made by the addition reaction shown.



2-methylpropene
GFM = 56·0 g

2-methyl-2-propanethiol
GFM = 90·1 g

(A) Draw the structure for the other isomer formed in this addition reaction. **1**

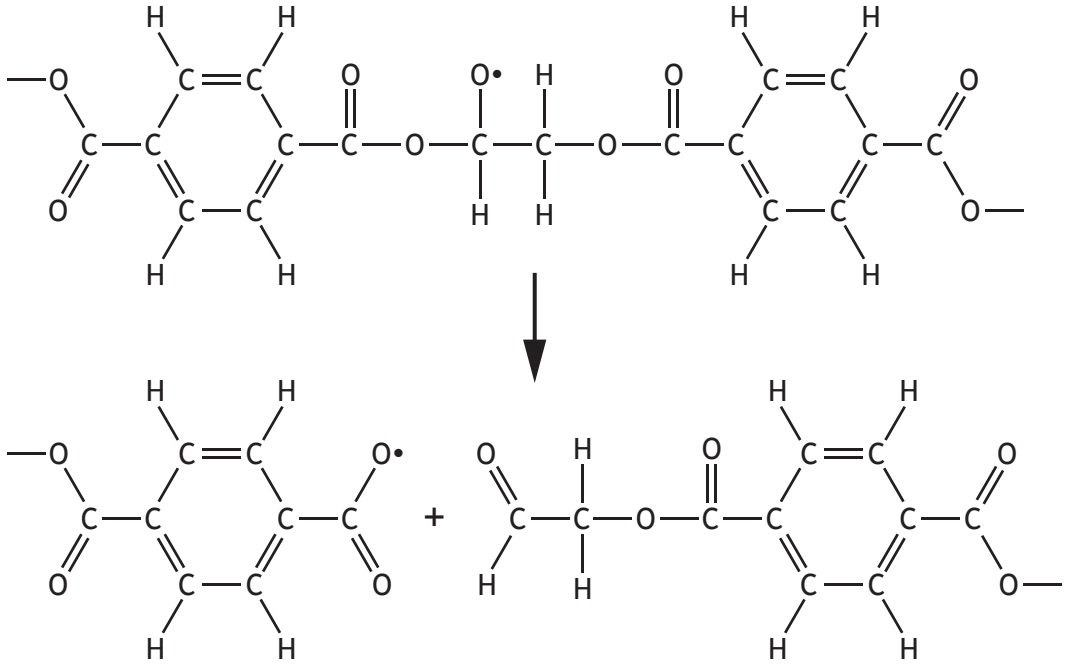
(B) A chemist obtained an 84% yield of 2-methyl-2-propanethiol after starting with 30·5 g of 2-methylpropene.

Calculate the mass, in g, of 2-methyl-2-propanethiol made by the chemist. **2**

7. Esters can be synthetic or natural.

(a) The synthetic polyester PET, poly(ethylene terephthalate), has many ester links. PET can break down by a free radical reaction.

One of the steps involved in breaking down PET is shown.



(i) State the name for this step. **1**

(ii) Name the component of sunlight that can cause plastics such as PET to break down. **1**

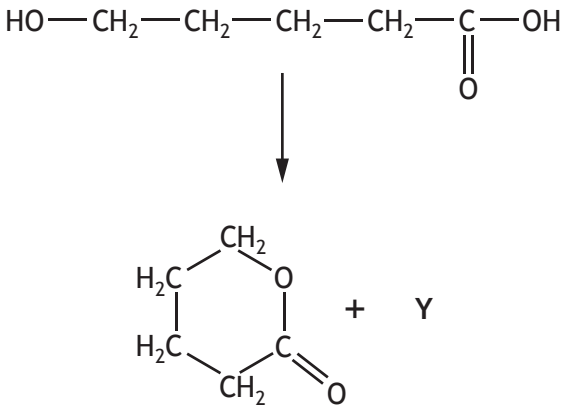
(iii) Name the type of substance that can be added to plastics to prevent them breaking down in this way. **1**

[Turn over

7. (continued)

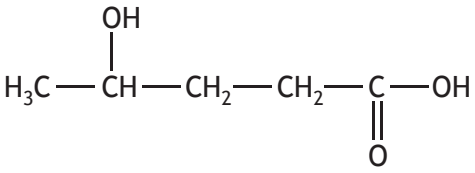
(b) (i) Natural cyclic esters called lactones can be formed from hydroxycarboxylic acids.

5-hydroxypentanoic acid is a hydroxycarboxylic acid that when heated, with dilute acid, will form a cyclic ester.



Name product **Y** in this reaction. **1**

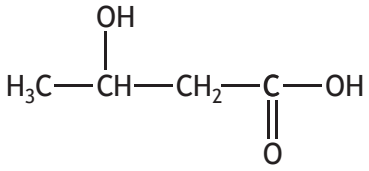
(ii) Draw the structure for the cyclic compound formed when 4-hydroxypentanoic acid is heated with dilute acid. **1**



4-hydroxypentanoic acid

7. (b) (continued)

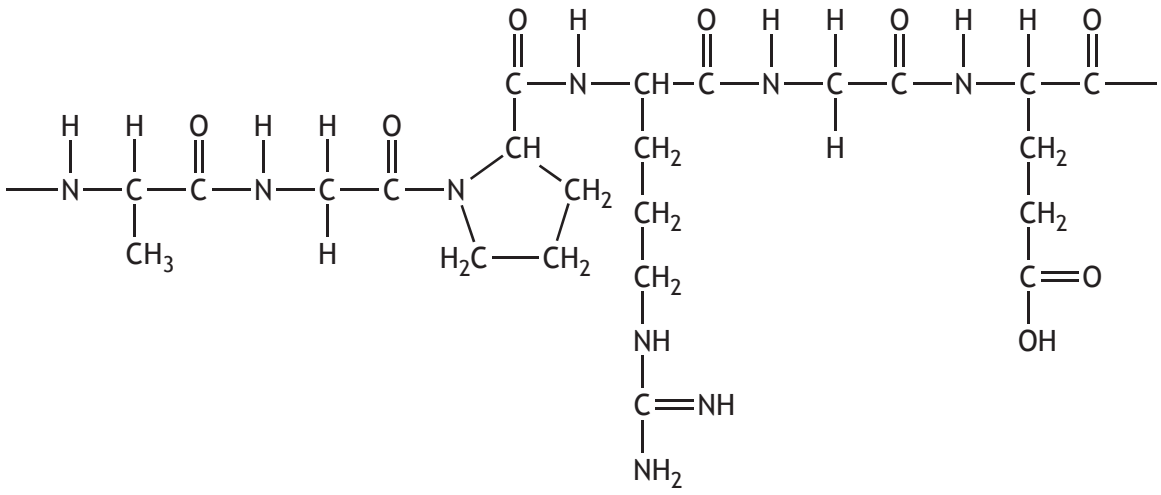
(iii) Name the hydroxycarboxylic acid shown below. **1**



[Turn over

8. Gelatin is a soluble protein that can be added to different food products.

(a) A structure for a section of a protein chain in gelatin is shown.



(i) State the number of amino acids that joined together to form the section of the protein chain shown. **1**

(ii) Name the weakest van der Waals' force between water and gelatin molecules. **1**

(b) A student was investigating the viscosity of different concentrations of gelatin solution.

(i) The student was asked to prepare a 2% gelatin solution, which is a solution that contains 2 g of gelatin per 100 cm^3 of solution.

The student prepared this solution by adding 100 cm^3 of distilled water into a volumetric flask, then adding 2 g of gelatin.

Describe how the student **should** have made up the solution. **3**

8. (b) (continued)

(ii) The results obtained from the student's viscosity experiment are shown.

Concentration of gelatin solution (%)	Viscosity (units)
2·0	1·0
4·0	2·0
6·0	4·0
8·0	7·0
10·0	

Predict the student's result for the viscosity, in units, of a 10·0% gelatin solution. **1**

(c) Bromelain is a mixture of enzymes found in pineapple that aid digestion.

(i) Adding raw pineapple to gelatin results in the gelatin molecules being hydrolysed. The rate of hydrolysis is reduced if the pineapple is cooked.

Explain why the rate of hydrolysis is reduced. **1**

(ii) Bromelain can be purchased as tablets that contain 500 mg of bromelain. The flesh from a pineapple contains 13·2 mg of bromelain per gram.

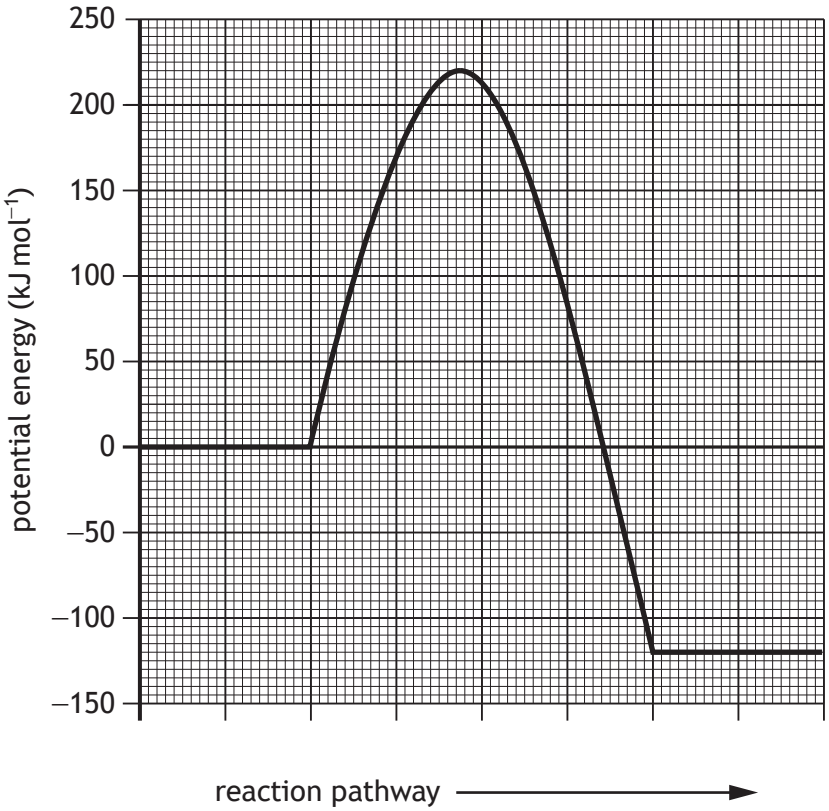
Calculate the mass, in g, of this pineapple that would be needed to provide 500 mg of bromelain. **1**

[Turn over

9. Chlorine is used in the production of many other chemicals.

(a) Chlorine can be produced by the reaction of hydrogen chloride with air using the Deacon process.

$$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$$

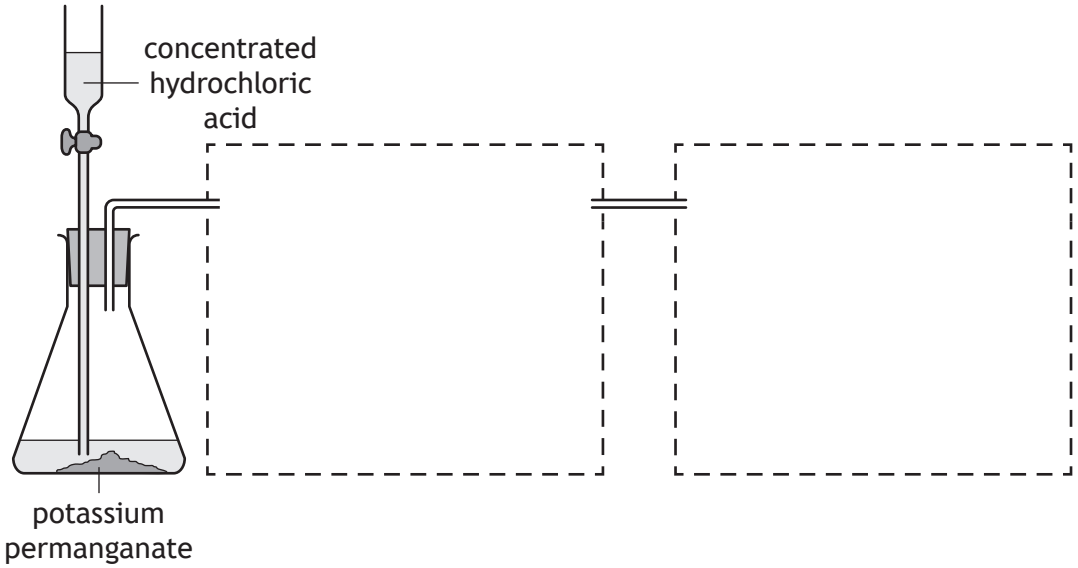


(i) Using the potential energy diagram, determine the activation energy, in kJ mol^{-1}, for the **forward** reaction. **1**

(ii) Explain why increasing the temperature in the Deacon process results in less chlorine being produced. **1**

9. (continued)

(b) One laboratory method for the preparation of chlorine gas involves adding concentrated hydrochloric acid to potassium permanganate. The chlorine gas produced also contains small amounts of hydrogen chloride gas. To remove the hydrogen chloride gas the gases are bubbled through water. Finally, insoluble chlorine gas is collected.



Complete a labelled diagram to show an apparatus suitable for carrying out this preparation. **2**

(An additional diagram, if required, can be found on *page 41*)

[Turn over

9. (continued)

(c) Carbon tetrachloride, CCl_4, is prepared by the reaction of chlorine gas, Cl_2, with methane, CH_4.

$$CH_4(g) + 4Cl_2(g) \rightarrow CCl_4(g) + 4HCl(g)$$

Calculate the enthalpy change, in kJ mol^{-1}, for this reaction using the following information. **2**

$C(s) + 2H_2(g) \rightarrow CH_4(g) \quad \Delta H = -75$ kJ mol^{-1}

$C(s) + 2Cl_2(g) \rightarrow CCl_4(g) \quad \Delta H = -98$ kJ mol^{-1}

$\frac{1}{2}H_2(g) + \frac{1}{2}Cl_2(g) \rightarrow HCl(g) \quad \Delta H = -92$ kJ mol^{-1}

[Turn over for next question

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10. A student investigated the purity of a sample of magnesium chloride, $MgCl_2$. The sample was dissolved in water and then an excess of silver nitrate, $AgNO_3$, was added to produce a precipitate of silver chloride, AgCl. The precipitate was collected, dried and weighed.

$$MgCl_2(aq) + 2AgNO_3(aq) \rightarrow 2AgCl(s) + Mg(NO_3)_2(aq)$$

(a) The student prepared the magnesium chloride solution by dissolving 2·503 g of impure magnesium chloride in water.

Explain why the student should use distilled or deionised water, rather than tap water, when preparing the solution. **1**

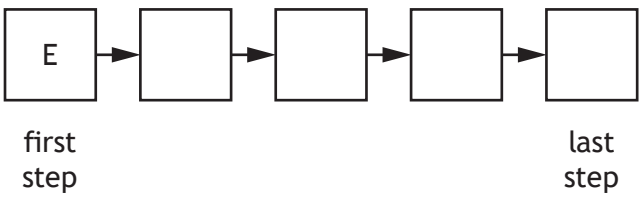
(b) (i) Complete the table to show the **most appropriate** piece of apparatus that could be used to measure the required volumes. **2**

Measurement	Apparatus
20·0 cm^3 **(accurately)**	
35 cm^3 **(approximately)**	

(ii) The steps required to collect, dry and weigh the precipitate are listed below. However, the steps are in the **wrong order**.

A. Weigh the precipitate and the filter paper
B. Wash the precipitate with water to remove any impurities
C. Filter the precipitate
D. Dry the precipitate in an oven
E. Weigh the filter paper

Complete the flow chart below to show the correct order of steps the student should carry out to collect, dry and weigh the precipitate. **1**



(An additional diagram, if required, can be found on *page 41*)

10. (b) (continued)

(iii) 1·393 g of silver chloride precipitate was produced from the magnesium chloride solution.

$$MgCl_2(aq) + 2AgNO_3(aq) \rightarrow 2AgCl(s) + Mg(NO_3)_2(aq)$$

GFM = 95·3 g GFM = 143·4 g

Calculate the mass of magnesium chloride, in g, present in the magnesium chloride solution. **2**

(c) The average mass of magnesium chloride in 2·503 g of the original impure sample was calculated to be 2·403 g.

Calculate the % of magnesium chloride present in the original sample. **1**

[Turn over

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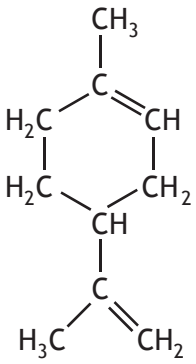
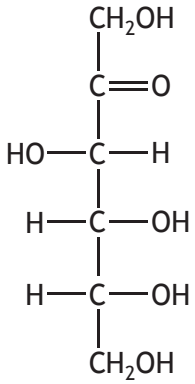
11. Differences in physical and chemical properties can be used to distinguish one compound from another.

The compounds extracted from orange juice include antioxidants, flavour molecules, essential oils, aroma molecules and coloured molecules.

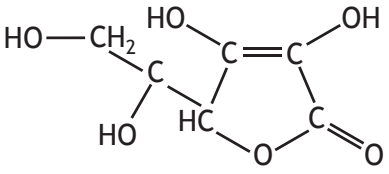
Some examples of these are shown below.



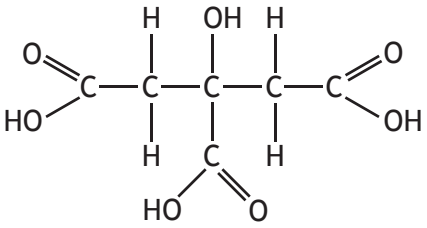
limonene



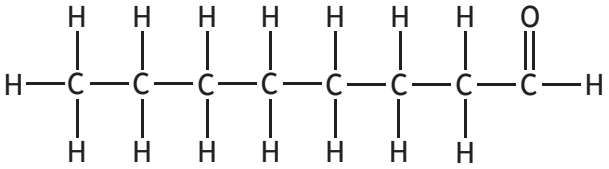
fructose



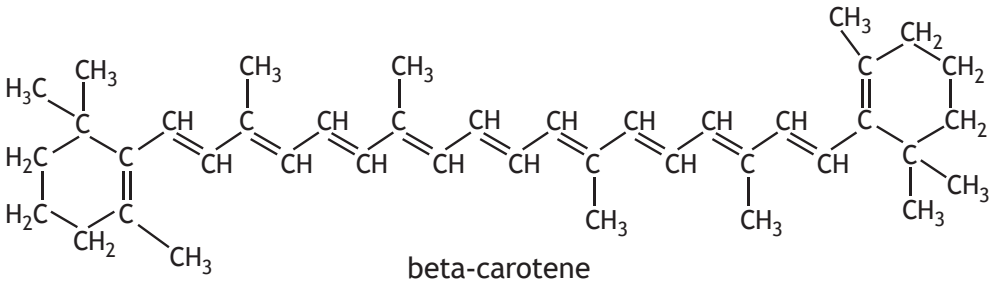
vitamin C



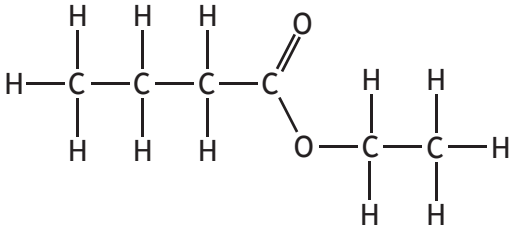
citric acid



octanal



beta-carotene



ethyl butanoate

11. (continued)

Using your knowledge of chemistry, comment on how the differences in physical and chemical properties can be used to distinguish between the compounds extracted from orange juice. **3**

[Turn over

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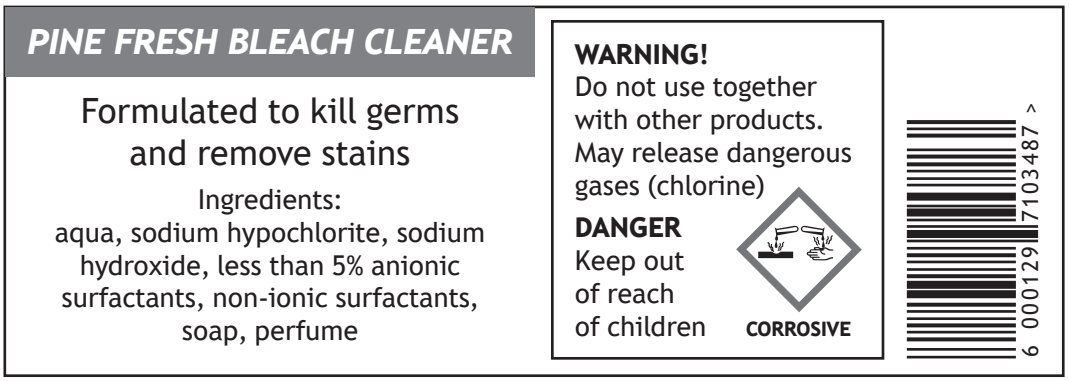
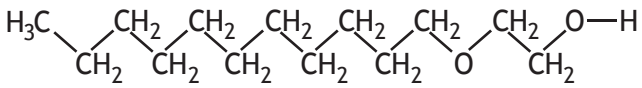
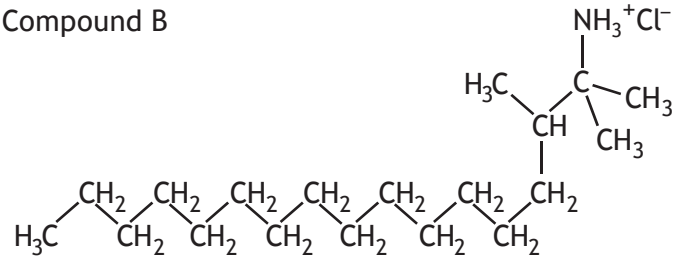
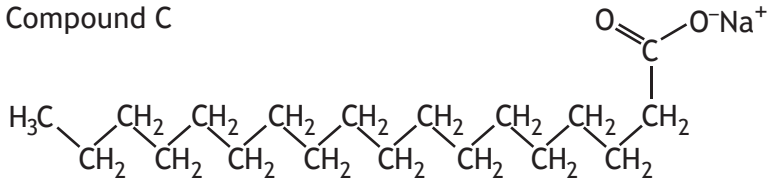
12. The label from a bottle of pine fresh bleach cleaner is shown.



(a) Surfactant molecules are added to bleach cleaner to act as detergents, soaps or emulsifiers.

Information on three of the surfactants in the bleach cleaner is shown in the table.

Surfactant structure	Type of surfactant	Head group
Compound A 	non-ionic	polar
Compound B 		
Compound C 	ionic	negatively charged

12. (a) (continued)

(i) Complete the table for compound B. **1**

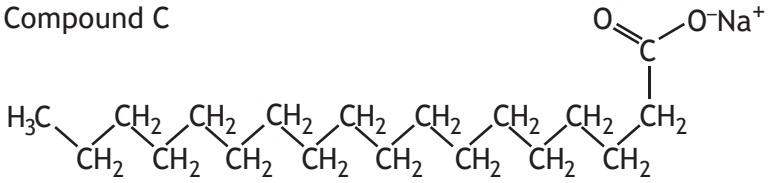
(ii) Compound C is a soap molecule.

(A) Soaps can be made from fats and oils.

Name the reaction used to make soaps from fats and oils. **1**

(B) Soap molecules allow oil to mix with water.

Compound C



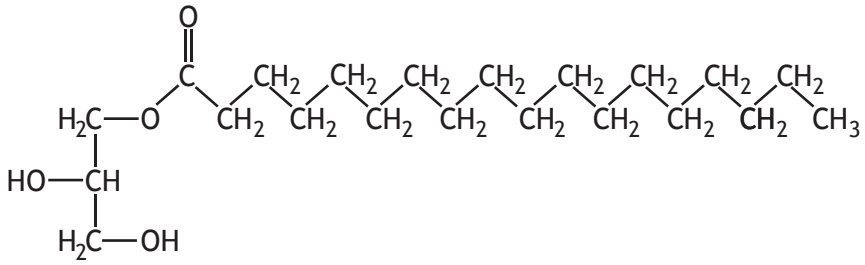
Explain fully the cleaning action of compound C. **3**

You may wish to use diagrams to illustrate your answers.

[Turn over

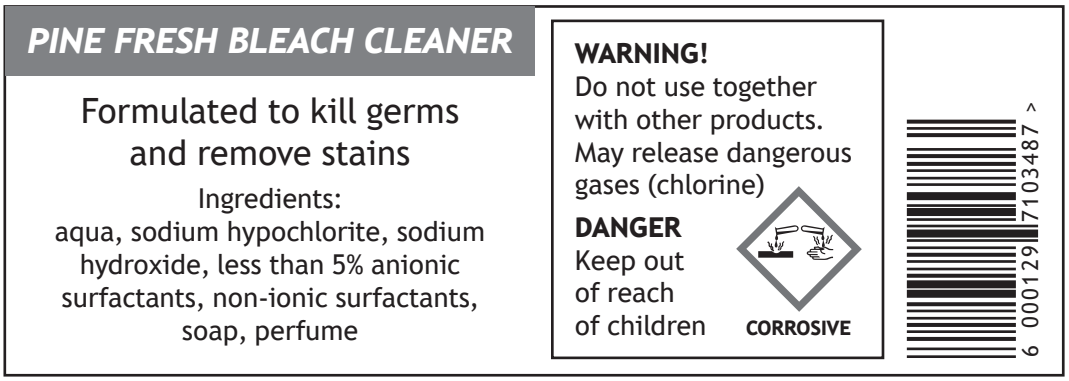
12. (a) (continued)

(iii) The structure of an emulsifier molecule is shown below.



State how emulsifiers are made from edible oils. **1**

(b) Sodium hypochlorite, Na^+OCl^-, is the main active compound in bleach.



Sodium hypochlorite, Na^+OCl^-, is produced by reacting chlorine with sodium hydroxide solution.

$$Cl_2(g) + 2Na^+OH^-(aq) \rightarrow Na^+OCl^-(aq) + Na^+Cl^-(aq) + H_2O(\ell)$$

(i) A chlorine molecule has a pure covalent bond.

Explain what is meant by a pure covalent bond. **1**

12. (b) (continued)

(ii) When the chlorine is reacted with sodium hydroxide solution an excess of sodium hydroxide is used.

Suggest why an excess of sodium hydroxide is used. **1**

(c) In the bleach cleaner an equilibrium exists.

$$2H^+(aq) + OCl^-(aq) + Cl^-(aq) \rightleftharpoons Cl_2(g) + H_2O(\ell)$$

The label warns that the bleach cleaner should not be used with other products as it may release chlorine gas.

Explain clearly why mixing the bleach with an acid would shift the equilibrium to the right, resulting in the release of chlorine gas from the bleach cleaner. **2**

[Turn over for next question

MARKS

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(d) The concentration of hypochlorite, OCl^-, in bleach can be determined by a redox reaction that involves two steps.

Step 1

An excess of acidified potassium iodide is added to the bleach. This converts the iodide ions into iodine.

$$OCl^-(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + Cl^-(aq) + H_2O(\ell)$$

Step 2

The iodine produced in step 1 is titrated with sodium thiosulfate, $Na_2S_2O_3$.

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

(i) Write the ion-electron equation for the reduction reaction taking place in **Step 1**. **1**

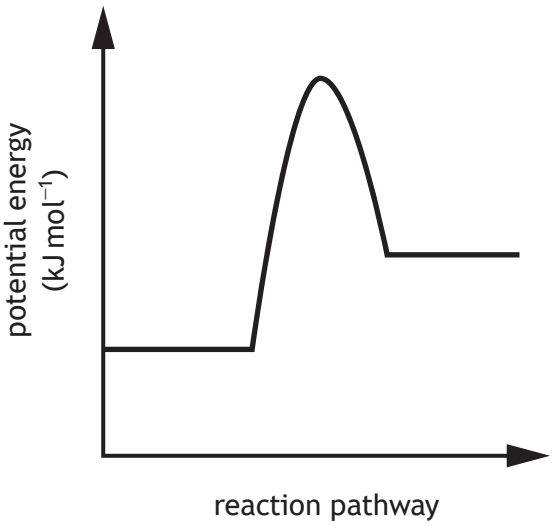
(ii) A 25 cm^3 sample of a diluted bleach was transferred into a conical flask and excess acidified potassium iodide added. The iodine produced was titrated with 0·098 $mol\,l^{-1}$ $Na_2S_2O_3$, requiring an average volume of 9·0 cm^3 to reach the end point.

Calculate the concentration, in $mol\,l^{-1}$, of sodium hypochlorite in the diluted bleach. **3**

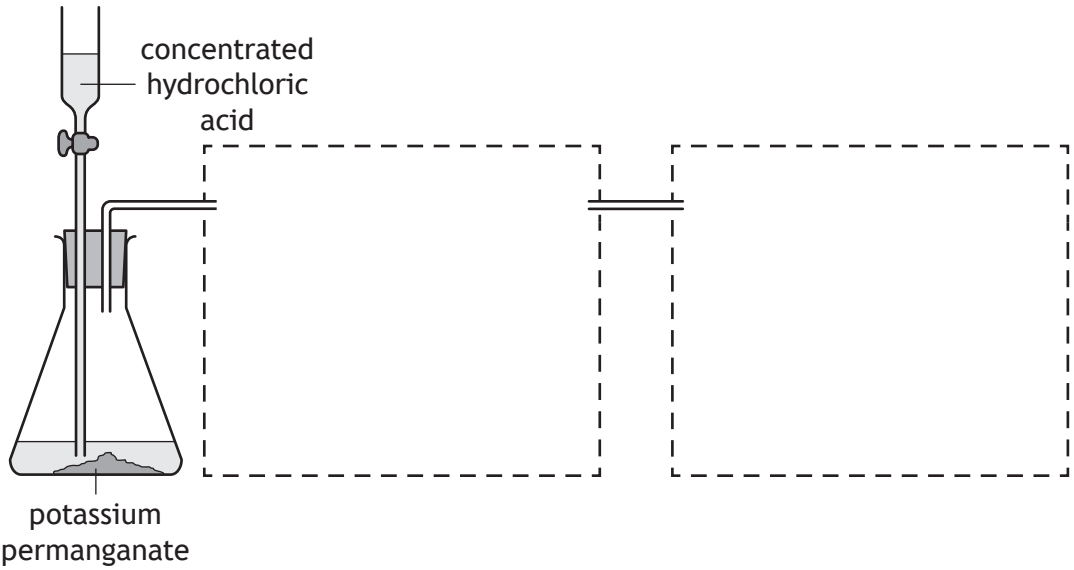
[END OF QUESTION PAPER]

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

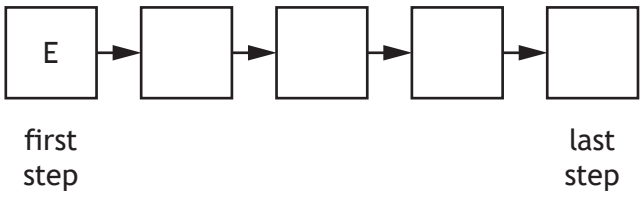
Additional diagram for question 1 (c)



Additional diagram for question 9 (b)



Additional diagram for question 10 (b) (ii)



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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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