Total
Section B

X012/301

CHEMISTRY HIGHER

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Date of birth
Day Month Year

Scottish candidate number

Number of seat

Reference may be made to the Chemistry Higher and Advanced Higher Data Booklet.

SECTION A—Questions 1–40 (40 marks)

Instructions for completion of **Section A** are given on page two.

For this section of the examination you must use an **HB pencil**.

SECTION B (60 marks)

1 All questions should be attempted.

2 The questions may be answered in any order but all answers are to be written in the spaces provided in this answer book, **and must be written clearly and legibly in ink**.

3 Rough work, if any should be necessary, should be written in this book and then scored through when the fair copy has been written. If further space is required, a supplementary sheet for rough work may be obtained from the invigilator.

4 Additional space for answers will be found at the end of the book. If further space is required, supplementary sheets may be obtained from the invigilator and should be inserted inside the **front** cover of this book.

5 The size of the space provided for an answer should not be taken as an indication of how much to write. It is not necessary to use all the space.

6 Before leaving the examination room you must give this book to the invigilator. If you do not, you may lose all the marks for this paper.

SQA
©

SECTION A

Read carefully

1 Check that the answer sheet provided is for **Chemistry Higher (Section A)**.

2 For this section of the examination you must use an **HB pencil** and, where necessary, an eraser.

3 Check that the answer sheet you have been given has **your name**, **date of birth**, **SCN** (Scottish Candidate Number) and **Centre Name** printed on it.

Do not change any of these details.

4 If any of this information is wrong, tell the Invigilator immediately.

5 If this information is correct, **print** your name and seat number in the boxes provided.

6 The answer to each question is **either** A, B, C or D. Decide what your answer is, then, using your pencil, put a horizontal line in the space provided (see sample question below).

7 There is **only one correct** answer to each question.

8 Any rough working should be done on the question paper or the rough working sheet, **not** on your answer sheet.

9 At the end of the exam, put the **answer sheet for Section A inside the front cover of your answer book**.

Sample Question

To show that the ink in a ball-pen consists of a mixture of dyes, the method of separation would be

        A chromatography

        B fractional distillation

        C fractional crystallisation

        D filtration.

The correct answer is **A**—chromatography. The answer **A** has been clearly marked in **pencil** with a horizontal line (see below).
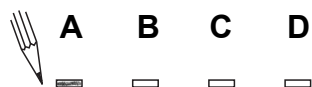
Changing an answer

If you decide to change your answer, carefully erase your first answer and using your pencil, fill in the answer you want. The answer below has been changed to **D**.
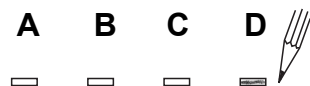
1. Which of the following oxides forms an aqueous solution with pH greater than 7?

   A Carbon dioxide

   B Copper(II) oxide

   C Sulphur dioxide

   D Sodium oxide

2. In which of the following reactions is a positive ion reduced?

   A Iodide $\longrightarrow$ iodine

   B Nickel(II) $\longrightarrow$ nickel(III)

   C Cobalt(III) $\longrightarrow$ cobalt(II)

   D Sulphate $\longrightarrow$ sulphite

3. Which of the following elements is most likely to have a covalent network structure?

Element	Melting point/°C	Boiling point/°C	Density/ g cm^{-3}	Conduction when solid
A	44	280	1·82	No
B	660	2467	2·70	Yes
C	1410	2355	2·33	No
D	114	184	4·93	No

4. Two identical samples of copper(II) carbonate were added to an excess of $1 \, mol \, l^{-1}$ hydrochloric acid and $1 \, mol \, l^{-1}$ sulphuric acid respectively.

   Which of the following would have been different for the two reactions?

   A The pH of the final solution

   B The volume of gas produced

   C The mass of water formed

   D The mass of copper(II) carbonate dissolved

5. The graph shows how the rate of a reaction varies with the concentration of one of the reactants.
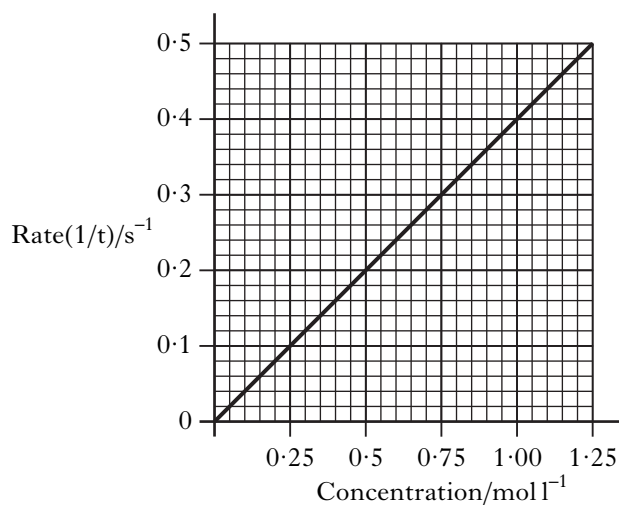

   What was the reaction time, in seconds, when the concentration of the reactant was $0·50 \, mol \, l^{-1}$?

   A 0·2

   B 0·5

   C 2·0

   D 5·0

6. 10 g of magnesium is added to 1 litre of $1 \, mol \, l^{-1}$ copper(II) sulphate solution and the mixture stirred until no further reaction occurs.

   Which of the following is a result of this reaction?

   A All the magnesium reacts.

   B 63·5 g of copper is displaced.

   C 2 mol of copper is displaced.

   D The resulting solution is colourless.

[Turn over

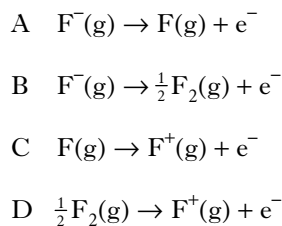**7.** A reaction was carried out with and without a catalyst as shown in the energy diagram.
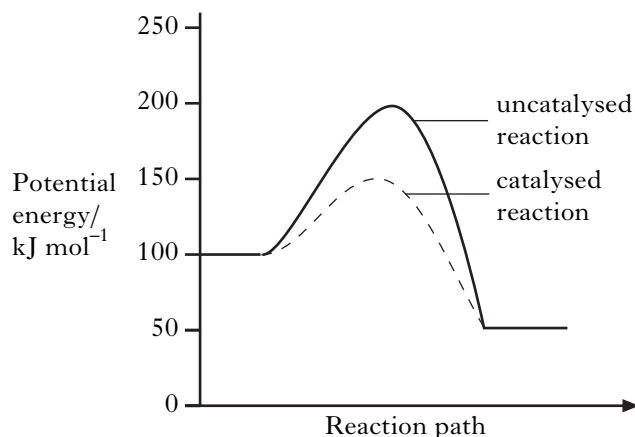
What is the enthalpy change, in kJ mol^{-1}, for the catalysed reaction?

A −100

B −50

C +50

D +100

8. Ethanol (C_2H_5OH) has a different enthalpy of combustion from dimethyl ether (CH_3OCH_3). This is because the compounds have different

A boiling points

B molecular masses

C products of combustion

D bonds within the molecules.

9. Which of the following compounds has the greatest ionic character?

A Caesium fluoride

B Caesium iodide

C Sodium fluoride

D Sodium iodide

10. Which line in the table is likely to be correct for the element francium?

|	State at 30 °C	First ionisation energy/kJ mol^{-1}
A	solid	less than 382
B	liquid	less than 382
C	solid	greater than 382
D	liquid	greater than 382

11. Which of the following equations represents the first ionisation energy of fluorine?

A $F^-(g) \rightarrow F(g) + e^-$

B $F^-(g) \rightarrow \frac{1}{2}F_2(g) + e^-$

C $F(g) \rightarrow F^+(g) + e^-$

D $\frac{1}{2}F_2(g) \rightarrow F^+(g) + e^-$

12. The two hydrogen atoms in a molecule of hydrogen are held together by

A a hydrogen bond

B a polar covalent bond

C a non-polar covalent bond

D a van der Waals' force.

13. In which of the following compounds would hydrogen bonding **not** occur?
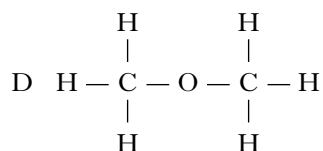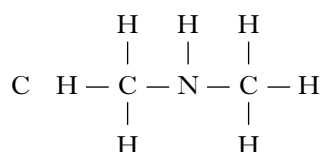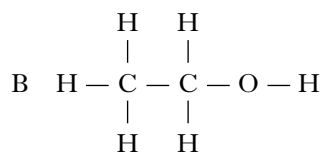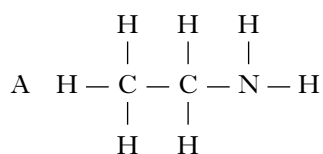
14. Which of the following shows the types of bonding in **decreasing** order of strength?

A Covalent : hydrogen : van der Waals'

B Covalent : van der Waals' : hydrogen

C Hydrogen : covalent : van der Waals'

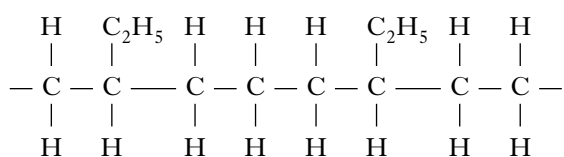D Van der Waals' : hydrogen : covalent

15. What type of bonding and structure is found in a fullerene?

A Ionic lattice

B Metallic lattice

C Covalent network

D Covalent molecular

16. Some covalent compounds are made up of molecules that contain polar bonds but the molecules are overall non-polar.

Which of the following covalent compounds is made up of non-polar molecules?

A Ammonia

B Water

C Carbon tetrachloride

D Hydrogen fluoride

17. The Avogadro Constant is the same as the number of

A ions in 1 mol of NaCl

B atoms in 1 mol of hydrogen gas

C electrons in 1 mol of helium gas

D molecules in 1 mol of oxygen gas.

18. Which of the following gas samples has the same volume as 7 g of carbon monoxide?

(All volumes are measured at the same temperature and pressure.)

A 1 g of hydrogen

B 3·5 g of nitrogen

C 10 g of argon

D 35·5 g of chlorine

19. What volume of oxygen (in litres) would be required for the complete combustion of a gaseous mixture containing 1 litre of carbon monoxide and 3 litres of hydrogen?

(All volumes are measured at the same temperature and pressure.)

A 1

B 2

C 3

D 4

20. Which of the following pollutants, produced during internal combustion in a car engine, is **not** the result of incomplete combustion?

A Carbon

B Carbon monoxide

C Hydrocarbons

D Nitrogen dioxide

21. Which of the following compounds does **not** have isomeric structures?

A C_2HCl_3

B $C_2H_4Cl_2$

C Propene

D Propan-1-ol

22. Which of the following compounds is an alkanone?

$$A \quad CH_3 — CH_2 — \overset{\overset{\displaystyle O}{\|}}{C} — H$$

$$B \quad CH_3 — \overset{\overset{\displaystyle O}{\|}}{C} — O — CH_3$$

$$C \quad CH_3 — \overset{\overset{\displaystyle O}{\|}}{C} — CH_3$$

$$D \quad CH_3 — \overset{\overset{\displaystyle O}{\|}}{C} — OH$$

23. What organic compound is produced by the dehydration of ethanol?

A Ethane

B Ethene

C Ethanal

D Ethanoic acid

24. The production of synthesis gas from methane involves

A steam reforming

B catalytic cracking

C hydration

D oxidation.

25. Compound **X** reacted with hot copper(II) oxide and the organic product did not give a colour change when heated with Fehling's solution.

   Compound **X** could be

   A butan-1-ol

   B butan-2-ol

   C butanone

   D butanoic acid.

26. Part of a polymer is shown.

$$\begin{array}{cccccccc} H & C_2H_5 & H & H & H & C_2H_5 & H & H \\ | & | & | & | & | & | & | & | \\ -C- & C- & C- & C- & C- & C- & C- & C- \\ | & | & | & | & | & | & | & | \\ H & H & H & H & H & H & H & H \end{array}$$

   Which two alkenes were used to make this polymer?

   A Ethene and propene

   B Ethene and but-1-ene

   C Propene and but-1-ene

   D Ethene and but-2-ene

27. Ammonia solution may be used to distinguish Fe^{2+}(aq) from Fe^{3+}(aq) as follows:

   Fe^{2+}(aq) gives a green precipitate of $Fe(OH)_2$;

   Fe^{3+}(aq) gives a brown precipitate of $Fe(OH)_3$.

   Which of the following types of compound is most likely to give similar results if used instead of ammonia?

   A An alcohol

   B An aldehyde

   C An amine

   D A carboxylic acid

28. Which of the following reactions takes place during the 'hardening' of vegetable oil?

   A Addition

   B Hydrolysis

   C Dehydration

   D Oxidation

29. Fats are formed by the condensation reaction between glycerol molecules and fatty acid molecules.

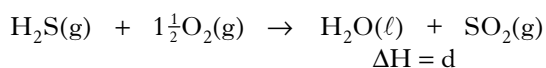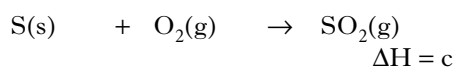   In this reaction the mole ratio of glycerol molecules to fatty acid molecules is
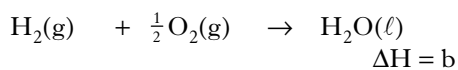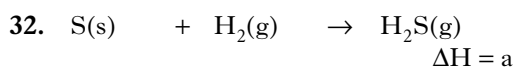
   A 1 : 1

   B 1 : 2

   C 1 : 3

   D 3 : 1.

30. Which of the following graphs shows how the rate of reaction varies with temperature for the fermentation of glucose?
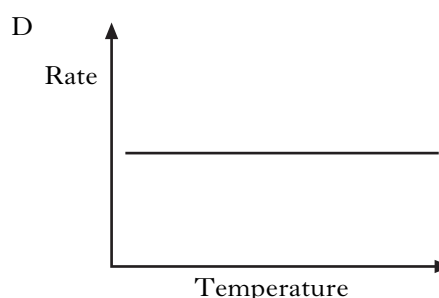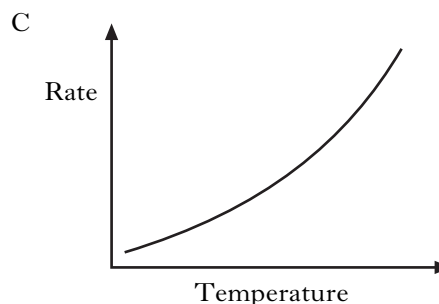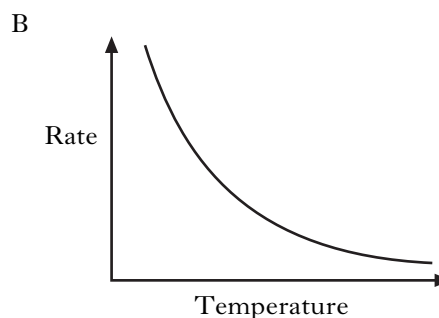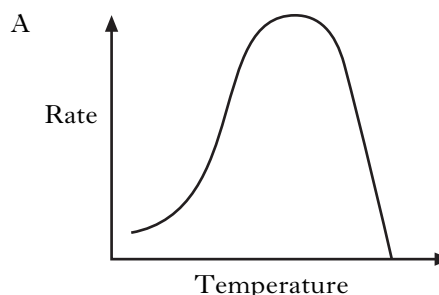
31. Which of the following is the best description of a feedstock?

A A consumer product such as a textile, plastic or detergent.

B A complex chemical that has been synthesised from small molecules.

C A mixture of chemicals formed by the cracking of the naphtha fraction from oil.

D A chemical from which other chemicals can be extracted or synthesised.

32.
$$S(s) + H_2(g) \rightarrow H_2S(g) \quad \Delta H = a$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(\ell) \quad \Delta H = b$$
$$S(s) + O_2(g) \rightarrow SO_2(g) \quad \Delta H = c$$
$$H_2S(g) + 1\tfrac{1}{2}O_2(g) \rightarrow H_2O(\ell) + SO_2(g) \quad \Delta H = d$$

What is the relationship between a, b, c and d?

A $a = b + c - d$

B $a = d - b - c$

C $a = b - c - d$

D $a = d + c - b$

33. A catalyst is added to a reaction at equilibrium.

Which of the following does **not** apply?

A The rate of the forward reaction increases.

B The rate of the reverse reaction increases.

C The position of equilibrium remains unchanged.

D The position of equilibrium shifts to the right.

34. Steam and carbon monoxide react to form an equilibrium mixture.
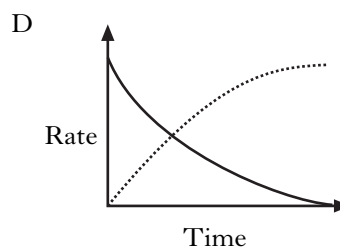
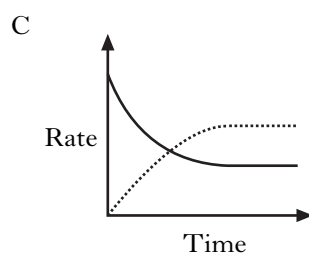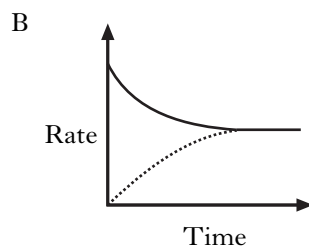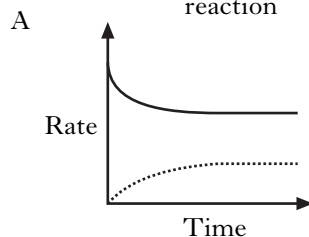$$CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g)$$
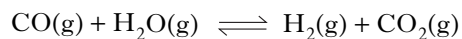
Which of the following graphs shows how the rates of the forward and reverse reactions change when carbon monoxide and steam are mixed?

KEY

——— forward reaction

·········· reverse reaction

A

B

C

D

[Turn over

35. Solid sodium sulphite is dissolved in distilled water, producing an alkaline solution.

Which of the following processes is the most important in causing this change?

A Sodium ions reacting with hydroxide ions

B Hydrogen ions reacting with sulphite ions

C Sodium ions reacting with sulphite ions

D Hydrogen ions reacting with hydroxide ions

36. Which of the following salts dissolves in water to form an acidic solution?

A CH_3COONa

B Na_2SO_4

C KCl

D NH_4NO_3

37. Iodide ions can be oxidised using acidified potassium permanganate solution.

The equations are:

$2I^-(aq) \rightarrow I_2(aq) + 2e^-$

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(\ell)$
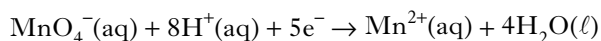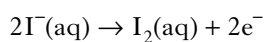
How many moles of iodide ions are oxidised by one mole of permanganate ions?

A 1·0

B 2·0

C 2·5

D 5·0

38. In the electrolysis of molten magnesium chloride, 1 mol of magnesium is deposited at the negative electrode by

A 96 500 coulombs

B 193 000 coulombs

C 1 mol of electrons

D 24·3 mol of electrons.

39. Alpha, beta and gamma radiation is passed from a source through an electric field onto a photographic plate.

source of α, β and γ radiations   electric field   photographic plate
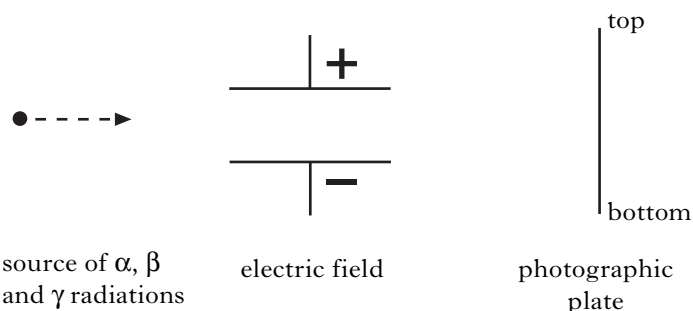
Which of the following patterns will be produced on the photographic plate?

40. From which of the following could $^{32}_{15}P$ be produced by neutron capture?

A $^{33}_{15}P$

B $^{32}_{16}S$

C $^{31}_{15}P$

D $^{31}_{16}S$

SECTION B

All answers must be written clearly and legibly in ink.

1. (*a*) Lithium starts the second period of the Periodic Table.

Li	Be	B	C	N	O	F

What is the trend in electronegativity values across this period from Li to F?

1

(*b*) **Graph 1** shows the first four ionisation energies for aluminium.

Graph 1

Ionisation
energy/kJ mol^{-1}

1st 2nd 3rd 4th
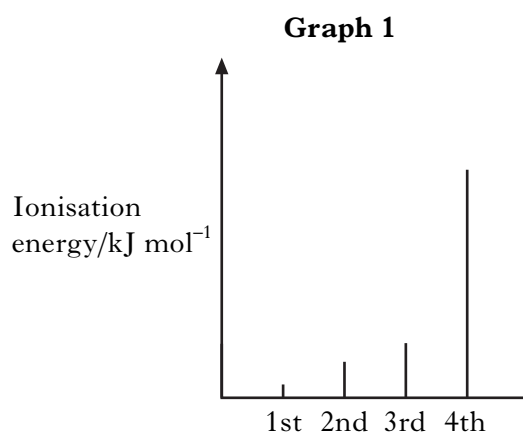
Why is the fourth ionisation energy of aluminium so much higher than the third ionisation energy?

1

1. **(continued)**

   (*c*) **Graph 2** shows the boiling points of the elements in Group 7 of the Periodic Table.

Graph 2

Boiling
point/°C

F   Cl   Br   I
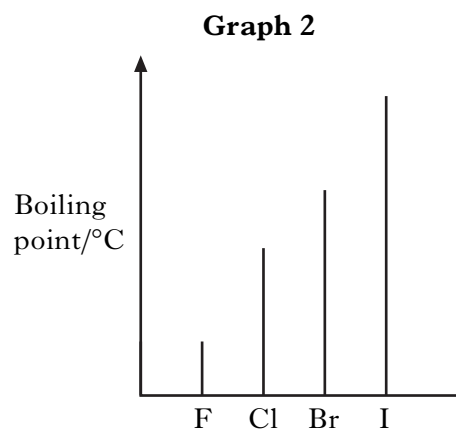
Why do the boiling points increase down Group 7?

1

(3)

[Turn over

Marks

2. Reactions are carried out in oil refineries to increase the octane number of petrol components. One such reaction is:

CH$_3$
|
CH
H$_2$C   CH$_2$
|　　　|
H$_2$C   CH$_2$
CH$_2$

⟶

CH$_3$

methylcyclohexane   methylbenzene
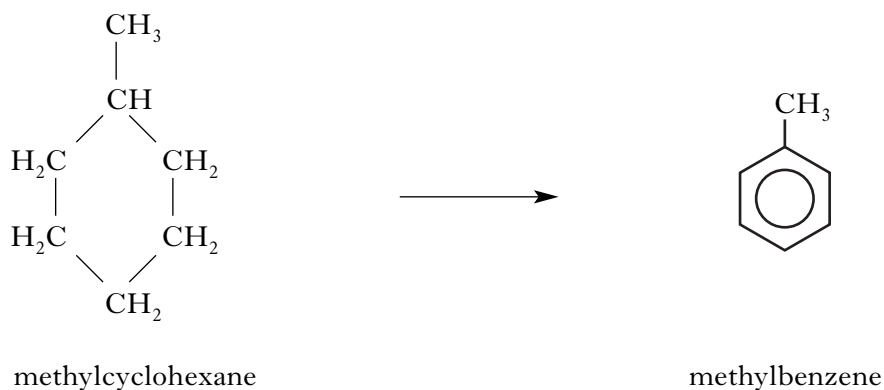
(*a*) The molecular formula for methylbenzene can be written C$_x$H$_y$.
Give the values for **x** and **y**.

x =

y =

1

(*b*) Hydrogen, the by-product of the reaction, can also be used as a fuel.
Give **one** advantage of using hydrogen as a fuel instead of petrol.

1

(*c*) In some countries oxygenates are added to the petrol. These improve the efficiency of burning. One common oxygenate is ethanol.
Give **one** other advantage of adding ethanol to petrol.

1
(3)

3. Alkanols can be oxidised to alkanoic acids.

$CH_3CH_2CH_2OH$ **Step 1** → CH_3CH_2CHO **Step 2** → CH_3CH_2COOH

propan-1-ol   propanal   propanoic acid
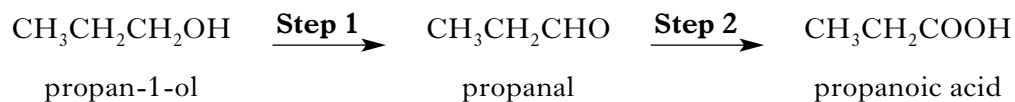
(*a*)   (i)   Why can **Step 1** be described as an oxidation reaction?

1

     (ii)   Acidified potassium dichromate solution can be used to oxidise propanal in **Step 2**.

          What colour change would be observed in this reaction?

1

(*b*)   Propan-1-ol and propanoic acid react to form an ester.

     The mixture of excess reactants and ester product is poured onto sodium hydrogencarbonate solution.

  (i)   What evidence would show that an ester is formed?

1

  (ii)   Draw a structural formula for this ester.

1

(4)

[Turn over

4. Ozone gas, O_3(g), is made up of triatomic molecules.

Marks

(*a*) Ozone is present in the upper atmosphere.
Why is the ozone layer important for life on Earth?

1

(*b*) The depletion of this layer is believed to be caused by chlorine radicals produced by the breakdown of certain CFCs. Some of the gaseous reactions are catalysed by ice crystals in clouds.

The crystals are acting as what type of catalyst?

1

(*c*) Ozone can be produced in the laboratory by electrical discharge.

$$3O_2(g) \quad \rightarrow \quad 2O_3(g)$$
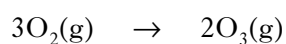
Calculate the approximate number of O_3(g) molecules produced from one mole of O_2(g) molecules.

1

(3)

Marks

5. Polymers can be classified as natural or synthetic.

(*a*) Keratin, a natural polymer, is a protein found in hair.
The hydrolysis of keratin produces different monomers of the type shown.
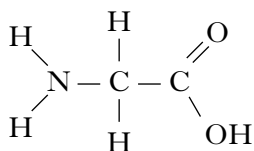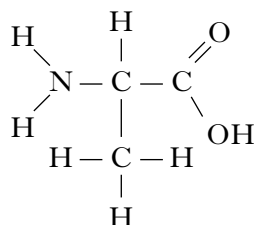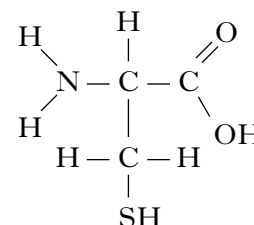
glycine   alanine   cysteine

(i) What name is given to monomers like glycine, alanine and cysteine?

1

(ii) What is meant by a **hydrolysis** reaction?

1

(*b*) Dacron, a synthetic polymer, is used in heart surgery.

A section of the polymer is shown.
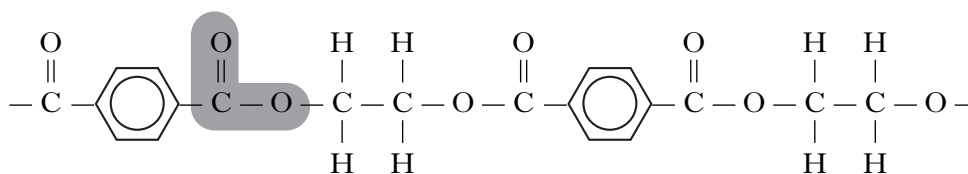
(i) What name is given to the link made by the shaded group of atoms in this section of the polymer?

1

(ii) Why would this polymer be formed as a fibre and not as a resin?

1

(4)

Marks

6. A student used the simple laboratory apparatus shown to determine the enthalpy of combustion of methanol.

thermometer

copper can

draught shield

methanol

water

spirit burner
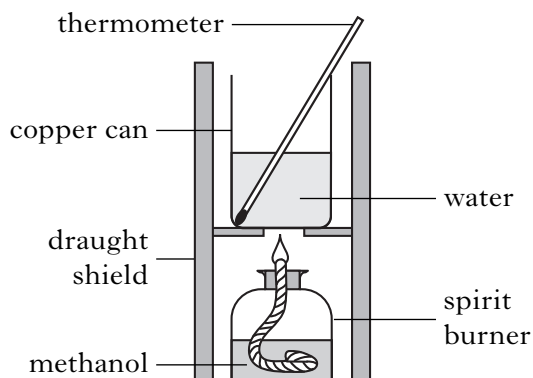
(*a*) (i) What measurements are needed to calculate the energy released by the burning methanol?

1

(ii) The student found that burning 0·370 g of methanol produces 3·86 kJ of energy.

Use this result to calculate the enthalpy of combustion of methanol.

1

(*b*) A more accurate value can be obtained using a bomb calorimeter.

electrical supply to ignite the methanol

methanol

platinum dish

thermometer

oxygen gas

thick walled 'bomb' container

water
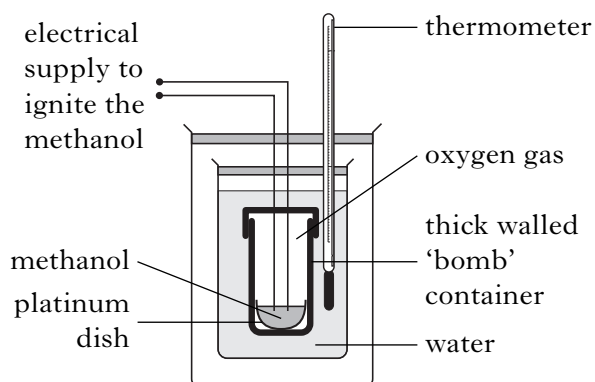
One reason for the more accurate value is that less heat is lost to the surroundings than in the simple laboratory method.

Give **one** other reason for the value being more accurate in the bomb calorimeter method.

1

Marks

7. An experiment was carried out to determine the rate of the reaction between hydrochloric acid and calcium carbonate chips. The rate of this reaction was followed by measuring the volume of gas released over a certain time.

gas syringe to collect
carbon dioxide

calcium carbonate chips
+
hydrochloric acid
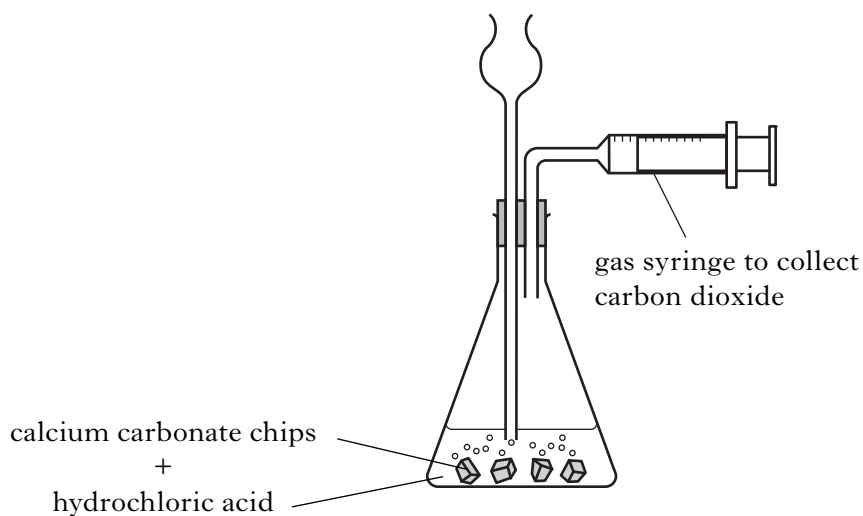
(*a*) Describe a different way of measuring volume in order to follow the rate of this reaction.

1

(*b*) What other variable could be measured to follow the rate of this reaction?

1

(2)

[Turn over

Marks

8. Ammonia is produced in industry by the Haber Process.

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

(*a*) State whether the industrial manufacture of ammonia is likely to be a batch or a continuous process.

1

(*b*) The graph shows how the percentage yield of ammonia changes with temperature at a pressure of 100 atmospheres.
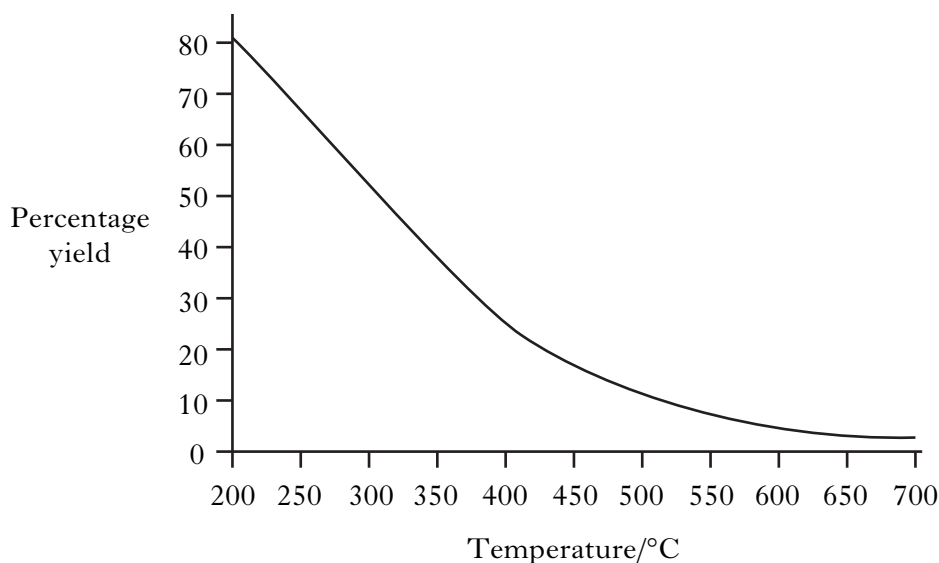
(i) A student correctly concludes from the graph that the production of ammonia is an exothermic process.

What is the reasoning that leads to this conclusion?

1

(ii) **Explain clearly** why the industrial manufacture of ammonia is carried out at a pressure greater than 100 atmospheres.

2

8. (continued)

    (*c*) Under certain conditions, 500 kg of nitrogen reacts with excess hydrogen to produce 405 kg of ammonia.

        Calculate the percentage yield of ammonia under these conditions.

        Show your working clearly.

2

(6)

[Turn over

        Page nineteen

Marks

9. Primary, secondary and tertiary alkanols can be prepared by the reaction of carbonyl compounds with Grignard reagents.

Step 1

The Grignard reagent reacts with the carbonyl compound.

$$CH_3-CH_2-CH_2-C\overset{O}{\underset{H}{\diagdown}} \quad + \quad CH_3MgCl \quad \longrightarrow \quad CH_3-CH_2-CH_2-\overset{OMgCl}{\underset{CH_3}{\overset{|}{\underset{|}{C}}}}-H$$

       butanal   Grignard reagent
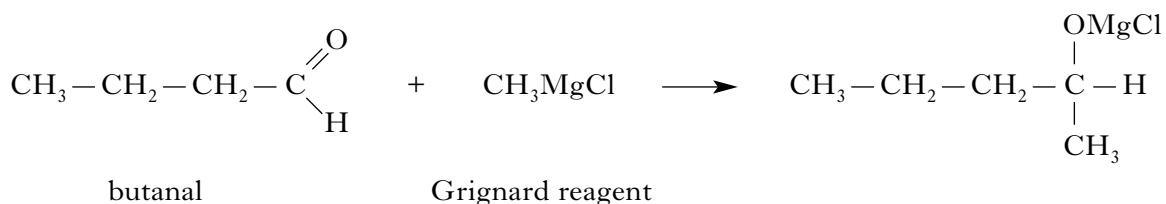
Step 2

The reaction of the product of **Step 1** with dilute acid produces the alkanol.

$$CH_3-CH_2-CH_2-\overset{OMgCl}{\underset{CH_3}{\overset{|}{\underset{|}{C}}}}-H \quad \longrightarrow \quad CH_3-CH_2-CH_2-\overset{OH}{\underset{CH_3}{\overset{|}{\underset{|}{C}}}}-H$$

       +   HCl   + $MgCl_2$
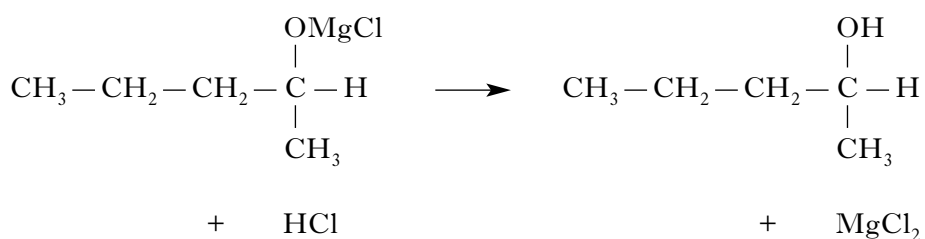
(*a*) Describe the difference between a primary, a secondary and a tertiary alkanol. You may wish to include labelled structures in your answer.

1

(*b*) Suggest a name for the type of reaction that takes place in **Step 1**.

1

9. (continued)

(*c*) The same Grignard reagent can be used to produce the alkanol below.

$$CH_3 - CH_2 - \underset{\underset{CH_3}{|}}{\overset{\overset{OH}{|}}{C}} - CH_2 - CH_3$$

Name the carbonyl compound used in this reaction.

1

(3)

[Turn over

10. Sherbet contains a mixture of sodium hydrogencarbonate and tartaric acid. The fizzing sensation in the mouth is due to the carbon dioxide produced in the following reaction.
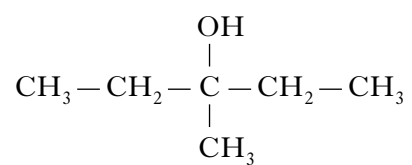
$$2NaHCO_3 \quad + \quad C_4H_6O_6 \quad \rightarrow \quad Na_2(C_4H_4O_6) \quad + \quad 2H_2O \quad + \quad 2CO_2$$

sodium   tartaric acid   sodium tartrate
hydrogencarbonate
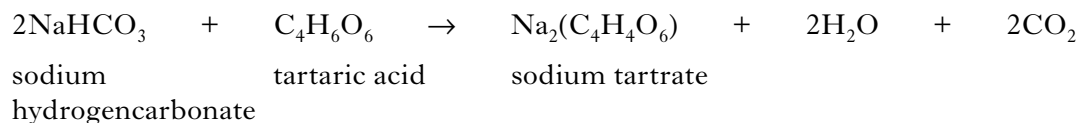
(*a*) Name the type of reaction taking place.

1

(*b*) The chemical name for tartaric acid is 2,3-dihydroxybutanedioic acid.

Draw a structural formula for tartaric acid.

1

(*c*) In an experiment, a student found that adding water to 20 sherbet sweets produced $105\,cm^3$ of carbon dioxide.

Assuming that sodium hydrogencarbonate is in excess, calculate the average mass of tartaric acid, in grams, in one sweet.

(Take the molar volume of carbon dioxide to be 24 litre mol^{-1}.)

Show your working clearly.

2

(4)

Marks

11. The following answers were taken from a student's examination paper.

The two answers are incorrect.

For each question, give the correct explanation.

(*a*) **Question** As a rough guide, the rate of a reaction tends to double for every 10 °C rise in temperature.

Why does a small increase in temperature produce a large increase in reaction rate?

Student answer Because rising temperature increases the activation energy which increases the number of collisions which speeds up the reaction greatly.

Correct explanation

1

(*b*) **Question** Explain the difference in atomic size between potassium and chlorine atoms.

Student answer A potassium nucleus has 19 protons but a chlorine nucleus has only 17 protons. The greater pull on the outer electron in the potassium atom means the atomic size of potassium is less than that of chlorine.

Correct explanation

1

(2)

[Turn over

12. Barium hydroxide solution neutralises dilute sulphuric acid. A white precipitate of barium sulphate is formed in the reaction.

$$H_2SO_4(aq) \quad + \quad Ba(OH)_2(aq) \quad \rightarrow \quad BaSO_4(s) \quad + \quad 2H_2O(\ell)$$

The reaction can be followed by measuring the conductivity of the solution as barium hydroxide solution is added to dilute sulphuric acid.

barium hydroxide solution

mA

d.c. supply

dilute
sulphuric
acid

carbon electrodes
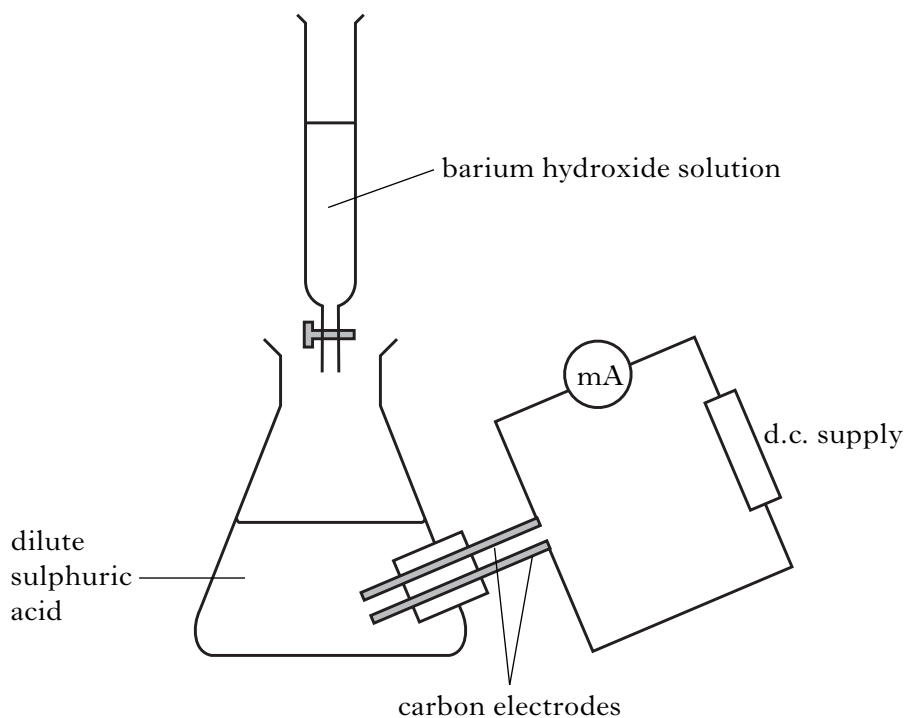
The graph shows how the conductivity changed in one experiment when barium hydroxide solution was added to $50\,cm^3$ of $0 \cdot 01\ mol\,l^{-1}$ sulphuric acid.

Conductivity/
mA

Volume of barium hydroxide
solution added/cm^3
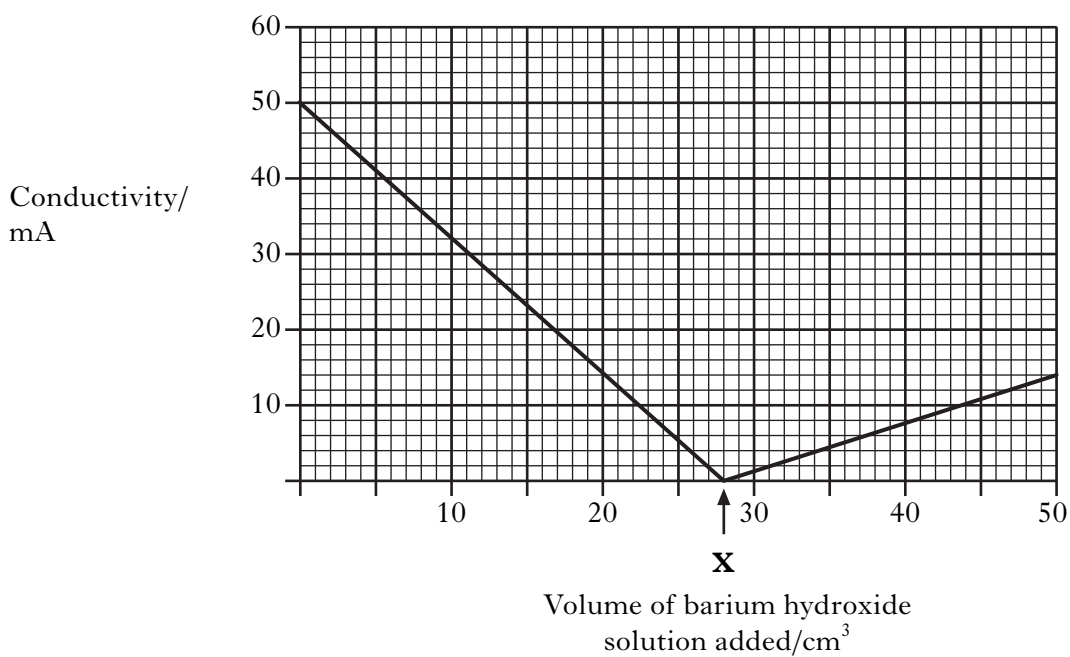
Marks

12. (continued)

(*a*) Point **X** corresponds to the end-point of the reaction.

Use the information on the graph to calculate the concentration of the barium hydroxide solution, in $mol\,l^{-1}$.
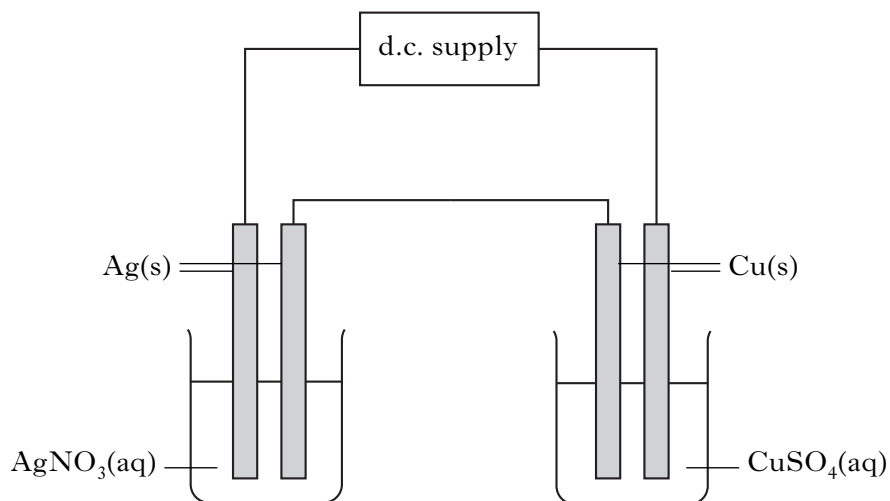
1

(*b*) **Explain clearly** why the conductivity is very close to zero at the end-point.

2

(3)

[Turn over

13. An electrolysis experiment was set up with two cells as shown.

The reaction at the silver electrode is:

$$Ag^+(aq) \quad + \quad e^- \quad \rightarrow \quad Ag(s)$$
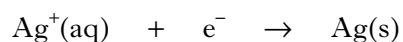
The mass of silver deposited in the reaction was $0.365\,g$.

(*a*) In addition to measuring the time, what **two** changes to the circuit would need to be made to find accurately the quantity of charge required to deposit $0.365\,g$ of silver?

1

(*b*) What mass of copper would be deposited in the same time?

Show your working clearly.

2

(3)

14. (*a*) A student compared the properties of equal concentrations of aqueous solutions of hydrochloric acid and ethanoic acid.

Marks

	Experiment	Hydrochloric acid	Ethanoic acid
1	Rate of reaction with magnesium	fast	faster (slower) same
2	Electrical conductivity	80 mA	higher lower same
3	Volume of $0 \cdot 1 \, mol \, l^{-1}$ sodium hydroxide to neutralise $20 \, cm^3$ acid	$20 \, cm^3$	more less same

The result for ethanoic acid has been circled for experiment 1.

Circle the expected results for ethanoic acid in experiments 2 and 3.

1

(*b*) Some of the hydrogen atoms in ethanoic acid can be replaced by chlorine atoms to give three chloroethanoic acids. The student measured the pH of aqueous solutions of the four related acids. All the acids had the same concentration.

Acid name	Molecular formula	pH
ethanoic acid	CH_3COOH	$2 \cdot 3$
chloroethanoic acid	$CH_2ClCOOH$	$1 \cdot 4$
dichloroethanoic acid	$CHCl_2COOH$	$1 \cdot 0$
trichloroethanoic acid	CCl_3COOH	$0 \cdot 2$

(i) What is the concentration of hydroxide ions, in $mol \, l^{-1}$, in the dichloroethanoic acid solution?

1

(ii) **Explain clearly** the way in which the number of chlorine atoms in the acid molecules affects the strength of the acid.
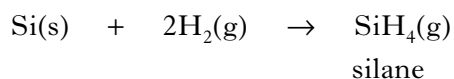
2

15. (*a*) Methane is produced in the reaction of aluminium carbide with water.

$$Al_4C_3 \quad + \quad H_2O \quad \rightarrow \quad Al(OH)_3 \quad + \quad CH_4$$

Balance the above equation.

1

(*b*) Silane, silicon hydride, is formed in the reaction of silicon with hydrogen.

$$Si(s) \quad + \quad 2H_2(g) \quad \rightarrow \quad SiH_4(g)$$
$$\text{silane}$$

The enthalpy change for this reaction is called the enthalpy of formation of silane.

The combustion of silane gives silicon dioxide and water.

$$SiH_4(g) \quad + \quad 2O_2(g) \quad \rightarrow \quad SiO_2(s) \quad + \quad 2H_2O(\ell) \quad \Delta H = -1517\,kJ\,mol^{-1}$$
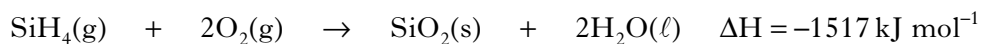
The enthalpy of combustion of silicon is $-911\,kJ\,mol^{-1}$.

Use this information and the enthalpy of combustion of hydrogen in the data booklet to calculate the enthalpy of formation of silane, in $kJ\,mol^{-1}$.

Show your working clearly.

2

(3)

Marks

16. Thorium-227 decays by alpha emission.

(*a*) Complete the nuclear equation for the alpha decay of thorium-227.

$$^{227}\text{Th} \quad \rightarrow$$

1

(*b*) A sample of thorium-227 was placed in a wooden box. A radiation detector was held 10 cm away from the box.

Why was alpha radiation **not** detected?

1

(*c*) Thorium-227 has a half-life of 19 days. If 0·42 g of thorium-227 has decayed after 57 days, calculate the initial mass of thorium-227, in grams.

1
(3)

[Turn over

Marks

17. Carbon-13 NMR is a technique used in chemistry to determine the structure of organic compounds.

(*a*) Calculate the neutron to proton ratio in an atom of carbon-13.

1

(*b*) The technique allows a carbon atom in a molecule to be identified by its 'chemical shift'. This value depends on the other atoms bonded to the carbon atom.

Shift table

Carbon environment	Chemical shift/ppm
$C=O$ (in ketones)	$205-220$
$C=O$ (in aldehydes)	$190-205$
$C=O$ (in acids and esters)	$170-185$
$C=C$ (in alkenes)	$115-140$
$C\equiv C$ (in alkynes)	$70-95$
$-CH$	$25-50$
$-CH_2$	$16-40$
$-CH_3$	$5-15$

In a carbon-13 NMR spectrum, the number of lines correspond to the number of chemically different carbon atoms and the position of the line (the value of the chemical shift) indicates the type of carbon atom.

Marks

17. **(*b*)** **(continued)**

The spectrum for propanal is shown.

**Spectrum 1**
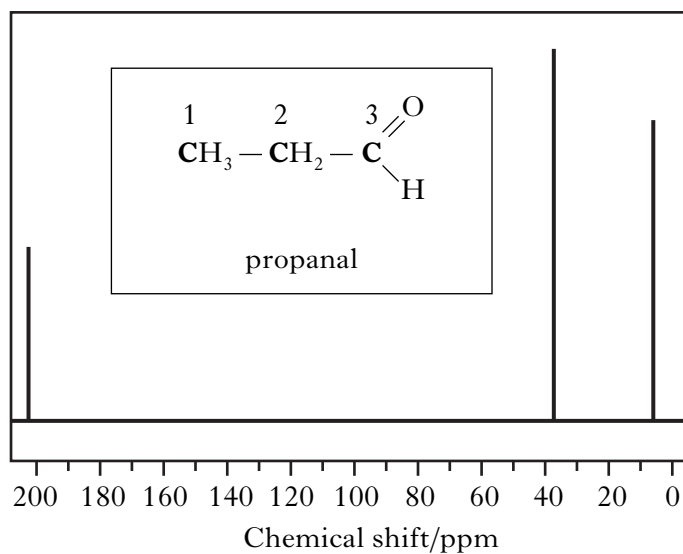
(i) Use the table of chemical shifts to label each of the peaks on the spectrum with a number to match the carbon atom in propanal that is responsible for the peak.

1

(ii) Hydrocarbon **X** has a relative formula mass of 54. Hydrocarbon **X** reacts with hydrogen. One of the products, hydrocarbon **Y**, has a relative formula mass of 56.

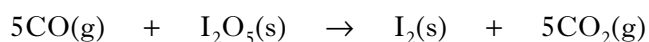The carbon-13 NMR spectrum for hydrocarbon **Y** is shown below.
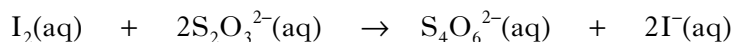
Spectrum 2
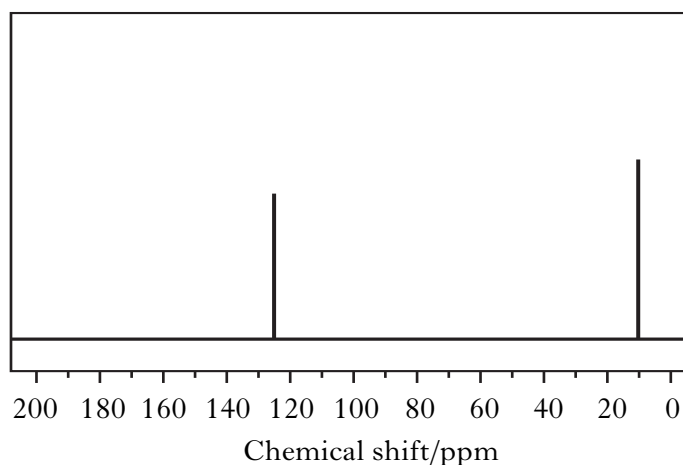
Name hydrocarbon **Y**.

1

(3)

18. The number of moles of carbon monoxide in a sample of air can be measured as follows.

Step 1 The carbon monoxide reacts with iodine(V) oxide, producing iodine.

$$5CO(g) \quad + \quad I_2O_5(s) \quad \rightarrow \quad I_2(s) \quad + \quad 5CO_2(g)$$

Step 2 The iodine is then dissolved in potassium iodide solution and titrated against sodium thiosulphate solution.

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

(*a*) Write the ion-electron equation for the oxidation reaction in **Step 2**.

1

(*b*) Name a chemical that can be used to indicate when all of the iodine has been removed in the reaction taking place in **Step 2**.

1

(*c*) If $50\cdot4\,cm^3$ of $0\cdot10\,mol\,l^{-1}$ sodium thiosulphate solution was used in a titration, calculate the number of moles of carbon monoxide in the sample of air.

Show your working clearly.

2
(4)

[*END OF QUESTION PAPER*]

ADDITIONAL SPACE FOR ANSWERS

Page thirty-three

ADDITIONAL SPACE FOR ANSWERS

Page thirty-four

ADDITIONAL SPACE FOR ANSWERS

Page thirty-five

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