FOR OFFICIAL USE

National Qualifications

Mark

X813/76/01

Chemistry Paper 2

Duration — 2 hours 20 minutes

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 ©

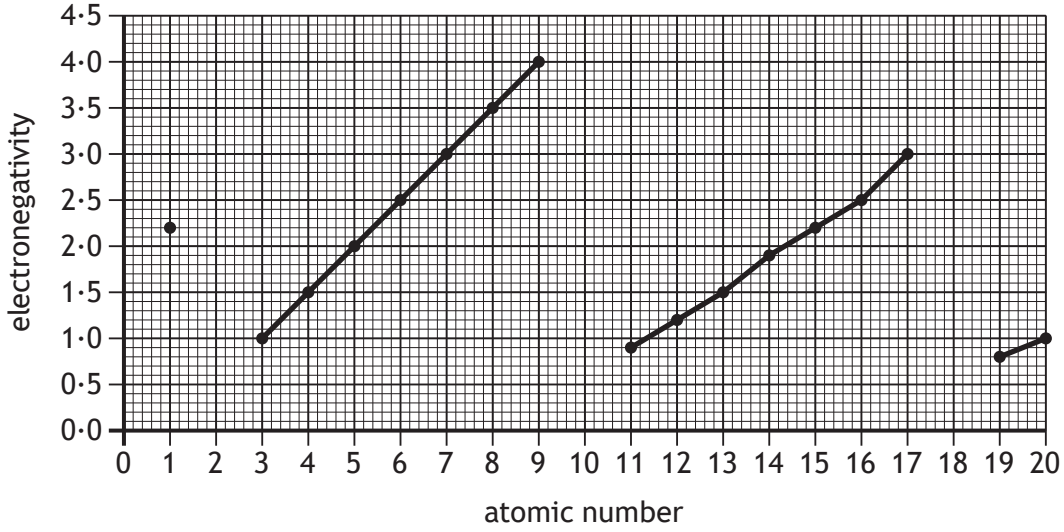
X813760101

Total marks — 95

Attempt ALL questions

1. Electronegativity is a measure of the attraction an atom involved in a bond has for the electrons of the bond.

The graph shows the trend in electronegativity for the first 20 elements.



(a) (i) State the trend in electronegativity as you go across period 2 from lithium to fluorine. **1**

(ii) No electronegativity values are shown for the elements with atomic numbers 2, 10 and 18.

Suggest why no values are provided for these elements. **1**

1. (a) (continued)

(iii) On descending Group 7 from fluorine to iodine, the electronegativity of the elements decreases.

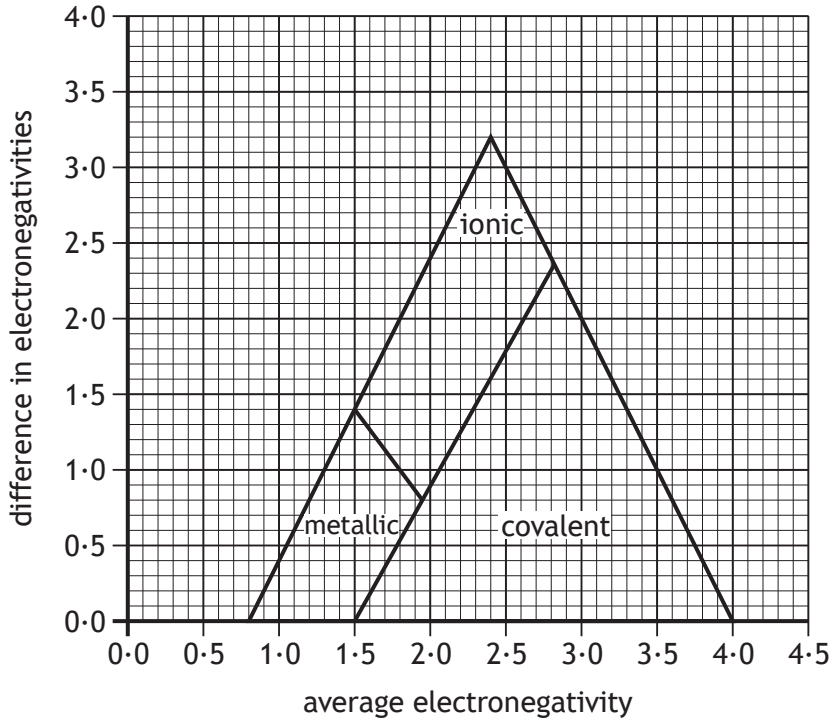
Explain why the electronegativity of the elements decreases as you go down the group. **1**

[Turn over

1. (continued)

(b) Electronegativity values can be used to predict the type of bonding present in substances.

The type of bonding between two elements can be predicted using the diagram below.



(i) Using the information in the diagram, state the highest average electronegativity found in **ionic** compounds. **1**

MARKS

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(ii) The electronegativity values of magnesium and nitrogen are shown.

Electronegativity of magnesium = 1·2
Electronegativity of nitrogen = 3·0

Draw an X on the diagram on *page 04* to show the position of magnesium nitride.

Show your calculations clearly. **2**

(An additional diagram, if required, can be found on *page 38*.)

(iii) Compounds with a difference in electronegativities of 1·5 can have ionic or covalent properties.

(A) The electronegativity difference between the elements in lithium sulfide is 1·5.

Write an **ionic** formula for lithium sulfide. **1**

(B) A compound contains two non-metal elements with an electronegativity difference of 1·5.

Suggest names for the two **non-metal** elements. **1**

(c) Fluorine has a greater attraction for bonding electrons than hydrogen.

State the term used to describe the type of **covalent** bond in hydrogen fluoride. **1**

2. Carbon and its compounds are important in the chemical industry.

(a) Carbon can exist in multiple forms. Two of these are fullerenes and diamond.

(i) Name another form of carbon. **1**

(ii) Both diamond and the fullerene, C_{60}, can change directly from a solid to a gas. This is called sublimation. For diamond this occurs at 3825 °C. The fullerene changes from a solid to a gas at approximately 550 °C. Complete the table below to show the strongest type of attraction broken when diamond and the fullerene sublime. **2**

Form of carbon	Strongest attraction broken
diamond	
fullerene	

(iii) The fullerene, C_{60}, reacts with bromine solution in an addition reaction to produce the bromofullerene, $C_{60}Br_{24}$.

Determine the number of double bonds present in a molecule of C_{60}. **1**

(b) Carbon can combine with oxygen to make carbon monoxide, CO. Carbon monoxide is used in the production of iron from iron(III) oxide.

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(\ell) + 3CO_2(g)$$

$GFM = 159{\cdot}6$ g $\quad GFM = 28{\cdot}0$ g $\quad GFM = 55{\cdot}8$ g $\quad GFM = 44{\cdot}0$ g

Calculate the atom economy for the production of iron. **2**

2. (continued)

(c) Carbon monoxide can be produced by the reaction of methane and steam.

$$CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$$

$$CO(g) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g) \qquad \Delta H = -283 \text{ kJ mol}^{-1}$$

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

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \qquad \Delta H = -891 \text{ kJ mol}^{-1}$$

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

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

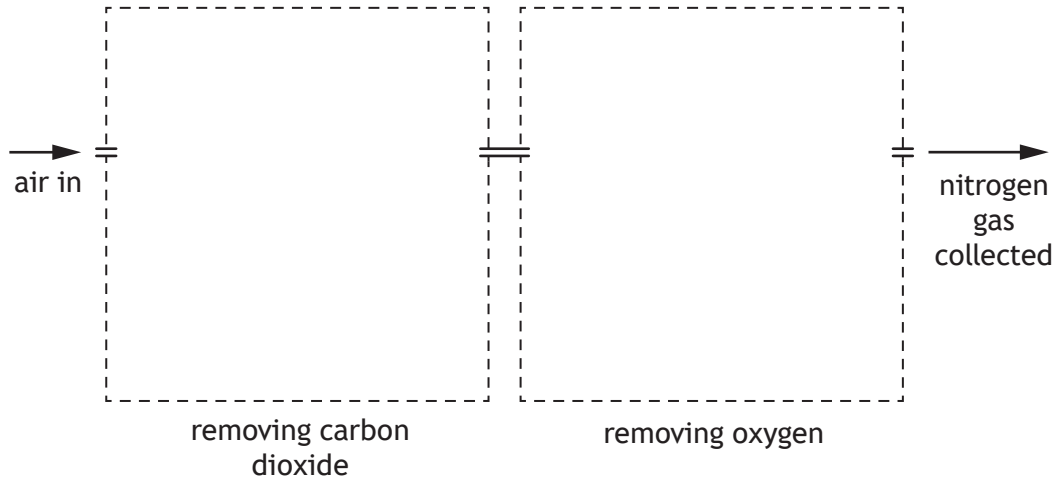
3. A teacher told a class that collisions were the key to chemical reactions.
Using your knowledge of chemistry, discuss this statement. **3**

4. Nitrogen is a stable element and only reacts with a few other elements.

(a) Explain, using bond enthalpy values, why the element nitrogen is so unreactive. **1**

(b) A laboratory preparation of nitrogen gas involves separating nitrogen from all of the other gases in the air and then collecting it.

Air is bubbled through potassium hydroxide solution to remove carbon dioxide. The remaining gases are passed over heated copper to remove oxygen before the remaining nitrogen is collected.



Complete a labelled diagram for the preparation of a sample of nitrogen by drawing suitable apparatus for carrying out this preparation. **2**

(An additional diagram, if required, can be found on *page 38*.)

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

(c) Nitrogen can react with lithium at room temperature to form the compound lithium nitride, Li_3N.

(i) A scientist prepared a sample of lithium nitride by reacting 0·9 litres of nitrogen gas with 0·5 g of lithium.

$$6Li(s) + N_2(g) \rightarrow 2Li_3N(s)$$

$GFM = 6{\cdot}9$ g

Determine, by calculation, which of the reactants was in excess. **3**

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

(Clearly show your working for the calculation.)

(ii) Lithium nitride reduces copper(I) ions to copper atoms.

Write the ion-electron equation to show the reduction of copper(I) ions. **1**

(iii) Lithium nitride is ionic.

State the term used to describe the structure of solid ionic compounds like lithium nitride. **1**

MARKS

DO NOT WRITE IN THIS MARGIN

(d) During thunderstorms, nitrogen can react with oxygen to form different compounds.

Nitrogen and oxygen can react to form the free radical molecule nitrogen monoxide, ·N=O.

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

(ii) The equation for this reaction is

$$N{\equiv}N + O{=}O \longrightarrow \begin{matrix} \cdot N{=}O \\ \cdot N{=}O \end{matrix}$$

The enthalpy change, ΔH, for this reaction is +91 kJ mol^{-1}.

Use this data and the bond enthalpy values shown in the data booklet to calculate the bond enthalpy, in kJ mol^{-1}, of the nitrogen to oxygen double bond in nitrogen monoxide. **2**

(iii) Nitrogen monoxide free radicals can react with hydroxyl free radicals to form a molecule of nitrous acid, HNO_2.

(A) Name the type of reaction that occurs when two free radicals join together. **1**

(B) Draw a possible structure for the HNO_2 molecule. **1**

4. (continued)

(e) Nitrogen can also react with hydrogen in the Haber process to form ammonia.

(i) The equation to produce ammonia is shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

Explain fully the effect of decreasing the reaction temperature on the yield of ammonia. **2**

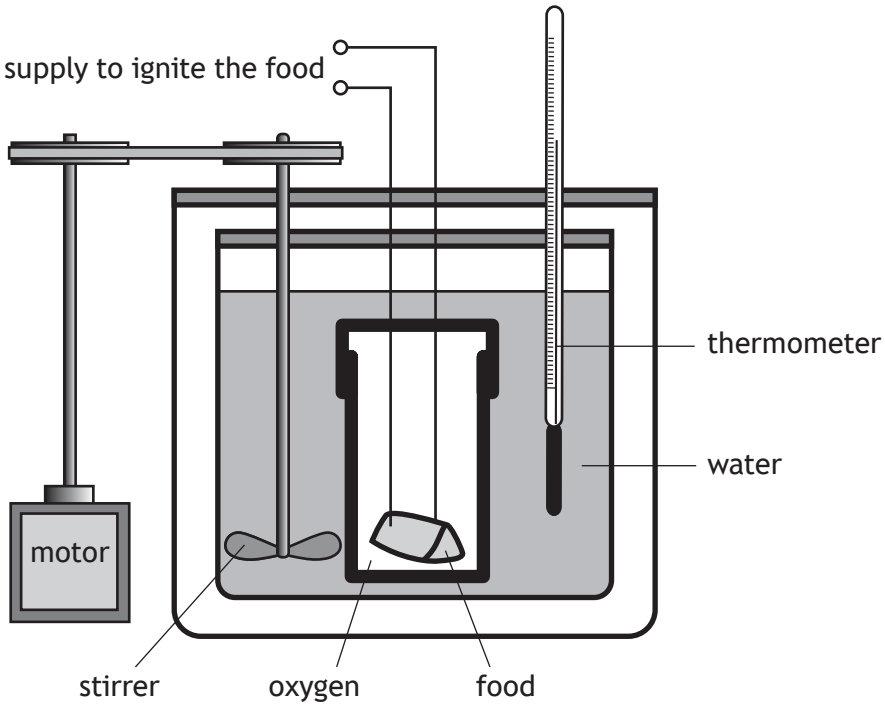
(ii) Ammonia can be reacted to produce the explosive nitroglycerin. A small shock or physical bump can make the nitroglycerin explode. The reaction that takes place is shown.

$$C_3H_5N_3O_9 \rightarrow CO_2 + H_2O + N_2 + O_2$$

(A) Balance this equation. **1**

(B) Suggest why a small shock or bump can cause nitroglycerin to react. **1**

5. A bomb calorimeter is used in the food industry to determine the energy released by foods when they are burned.



Bomb calorimeter

(a) Identify a feature of the bomb calorimeter and explain how this allows the accurate determination of the energy released by burning foods. **1**

[Turn over

5. (continued)

(b) Fats and oils release a large amount of energy when they are burned.

(i) A 1·00 g sample of the oil, triolein ($GFM = 884$ g) was burned in a bomb calorimeter.

The temperature rise in the 775 cm^3 of water was 11·9 °C.

Calculate the enthalpy of combustion, in kJ mol^{-1}, of triolein. **3**

(ii) Foods with a lower respiratory quotient are better for people who find it difficult to obtain energy from food.

The respiratory quotient, RQ, is the ratio of carbon dioxide, CO_2, produced to the oxygen, O_2, consumed when a food is burned in the body.

$$\text{Respiratory quotient} = \frac{CO_2 \text{ produced}}{O_2 \text{ consumed}}$$

The equation for the combustion of triolein, $C_{57}H_{104}O_6$, is shown.

$$C_{57}H_{104}O_6(\ell) + 80\ O_2(g) \rightarrow 57\ CO_2(g) + 52\ H_2O(\ell)$$

Determine the respiratory quotient for triolein. **1**

5. (continued)

(c) Tristearin, $C_{57}H_{110}O_6$, is a saturated fat.

The table shows the viscosity of different saturated fats at 70 °C.

Fat	Molecular formula	Viscosity at 70 °C (units)
Tributyrin	$C_{15}H_{26}O_6$	3·0
Tricaproin	$C_{21}H_{38}O_6$	5·9
Tricaprylin	$C_{27}H_{50}O_6$	8·8
Tricaprin	$C_{33}H_{62}O_6$	11·7
Trilaurin	$C_{39}H_{74}O_6$	14·6

(i) Predict the viscosity of tristearin at 70 °C. **1**

(ii) Edible fats and oils are molecules that contain three ester links.

Explain why glycerol is able to form fats and oils. **1**

[Turn over

6. Seaweed can contain high levels of iodine.

(a) One type of seaweed contains 0·133 g of iodine per kilogram of seaweed.

The World Health Organisation recommends a daily intake of iodine of 0·15 mg.

Calculate the mass of seaweed that would provide the recommended daily intake. **2**

(b) An experiment was carried out to determine the quantity of iodine in a sample of dried seaweed.

(i) The first step in this process involves burning an accurately known mass of dried seaweed to ash.

Describe the steps involved in measuring the mass of the seaweed by difference. **1**

(ii) The seaweed ash contains iodide ions. These react with hydrogen peroxide in acid conditions.

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(\ell) + I_2(aq)$$

Identify the reducing agent in this reaction. **1**

6. (b) (continued)

(iii) The released iodine reacts with sodium thiosulfate, $Na_2S_2O_3$.

A standard solution of sodium thiosulfate, $Na_2S_2O_3$, is required to react with the released iodine.

State what is meant by a standard solution. **1**

(iv) For this sample of seaweed, 0·00026 moles of sodium thiosulfate were required to fully react with the released iodine, I_2.

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

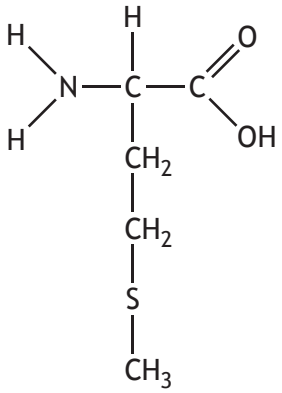
(A) Calculate the number of moles of iodine required to react with 0·00026 moles of sodium thiosulfate. **1**

(B) Using your answer to part (A), calculate the mass, in g, of iodine in the seaweed sample. **1**

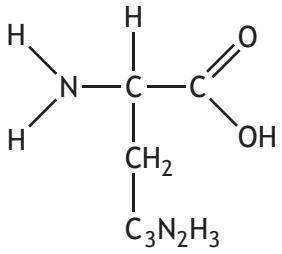
6. (continued)

(c) Seaweed is a major component of the diet of sheep living on the island of North Ronaldsay.

Sheep wool is made mainly of a protein. This protein contains the essential amino acids methionine and histidine.



methionine



histidine

(i) State what is meant by an essential amino acid. **1**

(ii) When two amino acids are joined together by a peptide link, a dipeptide is formed.

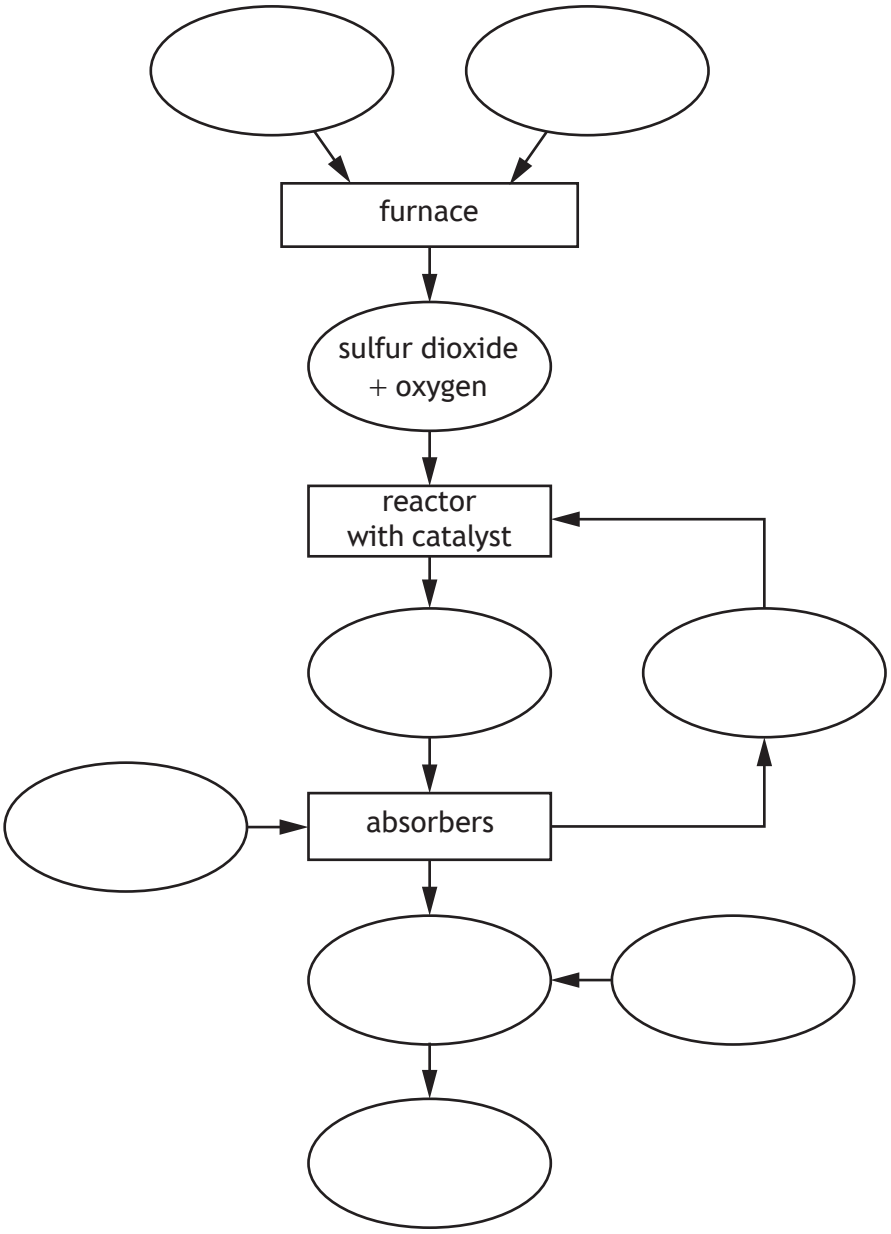
Draw a structural formula for the dipeptide formed from methionine and histidine. **1**

7. Sulfuric acid is an important chemical with many uses in industry. The main process used to make sulfuric acid is the Contact Process.

(a) The Contact Process starts when sulfur is burned in a furnace with excess air. This forms a gas mixture that contains sulfur dioxide and oxygen. The gas mixture is cooled and then passed into the reactor which contains a catalyst. Sulfur trioxide is formed and then passed into absorbers where it is absorbed into concentrated sulfuric acid to form a product called oleum. The oleum is diluted with water to give sulfuric acid. Unreacted sulfur dioxide is not absorbed and is recycled back into the reactor.

Use the information above to complete the flow diagram for the Contact Process. **2**

(An additional diagram, if required, can be found on *page 39*.)



7. (continued)

(b) The reactions involved in the Contact Process are highly exothermic.

State a disadvantage of industrial processes that involve reactions that are highly exothermic. **1**

(c) Sulfur and oxygen contain London dispersion forces.

(i) Explain how London dispersion forces arise. **2**

(ii) Explain fully why the London dispersion forces in sulfur are stronger than those in oxygen. **2**

7. (continued)

(d) The reaction that occurs in the reactor of the Contact Process is

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -192 \text{ kJ mol}^{-1}$$

Circle the correct statement in each column of the table to show the effect of using a catalyst in the reaction. **1**

Effect of catalyst on enthalpy change	Effect of catalyst on activation energy
increase stay the same decrease	increase stay the same decrease

(e) One use of sulfuric acid is in the production of soapless detergents.

(i) State the advantage that soapless detergents have over soap when used with hard water. **1**

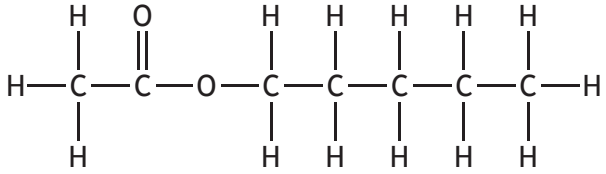
(ii) Describe the key structural features of a soapless detergent molecule. **1**

[Turn over

8. Sweets contain a wide variety of chemicals.

(a) Many sweets contain esters.

(i) The structure of an ester used to produce a pear flavour in some sweets is



Name this ester. **1**

(ii) Name the type of reaction used to form esters. **1**

(b) Fizzy sweets can contain citric acid, $C_6H_8O_7$, and sodium bicarbonate, $NaHCO_3$.

When the sweets dissolve, the citric acid and sodium bicarbonate react together to make carbon dioxide gas.

(i) To calculate the mass of citric acid in a sweet, 5 sweets were dissolved in water and the resulting carbon dioxide was collected and measured.

Suggest why carbon dioxide can be collected over water. **1**

8. (b) (continued)

(ii) In one experiment, 5 sweets were dissolved, and 55 cm^3 of carbon dioxide gas was produced.

$C_6H_8O_7(aq) + 3NaHCO_3(aq) \rightarrow 3CO_2(g) + 3H_2O(\ell) + C_6H_5O_7Na_3(aq)$

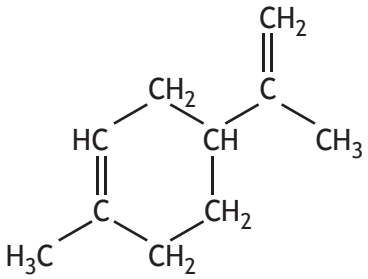
$GFM = 192$ g

Calculate the mass of citric acid, in g, in one sweet. **2**

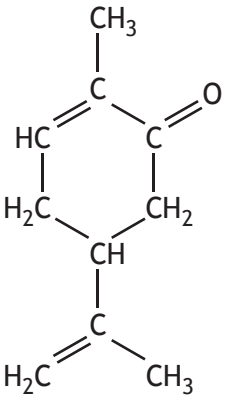
Take the volume of 1 mole of carbon dioxide to be 24 litres.

8. (continued)

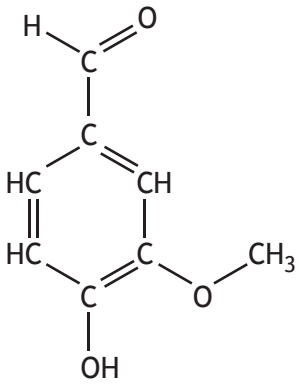
(c) The distinctive smell of some sweets is due to molecules such as limonene, carvone and vanillin.



limonene



carvone



vanillin

(i) Vanillin is an aldehyde and carvone is a ketone.

(A) State the colour change that would be observed when aldehydes react with acidified potassium dichromate. **1**

(B) Suggest a different chemical that could be used to distinguish aldehydes from ketones. **1**

(ii) Limonene is a terpene consisting of joined isoprene units.

State the number of isoprene units in a limonene molecule. **1**

8. (c) (continued)

(iii) 1 kg of natural vanillin costs £1050. To make a packet of sweets, 5 cm^3 of vanillin solution is used. This contains 0·184 g of vanillin per 100 cm^3 of solution.

Calculate the cost, in pence, of the natural vanillin required to make the packet of sweets. **2**

[Turn over

9. A brand of antiseptic mouthwash contains hydrogen peroxide along with several other chemicals such as water, flavourings and colouring.

(a) 100 cm^3 of mouthwash contains 1·5 g of 35% hydrogen peroxide solution.

A 35% hydrogen peroxide solution contains 35 g of hydrogen peroxide in 100 cm^3 of solution.

(i) Calculate the mass of hydrogen peroxide, in g, present in a 300 cm^3 bottle of the mouthwash. **1**

(ii) Enzymes in saliva act as catalysts in the decomposition of hydrogen peroxide.

Name the family of compounds to which enzymes belong. **1**

(iii) The concentration of hydrogen peroxide can be determined by a titration with a solution of potassium permanganate.

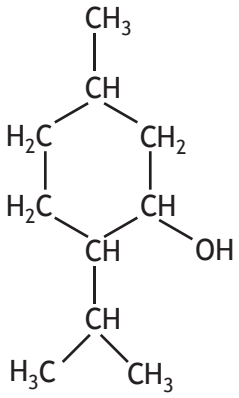
Name the **two** pieces of equipment that would be required to accurately measure the volumes of hydrogen peroxide and potassium permanganate used in the titration. **1**

(b) Volatile, non-water-soluble compounds obtained from plants can be used to provide the minty aroma of the mouthwash.

State the term used to describe the mixture of volatile, non-water-soluble aroma compounds obtained from plants. **1**

9. (continued)

(c) The mouthwash also contains menthol.



menthol

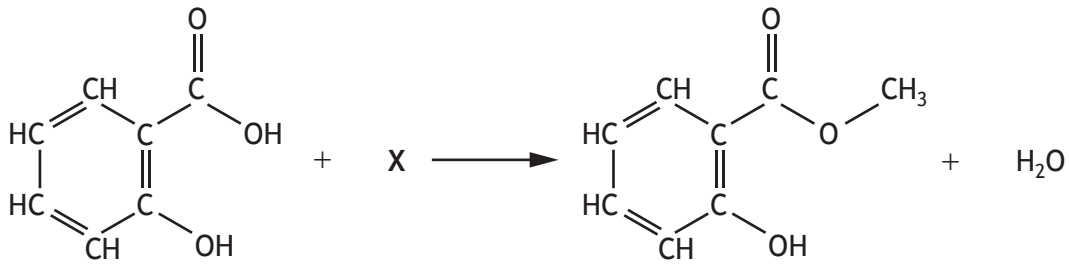
(i) Menthol is based on isoprene units.
State the systematic name for isoprene. **1**

(ii) Menthol can be oxidised to form a mint flavoured compound.
State the type of compound formed when menthol is oxidised. **1**

[Turn over

9. (continued)

(d) Methyl salicylate is an ester found in the mouthwash that can be formed from salicylic acid.



salicylic acid methyl salicylate

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

(ii) A scientist prepared a sample of methyl salicylate using 28·3 g salicylic acid and an excess of reactant **X**.

$C_7H_6O_3$ + **X** → $C_8H_8O_3$ + H_2O

salicylic acid methyl salicylate

$GFM = 138$ g $GFM = 152$ g

The scientist produced 24·7 g of methyl salicylate.

Calculate the percentage yield of methyl salicylate. **2**

9. (d) (continued)

(iii) Methyl salicylate can be toxic to humans at 0·14 g per kg of body mass. It can be obtained from a plant substance called oil of wintergreen. 5·0 cm^3 of oil of wintergreen contains 7·0 g of methyl salicylate.

Calculate the minimum volume, in cm^3, of oil of wintergreen that would provide a toxic dose to a human with body mass of 65 kg. **2**

[Turn over

10. Cow's milk is mostly made up of water, with small amounts of fats and oils, proteins, sugars and other compounds. Milk is white because it contains small droplets of fats and oils that are dispersed in the water. It also contains small droplets of proteins.

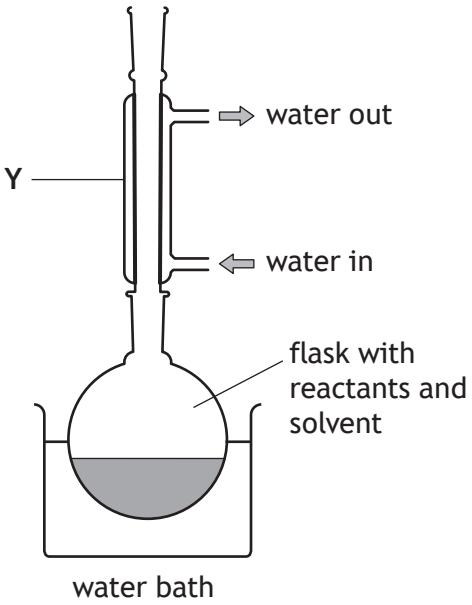
The fats in the milk depend on what the cow eats — in summer the fats obtained from the milk have a higher melting point than those obtained from winter milk.

Milk goes off because of reactions involving the hydroxyl groups on the sugar molecules in milk.

Using your knowledge of chemistry, discuss the chemistry of cow's milk. **3**

11. A Grignard reaction involves reacting compounds containing a carbonyl group with a Grignard reagent to make alcohols.

(a) The first step in the reaction involves heating the reactants in a solvent to form a Grignard reagent.



(i) Suggest why a water bath is used to heat the reaction. **1**

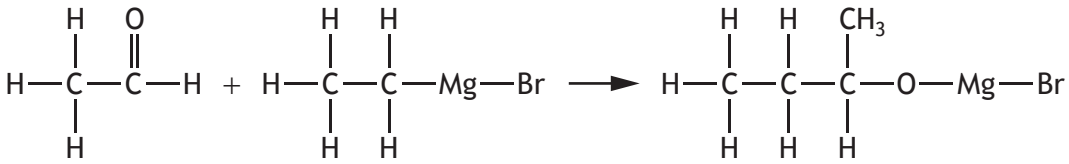
(ii) Name the piece of apparatus labelled **Y** in the diagram. **1**

[Turn over

11. (continued)

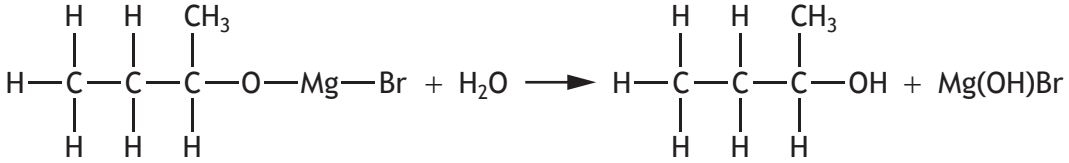
(b) Ethanal reacts with a Grignard reagent in two steps.

step 1



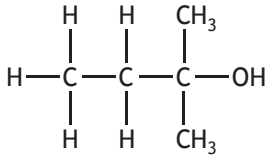
Grignard reagent

step 2



(i) Suggest a name for the reaction shown in step 1. **1**

(ii) The alcohol that is made when propanone reacts with the same Grignard reagent is shown.



Name this alcohol. **1**

11. (b) (continued)

(iii) Draw a structural formula for the alcohol formed when the Grignard reagent CH_3CH_2MgBr reacts with pentan-2-one. **1**

[Turn over

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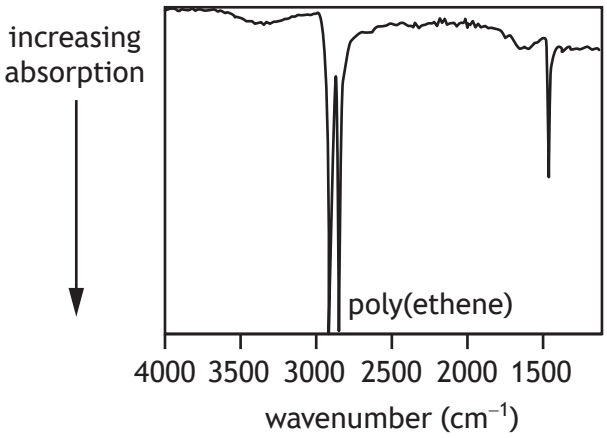
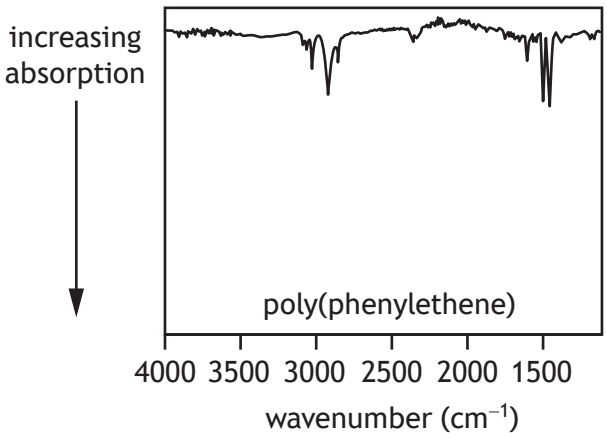
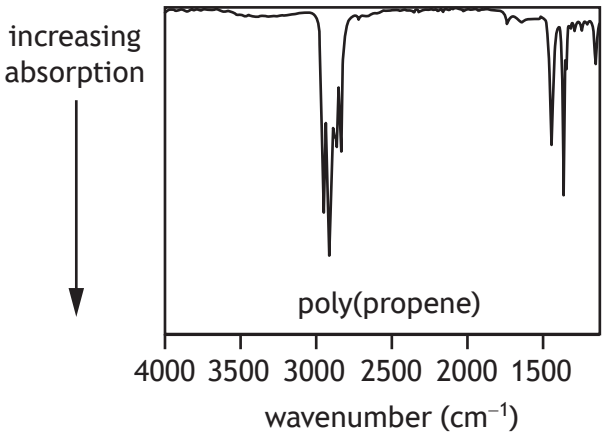
12. One of the problems with recycling plastics is identifying the type of plastic.

Infrared spectroscopy is a technique that can be used to identify the bonds present in plastics. A spectrum is produced for each sample analysed. The same bond always absorbs infrared radiation in the same range of wavenumbers, even in different molecules. For example C-H bonds absorb in the wavenumber range 2700–3300 cm^{-1}.

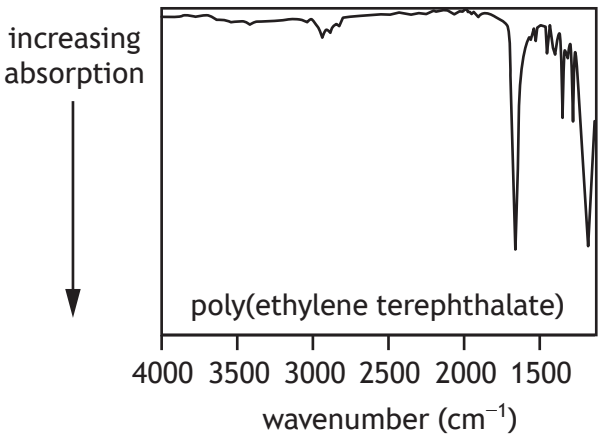
Four different types of plastic were analysed using infrared spectroscopy and the spectra produced are shown.



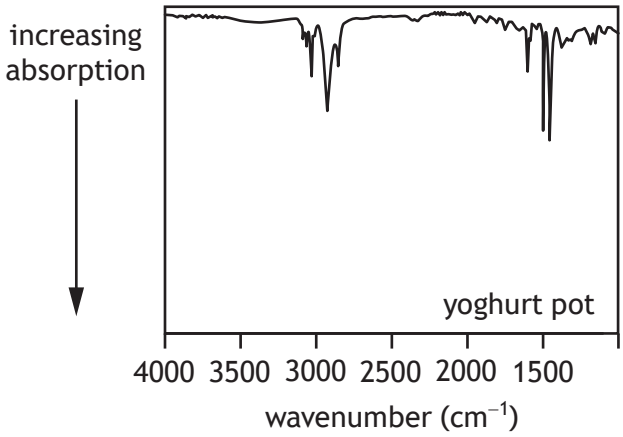




12. (continued)



(a) The spectrum obtained from the analysis of the plastic used to make a yoghurt pot is shown.



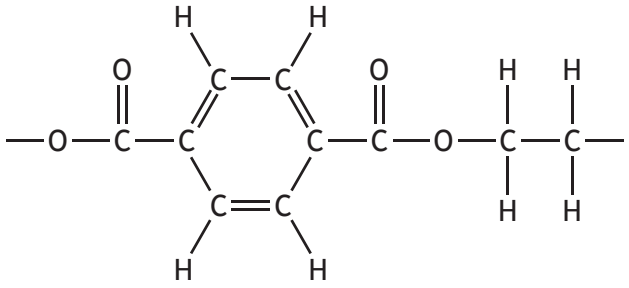
Identify the type of plastic used to make the yoghurt pot. **1**

[Turn over

12. (continued)

(b) The spectrum produced from poly(ethylene terephthalate) contains an absorption at a wavenumber of 1720 cm^{-1}.

Part of the structure of poly(ethylene terephthalate) is shown.

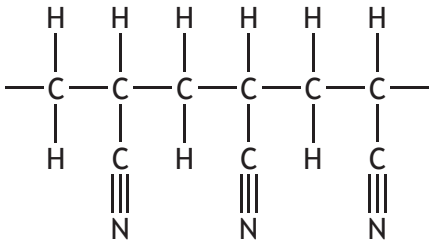


Using the information on page 14 of the data booklet, circle the bond in poly(ethylene terephthalate) that is responsible for this absorption. **1**

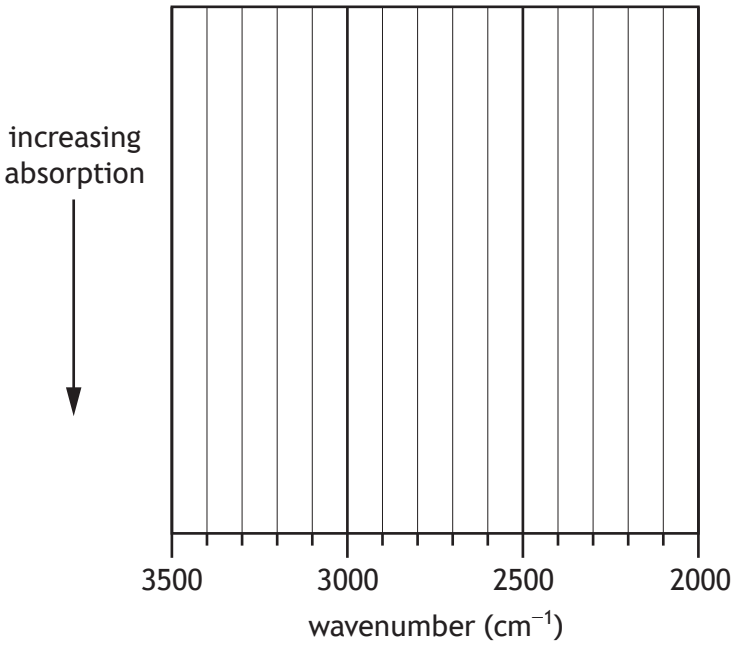
(An additional diagram, if required, can be found on *page 40*.)

12. (continued)

(c) Polyacrylonitrile plastic has the following structure.



Using the information on page 14 of the data booklet, sketch the infrared spectrum you would predict for polyacrylonitrile, showing only the absorptions within the range 3500–2000 cm^{-1}. **1**



(An additional diagram, if required, can be found on *page 40*.)

[END OF QUESTION PAPER]