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National Qualifications 2025

Mark

# X813/77/01

# Chemistry
# Section 1 — Answer grid and Section 2

THURSDAY, 1 MAY

9:00 AM – 12:00 NOON

*X8137701*

**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 — 110**

**SECTION 1 — 25 marks**

Attempt ALL questions.

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

**SECTION 2 — 85 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 ©

*X8137701 01*

## SECTION 1 — 25 marks

The questions for Section 1 are contained in the question paper X813/77/02.

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

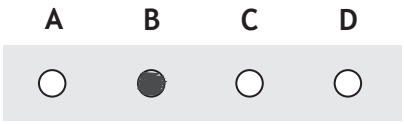
A fractional distillation

B chromatography

C fractional crystallisation

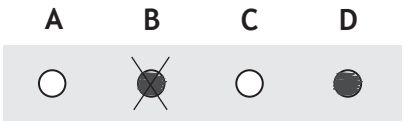
D filtration.

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

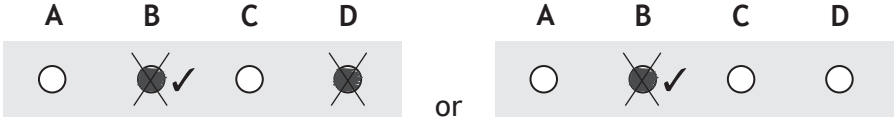



**Changing an answer**

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:



*0BJ25AD1*

You must record your answers to Section 1 questions on the answer grid on **page 03** of your **answer booklet**.

*X8137701103*

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## SECTION 2 — 85 marks

**Attempt ALL questions**

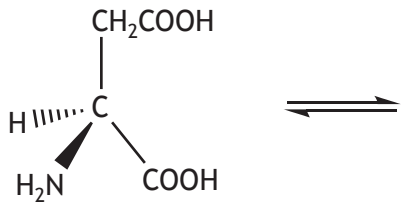
**1.** Aspartic acid can be used to date material from living things.

Only one optical isomer of aspartic acid is found in living things. This is called L-aspartic acid.

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

(b) After living things die, L-aspartic acid converts to the other optical isomer, called D-aspartic acid. An equilibrium is established.

Draw a structural formula for the optical isomer, D-aspartic acid. **1**




L-aspartic acid D-aspartic acid

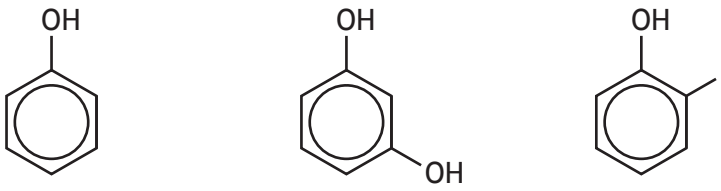
(c) Compare the effect that these isomers have on plane-polarised light. **1**

(d) State the name given to an equilibrium mixture with equal concentrations of L-aspartic acid and D-aspartic acid. **1**

**[Turn over**

**2.** Phenols are alcohols with at least one hydroxyl group bonded to a benzene ring.

The structures of some phenols are shown.




phenol 3-hydroxyphenol 2-methylphenol

(a) The carbon atoms in the benzene ring are $sp^2$ hybridised giving rise to a $\pi$ molecular orbital.

State how the $\pi$ molecular orbital is formed. **1**

**2. (continued)**

(b) Phenols are weak acids.

The table shows the p$K_a$ values of different phenols at 298 K.

| Name of phenol | p$K_a$ |
|---|---|
| phenol | 9.99 |
| 3-hydroxyphenol | 9.15 |
| 3,5-dihydroxyphenol | 8.45 |
| 2-methylphenol | 10.29 |
| 4-methylphenol | 10.26 |
| 2-ethylphenol | 10.20 |
| 4-ethylphenol | 10.00 |

(i) From the information in the table, state one conclusion about the structure of phenols and acid strength. **1**

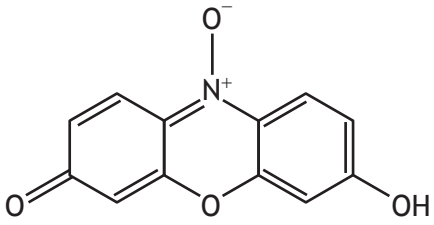
(ii) Calculate the concentration of hydronium ions, $H_3O^+$, in mol $l^{-1}$, in a 0.150 mol $l^{-1}$ aqueous solution of 2-methylphenol. **3**

**[Turn over**

**2. (continued)**

(c) 3-hydroxyphenol can be used to synthesise the indicator resazurin.

When used as a pH indicator, resazurin changes colour from violet to orange.




resazurin

(i) Explain fully, in terms of the conjugation in the molecule, why resazurin changes colour from violet to orange. **2**

(ii) The $K_{In}$ value for resazurin $= 7.9 \times 10^{-6}$.

Calculate the pH range over which this colour change occurs. **1**

**3.** Chloride ions are found in seawater.

A 50.0 $cm^3$ sample of seawater was diluted with deionised water to 100 $cm^3$ in a standard flask. 20.0 $cm^3$ of the diluted seawater was transferred to a conical flask using a pipette.

Silver(I) nitrate solution was added to the sample to produce a precipitate of silver(I) chloride. When precipitation was complete, the mass of precipitate was determined.

(a) State the name of this type of quantitative analysis. **1**

(b) Suggest what should be done to ensure the precipitation reaction has gone to completion. **1**

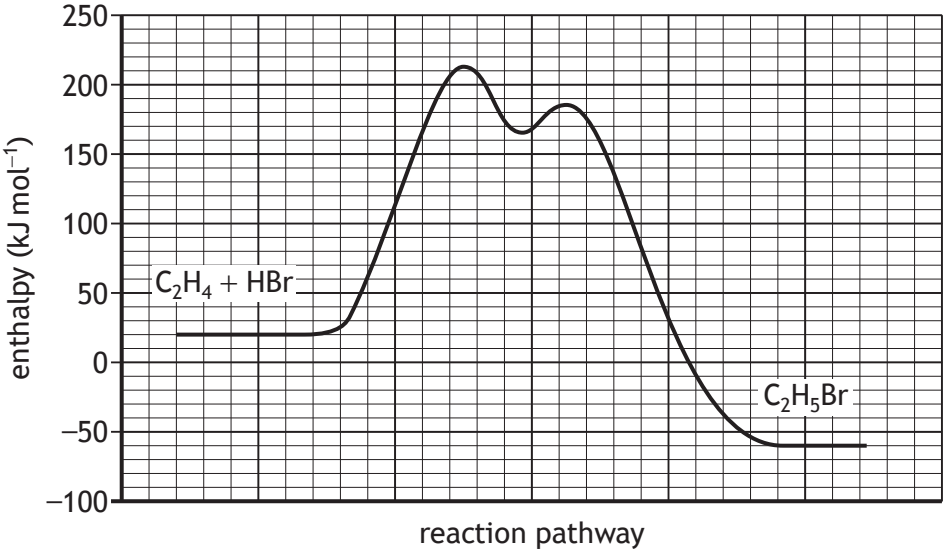
(c) The mass of the precipitate was determined to be 0.779 g.

Calculate the concentration of chloride ions, in g $l^{-1}$, in the undiluted seawater. **2**

**[Turn over**

**4.** Alkenes can undergo addition reactions.

(a) The graph shows how enthalpy changes during the reaction of ethene with hydrogen bromide.




(i) (A) Draw a structural formula for the intermediate formed in this reaction. **1**

(B) When the intermediate is formed there is a temporary increase in stability.

Draw an **X** on the line of the graph above to suggest where the intermediate is formed. **1**

(An additional graph, if required, can be found on *page 31*.)

**4. (a) (continued)**

**MARKS** DO NOT WRITE IN THIS MARGIN

(ii) This reaction is feasible at room temperature and has a negative value for entropy change, $\Delta S$.

(A) Explain why the second law of thermodynamics is obeyed even though the reaction decreases in entropy. **1**

(B) Using information from the graph, calculate the enthalpy change, $\Delta H$, in kJ mol$^{-1}$, for this reaction. **1**

(C) The entropy change, $\Delta S$, for this reaction is $-132$ J K$^{-1}$ mol$^{-1}$.

Calculate the temperature, in K, above which this reaction will no longer be feasible. **2**

(b) Propene undergoes an addition reaction with hydrogen bromide to form two isomeric products.

(i) The product that obeys Markovnikov's rule is known as the major product.

Explain, in terms of the reaction intermediate, why more of this product forms. **1**

**[Turn over**

**4. (b) (continued)**

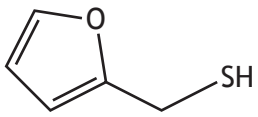
(ii) Propene can undergo other addition reactions that form two isomeric compounds. Some other unsaturated substances can also undergo addition reactions that produce a mixture of compounds including structural, geometric and optical isomers.

**Using your knowledge of chemistry**, discuss the mixture of compounds that could be produced in addition reactions and how these compounds could be isolated. **3**

**5.** Coffee is a drink made from roasted coffee beans.

The taste of coffee comes from a mixture of aroma and flavour molecules. These molecules can be identified using different techniques.

(a) A distinctive aroma molecule produced during coffee roasting is 2-furanmethanethiol.




2-furanmethanethiol

(i) Write the molecular formula for 2-furanmethanethiol. **1**

(ii) The mass spectrum of 2-furanmethanethiol has a peak at m/z 33.

Suggest a possible ion fragment that may be responsible for this peak. **1**

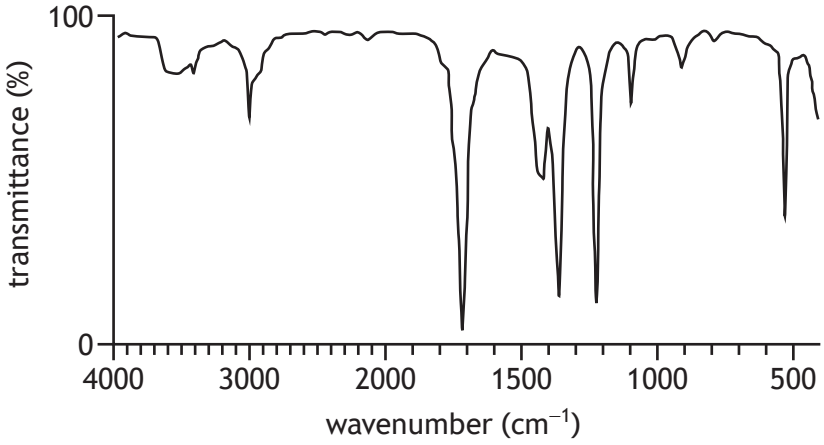
**[Turn over**

MARKS

DO NOT WRITE IN THIS MARGIN

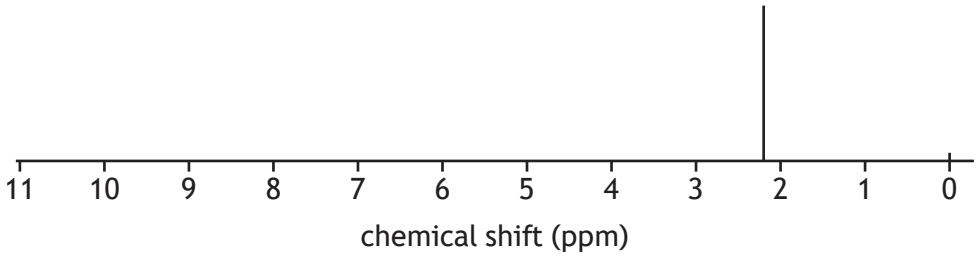
(b) Compounds **A** and **B** are also found in roasted coffee beans and they have the molecular formula $C_3H_6O$.

(i) The infrared spectrum of **A** is given below.




Identify the bond responsible for the peak at 1710 cm$^{-1}$. **1**

(ii) The low resolution $^1$H NMR spectrum for compound **A** is given below.




(A) Draw a structural formula for compound **A**. **1**

(B) Compound **B** contains the same functional group as compound **A**. Predict the number of peaks that would be found on the $^1$H NMR spectrum of compound **B**. **1**

**5. (continued)**

(c) Elemental analysis was carried out on a coffee flavour compound containing only carbon, hydrogen and oxygen.

Complete combustion of a 1.00 g sample of this compound produced 1.47 g of carbon dioxide and 0.60 g of water. No other product was formed.

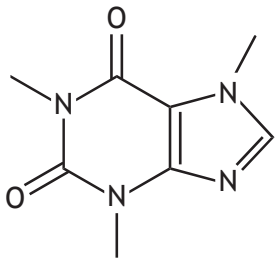
(i) Calculate the masses of carbon and hydrogen in the original sample and therefore determine the mass, in g, of oxygen present. **2**

(ii) Calculate the empirical formula of this compound. **1**

**[Turn over**

**5. (continued)**

(d) Coffee contains the compound caffeine, which can be isolated by solvent extraction using dichloromethane.



caffeine

A student carried out an investigation into the caffeine content of coffee.

Ground coffee was soaked in hot water to dissolve the caffeine. Dichloromethane was then added to extract the caffeine from this aqueous solution.

(i) Outline the steps that should have been carried out to extract the maximum mass of caffeine from the aqueous caffeine solution. **2**

**5. (d) (continued)**

(ii) The solvent extraction relies on the following equilibrium.

$$\text{caffeine (aq)} \rightleftharpoons \text{caffeine (dichloromethane)}$$

In an experiment to determine the equilibrium constant, 100 $cm^3$ of aqueous caffeine solution containing 0.150 g of caffeine was mixed with an equal volume of dichloromethane.

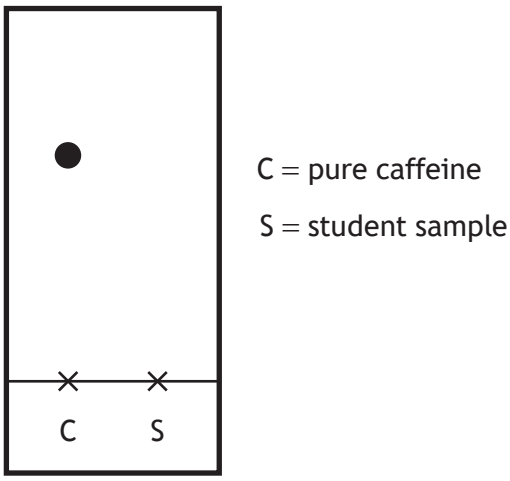
The mass of caffeine in the dichloromethane was found to be 0.136 g.

Calculate the value of the equilibrium constant for this extraction. **2**

(iii) The student carried out thin-layer chromatography on a sample of the extracted caffeine and determined that the sample was impure.

Complete the diagram of the thin-layer chromatogram showing a possible result for the impure sample. **1**

(An additional diagram, if required, can be found on *page 31*.)




C = pure caffeine

S = student sample

**[Turn over**

**6.** Iron deficiency can be treated using iron tablets.

(a) The mass of iron in a tablet was determined by titration with a 0.010 mol $l^{-1}$ solution of potassium permanganate.

(i) Describe fully how a 0.010 mol $l^{-1}$ solution of potassium permanganate should be prepared in a 500 $cm^3$ volumetric flask by accurately diluting a 0.200 mol $l^{-1}$ solution. **2**

(ii) 250 $cm^3$ of an $Fe^{2+}(aq)$ solution was prepared using five iron tablets.

25.0 $cm^3$ samples of this solution were titrated with 0.010 mol $l^{-1}$ acidified potassium permanganate solution.

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(\ell) + 5Fe^{3+}(aq)$$

The average titre volume was 11.8 $cm^3$.

Calculate the mass, in mg, of iron in one iron tablet. **3**

**6. (a) (continued)**

(iii) Dilute sulfuric acid is used to acidify potassium permanganate solutions. If dilute hydrochloric acid is used, chlorine gas is produced.

Suggest why chlorine gas is produced. **1**

(b) When the tablet dissolves, a green solution containing hexaaquairon(II) ions, $[Fe(OH_2)_6]^{2+}$, is formed.

(i) Explain fully why a solution of hexaaquairon(II) ions is green. **2**

(ii) In an aqueous solution of hexaaquairon(II) ions, $[Fe(OH_2)_6]^{2+}$, the following equilibrium exists.

$$[Fe(OH_2)_6]^{2+} + H_2O \rightleftharpoons [FeOH(OH_2)_5]^{+} + H_3O^{+}$$

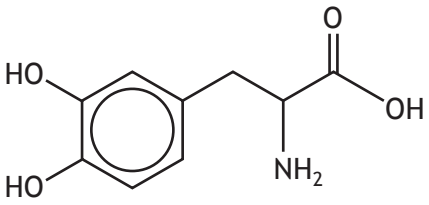
This equation shows that water is amphoteric.

Explain, with reference to the equation, why water can be described as amphoteric. **1**

**[Turn over**

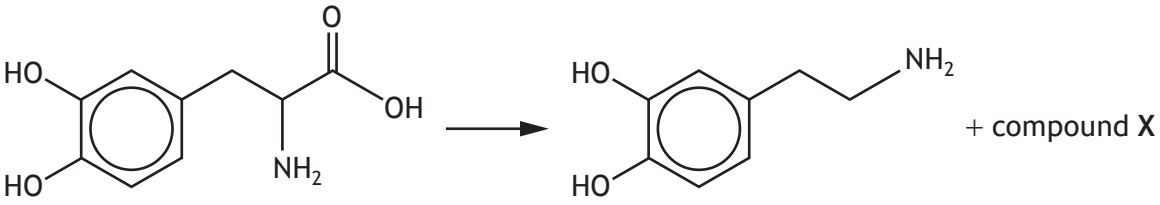
**7.** Parkinson's disease is caused by a lack of dopamine in the brain.

One of the main treatments for Parkinson's disease contains levodopa.




levodopa

(a) Levodopa, $C_9H_{11}NO_4$, can be converted to dopamine, $C_8H_{11}NO_2$, as shown.




levodopa dopamine

Identify compound **X**. **1**

**7. (continued)** **MARKS** DO NOT WRITE IN THIS MARGIN

(b) Some levodopa can be broken down by an enzyme before it reaches the brain.

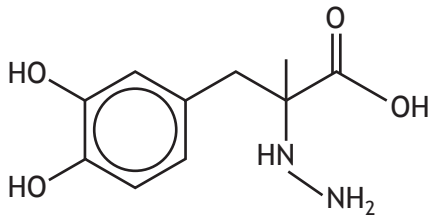
(i) An adult with a blood volume of 4.35 litres took a tablet containing 125 mg of levodopa.

Calculate the concentration, in mol $l^{-1}$, of levodopa remaining in the blood after 29.5% of it has been broken down.

The *GFM* of levodopa is 197 g. **2**

(ii) To prevent levodopa being broken down, a drug called carbidopa can be given.

Carbidopa binds to the enzyme instead of levodopa.




carbidopa

(A) State the classification of drug used to describe carbidopa. **1**

(B) Carbidopa can bind to enzymes through hydrogen bonds.

A hydrogen bond acceptor is an atom with a lone pair of electrons that can form a hydrogen bond.

Determine the number of hydrogen bond acceptors in carbidopa. **1**

**[Turn over**

**8.** Camphorquinone is used in dentistry as part of a process to form a protective coating around teeth.

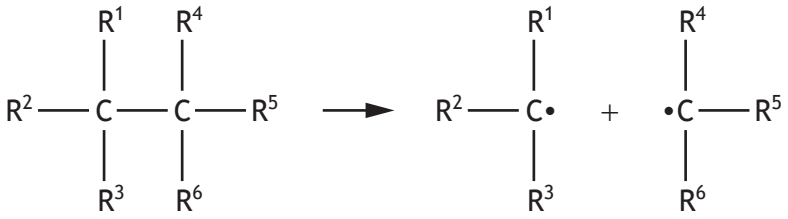
During the process camphorquinone undergoes homolytic fission to generate free radicals.

(a) Camphorquinone generates free radicals when exposed to radiation with a wavelength of 471 nm.

Calculate the energy, in kJ mol$^{-1}$, associated with this wavelength. **2**

(b) (i) Complete the equation, using curly arrow notation, to show a carbon-carbon bond undergoing homolytic fission to create two free radicals. **1**

(An additional equation, if required, can be found on *page 32*.)




(ii) State why homolytic fission is not commonly used in organic synthesis. **1**

**9.** A student stated that orbital box notation is the most useful way of representing electrons and their arrangements.

**Using your knowledge of chemistry**, discuss how different ways of representing electrons allow chemists to explain chemical concepts and reactions. **3**

**[Turn over**

**10.** Gold can be separated from rocks using a series of chemical reactions.

(a) In the first reaction a gold complex ion, $[Au(CN)_2]^-$, is formed.

$$2Au(s) + 4NaCN(aq) + \tfrac{1}{2}O_2(g) + H_2O(\ell) + 2OH^-(aq) \rightarrow 2[Au(CN)_2]^-(aq) + 4NaOH(aq)$$

(i) Calculate the minimum volume of 0.0550% NaCN(aq) that would be required to react with 1.00 g of Au in this step. **2**

(ii) (A) The coordination number of gold in $[Au(CN)_2]^-$ is 2.

State what is meant by the term coordination number. **1**

(B) When naming complex ions, the Latin term for gold ions, aurate, can be used.

State the name of the complex ion, $[Au(CN)_2]^-$. **1**

**10. (continued)**

(b) In the second reaction the complex ion, $[Au(CN)_2]^-$, is changed into gold metal, Au, which then precipitates from the solution.

(i) Name this type of reaction. **1**

(ii) Describe the steps required to produce a pure, dry sample of gold metal from the reaction mixture. **2**

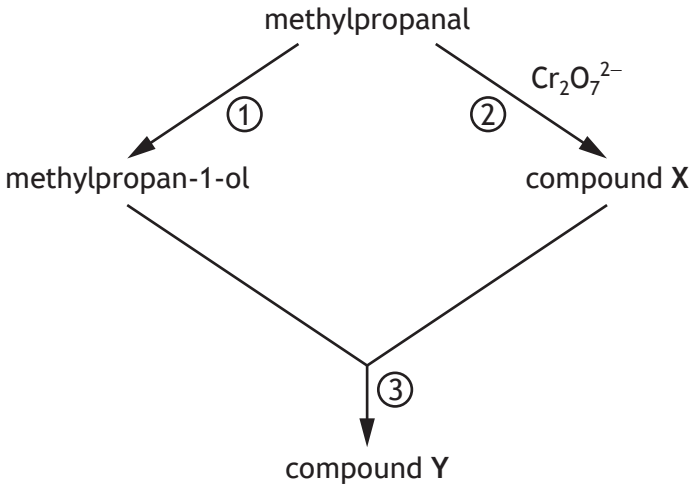
(iii) Rock from one gold mine contains 21.5 ppm of gold.

Calculate the mass of rock, in kg, that would produce 1.00 g of gold if the percentage yield for the entire process is 91.5%. **2**

**[Turn over**

**11.** Carbonyl compounds can take part in a variety of chemical reactions.

(a) The following reaction scheme involves methylpropanal.




(i) Name a reagent that could be used to carry out step ①. **1**

(ii) Name the type of reaction taking place in step ②. **1**

(iii) In step ③ methylpropan-1-ol and compound **X** react to produce compound **Y**.

Draw a structural formula for compound **Y**. **1**

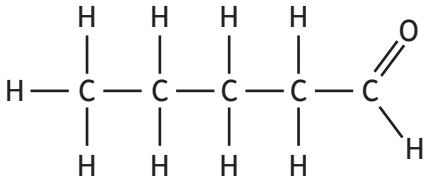
**11. (continued)**

(b) (i) Aldol reactions involve two molecules of aldehydes or ketones reacting together.

An aldol reaction can only take place if the aldehyde or ketone has an $\alpha$-hydrogen atom. An $\alpha$-hydrogen atom is bonded to a carbon atom next to the carbonyl group.

(A) Circle an $\alpha$-hydrogen atom on the structure of pentanal shown below. **1**

(An additional structure, if required, can be found on *page 32*.)

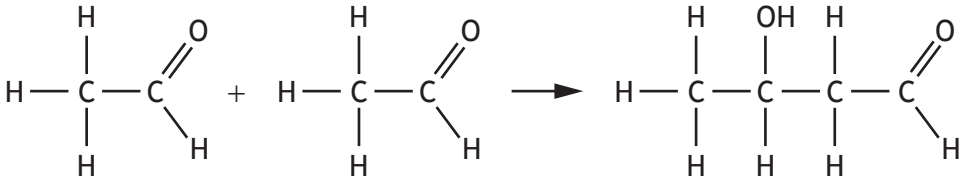


(B) Draw a structural formula for an isomer of pentanal that contains a carbonyl group but cannot take part in an aldol reaction. **1**

**[Turn over**

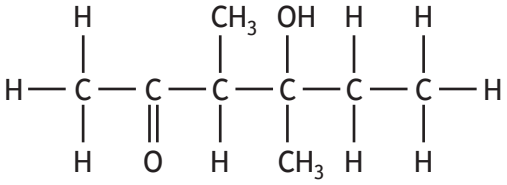
**11. (b) (continued)**

(ii) (A) The aldol reaction between two molecules of ethanal is shown.

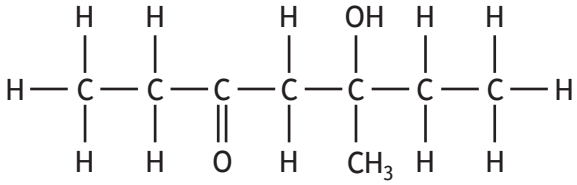


Draw a structural formula for the product formed in the aldol reaction between two molecules of propanone. **1**

(B) When butanone takes part in an aldol reaction the two isomeric compounds shown below are formed.



4-hydroxy-3,4-dimethylhexan-2-one



compound **Z**

(I) Suggest why two isomers are formed. **1**

(II) Name compound **Z**. **1**

MARKS DO NOT WRITE IN THIS MARGIN

**12.** Sulfur is formed in the reaction between sodium thiosulfate and hydrochloric acid.

(a) In an experiment to determine the rate equation for this reaction, a student obtained the following data.

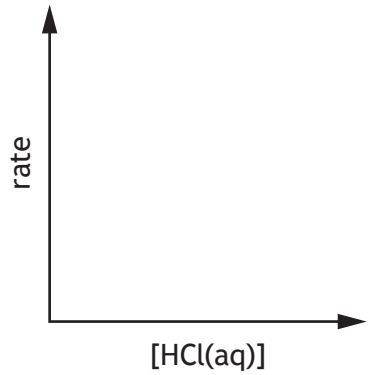
| Experiment | $[Na_2S_2O_3(aq)]$ (mol $l^{-1}$) | [HCl(aq)] (mol $l^{-1}$) | Initial rate (mol $l^{-1}$ $s^{-1}$) |
|---|---|---|---|
| 1 | $5.00 \times 10^{-2}$ | $2.00 \times 10^{-1}$ | $6.55 \times 10^{-3}$ |
| 2 | $1.00 \times 10^{-1}$ | $2.00 \times 10^{-1}$ | $1.31 \times 10^{-2}$ |
| 3 | $1.00 \times 10^{-1}$ | $4.00 \times 10^{-1}$ | $1.31 \times 10^{-2}$ |

(i) Determine the order of reaction with respect to $Na_2S_2O_3$. **1**

(ii) The reaction is zero order with respect to HCl.

Complete the diagram below to show the effect of changing the concentration of HCl on the reaction rate. **1**

(An additional diagram, if required, can be found on *page 33*.)




(iii) Write the overall rate equation for the reaction. **1**

(iv) Calculate the value for the rate constant, $k$, including the appropriate units. **2**

**[Turn over**

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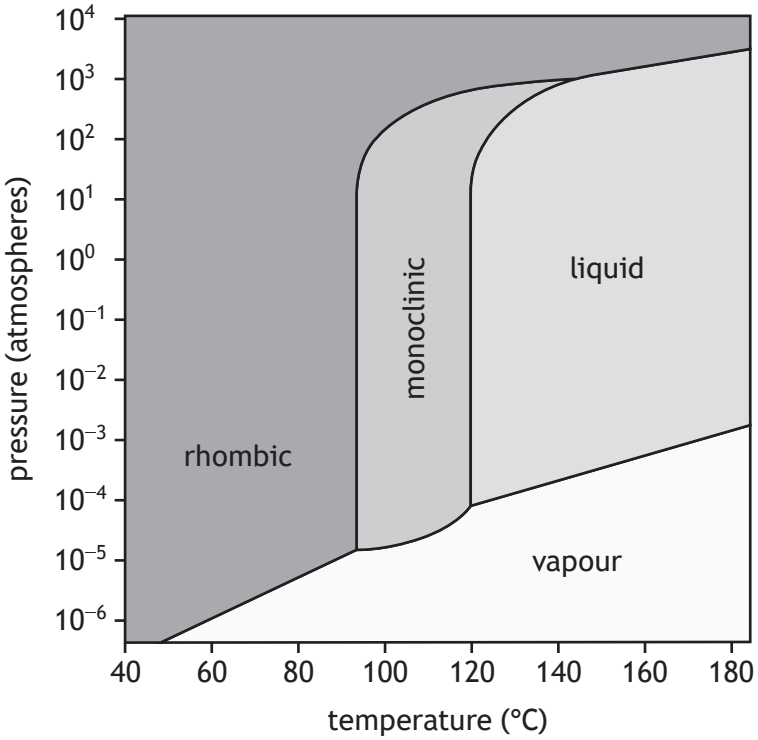
(b) Sulfur, $S_8$, can exist in four forms — liquid, vapour, and two solid forms (rhombic and monoclinic).

The phase diagram below shows the forms of $S_8$ that exist at different temperatures and pressures.




(i) Determine the form in which $S_8$ exists at a temperature of 100°C and a pressure of $10^0$ atmospheres. **1**

(ii) A triple point on a phase diagram shows the temperature and pressure at which three forms exist in equilibrium with each other.

(A) Circle the triple point on the phase diagram where rhombic, monoclinic and vapour forms exist in equilibrium with each other. **1**

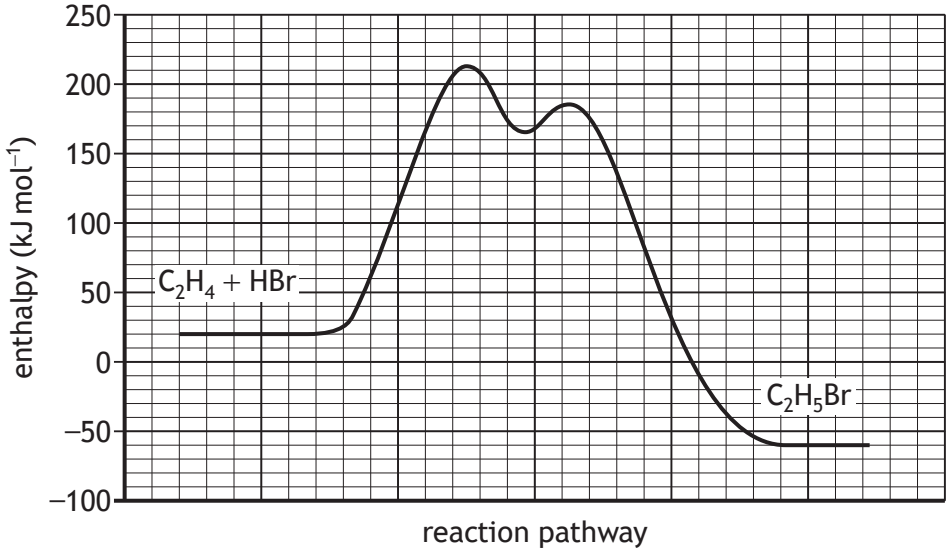
(An additional diagram, if required, can be found on *page 33*.)

(B) Determine the three forms of $S_8$ that can never exist in equilibrium with each other. **1**

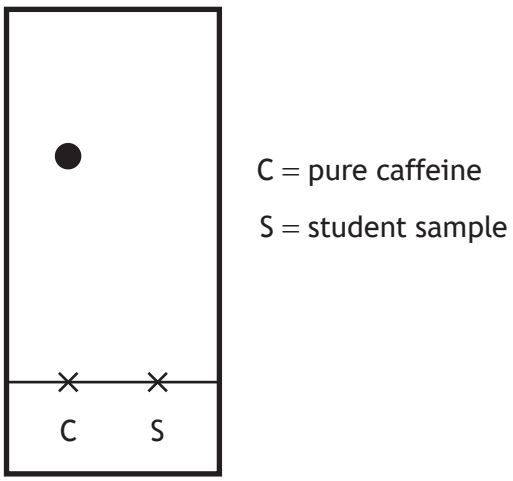
**[END OF QUESTION PAPER]**

## ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional graph for question 4 (a) (i) (B)




Additional diagram for question 5 (d) (iii)

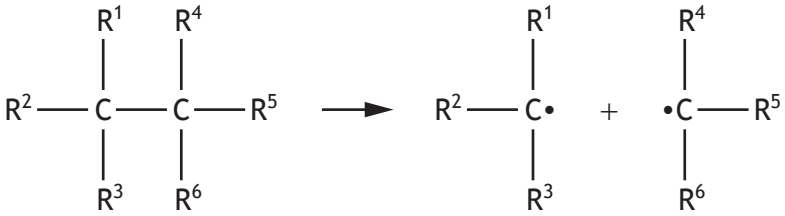



C = pure caffeine

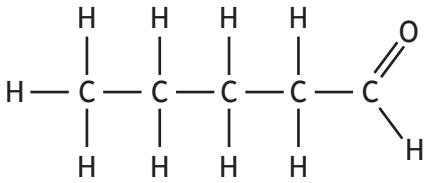
S = student sample

## ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional equation for question 8 (b) (i)

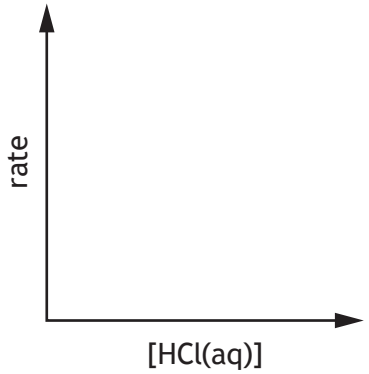


Additional structure for question 11 (b) (i) (A)

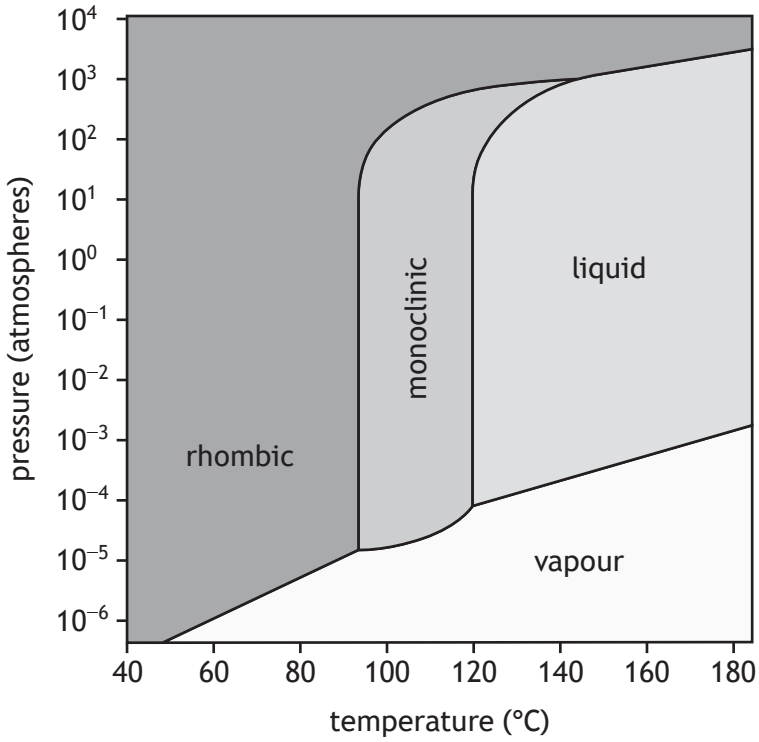


## ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

Additional diagram for question 12 (a) (ii)




Additional diagram for question 12 (b) (ii) (A)



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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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