FOR OFFICIAL USE

National Qualifications 2019

Mark

X713/77/01

Chemistry
Section 1 — Answer grid and Section 2

FRIDAY, 10 MAY

9:00 AM – 11:30 AM

X7137701

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

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

Total marks — 100

SECTION 1 — 30 marks

Attempt ALL questions.

Instructions for the completion of Section 1 are given on *page 02*.

SECTION 2 — 70 marks

Attempt ALL questions.

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. You should score through your rough work when you have written your final copy.

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

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

SQA ©

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SECTION 1 — 30 marks

The questions for Section 1 are contained in the question paper X713/77/02.

Read these and record your answers on the answer grid on *page 03* opposite.

Use **blue** or **black** ink. Do NOT use gel pens or pencil.

1. The answer to each question is **either** A, B, C or D. Decide what your answer is, then fill in the appropriate bubble (see sample question below).

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

3. Any rough working should be done on the additional space for answers and rough work at the end of this booklet.

Sample question

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

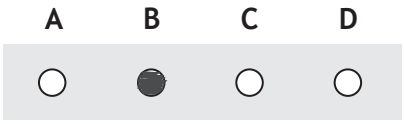
A fractional distillation

B chromatography

C fractional crystallisation

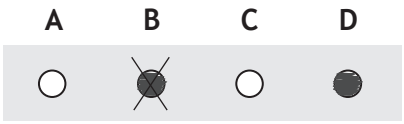
D filtration.

The correct answer is **B** — chromatography. The answer **B** bubble has been clearly filled in (see below).

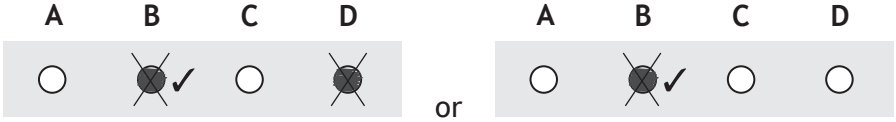


Changing an answer

If you decide to change your answer, cancel your first answer by putting a cross through it (see below) and fill in the answer you want. The answer below has been changed to **D**.



If you then decide to change back to an answer you have already scored out, put a tick (✓) to the **right** of the answer you want, as shown below:



or

SECTION 1 — Answer grid

OBJ30AD1

	A	B	C	D		A	B	C	D
1	○	○	○	○	16	○	○	○	○
2	○	○	○	○	17	○	○	○	○
3	○	○	○	○	18	○	○	○	○
4	○	○	○	○	19	○	○	○	○
5	○	○	○	○	20	○	○	○	○
6	○	○	○	○	21	○	○	○	○
7	○	○	○	○	22	○	○	○	○
8	○	○	○	○	23	○	○	○	○
9	○	○	○	○	24	○	○	○	○
10	○	○	○	○	25	○	○	○	○
11	○	○	○	○	26	○	○	○	○
12	○	○	○	○	27	○	○	○	○
13	○	○	○	○	28	○	○	○	○
14	○	○	○	○	29	○	○	○	○
15	○	○	○	○	30	○	○	○	○

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SECTION 2 — 70 marks

Attempt ALL questions

1. Chlorine forms many compounds with other elements.

(a) The electronic configuration for a chlorine atom in its ground state is shown.

Circle **one** electron in the above diagram that can be described by the following set of quantum numbers.

$$n = 2,\ l = 1,\ m = -1,\ s = +\tfrac{1}{2}$$ **1**

(An additional diagram, if required, can be found on *page 28*.)

(b) A compound of chlorine, boron trichloride, reacts with hydrogen to produce boron.

$$BCl_3(g) + \tfrac{3}{2}H_2(g) \rightarrow B(s) + 3HCl(g) \qquad \Delta H^\circ = 127\ kJ\ mol^{-1}$$

The standard entropy change, ΔS°, is $79{\cdot}4\ J\ K^{-1}\ mol^{-1}$.

Calculate ΔG°, in $kJ\ mol^{-1}$, for this reaction at 298 K. **2**

1. (continued)

(c) Another compound of chlorine, silver(I) chloride, forms an equilibrium mixture with excess chloride ions.

$$AgCl(s) + Cl^-(aq) \rightleftharpoons AgCl_2^-(aq) \qquad \Delta G° = 25{\cdot}6\ kJ\ mol^{-1} \text{ at } 298\ K$$

$\Delta G°$ and the equilibrium constant, K, are related as shown.

$$\Delta G° = -2{\cdot}30\, RT \log_{10} K$$

$R = 8{\cdot}31 \times 10^{-3}\ kJ\ K^{-1}\ mol^{-1}$

T = Temperature in Kelvin

Use this information to calculate the equilibrium constant, K, for this reaction. **2**

2. Reaction kinetics can be used to determine the order and mechanism of chemical reactions.

A proposed mechanism for the reaction between hydrogen peroxide, $H_2O_2(aq)$, and iodide ions, $I^-(aq)$, is shown below.

Step 1 $H_2O_2(aq) + I^-(aq) \rightarrow IO^-(aq) + H_2O(\ell)$ slow

Step 2 $IO^-(aq) + H_3O^+(aq) \rightarrow HIO(aq) + H_2O(\ell)$ fast

Step 3 $HIO(aq) + H_3O^+(aq) + I^-(aq) \rightarrow I_2(aq) + 2H_2O(\ell)$ fast

(a) State what is meant by the order of a reaction. **1**

(b) (i) Determine the overall order of reaction for the mechanism above. **1**

(ii) Write the rate equation for this reaction. **1**

(c) Write a balanced equation for the overall reaction. **1**

3. Brass is a useful alloy of copper and zinc.

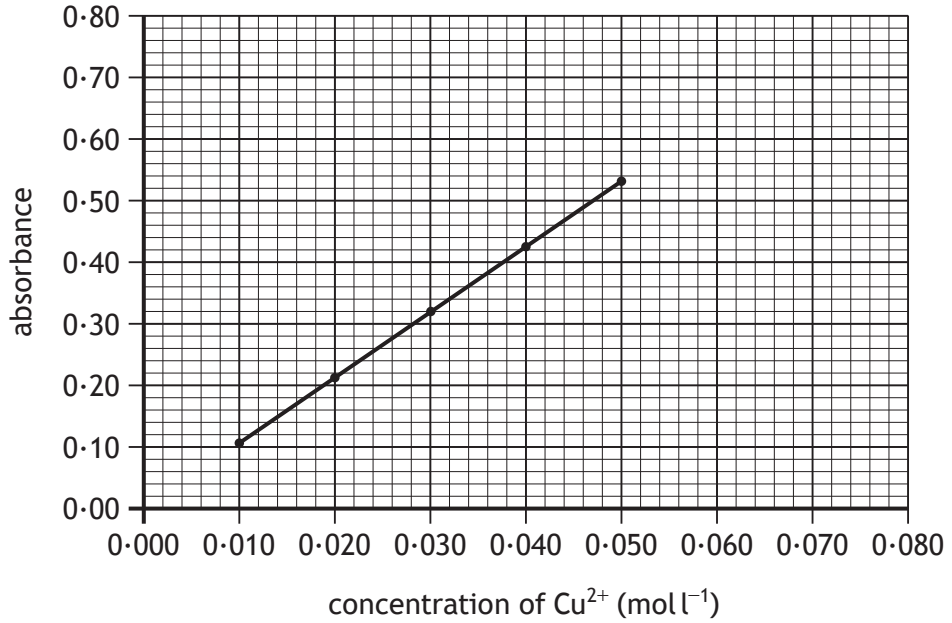
To determine the percentage of copper in a brass screw, a student dissolved the screw in 20 cm^3 of concentrated nitric acid and made the resulting solution up to 250 cm^3 in a volumetric flask.

Five standard solutions were prepared by diluting a 0·10 mol l^{-1} stock solution of copper(II) nitrate with deionised water.

(a) One of the standard solutions had a concentration of 0·010 mol l^{-1}.

Describe fully how this 0·010 mol l^{-1} solution should be prepared in a 50 cm^3 volumetric flask from the 0·10 mol l^{-1} stock solution. **2**

(b) The colorimeter was fitted with a suitable filter and set to zero using a reference sample. The absorbance of the five standard solutions was determined and a calibration graph was drawn.



(i) Name the substance that should be used to set the colorimeter to zero. **1**

3. (b) (continued)

(ii) The absorbance of the sample solution was 0·71. The sample solution was then diluted to decrease the concentration by half.

The absorbance of this diluted solution was then measured.

Explain why the sample solution was diluted. **1**

(iii) The mass of the screw was 1·43 g.

The absorbance of the diluted solution was 0·34.

Calculate the percentage by mass of copper in the screw. **3**

4. There are different definitions for acids and bases.

(a) One definition for acids and bases was proposed by Johannes Brønsted and Thomas Lowry.

(i) State the Brønsted-Lowry definition for a base. **1**

(ii) A solution of hydrogen peroxide consists of two acid-conjugate base pairs.

$$H_2O_2(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + HO_2^-(aq)$$

Complete the table to identify one of the acid-conjugate base pairs. **1**

Acid	
Conjugate base	

(b) Another definition for acids and bases was proposed by Gilbert Lewis. A Lewis acid is a substance that can accept a pair of non-bonding electrons. A Lewis base is a substance that can donate a pair of non-bonding electrons.

An example of a Lewis acid-base reaction is shown.

$$B(OH)_3(aq) + 2H_2O(\ell) \rightleftharpoons [B(OH)_4]^-(aq) + H_3O^+(aq)$$

Explain why this is a Lewis acid-base reaction. **1**

4. (continued)

(c) Acids can be classified as strong or weak. The table contains information about four acids.

Name of acid	Formula	K_a at 298 K
ethanoic	CH_3COOH	$1{\cdot}7 \times 10^{-5}$
chloroethanoic	$CH_2ClCOOH$	$1{\cdot}6 \times 10^{-3}$
dichloroethanoic	$CHCl_2COOH$	$5{\cdot}0 \times 10^{-2}$
trichloroethanoic	CCl_3COOH	$2{\cdot}3 \times 10^{-1}$

(i) Describe the relationship between the number of chlorine atoms in an acid molecule and the strength of the acid. **1**

(ii) 1·89 g of chloroethanoic acid was dissolved in deionised water and the solution was made up to 250 cm^3 in a volumetric flask.

(A) Calculate the concentration, in mol l^{-1}, of the chloroethanoic acid solution. **1**

(B) Using your answer to (A) calculate the pH of the chloroethanoic acid solution. **2**

4. (continued)

(d) The action of pH indicators and buffer solutions involves the chemistry of acids and bases.

Using your knowledge of chemistry, discuss the role of acids and bases in pH indicators and buffer solutions. **3**

5. Electron transitions are responsible for some of the properties of metals such as sodium, zinc and strontium, and their compounds.

(a) The orange-yellow colour emitted by some fireworks is due to electron transitions in sodium.

The colour is produced when excited electrons return to their ground state.

State what caused the electrons to become excited. **1**

(b) A solution containing the complex ion $[Zn(H_2O)_6]^{2+}$ is colourless.

(i) State the name of this complex ion. **1**

(ii) Electron transitions involving the d-subshell can give rise to colour in transition metal complexes.

Explain fully why a solution of the complex ion $[Zn(H_2O)_6]^{2+}$ is colourless. **2**

5. (continued)

(c) Photoelectron spectroscopy is a technique that provides information on electrons and energy levels in atoms. It uses electromagnetic radiation to eject electrons from an atom and measures the kinetic energy of these emitted electrons.

(i) A sample of strontium was exposed to electromagnetic radiation with a frequency of $3{\cdot}08 \times 10^{17}\,s^{-1}$.

Calculate the energy, in J, of this electromagnetic radiation. **1**

(ii) Binding energy, E_b, is the energy required to eject an electron from an atom. Binding energy is calculated in electron volts, eV, using the relationship

$$E_b = E - E_k$$

E_b = binding energy

E = energy of electromagnetic radiation

E_k = kinetic energy of electron emitted

1 Joule = $6{\cdot}24 \times 10^{18}$ eV

An electron was emitted with a kinetic energy, E_k, of 1254 eV.

Using your answer to part (i), calculate the binding energy, in eV, for this electron. **2**

[Turn over for next question

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6. The concentration of ethanol in vodka can be determined by reacting the ethanol with excess acidified potassium dichromate solution.

$20{\cdot}0\,cm^3$ of vodka was transferred to a 1 litre volumetric flask and made up to the mark with deionised water. $1{\cdot}0\,cm^3$ of the diluted vodka was pipetted into a conical flask. $25{\cdot}0\,cm^3$ of $0{\cdot}010\,mol\,l^{-1}$ acidified potassium dichromate was added to the conical flask. The conical flask was then stoppered and warmed until the reaction was complete.

$$3C_2H_5OH(aq) + 2Cr_2O_7^{2-}(aq) + 16H^+(aq) \longrightarrow 3CH_3COOH(aq) + 4Cr^{3+}(aq) + 11H_2O(\ell)$$

It was found that $1{\cdot}65 \times 10^{-4}$ moles of dichromate ions were left unreacted.

(a) Calculate the concentration of ethanol, in $mol\,l^{-1}$, in the undiluted vodka. **3**

(b) Explain why the acidified potassium dichromate was added in excess. **1**

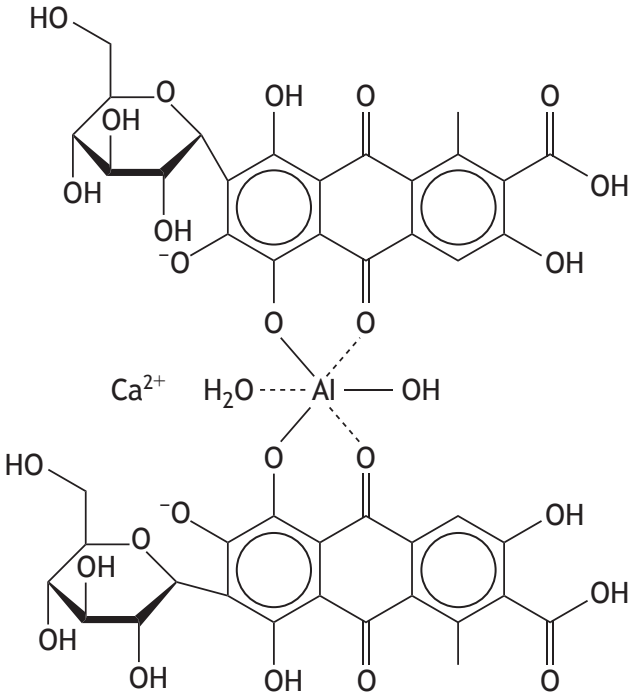
6. (continued)

(c) The experimentally determined value was higher than the actual concentration of ethanol in the vodka.

Other than apparatus uncertainties and transfer errors, suggest a reason why the experimentally determined concentration of ethanol was higher. **1**

(d) Describe a suitable control experiment that could be used to validate this technique. **1**

7. Carmine is a red pigment formed in a precipitation reaction.



carmine

(a) Carmine can be removed from the reaction mixture by filtration.
Suggest how the filtration could be carried out to ensure fast separation. **1**

(b) The structure shown above contains both pi and sigma bonds.

(i) Explain how a sigma bond is formed. **1**

(ii) A pi bond is formed as a result of sp^2 hybridisation.
Explain what is meant by sp^2 hybridisation. **1**

7. (continued)

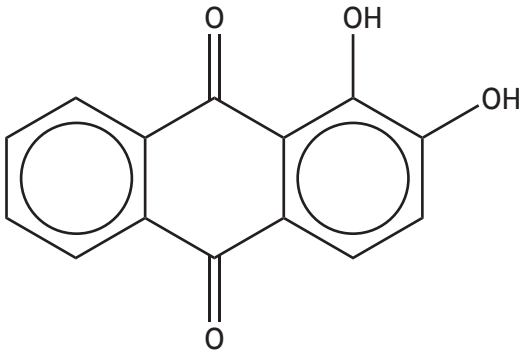
(c) Carmine contains a conjugated system.

Explain fully how this conjugated system gives rise to the red colour of carmine. **2**

(d) The use of carmine as a dye was largely abandoned in the nineteenth century.

One of the pigments used to replace carmine is alizarin.

Alizarin can be extracted from the root of a plant using methanol.

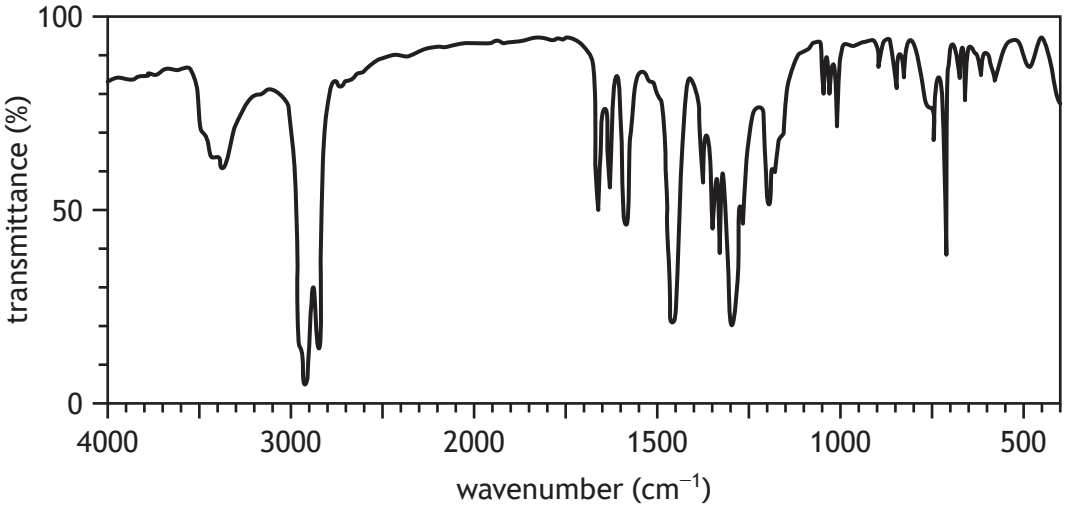


alizarin

(i) Explain why methanol is a suitable solvent for this extraction. **1**

7. (d) (continued)

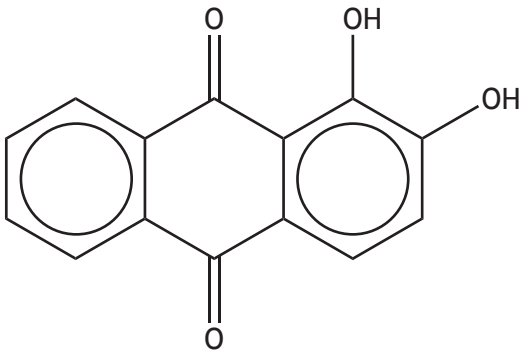
(ii) The infrared spectrum of alizarin is shown below.



(A) Explain the effect infrared radiation has on the bonds within molecules and how this allows different functional groups to be identified. **2**

(B) Circle a functional group in the structure below that is responsible for the peak at 3395 cm^{-1}. **1**

(An additional diagram, if required, can be found on *page 28*.)



7. (d) (ii) continued

(C) For the peak at 3395 cm^{-1} calculate

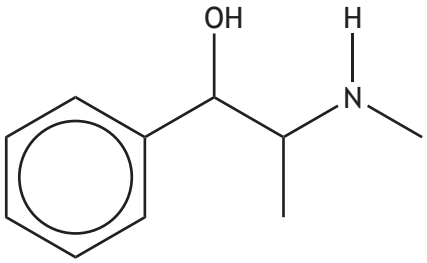
(I) the wavelength, in metres **1**

(II) the energy, in kJ mol^{-1}, associated with this wavelength. **2**

8. Benzene, cyclohexene and cyclohexane are cyclic hydrocarbons with six carbon atoms. Each hydrocarbon takes part in a wide variety of chemical reactions.

Using your knowledge of chemistry, discuss the reactions of these hydrocarbons. **3**

9. Ephedrine can be used to prevent low blood pressure.



ephedrine

(a) Ephedrine can exist as different optical isomers due to the presence of chiral centres.

(i) Circle a chiral centre in the structure of ephedrine shown above. **1**

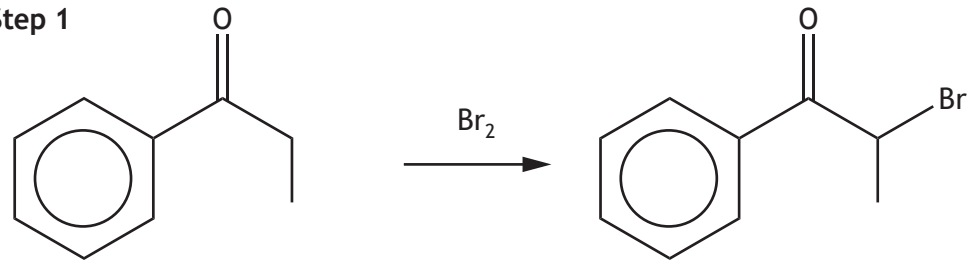
(An additional diagram, if required, can be found on *page 28*.)

(ii) State what is meant by the term optical isomers. **1**

9. (continued)

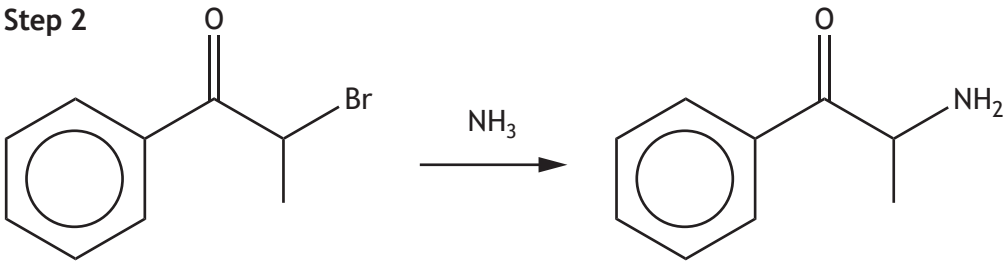
(b) The psychoactive substance cathinone has a similar structure to ephedrine and can be synthesised under certain conditions in two steps as shown.

Step 1



1-phenylpropanone,
GFM = 134 g

Step 2

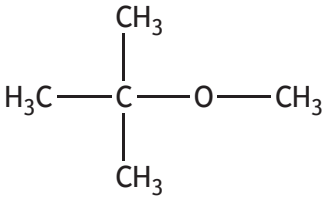


cathinone,
GFM = 149 g

(i) Suggest the type of chemical reaction taking place in **Step 2** of the synthesis. **1**

(ii) Calculate the mass of cathinone produced from 9·50 g of 1-phenylpropanone, assuming a percentage yield of 71·8%. **3**

10. Compound **X** can be added to petrol to make it burn more smoothly.



compound **X**

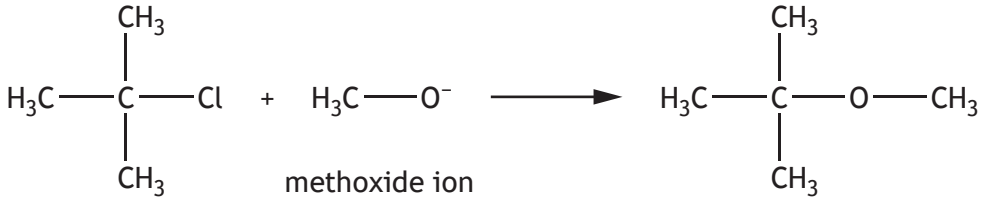
(a) Compound **X** belongs to a class of organic compounds.
Name this class of organic compounds. **1**

(b) (i) Draw a skeletal structural formula for compound **X**. **1**

(ii) Write the systematic name for compound **X**. **1**

10. (continued)

(c) Compound **X** can be produced by reacting 2-chloromethylpropane with methoxide ions.



2-chloromethylpropane compound **X**

(i) Methoxide ions can be produced by reacting sodium with a reagent.

Name the reagent. **1**

(ii) The reaction between 2-chloromethylpropane and methoxide ions proceeds by an S_N1 mechanism involving a carbocation intermediate.

Using structural formulae and curly arrow notation, outline the mechanism for this reaction. **2**

(iii) Suggest why this reaction is more likely to proceed by an S_N1 mechanism rather than an S_N2 mechanism. **1**

10. (continued)

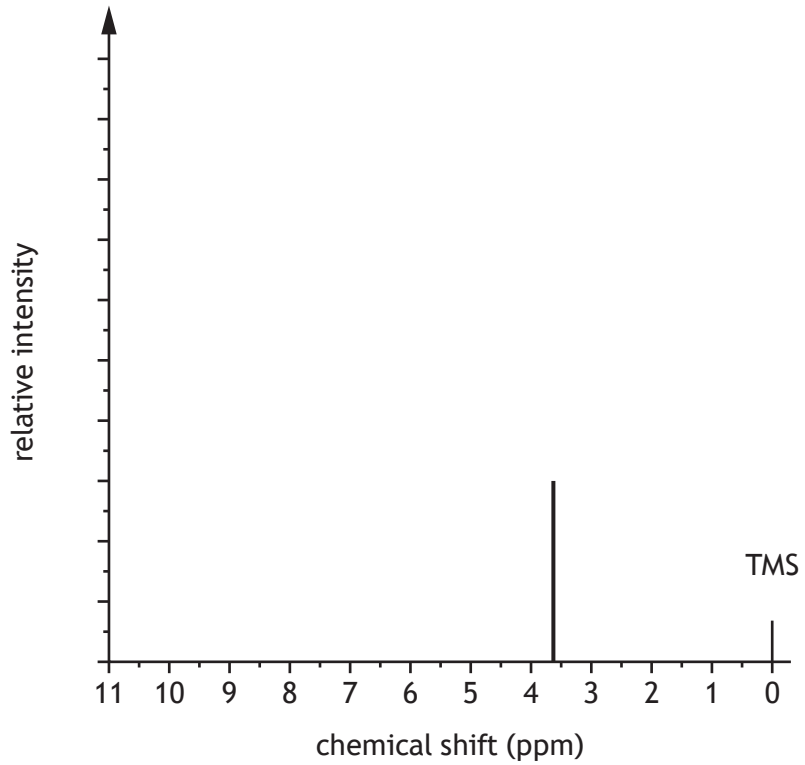
(d) Compound **X** is not optically active.

Draw an isomer of compound **X** that is optically active. **1**

(e) The low resolution ^{1}H NMR spectrum for compound **X** shown below is incomplete.

Complete the spectrum by drawing one line to show the correct chemical shift and relative intensity for the other hydrogen environment. **2**

(An additional diagram, if required, can be found on *page 29*.)



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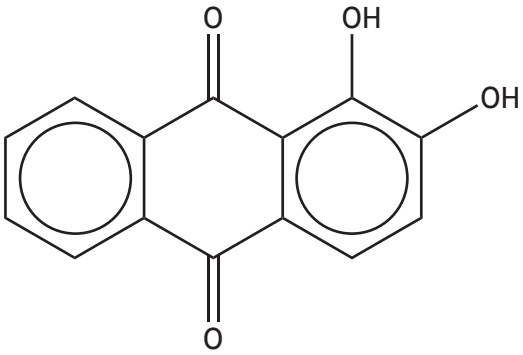
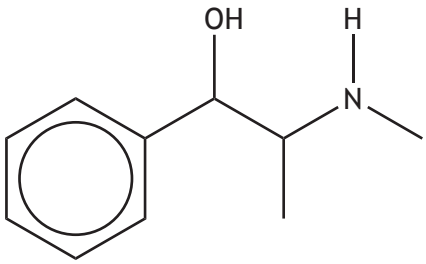
ADDITIONAL DIAGRAM FOR USE IN QUESTION 1 (a)

ADDITIONAL DIAGRAM FOR USE IN QUESTION 7 (d) (ii) B

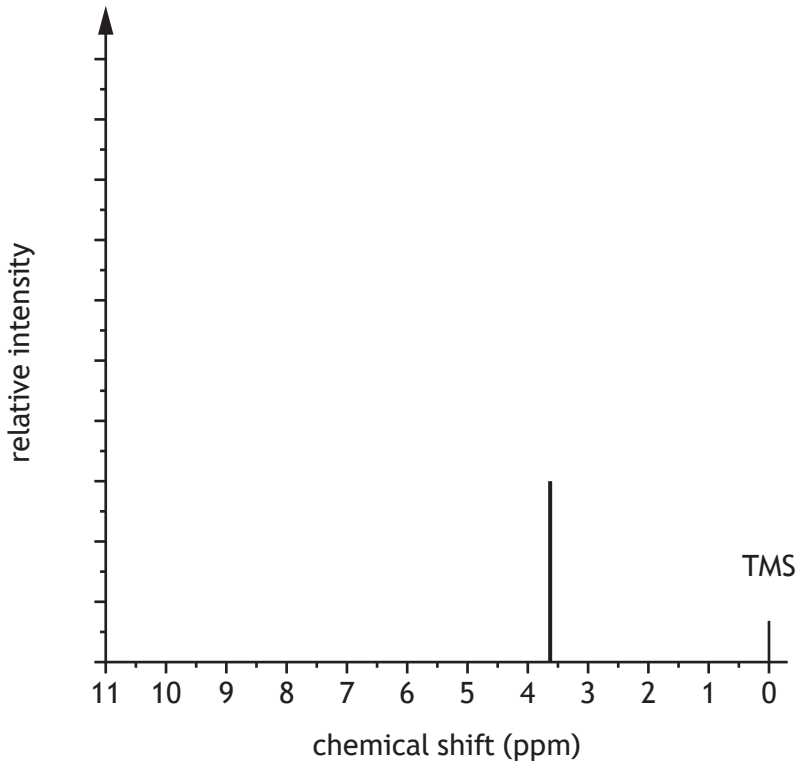


ADDITIONAL DIAGRAM FOR USE IN QUESTION 9 (a) (i)



ephedrine

ADDITIONAL DIAGRAM FOR USE IN QUESTION 10 (e)



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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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