Total
Section B

X012/12/02

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 examination, 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).

    A   B   C   D
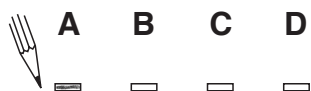
Changing an answer

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**.

    A   B   C   D

1. Which of the following chlorides conducts electricity when molten?

   A   Calcium chloride

   B   Nitrogen chloride

   C   Phosphorus chloride

   D   Silicon chloride

2. Particles with the same electron arrangement are said to be isoelectronic.

   Which of the following compounds contains ions which are isoelectronic?

   A   CaO

   B $CaBr_2$

   C Na_2O

   D   LiF

3. Which of the following would be expected to react?

   A   Iron and zinc sulphate solution

   B   Tin and silver nitrate solution

   C   Copper and dilute sulphuric acid

   D   Lead and magnesium chloride solution

4. An excess of silver nitrate solution is added to a solution of sodium chloride, and a white precipitate is formed. The precipitate is then filtered off.

   Which solution would **not** give a precipitate when added to the filtrate?

   A   Barium chloride

   B   Potassium nitrate

   C   Calcium iodide

   D   Sodium bromide

   (You may wish to refer to the Data Booklet.)

5. Excess marble chips (calcium carbonate) were added to $25\,cm^3$ of hydrochloric acid, concentration $2\,mol\,l^{-1}$.
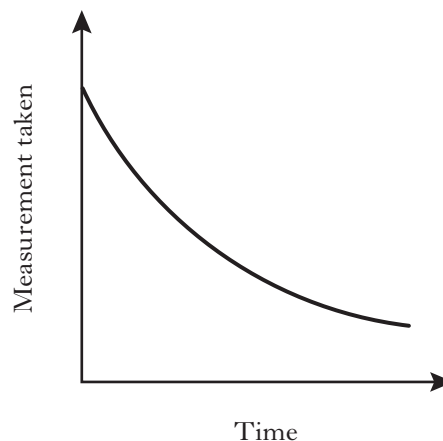
   Which of the following measurements, taken at regular intervals and plotted against time, would give the graph shown above?

   A   Temperature

   B   Volume of gas produced

   C   pH of solution

   D   Mass of the beaker and contents

6. In which of the following will **both** changes result in an increase in the rate of a chemical reaction?

   A   A decrease in activation energy and an increase in the frequency of collisions

   B   An increase in activation energy and a decrease in particle size

   C   An increase in temperature and an increase in the particle size

   D   An increase in concentration and a decrease in the surface area of the reactant particles

[Turn over

7. When $50\,cm^3$ of $2\,mol\,l^{-1}$ hydrochloric acid was added to $50\,cm^3$ of $1\,mol\,l^{-1}$ sodium hydroxide, the temperature increased by $6\,°C$.

Which of the following changes to one of the reactants would bring about a greater increase in temperature, assuming the other reactant was not changed?

A Use $500\,cm^3$ of $2\,mol\,l^{-1}$ hydrochloric acid.

B Use $50\,cm^3$ of $4\,mol\,l^{-1}$ hydrochloric acid.

C Use $50\,cm^3$ of $1\,mol\,l^{-1}$ potassium hydroxide.

D Use $50\,cm^3$ of $2\,mol\,l^{-1}$ sodium hydroxide.

8. Which of the following statements is **not** correct?

A The surface activity of a catalyst can be reduced by poisoning.

B Impurities in the reactants can result in a catalyst having to be regenerated.

C Homogenous catalysts are found in the catalytic converters fitted to cars.

D Heterogenous catalysts work by adsorbing reactant molecules.

9. Which of the following diagrams represents an exothermic reaction which is most likely to take place at room temperature?
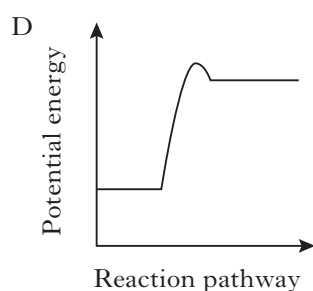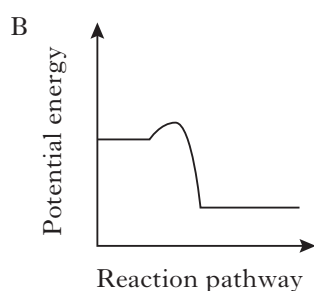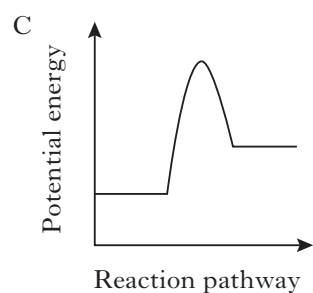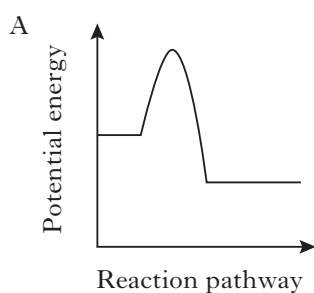

10. The enthalpy of combustion of methanol is $-727\,kJ\,mol^{-1}$.

What mass of methanol has to be burned to produce $72.7\,kJ$?

A $3.2\,g$

B $32\ \ g$

C $72.7\,g$

D $727\ \ g$

11. Which of the following elements has the greatest attraction for bonding electrons?

A Lithium

B Chlorine

C Sodium

D Bromine

12. Which of the following statements is true?

A The potassium ion is larger than the potassium atom.

B The chloride ion is smaller than the chlorine atom.

C The sodium atom is larger than the sodium ion.

D The oxygen atom is larger than the oxide ion.

13. The diagram shows the melting points of successive elements across a period in the Periodic Table.
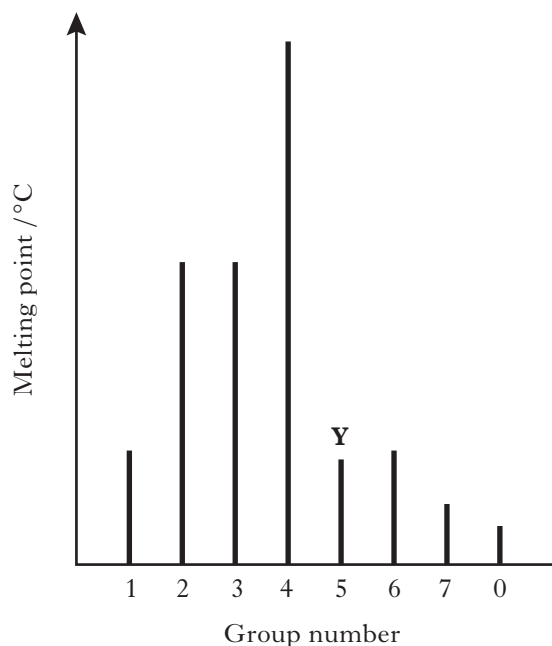

Which of the following is a correct reason for the low melting point of element **Y**?

A It has weak ionic bonds.

B It has weak covalent bonds.

C It has weakly-held outer electrons.

D It has weak forces between molecules.

14. Which type of bonding is **never** found in elements?

A Metallic

B van der Waals'

C Polar covalent

D Non-polar covalent

15. Which of the following elements exists as discrete molecules?

A Boron

B Carbon (diamond)

C Silicon

D Sulphur

16. The structures for molecules of four liquids are shown below.

Which liquid will be the most viscous?

A

B

C

D
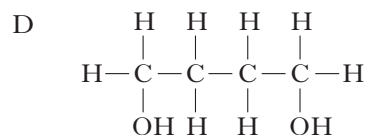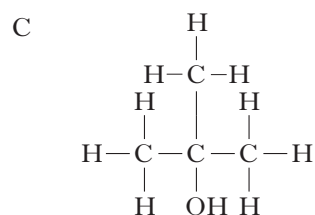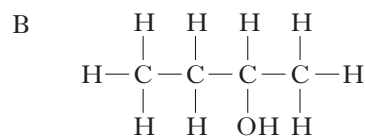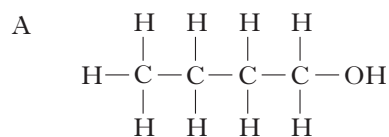
17. A mixture of magnesium bromide and magnesium sulphate is known to contain 3 mol of magnesium and 4 mol of bromide ions.

How many moles of sulphate ions are present?

A 1

B 2

C 3

D 4

[Turn over

18.

$$2C_2H_2(g) \; + \; 5O_2(g) \longrightarrow 4CO_2(g) \; + \; 2H_2O(\ell)$$
ethyne

What volume of gas would be produced by the complete combustion of $100\,cm^3$ of ethyne gas?

All volumes were measured at atmospheric pressure and room temperature.

A $200\,cm^3$

B $300\,cm^3$

C $400\,cm^3$

D $800\,cm^3$

19. Which equation could represent an industrial cracking process?

A $CH_3(CH_2)_6CH_2OH$
         $\downarrow$
   $CH_3(CH_2)_5\,CH = CH_2 + H_2O$

B $CH_3(CH_2)_6\,CH_3$
         $\downarrow$
   $CH_3C(CH_3)_2CH_2CH(CH_3)_2$

C $CH_3(CH_2)_6CH_3$
         $\downarrow$
   $CH_3(CH_2)_4CH_3 + CH_2 = CH_2$

D $4CH_2 = CH_2 \rightarrow \quad -(CH_2CH_2)_4-$

20. Which of the following hydrocarbons is an isomer of 2-methylpent-2-ene?

A
$$\begin{array}{c} CH_3 \\ | \\ C = CH \\ |\quad\;\; | \\ CH_3 \;\; CH_2CH_3 \end{array}$$

B
$$\begin{array}{c} \qquad CH_3 \\ \qquad | \\ CH{=}C \\ |\quad\;\; | \\ CH_3 \;\; CH_2CH_3 \end{array}$$

C
$$\begin{array}{c} CH_3 \\ | \\ C = CH-CH_2-CH_3 \\ | \\ CH_3 \end{array}$$

D
$$\begin{array}{c} CH_3 \qquad\quad CH_3 \\ | \qquad\qquad | \\ CH_2-CH=C \\ \qquad\qquad | \\ \qquad\qquad CH_3 \end{array}$$

21. A compound with molecular formula $C_6H_{12}O_2$, could be
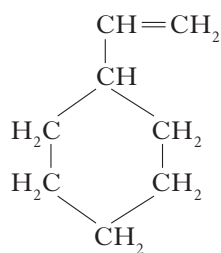
A   hexanal

B   hexan-2-ol

C   hexan-2-one

D   hexanoic acid.

22. An ester has the following structural formula
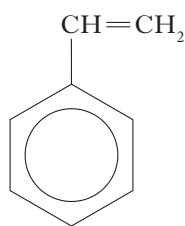$$CH_3CH_2CH_2COOCH_2CH_3$$

The name of this ester is

A   propyl propanoate

B   ethyl butanoate

C   butyl ethanoate

D   ethyl propanoate.

23. Cyclohexylethene and phenylethene are important industrial feedstocks.

$$CH=CH_2$$

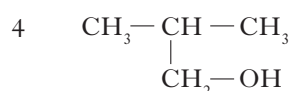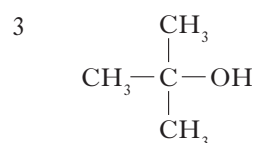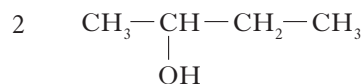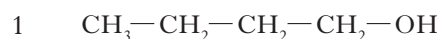cyclohexylethene   phenylethene

Phenylethene

A   cannot undergo addition polymerisation but cyclohexylethene can

B   undergoes addition reactions much more quickly than cyclohexylethene

C   contains 5 fewer hydrogen atoms per molecule than cyclohexylethene

D   decolourises the same number of moles of bromine as cyclohexylethene.

24. The product formed when propan–1–ol is dehydrated is

A   propane

B   propene

C   propanal

D   propanoic acid.

25. Which **two** isomers would each produce an acid when warmed with acidified potassium dichromate solution?

1   $CH_3-CH_2-CH_2-CH_2-OH$

2   $CH_3-CH-CH_2-CH_3$ with OH

3   $CH_3-\underset{CH_3}{\overset{CH_3}{C}}-OH$

4   $CH_3-CH-CH_3$ with CH_2-OH

A   1 and 2

B   2 and 3

C   1 and 4

D   3 and 4

26. Esters are formed by the reaction between which **two** functional groups?

A   A hydroxyl group and a carboxyl group

B   A hydroxyl group and a carbonyl group

C   A hydroxide group and a carboxyl group

D   A hydroxide group and a carbonyl group

27. Polyamides and polyesters are always made from monomers

A   which are unsaturated

B   with one functional group per molecule

C   containing a benzene ring structure

D   with two functional groups per molecule.

28. The process of cross-linking occurs in the

A   conversion of vegetable oils to margarine

B   curing of polyester resins

C   production of aromatic compounds from naphtha
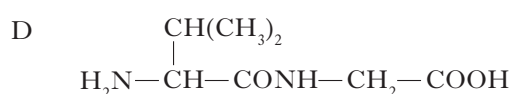
D   manufacture of thermoplastics.

29. Oils are generally

    A liquid at room temperature and contain a high proportion of unsaturated molecules

    B liquid at room temperature and contain a high proportion of saturated molecules

    C solid at room temperature and contain a high proportion of unsaturated molecules

    D solid at room temperature and contain a high proportion of saturated molecules.

30. A tripeptide **X** has the structure

$$\underset{|}{\overset{CH_3}{}}\qquad\qquad\underset{|}{\overset{CH(CH_3)_2}{}}$$
$$H_2N-CH-CONH-CH_2-CONH-CH-COOH$$
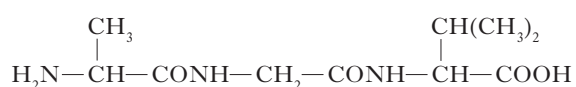
    Partial hydrolysis of **X** yields a mixture of dipeptides.

    Which of the following dipeptides could be produced on hydrolysing **X**?

    A
    $$\underset{|}{\overset{CH(CH_3)_2}{}}$$
    $$H_2N-CH_2-CONH-CH-COOH$$

    B
    $$\underset{|}{\overset{CH_3}{}}$$
    $$H_2N-CH_2-CONH-CH-COOH$$

    C
    $$\underset{|}{\overset{CH_3}{}}\qquad\underset{|}{\overset{CH(CH_3)_2}{}}$$
    $$H_2N-CH-CONH-CH-COOH$$

    D
    $$\underset{|}{\overset{CH(CH_3)_2}{}}$$
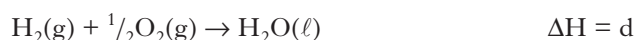 $$H_2N-CH-CONH-CH_2-COOH$$

31. The costs involved in the industrial production of a chemical are made up of fixed costs and variable costs.

    Which of the following is most likely to be classified as a variable cost?

    A The cost of labour

    B The cost of land rental

    C The cost of raw materials

    D The cost of plant construction

32.

$$C(s) + H_2(g) + O_2(g) \rightarrow HCOOH(\ell) \qquad \Delta H = a$$
$$HCOOH(\ell) + {}^1/_2O_2(g) \rightarrow CO_2(g) + H_2O(\ell) \qquad \Delta H = b$$
$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = c$$
$$H_2(g) + {}^1/_2O_2(g) \rightarrow H_2O(\ell) \qquad \Delta H = d$$

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

    A a = c + d − b

    B a = b − c − d

    C a = −b − c − d

    D a = c + b + d

33. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

    The equation represents a mixture at equilibrium.

    Which line in the table is true for the mixture after a further 2 hours of reaction?

	Rate of forward reaction	Rate of back reaction
A	unchanged	unchanged
B	increases	increases
C	decreases	decreases
D	unchanged	decreases

34. In which of the following would an increase in pressure result in the equilibrium position being moved to the left?

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

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

    C $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$

    D $Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(s) + 3CO_2(g)$
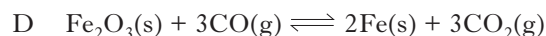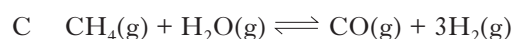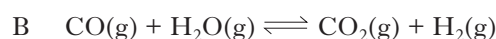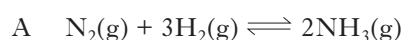
35. Which of the following is the same for equal volumes of $0\cdot1\,mol\,l^{-1}$ solutions of sodium hydroxide and ammonia?

    A The pH of solution

    B The mass of solute present

    C The conductivity of solution

    D The number of moles of hydrochloric acid needed for neutralisation

36. The concentration of $OH^-(aq)$ ions in a solution is $0.1\,mol\,l^{-1}$.
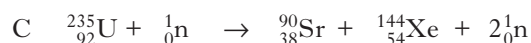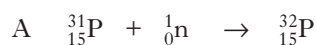
What is the pH of the solution?

A   1

B   8

C   13

D   14

37. Which of the following $1\,mol\,l^{-1}$ solutions has a pH greater than 1 but less than 7?

A $HCl(aq)$

B $NaCl(aq)$

C $Na_2CO_3(aq)$

D $CH_3COOH(aq)$

38. During electrolysis, which of the following would be formed by the passage of 96 500 C?

A $0.5\,mol$ Ag from $AgNO_3(aq)$

B $1.0\,mol$ Ag from $AgNO_3(aq)$

C $1.0\,mol$ Cu from $CuSO_4(aq)$

D $2.0\,mol$ Cu from $CuSO_4(aq)$

39. Identify the graph which shows how rate varies with temperature for the radioactive decay of uranium-235.

A

B

C

D
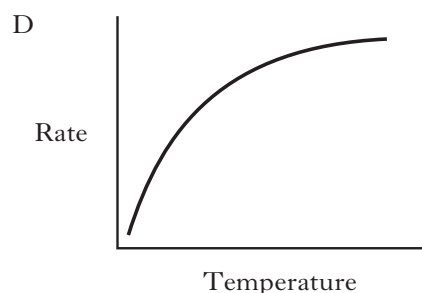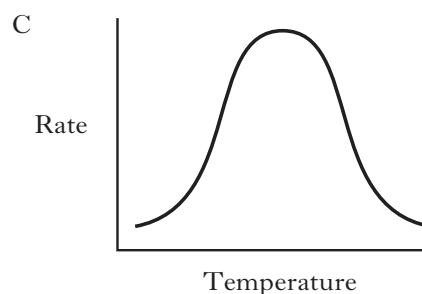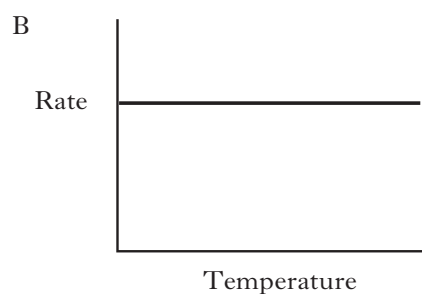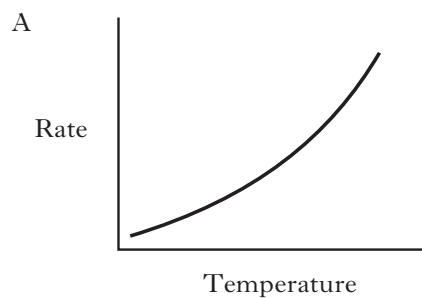
40. Which of the following equations represents a nuclear fission process?

A $^{31}_{15}P\ +\ ^{1}_{0}n\ \rightarrow\ ^{32}_{15}P$

B $^{2}_{1}H\ +\ ^{3}_{1}H\ \rightarrow\ ^{4}_{2}He\ +\ ^{1}_{0}n$

C $^{235}_{92}U\ +\ ^{1}_{0}n\ \rightarrow\ ^{90}_{38}Sr\ +\ ^{144}_{54}Xe\ +\ 2^{1}_{0}n$

D $^{27}_{13}Al\ +\ ^{4}_{2}He\ \rightarrow\ ^{30}_{15}P\ +\ ^{1}_{0}n$

Candidates are reminded that the answer sheet MUST be returned INSIDE the front cover of this answer book.
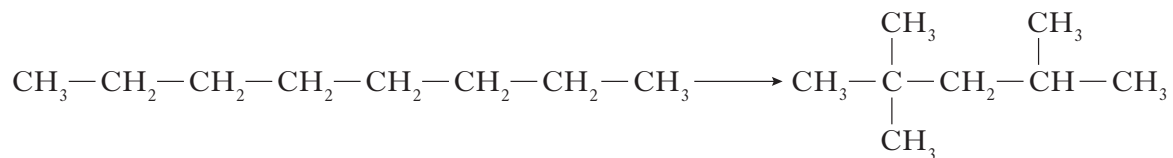
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Marks

SECTION B

All answers must be written clearly and legibly in ink.

1. An example of a reaction used to produce hydrocarbons for use in unleaded petrol is shown.

$$CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3 \longrightarrow CH_3-\overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}-CH_2-\overset{\overset{\displaystyle CH_3}{|}}{CH}-CH_3$$

octane   compound A

(a) Name the type of reaction shown above.

1

(b) Give the systematic name for compound **A**.

1

(c) What structural feature of compound **A** makes it suitable for use in unleaded petrol?

1

(d) Methanol can be used as an alternative fuel to petrol.

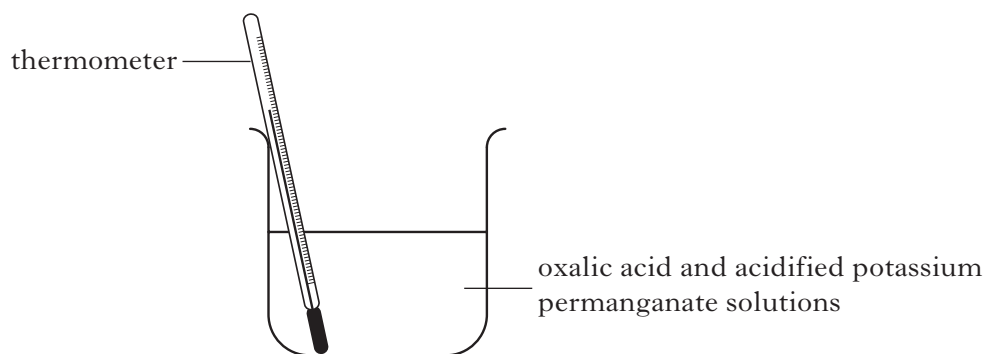State one disadvantage of using methanol as a fuel.

1

(4)

[Turn over

Marks

2. A student carries out a Prescribed Practical Activity (PPA) to determine the effect of temperature on the rate of the reaction between oxalic acid and acidified potassium permanganate solution.

thermometer

oxalic acid and acidified potassium permanganate solutions

(*a*) What colour change indicates that the reaction is complete?

1

(*b*) The student's results are shown on the graph below.

Rate/s^{-1}
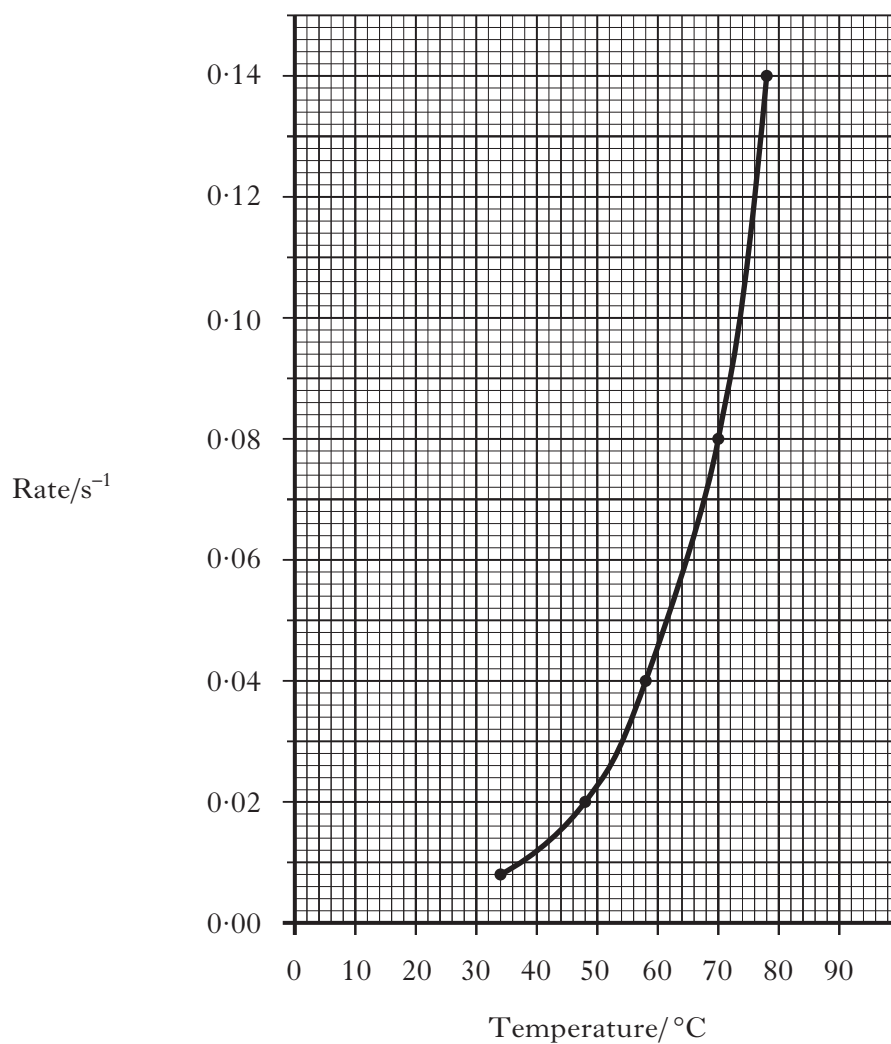
Temperature/°C

2. (*b*) (continued)

(i) The reaction time recorded in one experiment was 25 s.

Use the graph to determine the temperature, in °C, of this reaction.

1

(ii) Why is it difficult to obtain an accurate reaction time when the reaction is carried out below 30 °C?

1

(*c*) A small increase in temperature can cause a large increase in reaction rate.

As temperature is increased, collisions occur more frequently.

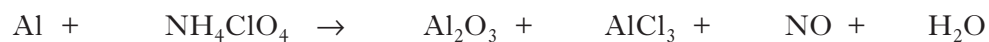What other reason is there for the large increase in reaction rate observed when the temperature is increased?

1

(4)

[Turn over

3. Ammonium perchlorate, NH_4ClO_4, is used in solid fuel rocket boosters.

(*a*) In the rocket boosters, ammonium perchlorate reacts with aluminium as shown.

$$Al + NH_4ClO_4 \rightarrow Al_2O_3 + AlCl_3 + NO + H_2O$$

Balance this equation.

1

(*b*) Calculate the mass of aluminium oxide, in g, that would contain $3 \cdot 01 \times 10^{21}$ aluminium ions.

(The mass of one mole of $Al_2O_3 = 102 \cdot 0$ g).

Show your working clearly.

2

(3)

Marks

4. Attempts have been made to make foods healthier by using alternatives to traditional cooking ingredients.

(*a*) An alternative to common salt contains potassium ions and chloride ions.

(i) Write an ion-electron equation for the first ionisation energy of potassium.

1

(ii) **Explain clearly** why the first ionisation energy of potassium is smaller than that of chlorine.

2

(*b*) A calorie-free replacement for fat can be made by reacting fatty acids with the hydroxyl groups on a molecule of sucrose. A structural formula for sucrose is shown.
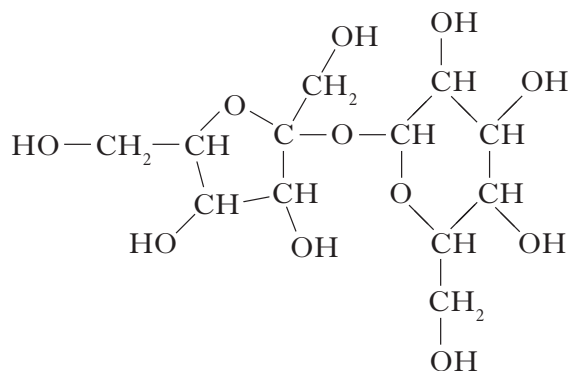
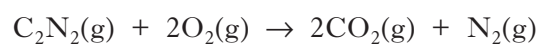How many fatty acid molecules can react with one molecule of sucrose?

1

(4)

Marks

5. Cyanogen gas, $C_2N_2(g)$, is a compound of carbon and nitrogen.

(*a*) Draw a full structural formula for a cyanogen molecule.

1

(*b*) In a combustion chamber, cyanogen gas burns to form a mixture of carbon dioxide and nitrogen.

$$C_2N_2(g) + 2O_2(g) \rightarrow 2CO_2(g) + N_2(g)$$

Carbon dioxide can be removed by passing the gas mixture through sodium hydroxide solution.

Complete the diagram to show how carbon dioxide can be removed from the products and the volume of nitrogen gas measured.

(An additional diagram, if required, can be found on *Page thirty-four*.)
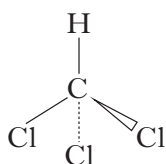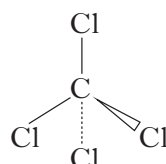
oxygen ⟶

cyanogen ⟶

combustion chamber
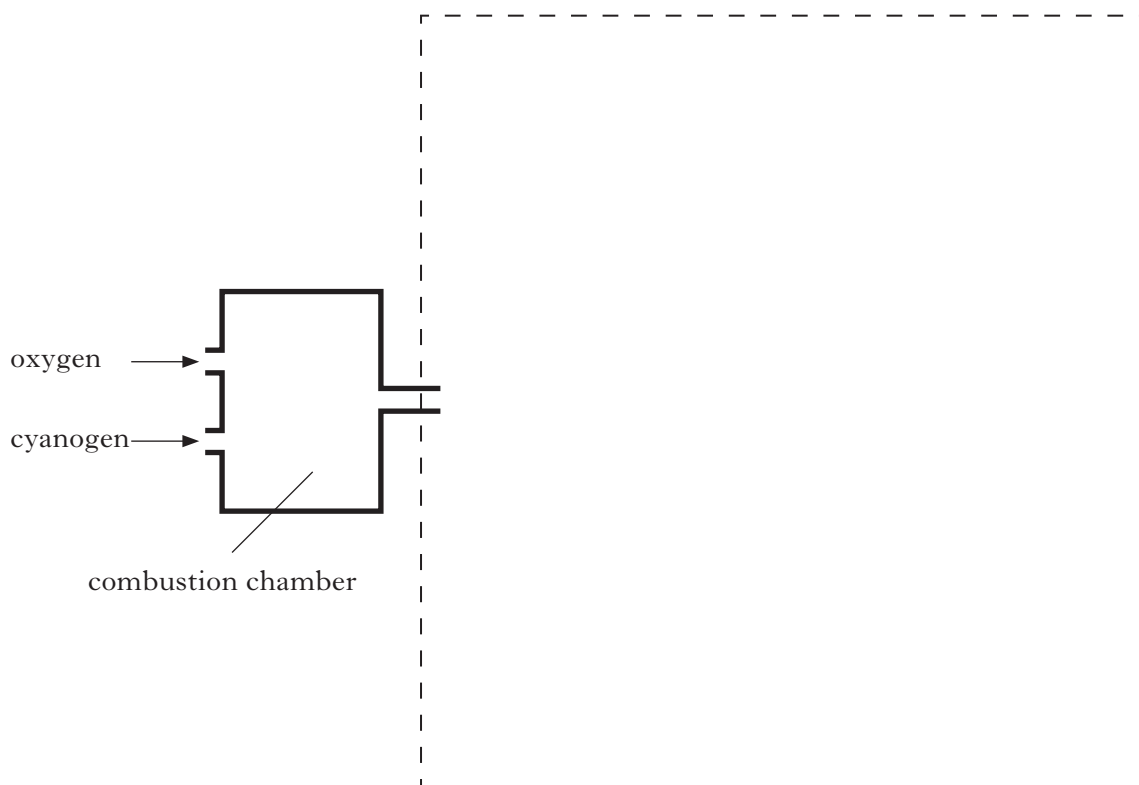
2

(3)

Marks

6. The structures below show molecules that contain chlorine atoms.

H
|
C
Cl   Cl
Cl

trichloromethane

Cl
|
C
Cl   Cl
Cl

tetrachloromethane

(*a*) **Explain clearly** why trichloromethane is more soluble in water than tetrachloromethane.

Your answer should include the names of the intermolecular forces involved.

2

(*b*) Tetrachloromethane damages the Earth's ozone layer.
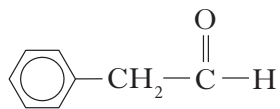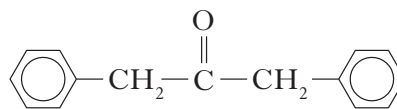
Why is the ozone layer important?

1

(3)

7. Many of the flavour and aroma molecules found in chocolate are aldehydes and ketones.

Two examples are shown below.

$$\underset{\text{phenylethanal}}{\langle \bigcirc \rangle - CH_2 - \overset{\overset{\displaystyle O}{\|}}{C} - H} \qquad \underset{\text{1,3-diphenylpropan-2-one}}{\langle \bigcirc \rangle - CH_2 - \overset{\overset{\displaystyle O}{\|}}{C} - CH_2 - \langle \bigcirc \rangle}$$

(*a*) Name a chemical that could be used to distinguish between these two compounds.

1

(*b*)   (i) How many hydrogen atoms are present in a molecule of phenylethanal?

1

(ii) Phenylethanal can be converted to phenylethanoic acid.
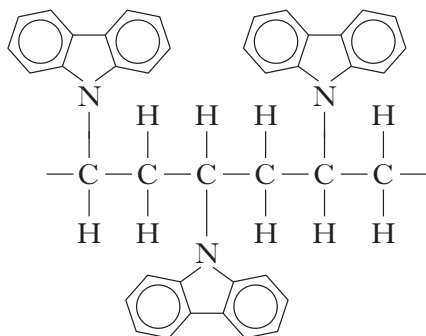
Name the type of chemical reaction taking place.

1

(3)

8. Poly(vinyl carbazole) is a useful polymer.

The structure of a section of the polymer is shown below.

(*a*) Draw a structural formula for the vinyl carbazole monomer used to make poly(vinyl carbazole).
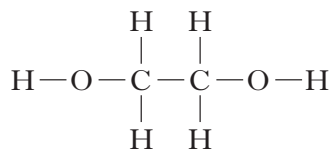
1

(*b*) Give a use for poly(vinyl carbazole).

1
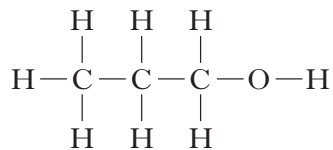
(2)

Page nineteen   **[Turn over**

9. Alcohols are widely used in antifreeze and de-icers.

ethane-1,2-diol

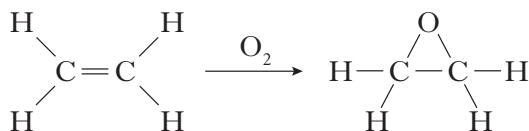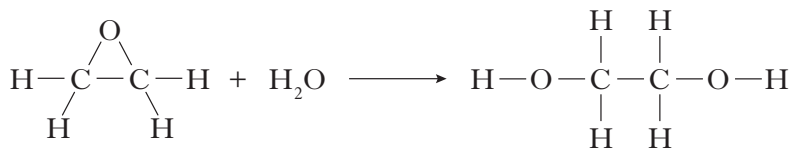molecular mass 62

boiling point 197 °C

propan-1-ol

molecular mass 60

boiling point 98 °C

(*a*) Why is the boiling point of ethane-1,2-diol much higher than the boiling point of propan-1-ol?

1

(*b*) Ethane-1,2-diol can be produced industrially from ethene in a two stage process:
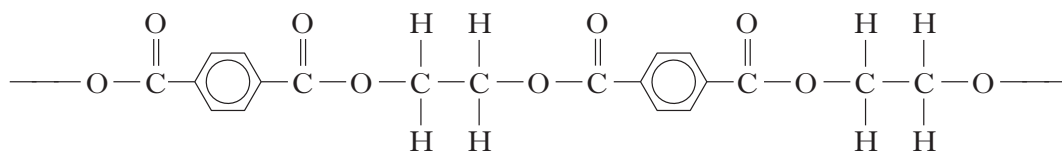
Stage one

Stage two

Name the alkene required to produce 2-methylbutane-2,3-diol.
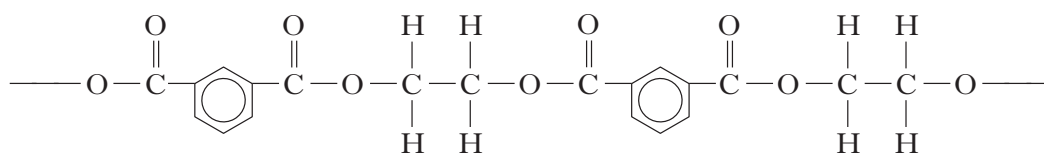
1

9. **(continued)**

(*c*) Ethane-1,2-diol can react with benzene-1,4-dicarboxylic acid to produce a polymer.

Name the acid which, when added to ethane-1,2-diol, would produce the polymer shown below.
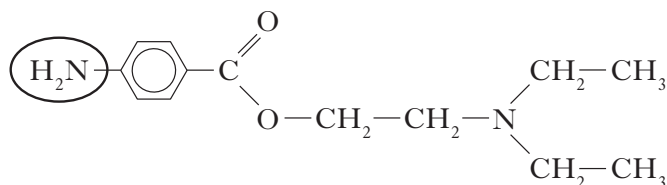
1

(3)

[Turn over

10. Dental anaesthetics are substances used to reduce discomfort during treatment.
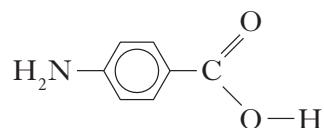
(*a*) Procaine is a dental anaesthetic.

(i) Name the functional group circled above.

1

(ii) Procaine causes numbness when applied to the gums. This effect wears off as the procaine is hydrolysed.

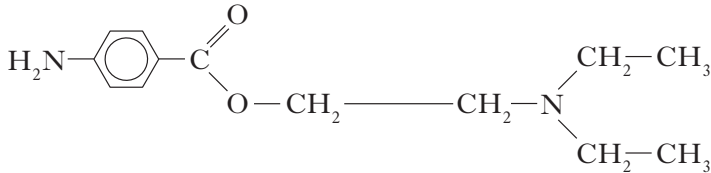One of the products of the hydrolysis of procaine is shown below.
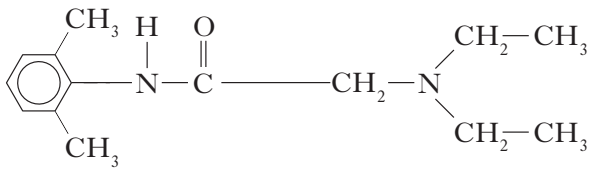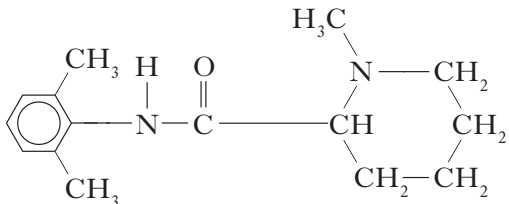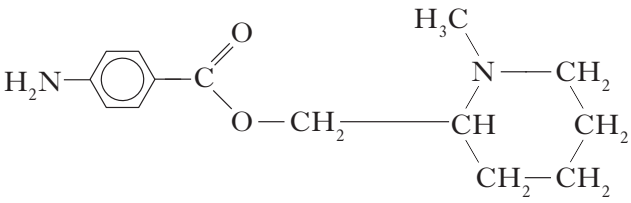
Draw a structural formula for the other compound produced when procaine is hydrolysed.

1

10. (continued)

(*b*) The table below shows the duration of numbness for some anaesthetics.

Name of anaesthetic	Structure	Duration of numbness/ minutes
procaine	H_2N—⬡—C(=O)—O—CH_2——CH_2—N(CH_2—CH_3)(CH_2—CH_3)	7
lidocaine	⬡(CH_3)(CH_3)—N(H)—C(=O)——CH_2—N(CH_2—CH_3)(CH_2—CH_3)	96
mepivacaine	⬡(CH_3)(CH_3)—N(H)—C(=O)——CH (ring: H_3C—N—CH_2, CH_2, CH_2—CH_2)	114
anaesthetic **X**	H_2N—⬡—C(=O)—O—CH_2——CH (ring: H_3C—N—CH_2, CH_2, CH_2—CH_2)	

Estimate the duration of numbness, in minutes, for anaesthetic **X**.

1

(3)

[Turn over

Marks

11. Aspirin, a common painkiller, can be made by the reaction of salicylic acid with ethanoic anhydride.

$C_7H_6O_3$ $C_4H_6O_3$ $C_9H_8O_4$ $C_2H_4O_2$
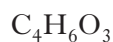
salicylic acid   ethanoic anhydride   aspirin   ethanoic acid

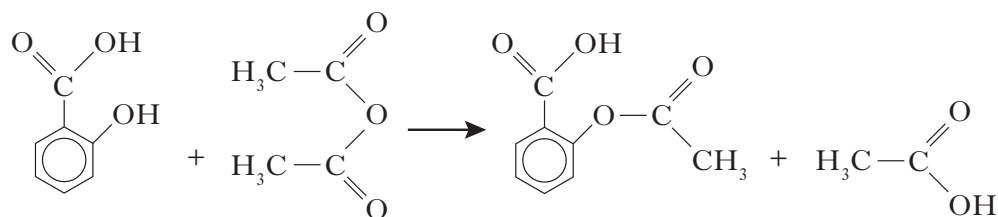(*a*) Name the type of reaction that takes place in the formation of aspirin from salicylic acid and ethanoic anhydride.

1

(*b*) In a laboratory preparation of aspirin, 5·02 g of salicylic acid produced 2·62 g of aspirin.

Calculate the percentage yield of aspirin.

Show your working clearly.

2

(*c*) The sodium salt of aspirin is more soluble in water than aspirin itself.

Why does a solution of the sodium salt of aspirin have an alkaline pH?

1

(4)

12. The age of a rock found in Canada was determined by measuring the amounts of argon-40 and potassium-40 present in a sample.

(*a*) Each potassium-40 atom can emit a single positron particle to form an argon-40 atom.

Complete the table below to show the mass number and atomic number for a positron.

(An additional table, if required, can be found on *Page thirty-four*.)

Mass number	
Atomic number	

1

(*b*) 75% of the potassium-40 atoms originally present in the rock sample were found to have undergone radioactive decay.

The half-life of potassium-40 is $1\cdot26 \times 10^9$ years.

Calculate the age of the rock, in years.

1

(2)

[Turn over

13. Hydrogen sulphide is a toxic gas with the smell of rotten eggs.

(*a*) Hydrogen sulphide dissolves readily in water:

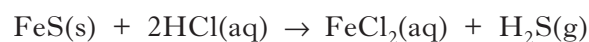$$H_2S(aq) \rightleftharpoons HS^-(aq) + H^+(aq)$$

(i) Why can hydrogen sulphide be described as a weak acid?

1

(ii) What effect would the addition of ammonia solution have on the position of equilibrium in the above reaction?

1

(*b*) Hydrogen sulphide gas can be prepared by the reaction of iron(II) sulphide with excess dilute hydrochloric acid:

$$FeS(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2S(g)$$

Calculate the mass of iron(II) sulphide required to produce $79\,cm^3$ of hydrogen sulphide gas.

(Take the molar volume of hydrogen sulphide to be 24 litres mol^{-1}.)

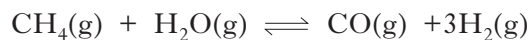**Show your working clearly.**

2

(4)

14. Mobile phones are being developed that can be powered by methanol.

Methanol can be made by a two-stage process.

(*a*) In the first stage, methane is reacted with steam to produce a mixture of carbon monoxide and hydrogen.

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

(i) Give the name for the mixture of carbon monoxide and hydrogen which is produced.

1

(ii) Use the data below to calculate the enthalpy change, in $kJ\,mol^{-1}$, for the forward reaction.

$$CO(g) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g) \qquad\qquad \Delta H = -283\,kJ\,mol^{-1}$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(g) \qquad\qquad \Delta H = -242\,kJ\,mol^{-1}$$
$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \qquad \Delta H = -803\,kJ\,mol^{-1}$$

Show your working clearly.

2

(*b*) In the second stage, the carbon monoxide and hydrogen react to produce methanol.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\,kJ\,mol^{-1}$$

Circle the correct words in the table to show the changes to temperature and pressure that would favour the production of methanol.

| temperature	decrease / keep the same / increase
pressure	decrease / keep the same / increase

(An additional table, if required, can be found on *Page thirty-four*.)

1

(4)

Marks

15. In an experiment to determine the enthalpy of neutralisation, dilute hydrochloric acid was added to a solution of potassium hydroxide in the apparatus shown below.

thermometer

glass beaker

reaction mixture
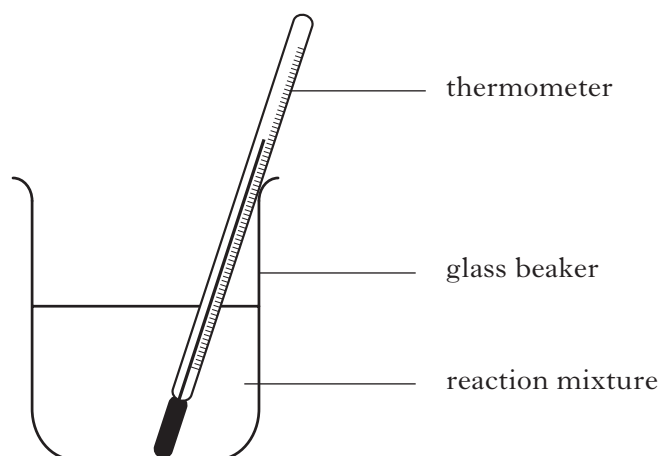
(*a*) Using the following information, calculate the enthalpy of neutralisation, in kJ mol^{-1}.

volume of 1·0 mol l^{-1} KOH $=$ 25 cm^3

volume of 1·0 mol l^{-1} HCl $=$ 25 cm^3

temperature change $=$ 4·5 °C

Show your working clearly.

2

15. **(continued)**

(*b*) The enthalpy of neutralisation obtained using this apparatus is much smaller than the value given in data booklets.

Suggest a modification to this apparatus that would give a value closer to that given in data booklets.

1

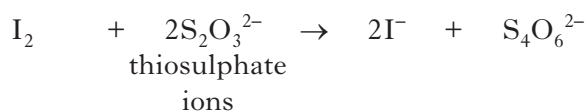(*c*) What measurements would be taken to determine the temperature change?

1

(4)

[Turn over

16. Solutions containing iodine are used to treat foot rot in sheep.

The concentration of iodine in a solution can be determined by titrating with a solution of thiosulphate ions.

$$I_2 \quad + \quad 2S_2O_3^{2-} \quad \rightarrow \quad 2I^- \quad + \quad S_4O_6^{2-}$$
thiosulphate
ions

(*a*) Write an ion-electron equation for the reaction of the oxidising agent in the titration.

1

(*b*) Three $20 \cdot 0 \, cm^3$ samples of a sheep treatment solution were titrated with $0 \cdot 10 \, mol \, l^{-1}$ thiosulphate solution.

The results are shown below.

Sample	Volume of thiosulphate/cm^3
1	18·60
2	18·10
3	18·20

(i) Why is the volume of sodium thiosulphate used in the calculation taken to be $18 \cdot 15 \, cm^3$, although this is not the average of the three titres in the table?

1

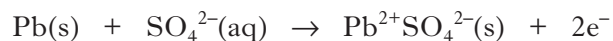(ii) Calculate the concentration of iodine, in mol l^{-1}, in the foot rot treatment solution.

Show your working clearly.

2

(4)

Marks

17. When a lead-acid car battery is in use, the following half reaction takes place at the negative electrode:

$$Pb(s) \ + \ SO_4^{2-}(aq) \ \rightarrow \ Pb^{2+}SO_4^{2-}(s) \ + \ 2e^-$$

(*a*) A lead-acid battery was used to power a car radio for 2 hours.

The radio used a current of 0·5 A.

Calculate the mass of lead, in g, converted into lead(II) sulphate.

Show your working clearly.

2

(*b*) Complete the ion-electron equation for the reaction taking place at the other electrode.

(An additional copy of this question, if required, can be found on *Page thirty-five*.)
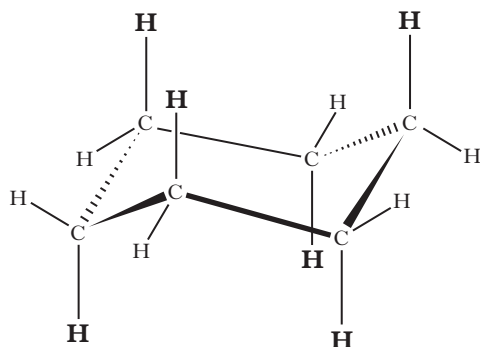
$$PbO_2(s) \ + \ SO_4^{2-}(aq) \qquad\qquad \rightarrow \ PbSO_4(s)$$
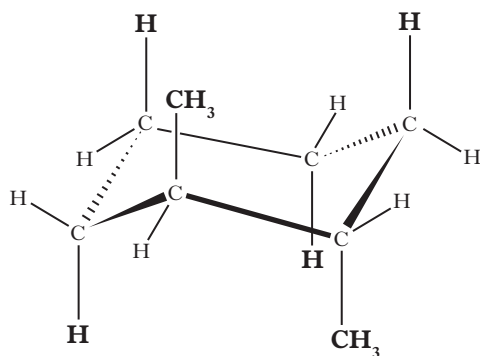
1

(3)

[Turn over

18. Cycloalkanes are found in nature.

A representation of cyclohexane is shown below.

The six hydrogen atoms marked in **bold** are said to be in axial positions.

In the molecule of **1,2-**dimethylcyclohexane shown below, two methyl groups are in axial positions.

(*a*) Complete the structure below to show a molecule of **1,3-**dimethylcyclohexane in which both the methyl groups are in axial positions.

(An additional diagram, if required, can be found on *Page thirty-five*.)
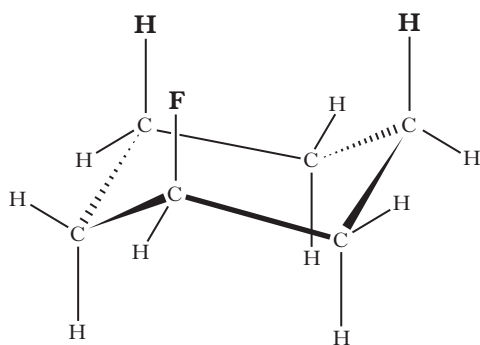

1
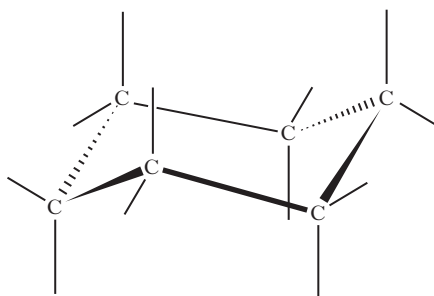
18. (continued)

(*b*) Axial groups **on the same side** of a cyclohexane ring can repel each other. The strength of the repulsion is known as the "steric strain."

The table below shows values which allow the steric strain to be calculated.

Axial groups	Steric strain/kJ mol^{-1}
H and H	0·0
H and F	0·5
H and Br	1·0
H and CH$_3$	3·8
H and (CH$_3$)$_3$C	11·4

For example:

Steric strain = 2 × (Steric strain between **H** and **F**)
          = 2 × 0·5
          = 1·0 kJ mol^{-1}

(i) Write a general statement, linking the size of the steric strain to the type of axial group present.

1

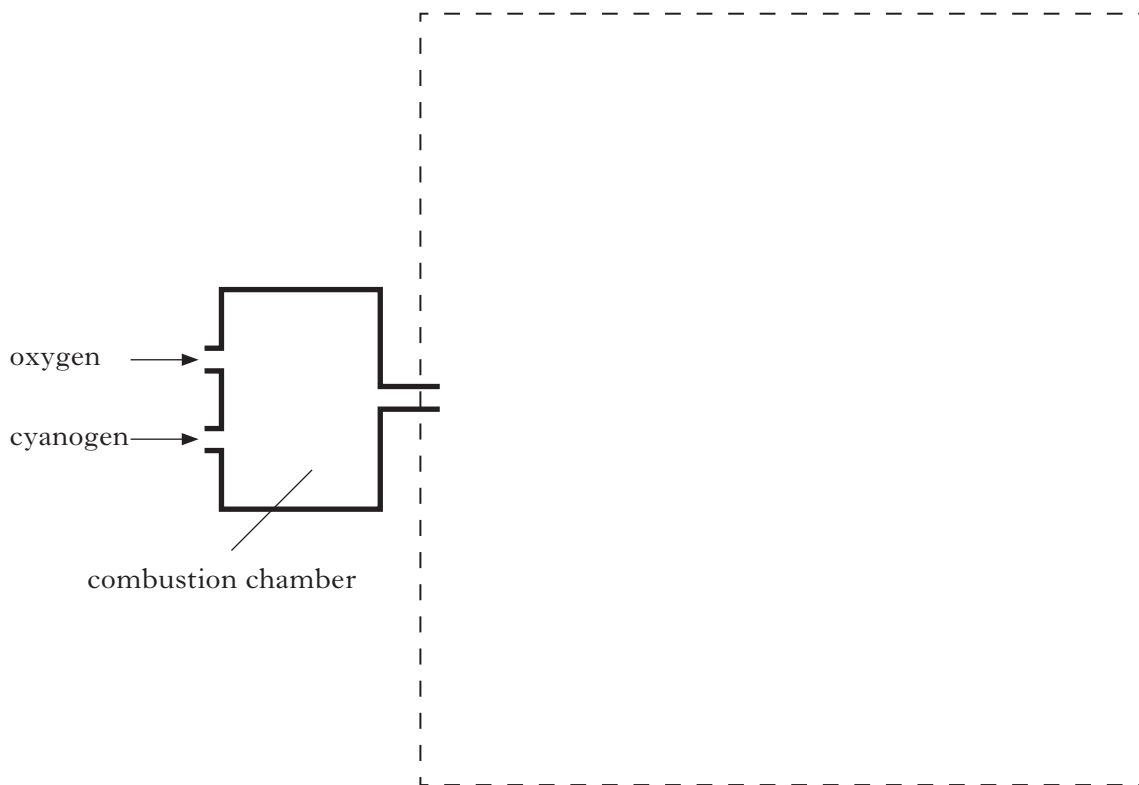(ii) Calculate, in kJ mol^{-1}, the steric strain for the molecule shown below.
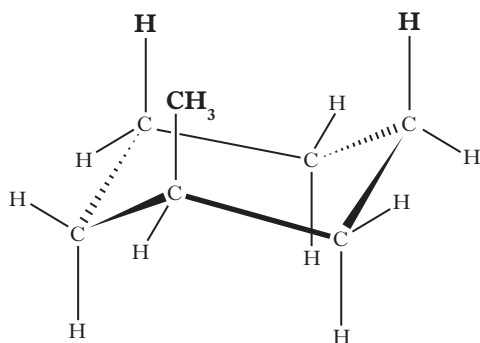
Steric strain   =

1

(3)

[*END OF QUESTION PAPER*]

ADDITIONAL DIAGRAM FOR USE IN QUESTION 5(*b*)

oxygen ⟶

cyanogen ⟶

combustion chamber

ADDITIONAL TABLE FOR USE IN QUESTION 12(*a*)

Mass number	
Atomic number	

ADDITIONAL TABLE FOR USE IN QUESTION 14(*b*)

temperature	decrease / keep the same / increase
pressure	decrease / keep the same / increase

ADDITIONAL COPY OF QUESTION 17(*b*)

17. (*b*) Complete the ion-electron equation for the reaction taking place at the other electrode.

$$PbO_2(s) \; + \; SO_4^{2-}(aq) \qquad\qquad \rightarrow \; PbSO_4(s)$$

ADDITIONAL DIAGRAM FOR USE IN QUESTION 18(*a*)

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