1. The functional group in an organic compound, **W**, was identified by carrying out two chemical tests. The results of the tests are shown below.

Heating with acidified sodium dichromate(VI)(aq)	Addition of 2,4-dinitrophenylhydrazine(aq)
orange solution turns green	yellow/orange precipitate formed

Which compound could be **W**?

A $CH_3CH_2CH_2OH$

B CH_3COCH_3

C $CH_3CH(OH)CH_3$

D CH_3CH_2CHO

Your answer ☐

[1]

2. Cyclohexanone can be prepared in the laboratory by reacting cyclohexanol with concentrated sulfuric acid and sodium dichromate.

Ethanedioic acid is added to the reaction mixture to react with any excess dichromate.

The mixture is then distilled. The impure distillate is a mixture of cyclohexanone and water.

You will need to refer to some or all of the following data to answer these questions.

	Boiling point /°C	**Density /g cm^{-3}**	M_r
Cyclohexanol	161	0.962	100.0
Cyclohexanone	156	0.948	98.0

(a)* Draw a labelled diagram to show how you would safely set up apparatus for distillation and describe a method to obtain a pure sample of cyclohexanone from the distillate.

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…… **[6]**

(b) Ethanedioic acid removes excess dichromate ions, $Cr_2O_7^{2-}$, as in the equation below.

$$3(COOH)_2 + Cr_2O_7^{2-} + 8H^+ \rightarrow 6CO_2 + 2Cr^{3+} + 7H_2O$$

Suggest how you could tell when the excess dichromate has completely reacted with the ethanedioic acid.

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…… **[1]**

(c) A student monitors the course of this reaction using thin-layer chromatography (TLC).

Outline how TLC could be used to monitor the course of the reaction.

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…… **[2]**

(d) Plan an experiment that would allow the student to confirm the identity of the pure organic product by means of a chemical test.

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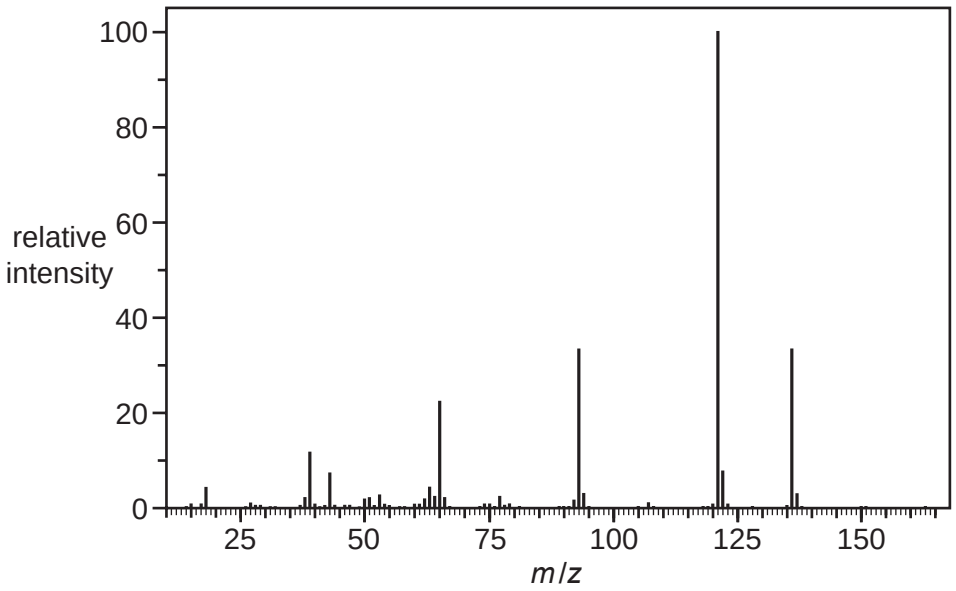
…… **[3]**

3. A chemist analyses a naturally occurring aromatic compound.

(a) The percentage composition and mass spectrum of the compound are shown below.

Percentage composition by mass: C, 70.58%; H, 5.92%; O, 23.50%.

Mass spectrum



Determine the molecular formula of the compound.

Show your working.

molecular formula = ... **[3]**

(b) Qualitative tests are carried out on the aromatic compound. The results are shown below.

Test	**Acidity**	**Na_2CO_3(aq)**	**2,4-DNP**	**Tollens' reagent**
Observation	pH = 5	No observable change	Orange precipitate	No observable change

Determine the functional groups in the compound. Explain your reasoning.

Functional groups .....

Explanation .....

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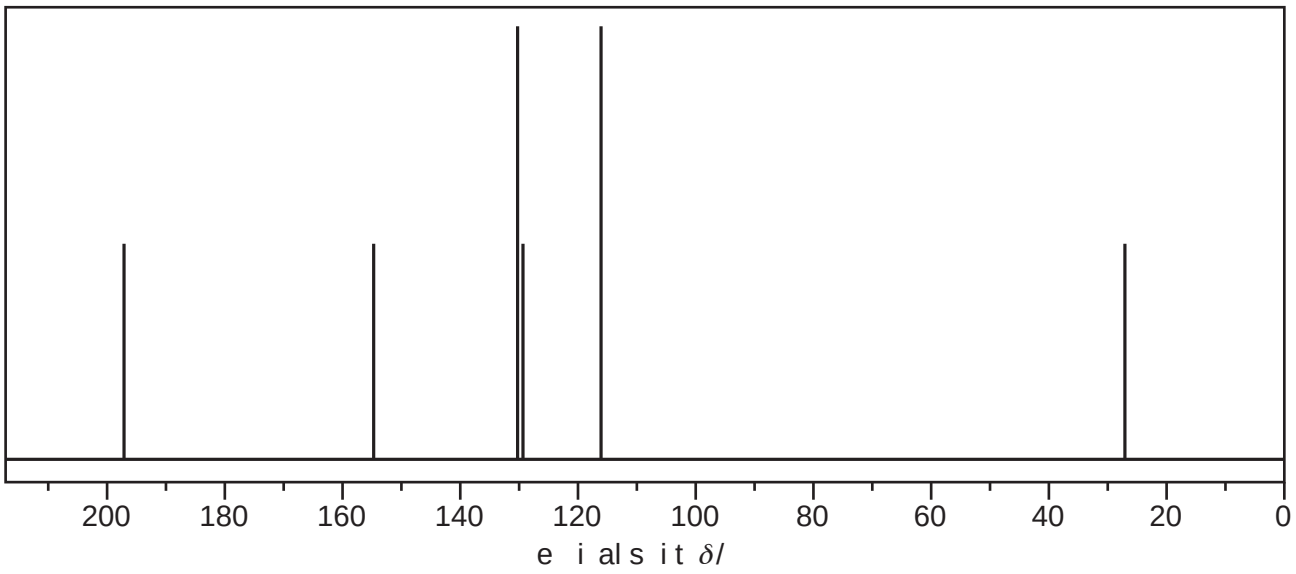
..... **[3]**

(c) The carbon-13 NMR spectrum of the compound is shown below.



Using the spectrum and the results from **(a)** and **(b)**, determine the structure of the compound. Explain your reasoning.

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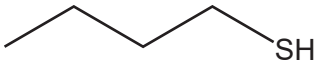
Structure of compound

[3]

4. This question is about organic molecules that have a strong smell.

(a) Thiols are foul-smelling, organic sulfur compounds with the functional group –SH.

Butane-1-thiol, shown below, contributes to the strong smell of skunks.



butane-1-thiol

(i) Thiols are weak acids.

Write the expression for the acid dissociation constant, K_a, for butane-1-thiol.

[1]

(ii) Thiols react with carboxylic acids to form thioesters.

Write an equation for the reaction of butane-1-thiol with ethanoic acid.

Use structures for all organic compounds with the functional groups clearly displayed.

[2]

(iii) When beer is exposed to light, 3-methylbut-2-ene-1-thiol is formed, which gives an unpleasant smell and flavour to the beer.

Draw the **skeletal** formula for 3-methylbut-2-ene-1-thiol.

[1]

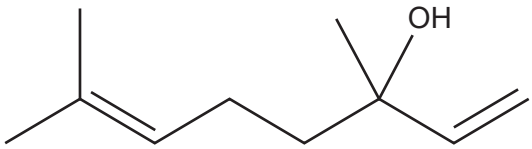
(iv) Propane-1,3-dithiol reacts with carbonyl compounds in a condensation reaction to form a cyclic organic sulfur product.

Write an equation for the reaction of propane-1,3-dithiol with propanone.

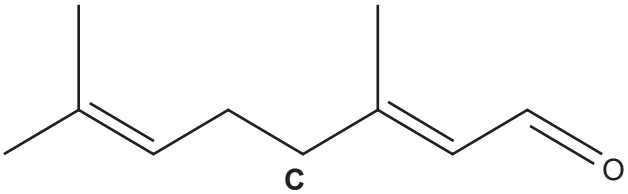
Use structures for organic compounds.

[2]

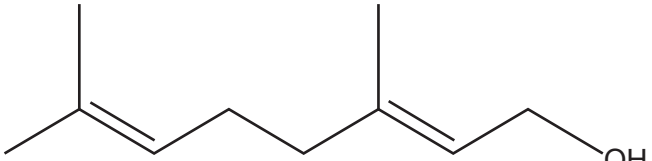
(b)* The structures for six naturally occurring organic compounds with pleasant smells, **B**–**G**, are shown below. The common names in brackets relate to their source and smell.



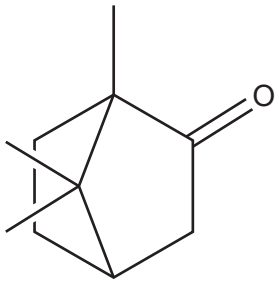
B
(linalool)



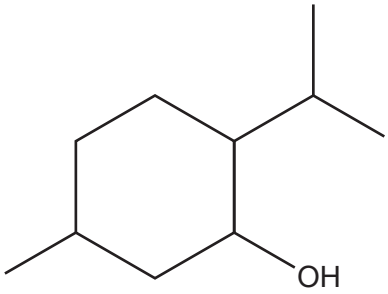
C
(citral)



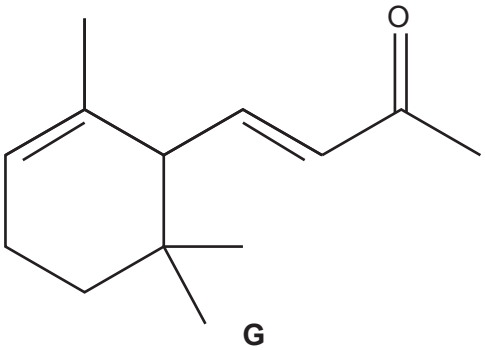
D
(geraniol)



E
(camphor)



F
(menthol)



G
(ionone)

Explain how chemical tests would allow each compound to be distinguished from the other compounds.

In your answer, include essential details for all test procedures and observations.

Details of apparatus and quantities are **not** required.

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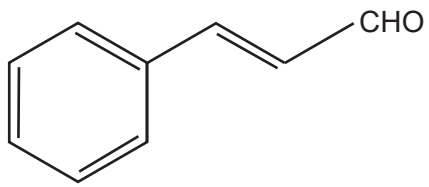
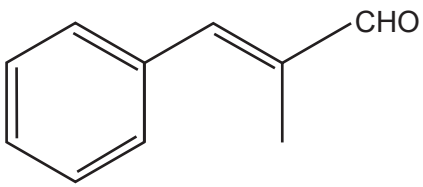
..... **[6]**

5. Cinnamaldehyde and methylcinnamaldehyde are naturally occurring organic compounds.



cinnamaldehyde



methylcinnamaldehyde

(a) Methylcinnamaldehyde is an *E* stereoisomer.

Explain this statement in terms of the Cahn-Ingold-Prelog (CIP) rules.

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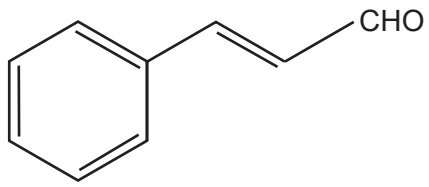
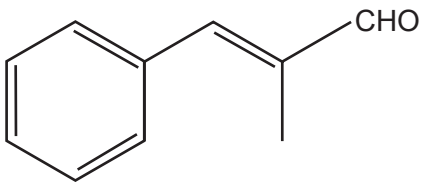
..... **[2]**

(b) A student plans to carry out some chemical tests on both cinnamaldehyde and methylcinnamaldehyde.



cinnamaldehyde



methylcinnamaldehyde

(i) Suggest a suitable chemical test to confirm that both compounds contain an unsaturated carbon chain.

Your answer should include the reagent and observations.

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..... **[1]**

(ii) Describe a chemical test to confirm that both compounds contain an aldehyde functional group.

Your answer should include the reagent and observations.

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..... **[1]**

(iii) Describe a chemical test to confirm that cinnamaldehyde and methylcinnamaldehyde contain a carbonyl group.

How could the products of this test be used to distinguish between the two compounds?

Your answer should **not** include spectroscopy.

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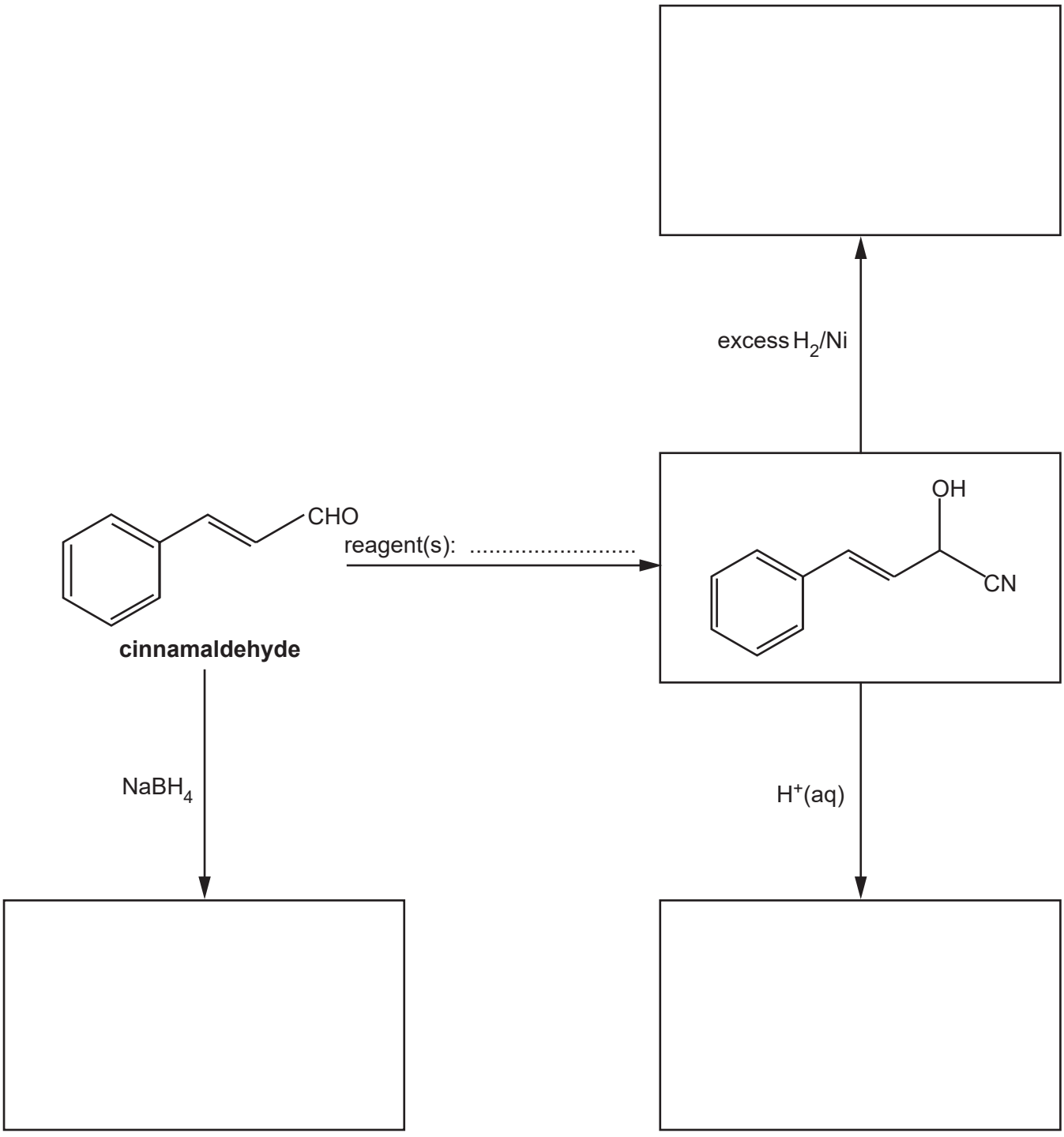
..... **[3]**

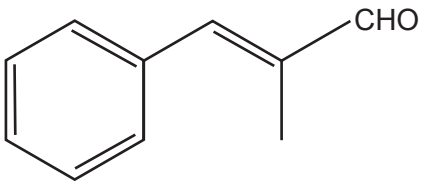
(c) The flowchart below shows some reactions starting with cinnamaldehyde.

Draw the structures of the missing organic compounds in the boxes and add the missing reagent(s) on the dotted line.



[5]

(d)* Methylcinnamaldehyde reacts with iodine monochloride, IC*l*, by electrophilic addition. The reaction produces a mixture containing two different organic products.



methylcinnamaldehyde

The electronegativity values of chlorine and iodine are given in the table below.

	Pauling electronegativity value
C*l*	3.0
I	2.5

Outline the mechanism, using the 'curly arrow' model, for the formation of **one** of the organic products and explain which of the two possible organic products is more likely to be formed.

In your mechanism, you can show the phenyl group as C_6H_5. **[6]**

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Additional answer space if required.

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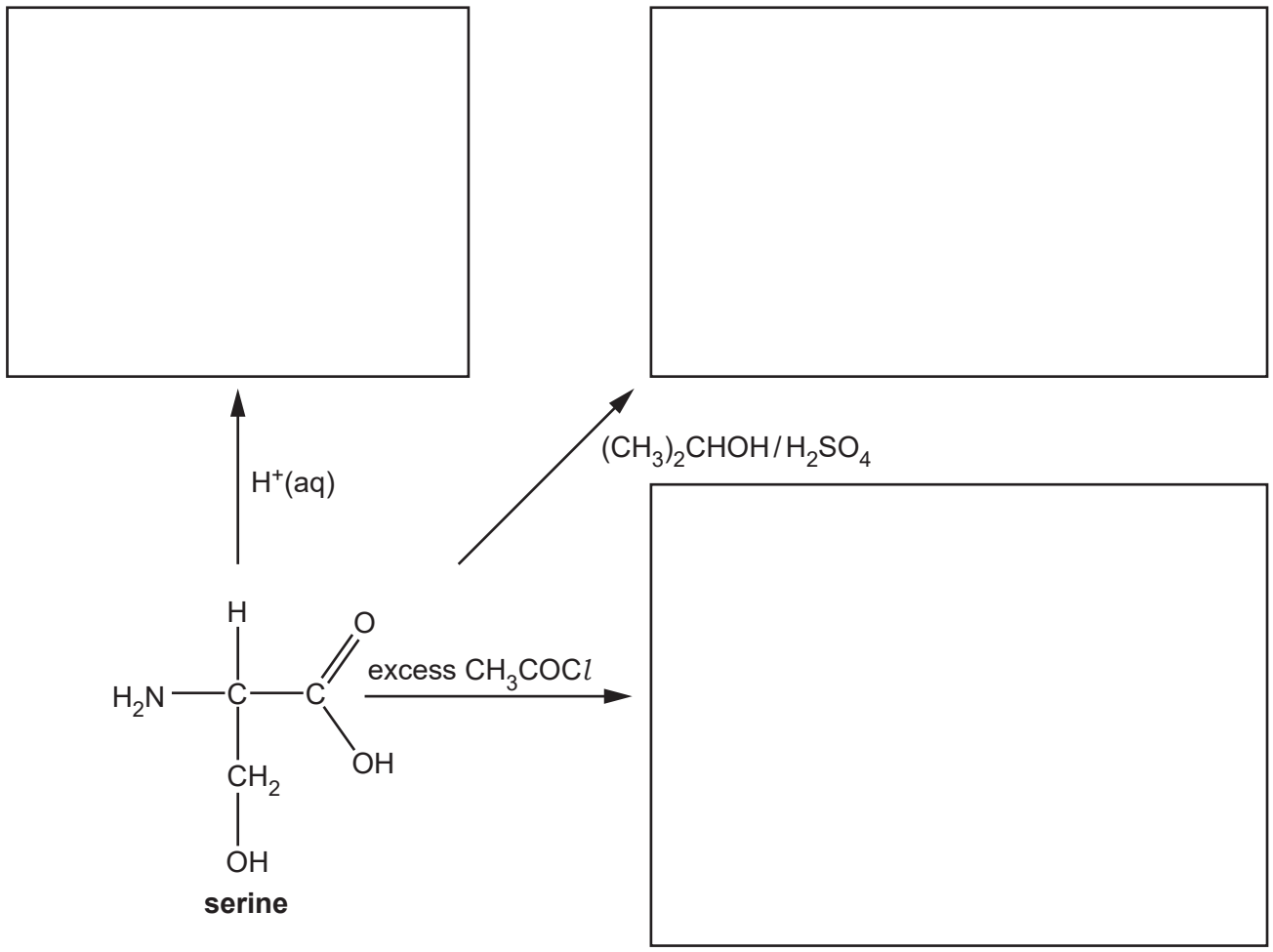
6. This question is about α-amino acids, $RCH(NH_2)COOH$.

(a) **Table 17.1** shows the R groups in four amino acids.

Amino acid	R group
alanine (ala)	CH_3–
serine (ser)	$HOCH_2$–
leucine (leu)	$(CH_3)_2CHCH_2$–
glycine (gly)	H–

Table 17.1

(i) In the boxes, draw the organic products for the reactions of serine shown below.



[4]

(ii) A student is provided with one of the four amino acids in **Table 17.1**.

A student carries out a titration with a standard solution of hydrochloric acid to identify the amino acid. The student's method is outlined below.

- The student dissolves 5.766 g of the amino acid in water and makes the solution up to 250.0 cm^3 in a volumetric flask.
- The student titrates this solution with 25.0 cm^3 of 0.150 mol dm^{-3} hydrochloric acid.
- 21.30 cm^3 of the amino acid solution were required for complete neutralisation of the hydrochloric acid.

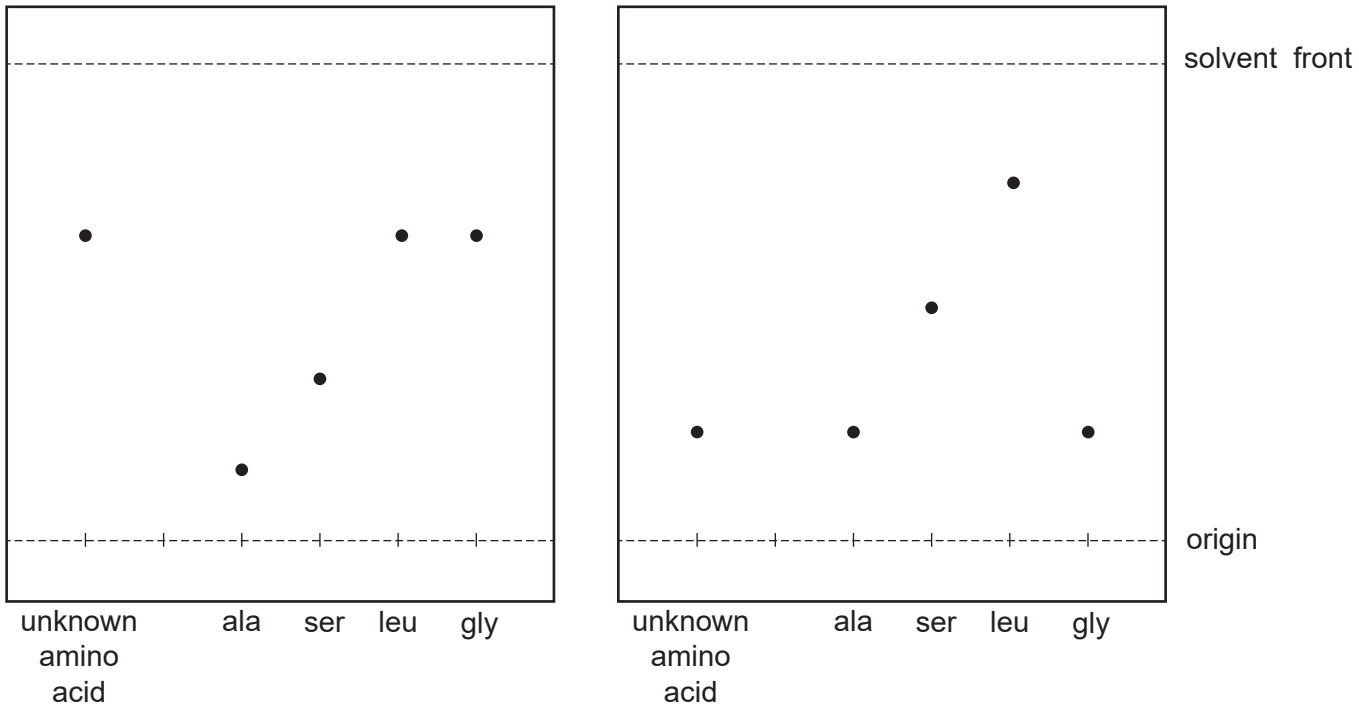
Determine which amino acid the student used.

[4]

(b) The student is provided with another amino acid.

The student attempts to identify the unknown amino acid using chromatography.

The student obtains two TLC chromatograms of the unknown amino acid and the four amino acids in **Table 17.1**, using two different solvents, **W** and **X**.



Solvent **W** Solvent **X**

(i) What is the R_f value of serine (ser) in solvent **W**?

R_f = ... **[1]**

(ii) Analyse the chromatograms to identify the unknown amino acid.

Explain your reasoning.

Name of unknown amino acid .....

Explanation .....

.....

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..... **[2]**

7. Which statement(s) is/are correct for gas chromatography?

1 The components in a mixture can be identified from their retention time.

2 The relative peak areas give the proportions of components in a mixture.

3 Calibration curves are used to confirm the concentrations of components in a mixture.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

[1]