



GCE A LEVEL

1410U40-1

MONDAY, 20 JUNE 2022 – MORNING

CHEMISTRY – A2 UNIT 4

ORGANIC CHEMISTRY AND ANALYSIS

1 hour 45 minutes plus your additional time allowance

Surname: _____

First name(s): _____

Centre Number: _____

Candidate Number: 2 _____

For Examiner's use only			
	Question	Maximum Mark	Mark Awarded
Section A	1. to 7.	10	
Section B	8.	14	
	9.	17	
	10.	13	
	11.	12	
	12.	14	
	Total	80	

(Turn over)

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:

- calculator;
- DATA BOOKLET supplied by WJEC.

ITEMS INCLUDED WITH QUESTION PAPER

A separate Diagram Booklet.

The Diagram Booklet MUST be handed in to the invigilators and sent for marking.

INSTRUCTIONS TO CANDIDATES

Use black ink, black ball – point pen, black felt tip or your usual method.

Write your name, centre number and candidate number in the spaces on the front cover.

Answer ALL questions in SECTION A.

Answer ALL questions in SECTION B.

Write your answers in the spaces provided.

If you run out of space, use the additional pages at the back of the booklet, taking care to number the question(s) correctly.

Candidates are advised to allocate their time appropriately between SECTION A (10 MARKS) and SECTION B (70 MARKS).

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part – question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in Question 10 (a).

SECTION A**ANSWER ALL QUESTIONS.**

1. A hydrocarbon is either cyclopentane or pent – 1 – ene.

Use the DATA BOOKLET to choose a characteristic infrared absorption that will positively identify the compound as pent – 1 – ene.

[1 mark]

(Turn over)

2. Give the NAME of a compound of formula C_4H_8 that will decolourise acidified potassium manganate(VII).

[1 mark]

- 3. Look at the diagram for Question 3 in the separate Diagram Booklet.**

The diagram shows an incomplete chemical equation.

Complete the equation for the reaction shown in the diagram.

[1 mark]

4. Give the structure of a compound of molecular formula $\text{C}_4\text{H}_8\text{Br}_2$ whose low resolution

$^1\text{H NMR}$ spectrum consists of three peaks.

[1 mark]

(Turn over)

5. Look at the diagram for Question 5 in the separate Diagram Booklet.

The diagram shows the formula of an azo dye, produced by reacting a diazonium compound with phenol.

Write the formula of the amine that is used to produce this diazonium compound.

[1 mark]

(Turn over)

6. Ethanal reacts with hydrogen cyanide to give 2-hydroxypropanenitrile, $\text{CH}_3\text{CH}(\text{OH})(\text{CN})$.

(a) State the type of mechanism occurring during this reaction.

[1 mark]

(b) Draw the structures of the two enantiomers of 2-hydroxypropanenitrile.

[1 mark]

(Turn over)

7. Three isomers have the molecular formula $C_4H_8O_2$.

- (a) (i) Give the structure of an isomer that gives bubbles of carbon dioxide when tested with aqueous sodium hydrogencarbonate.

[1 mark]

continued on the next page . . .

(Turn over)

Question 7 (a) continued

- 7. (a) (ii) Give the structure of an isomer that is both a ketone and a secondary alcohol.**

[1 mark]

continued on the next page . . .

(Turn over)

Question 7 continued

7. (b) Look at the diagram for Question 7 (b) in the separate Diagram Booklet. The diagram shows the structure of 1,4-dioxane.

Describe and explain the high resolution $^1\text{H NMR}$ spectrum of 1,4-dioxane.

The position of the signal(s) is NOT required.

[1 mark]

(Total for SECTION A = 10 marks)

(Turn over)

SECTION B**ANSWER ALL QUESTIONS.**

8. (a) The starting material for making polyamides is often benzene, obtained from petroleum.

(i) Look at the diagram for Question 8 (a) (i) in the separate Diagram Booklet.

The first stage in the production of a particular polyamide is the hydrogenation of benzene at increased temperature and pressure, as shown in the diagram.

Suggest the name of a catalyst that can be used for the hydrogenation of alkenes and an arene, such as benzene.

[1 mark]

(Turn over)

Question 8 (a) continued

- 8. (a) (ii) Look at the diagram for Question 8 (a) (ii) in the separate Diagram Booklet.**
- Cyclohexane, the product from the first stage, is then catalytically oxidised using air. This results in KA (a mixture of cyclohexanol and cyclohexanone).**
- The mixture typically contains around 60% of cyclohexanone.**

continued on the next page . . .

Question 8 (a) (ii) continued

- 8. (a) (ii) I. Using characteristic infrared values, describe how you could identify both cyclohexanol and cyclohexanone in KA. You should identify the bonds and their absorption frequencies in your answer.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 8 (a) (ii) continued

8. (a) (ii) II. A student suggested that you could find the proportion of cyclohexanol and cyclohexanone in **KA** by comparing the percentage of oxygen in each compound.

Calculate the percentage of oxygen in each compound.

Use your answers to explain why this method would probably not give an accurate answer for the proportion of each compound present in **KA.**

Space for working

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(Turn over)

Space for working continued

[3 marks]

continued on the next page . . .

(Turn over)

Question 8 (a) (ii) continued

8. (a) (ii) III. The proportions present in KA can be found more effectively by using gas chromatography.

Look at the diagram for Question 8 (a) (ii) III in the separate Diagram Booklet. The diagram shows a typical chromatogram of a sample of KA. The largest peak is due to cyclohexanone.

Calculate the percentage by volume of cyclohexanone in the mixture.

Space for working

Percentage of cyclohexanone = _____ %
[1 mark]

(Turn over)

Question 8 (a) continued

8. (a) (iii) A sample of the cyclohexanol in KA is oxidised in the laboratory by refluxing with a suitable reagent.

State a suitable oxidising agent that can be used.

[1 mark]

continued on the next page . . .

(Turn over)

Question 8 continued

- 8. (b) Look at the diagram for Question 8 (b) in the separate Diagram Booklet.**

The diagram shows the formula of the polyamide 'Kevlar'.

Give the structures of two starting materials that can react together to produce this polymer.

continued on the next page . . .

(Turn over)

Space for structures continued

[2 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (c) Look at the diagram for Question 8 (c) in the separate Diagram Booklet.

The polymer poly(sodiumacrylate) is an example of a super absorbing polymer.

(i) Explain why this polymer is described as an addition polymer and not as a polyester.

[2 marks]

continued on the next page . . .

(Turn over)

Question 8 (c) continued

- 8. (c) (ii) Poly(sodiumacrylate) is capable of absorbing several hundred times its own mass of water, whilst remaining as a solid material.**

In an experiment, 4.0×10^{-6} mol of the polymer absorbed 150 g of water. This mass of water is 300 times the mass of the polymer used.

Calculate the relative molecular mass of the polymer.

Space for working

continued on the next page . . .

(Turn over)

Space for working continued

$$M_r = \underline{\hspace{15em}}$$

[2 marks]

(Total for Question 8 = 14 marks)

(Turn over)

9. (a) Look at the diagram for Question 9 (a) in the separate Diagram Booklet.

The diagram represents the process for producing guaiacol (2 – methoxyphenol).

Guaiacol (2 – methoxyphenol) can be produced in a three – stage method from anisole (methoxybenzene).

The boiling temperature of each product of stage 1 is shown in the diagram.

Use your knowledge of a similar reaction, using benzene as the starting material, to answer parts (i) – (iii).

- (i) Suggest a reagent(s) for stage 1.

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 (a) continued

9. (a) (ii) Suggest a reagent(s) for stage 2.

[1 mark]

(iii) Suggest and explain a practical problem that might occur at the end of stage 1, before proceeding to stage 2.

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 (a) continued

9. (a) (iv) Complete the table below, indicating what is observed (if anything) when guaiacol reacts with aqueous solutions of these reagents.

Reagent	FeCl_3	NaHCO_3
Observation		

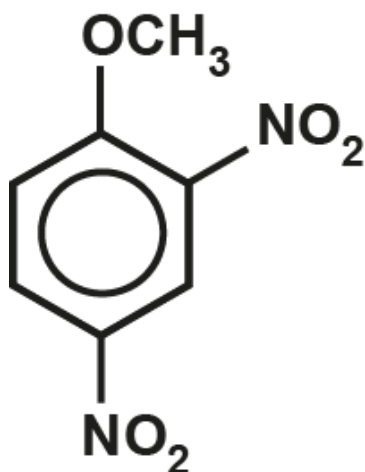
[2 marks]

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(Turn over)

Question 9 continued

9. (b) 2,4 – Dinitroanisole can also be made by the nitration of anisole.



This compound has been used as an explosive. On detonation, it gives carbon, carbon monoxide, nitrogen and steam. Look at the diagram for Question 9 (b) in the separate Diagram Booklet. The diagram shows an unbalanced equation for the reaction.

Balance the equation for this reaction.

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 continued

9. (c) (1 – Methyl)benzene (commonly called cumene) can be prepared from benzene by a Friedel – Crafts reaction. Look at Diagram 1 for Question 9 (c) in the separate Diagram Booklet. The diagram shows the equation for the reaction.

The products of the first step of the reaction are given in Diagram 2 for Question 9 (c) in the separate Diagram Booklet.

Complete the mechanism in Diagram 2, showing how cumene, hydrogen chloride and the catalyst are formed from the intermediate product.

[2 marks]

continued on the next page . . .

(Turn over)

Question 9 continued

9. (d) Cumene is an important material in the industrial preparation of phenol and propanone.

Look at the diagram for Question 9 (d) in the separate Diagram Booklet.

The diagram shows the equation for this reaction.

- (i) The yield of phenol (M_r 94) in this process is 86% with benzene (M_r 78) as the starting material.
- Calculate the mass of phenol produced from 234 kg of benzene.

Space for working

continued on the next page . . .

(Turn over)

Space for working continued

Mass of phenol = _____ kg

[2 marks]

continued on the next page . . .

(Turn over)

Question 9 (d) continued

9. (d) (ii) During this reaction a cumene radical is produced.

State what is meant by the term 'radical'.

[1 mark]

- (iii) Give the formula of a radical formed during the reaction of methane with chlorine.**

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 continued

9. (e) Phenol reacts with aqueous bromine to give 2, 4, 6 – tribromophenol.

If aqueous bromine is added slowly to an aqueous solution of phenol, describe how you would know when the reaction is just complete.

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 continued

9. (f) Phenol reacts with benzoyl chloride, to give the ester phenyl benzoate and hydrogen chloride.

(i) Write the equation for this reaction.

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 (f) continued

9. (f) (ii) The reaction in part (i) is carried out in the presence of aqueous sodium hydroxide, which removes HCl as it is formed.

Explain why this method would not be suitable for a similar reaction, using ethanoyl chloride in place of benzoyl chloride.

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 (f) continued

9. (f) (iii) Esterification reactions, such as those in part (i), are sometimes carried out using pyridine in place of sodium hydroxide.

Look at the diagram for Question 9 (f) (iii) in the separate Diagram Booklet. The diagram shows the structure of pyridine.

Explain the feature present in the structure of pyridine that enables it to react in this way.

[2 marks]

(Total for Question 9 = 17 marks)

(Turn over)

10. (a) Compound **G** contains only carbon, hydrogen and oxygen.

It has a molar mass of 72 g mol^{-1} of which **50.0%** is carbon. The compound reacts positively with Tollens' reagent and gives a yellow solid when treated with alkaline iodine solution. It reacts with sodium tetrahydridoborate(III) to give a new compound which has a molar mass of 76 g mol^{-1} .

Look at the diagram for Question 10 (a) in the separate Diagram Booklet.

The high resolution $^1\text{H NMR}$ spectrum of compound **G** is shown in the diagram.

continued on the next page . . .

Question 10 continued

10. (b) The absorption spectrum of compound **G** shows a maximum absorption at **450 nm**. Light energy measured in kJ mol^{-1} (**E**) is related to wavelength (λ) by the equation below.

$$E = \frac{\text{constant}}{\lambda}$$

The energy of light of wavelength **656 nm** is **183 kJ mol⁻¹**.

Calculate the energy of the maximum absorption of compound **G** at **450 nm**.

Space for working

continued on the next page . . .

(Turn over)

Space for working continued

Energy = _____ kJ mol^{-1}

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 continued

10. (c) Look at the diagram for Question 10 (c) in the separate Diagram Booklet.

The diagram shows the formula of 4 – aminobenzamide.

(i) When this compound is warmed with excess aqueous sodium hydroxide, only the amide group reacts.

I. Give the structure of the organic product.

[1 mark]

(Turn over)

Question 10 (c) (i) continued

- 10. (c) (i) II. State the nature of the attacking reagent and explain why the NH_2 group bonded to the benzene ring is not removed.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 (c) continued

- 10. (c) (ii) Both the functional groups in 4 – aminobenzamide are attacked by nitric(III) acid at room temperature, giving 4 – hydroxybenzoic acid, nitrogen gas and water as the products.**

Look at the diagram for Question 10 (c) (ii) in the separate Diagram Booklet.

The diagram shows an incomplete equation for the reaction.

Complete the equation for this reaction.

[2 marks]

(Total for Question 10 = 13 marks)

(Turn over)

11. (a) Look at the diagram for Question 11 (a) in the separate Diagram Booklet.

The diagram shows the structure of tyrosine.

Tyrosine is one of the amino acids making up casein, the protein in milk.

(i) Look at the diagram for Question 11 (a) (i) in the separate Diagram Booklet.

The diagram shows a chromatogram.

Using a particular solvent tyrosine has an R_f value of 0.67



On the chromatogram, show the spot given by tyrosine.

[1 mark]

continued on the next page . . .

(Turn over)

Question 11 (a) continued

11. (a) (ii) Write the formula for the zwitterion of tyrosine.

[1 mark]

continued on the next page . . .

(Turn over)

Question 11 (a) continued

11. (a) (iii) Tyrosine is described as a hydrophobic amino acid, as its solubility in water is very low.

Use the formula of tyrosine to give a reason for this low solubility.

[1 mark]

continued on the next page . . .

(Turn over)

Question 11 (a) continued

11. (a) (iv) Look at the diagram for Question 11 (a) (iv) in the separate Diagram Booklet.

The diagram shows the equation for the reaction of tyrosine with nitric(III) acid.

Amino acids, such as tyrosine, react with nitric(III) acid to give the corresponding hydroxy acid and nitrogen gas.

continued on the next page . . .

Question 11 (a) (iv) continued

- 11. (a) (iv) I. A sample of tyrosine was treated with an excess of nitric(III) acid and produced 147 cm^3 of nitrogen, measured at 298 K and 1 atm pressure.**

Show that this volume of nitrogen will be produced from 1.09 g of tyrosine.

Space for working

[2 marks]

continued on the next page . . .

(Turn over)

Question 11 (a) (iv) continued

11. (a) (iv) II. The experiment was repeated with a sample of tyrosine from a different batch.

This time the same starting mass gave 132 cm^3 of nitrogen under the same conditions.

Suggest ONE reason for this different result.

[1 mark]

continued on the next page . . .

(Turn over)

Question 11 continued

- 11. (b) There is increasing interest in the production of important chemicals by biotechnology, rather than from the use of fossil fuels.**

One of these compounds is butane – 1, 4 – dioic acid, which can be made from glucose.

Look at equation 1 for Question 11 (b) in the separate Diagram Booklet.

In practice, a constant pH is maintained by the addition of calcium hydroxide.

As butane – 1, 4 – dioate ions are produced they react with calcium hydroxide to give insoluble calcium butane – 1, 4 – dioate, which is then filtered from the mixture.

Look at equation 2 for Question 11 (b) in the separate Diagram Booklet.

continued on the next page . . .

(Turn over)

Question 11 (b) continued

- 11. (b) (i) Calculate the atom economy for the production of calcium butane – 1, 4 – dioate.**

Space for working

Atom economy = _____ %

[2 marks]

continued on the next page . . .

(Turn over)

Question 11 (b) continued

11. (b) (ii) In an experiment, 54.0 g of glucose produced 41.2 g of calcium butane – 1, 4 – dioate.

The equation for the reaction for Question 11 (b) (ii) is given in the separate Diagram Booklet.

Calculate the minimum volume of sulfuric acid, of concentration 2.5 mol dm^{-3} , necessary to convert all the calcium butane – 1, 4 – dioate into butane – 1, 4 – dioic acid.

Space for working

continued on the next page . . .

(Turn over)

Space for working continued

Volume of sulfuric acid = _____ cm^3

[2 marks]

continued on the next page . . .

(Turn over)

Question 11 continued

11. (c) Look at the diagram for Question 11 (c) in the separate Diagram Booklet.

The diagram shows the structural formula for hexa – 2, 4 – diene.

Hexa – 2, 4 – diene is one of the important products that can be produced from butane – 1, 4 – dioic acid.

Use the formula to help you to describe the ^{13}C NMR spectrum of this compound.

Your answer should include the number of peaks seen and your reasoning.

The position and size of the peaks is not required.

(Turn over)

[2 marks]

(Total for Question 11 = 12 marks)

(Turn over)

12. (a) People are increasingly concerned about the effect of the Sun's ultraviolet rays on the skin. A number of compounds have been developed for use as sunscreens. One of these compounds is compound **A**, shown in the diagram for Question 12 (a) in the separate Diagram Booklet.

(i) Look at the diagram for Question 12 (a) (i) in the separate Diagram Booklet.

The diagram shows the ultraviolet absorption spectrum of compound **A**.

Ultraviolet radiation is divided into three regions, as shown in the table below.

Region	Wavelength / nm
UVA	320 – 400
UVB	290 – 320
UVC	200 – 290

Question 12 (a) (i) continued

Use this information to explain why it may be necessary to use another sunscreen compound, together with compound **A, when producing a commercial sunscreen.**

[1 mark]

continued on the next page . . .

(Turn over)

Question 12 (a) continued

12. (a) (ii) Compound A is an ester that is made by reacting together 2-ethylhexanol and the appropriate acid, in the presence of a catalyst.

Give the molecular formula of the acid used in this reaction.

[1 mark]

continued on the next page . . .

(Turn over)

Question 12 (a) continued

12. (a) (iii) Compound A displays both forms of stereoisomerism.

I. State how structural isomerism differs from stereoisomerism.

[2 marks]

continued on the next page . . .

(Turn over)

Question 12 (a) (iii) continued

12. (a) (iii) II. Look at the diagram for Question 12 (a) (iii) II in the separate Diagram Booklet. The diagram shows compound A. Indicate the position of a chiral centre on the formula of compound A in the diagram.

[1 mark]

III. When compound A is made by the method described in part (ii) above, an equimolar mixture of both enantiomers is produced.

State how a solution of this mixture affects the plane of plane polarised light.

[1 mark]

continued on the next page . . .

(Turn over)

Question 12 (a) (iii) continued

12. (a) (iii) IV. Exposure of a mixture of both ***E***- and ***Z***- forms of compound **A** to UV radiation results in the ***E***- form gradually changing to the ***Z***- form.

Using the general formula of compound **A** as $\text{R}-\text{CH}=\text{CH}-\text{R}'$, draw and label these two forms of compound **A**.

[2 marks]

(Turn over)

Question 12 continued

12. (b) Palm oil contains around **40%** of unsaturated oil and **60%** of saturated oil. The amount of unsaturation in an oil can be measured indirectly in a reaction with iodine.

(i) In the first stage of this method bromine adds across the **C=C** double bonds present.

State the type of mechanism occurring when bromine adds across these double bonds.

[1 mark]

continued on the next page . . .

(Turn over)

Question 12 (b) continued

12. (b) (ii) Look at the diagram for Question 12 (b) (ii) in the separate Diagram Booklet.

The diagram shows an equation representing the overall reaction with iodine.

In palm oil, most of the unsaturated oils are present as glyceryl trioleate (M_r 885). This compound contains three $C=C$ double bonds per molecule.

An 8.41 g sample of palm oil reacted indirectly with 0.0128 mol of iodine (I_2).

Calculate the percentage of unsaturated oil (as glyceryl trioleate) present in the palm oil.

continued on the next page . . .

(Turn over)

Question 12 (b) (ii) continued

Space for working

Percentage of unsaturated oil

= _____ %

[2 marks]

continued on the next page . . .

(Turn over)

Question 12 (b) continued

- 12. (b) (iii) Oils such as palm oils can be refined and used to make soaps such as sodium oleate.**

Look at the diagram for Question 12 (b) (iii) in the separate Diagram Booklet.

The diagram represents the alkaline hydrolysis of the unsaturated oil.

Complete the equation.

[2 marks]

continued on the next page . . .

(Turn over)

Question 12 (b) continued

12. (b) (iv) Fats and oils are esters of carboxylic acids and glycerol.

Give the systematic name of glycerol (seen in part (iii)).

[1 mark]

(Total for Question 12 = 14 marks)

TOTAL SECTION B = 70 MARKS

END OF PAPER

TOTAL 80 MARKS

(Turn over)



GCE A LEVEL

1410U40-1

MONDAY, 20 JUNE 2022 – MORNING

CHEMISTRY – A2 UNIT 4

ORGANIC CHEMISTRY AND ANALYSIS

**The Diagram Booklet MUST be handed in
to the invigilators and sent for marking.**

Diagram Booklet

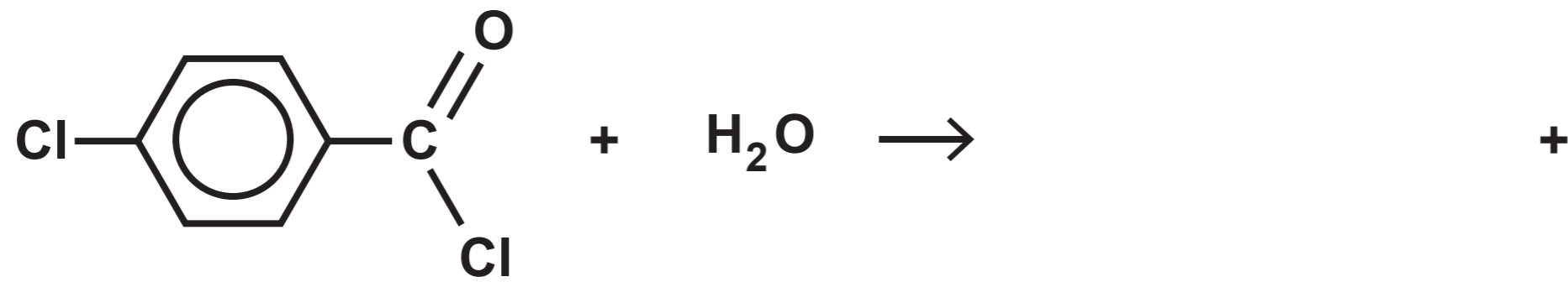
Surname: _____

First name(s): _____

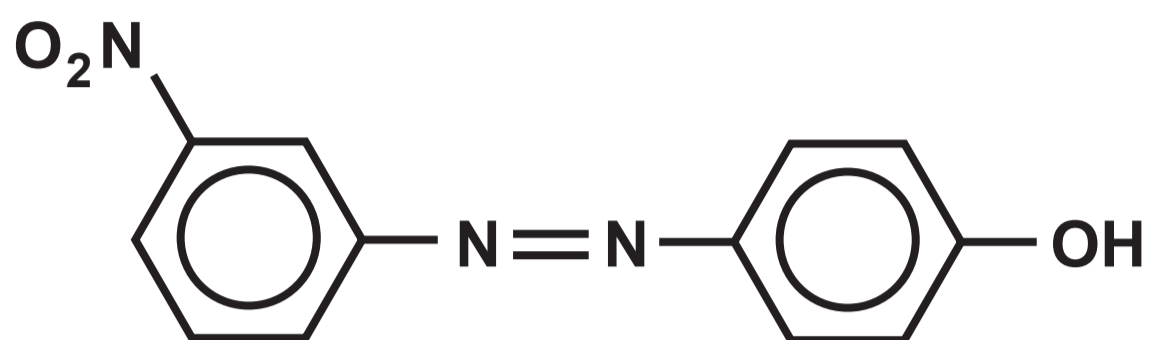
Centre Number: _____

Candidate Number: 2 _____

Question 3

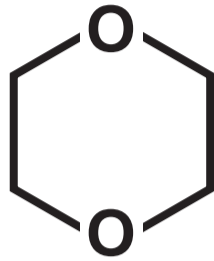


Question 5

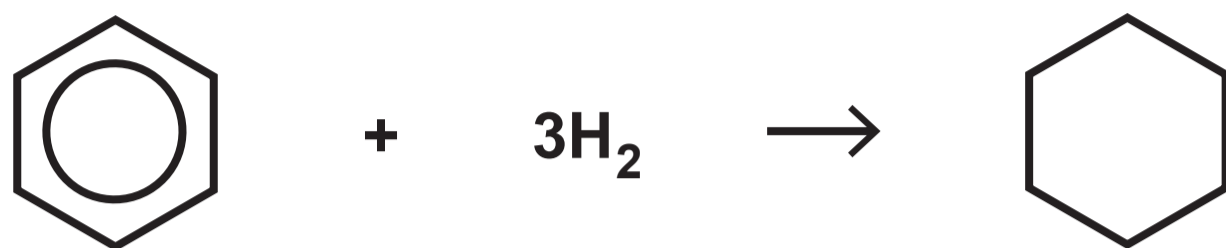


Question 7 (b)

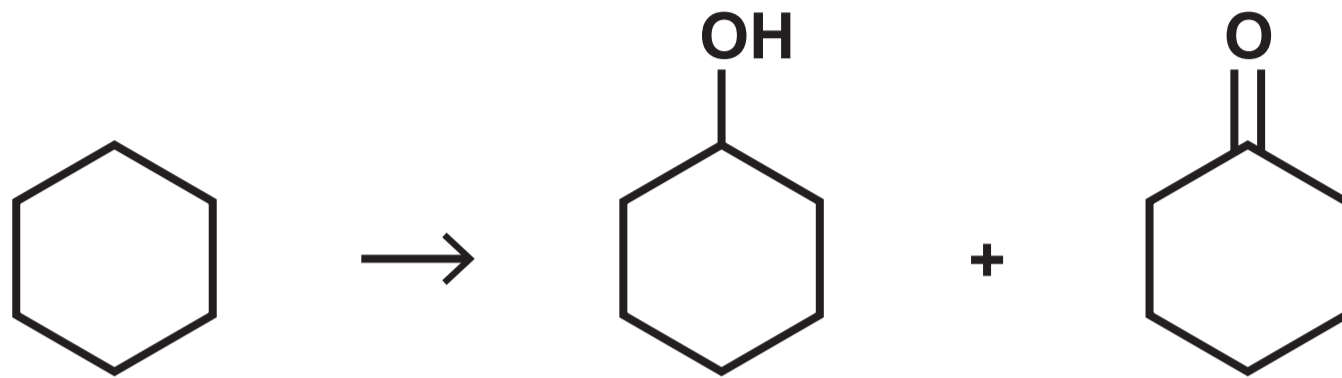
1,4 – dioxane



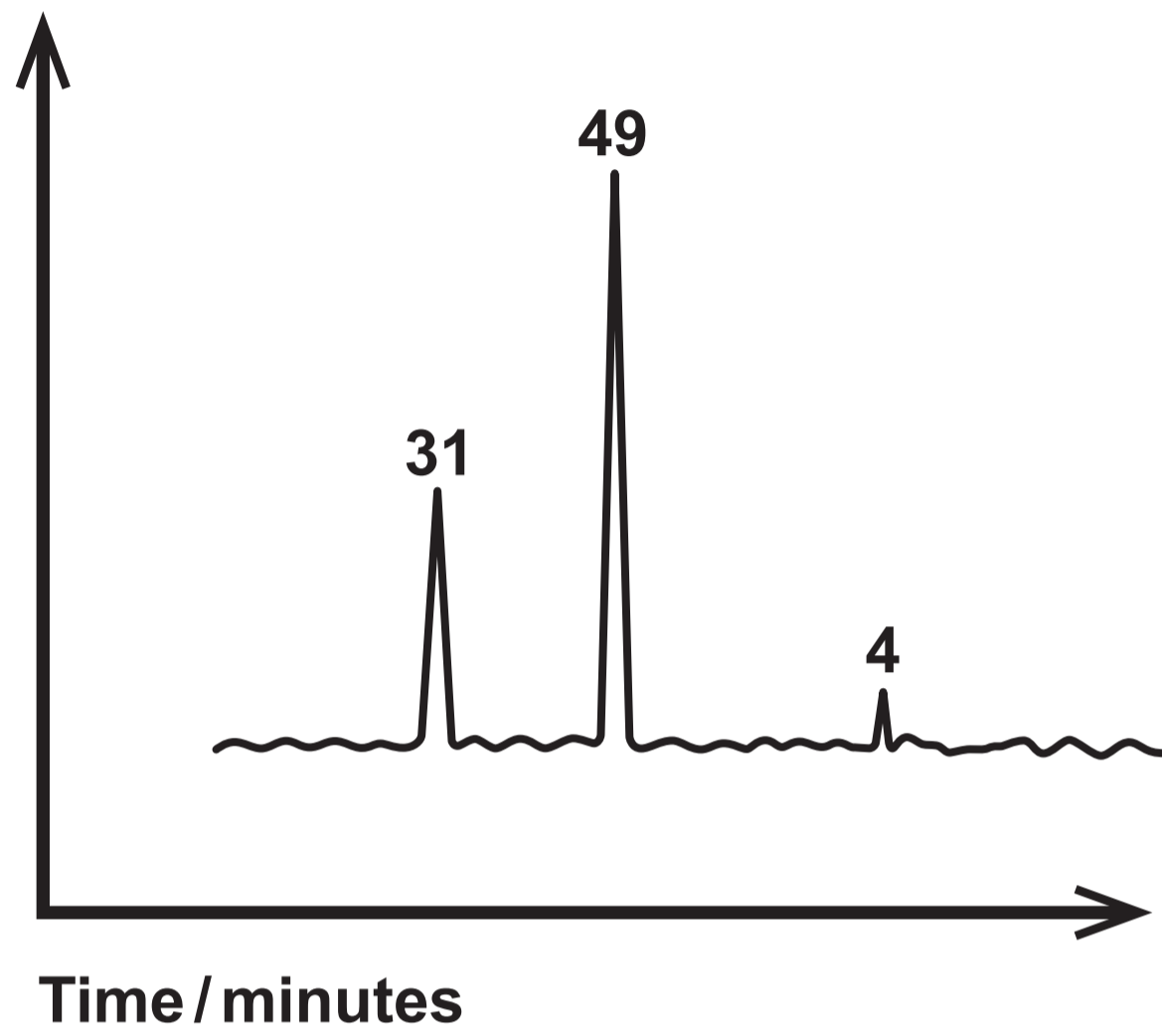
Question 8 (a) (i)



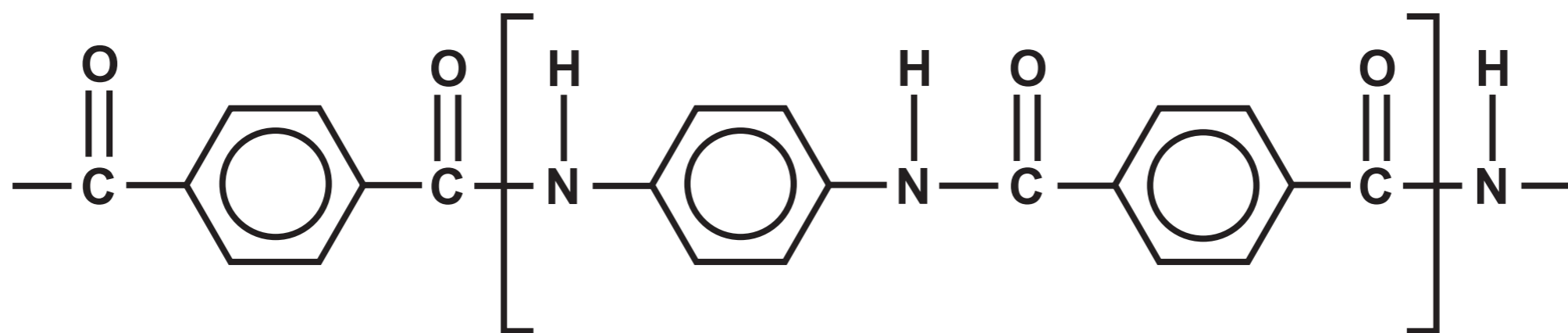
Question 8 (a) (ii)



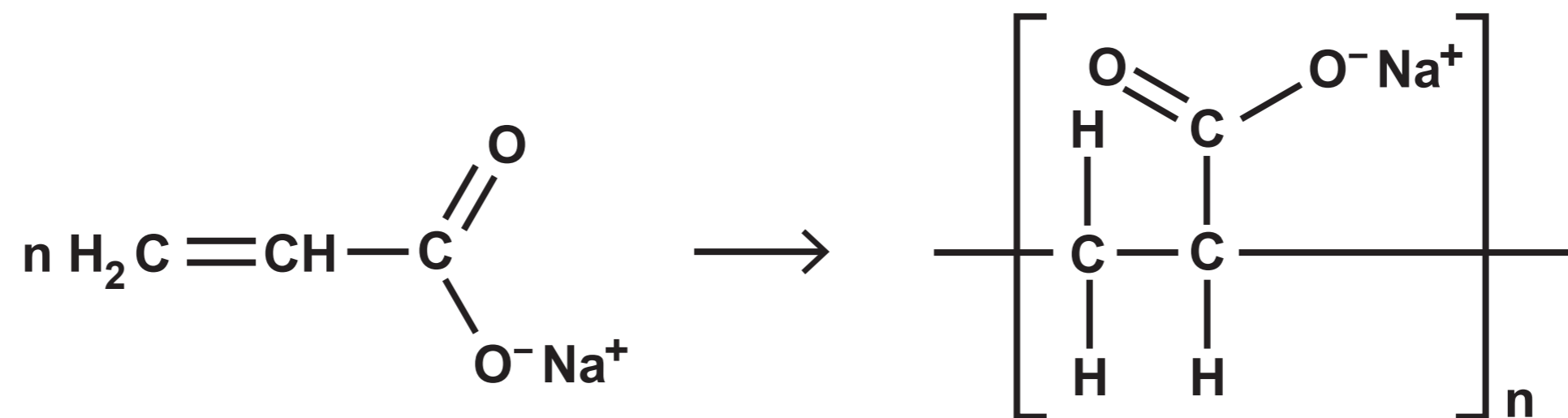
Question 8 (a) (ii) III



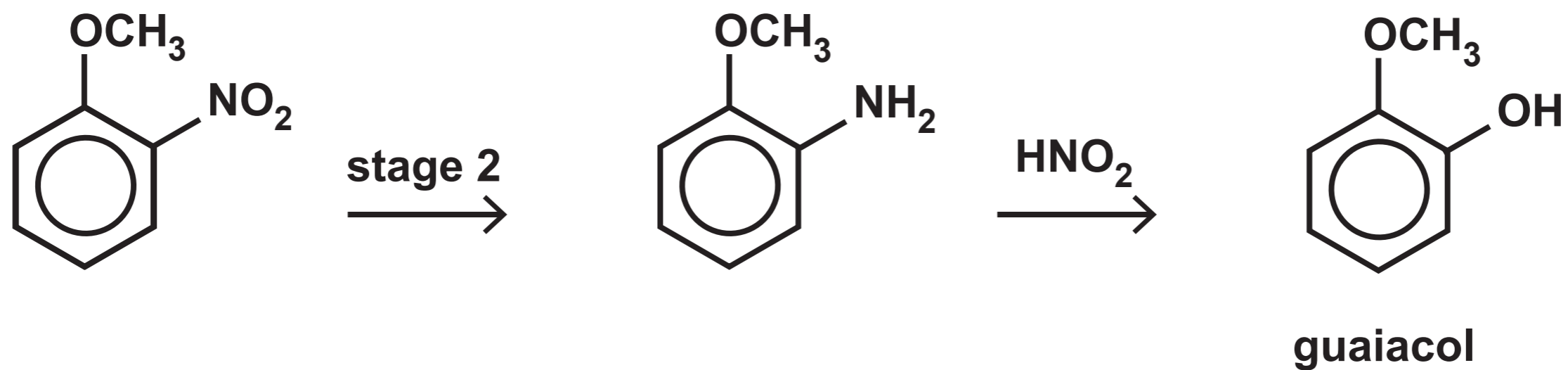
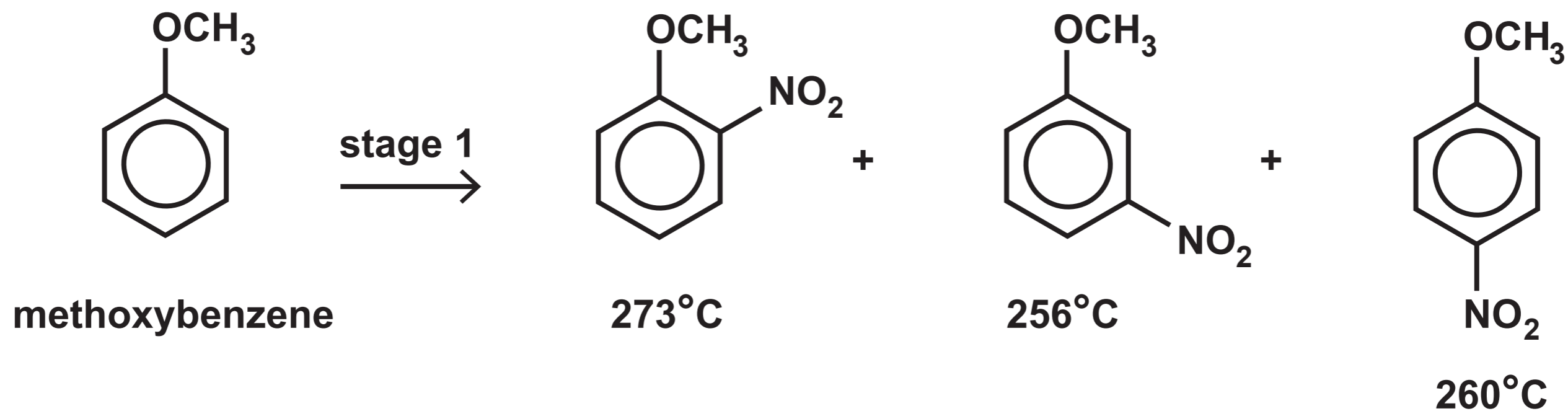
Question 8 (b)



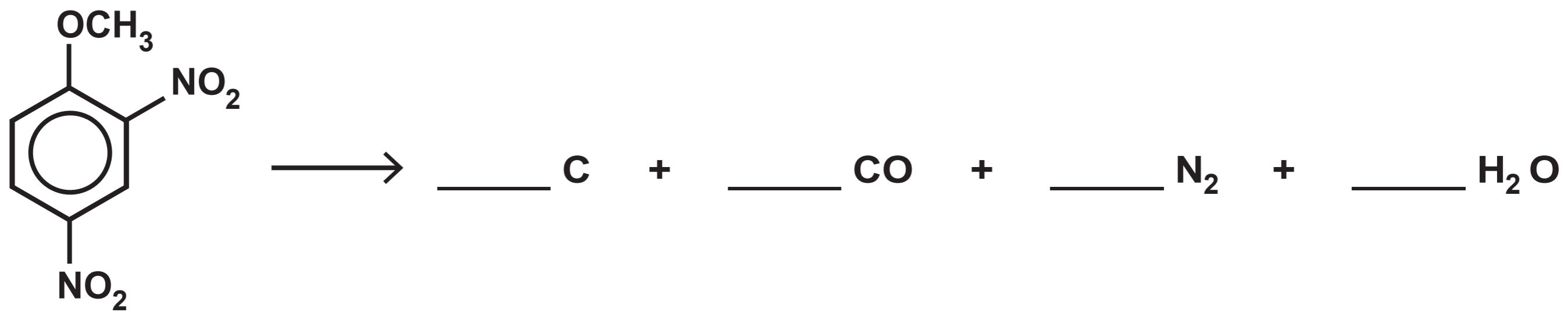
Question 8 (c)



Question 9 (a)

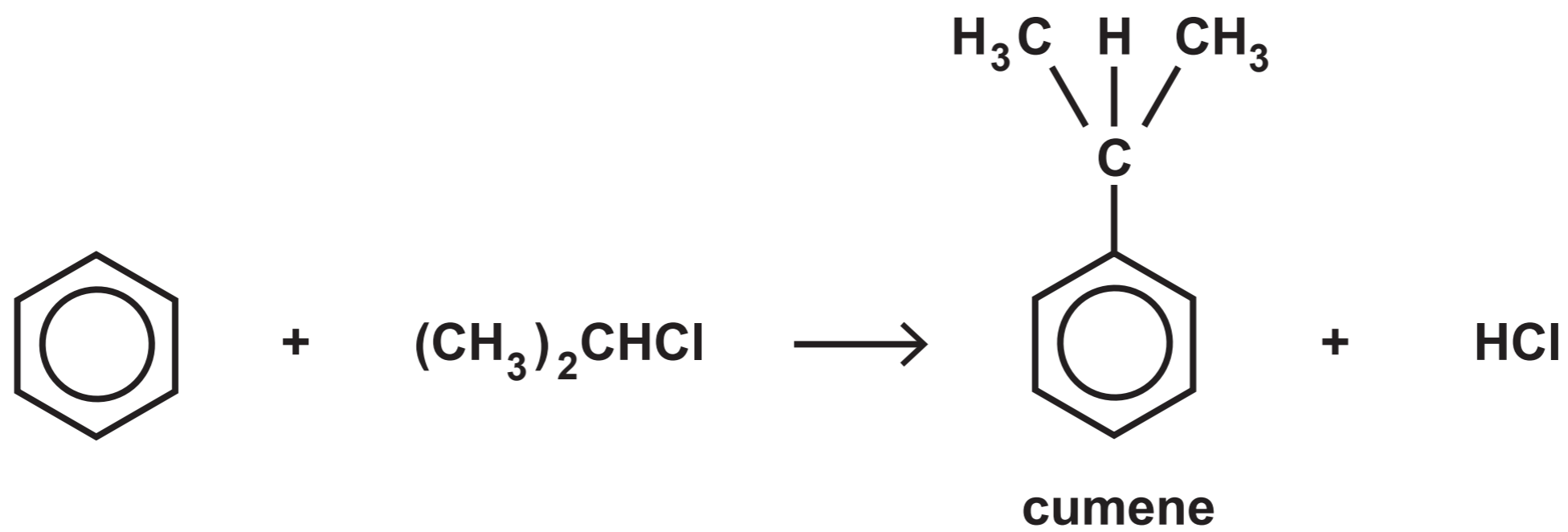


Question 9 (b)



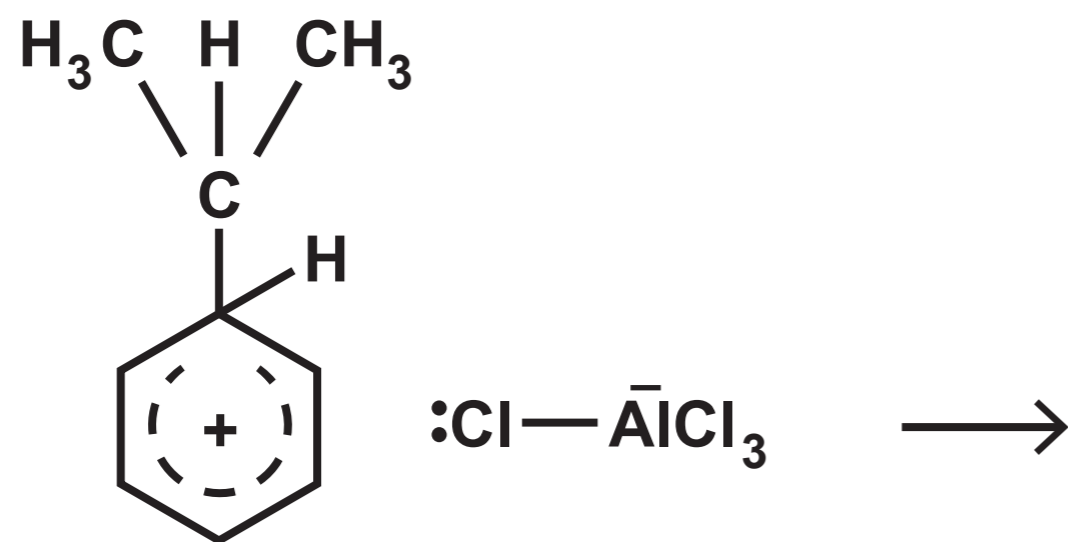
Question 9 (c)

Diagram 1

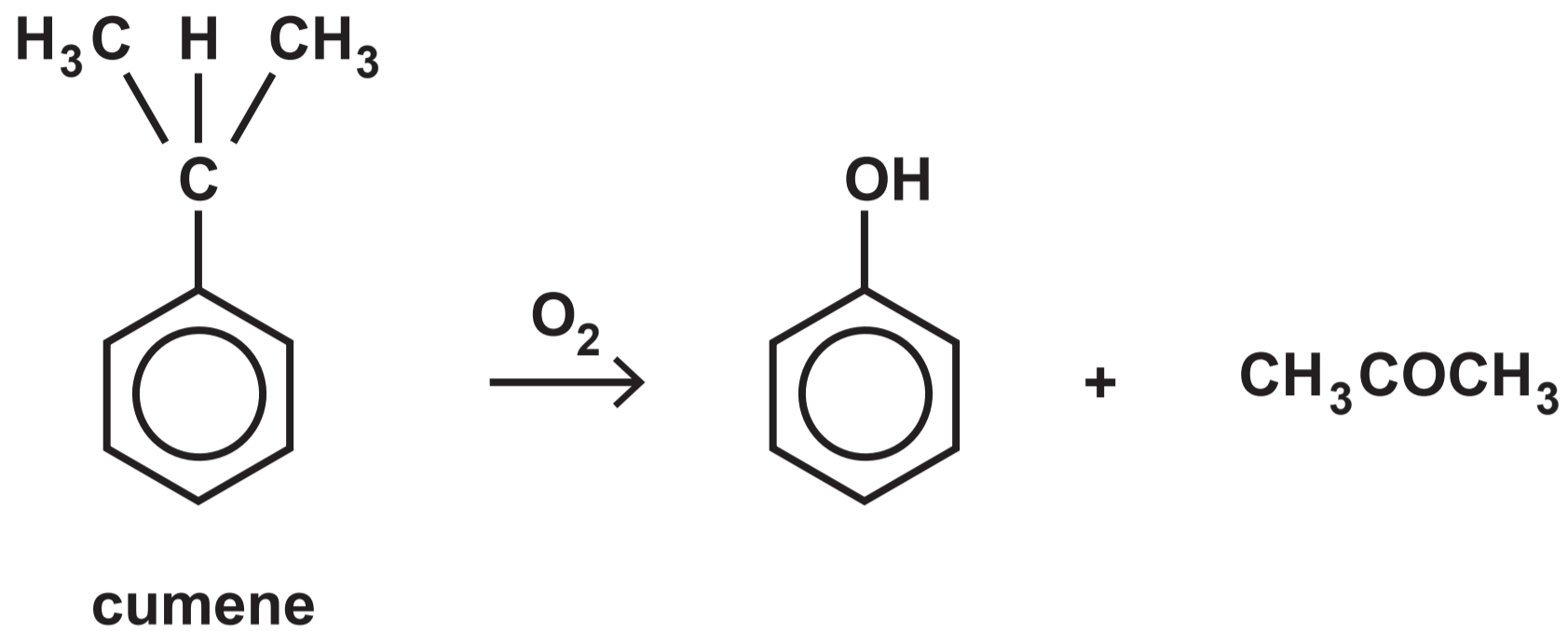


Question 9 (c)

Diagram 2

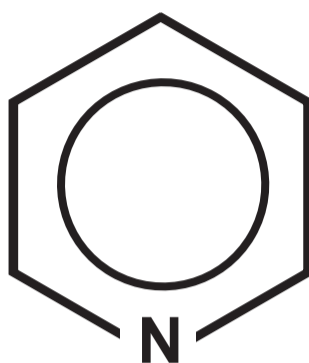


Question 9 (d)

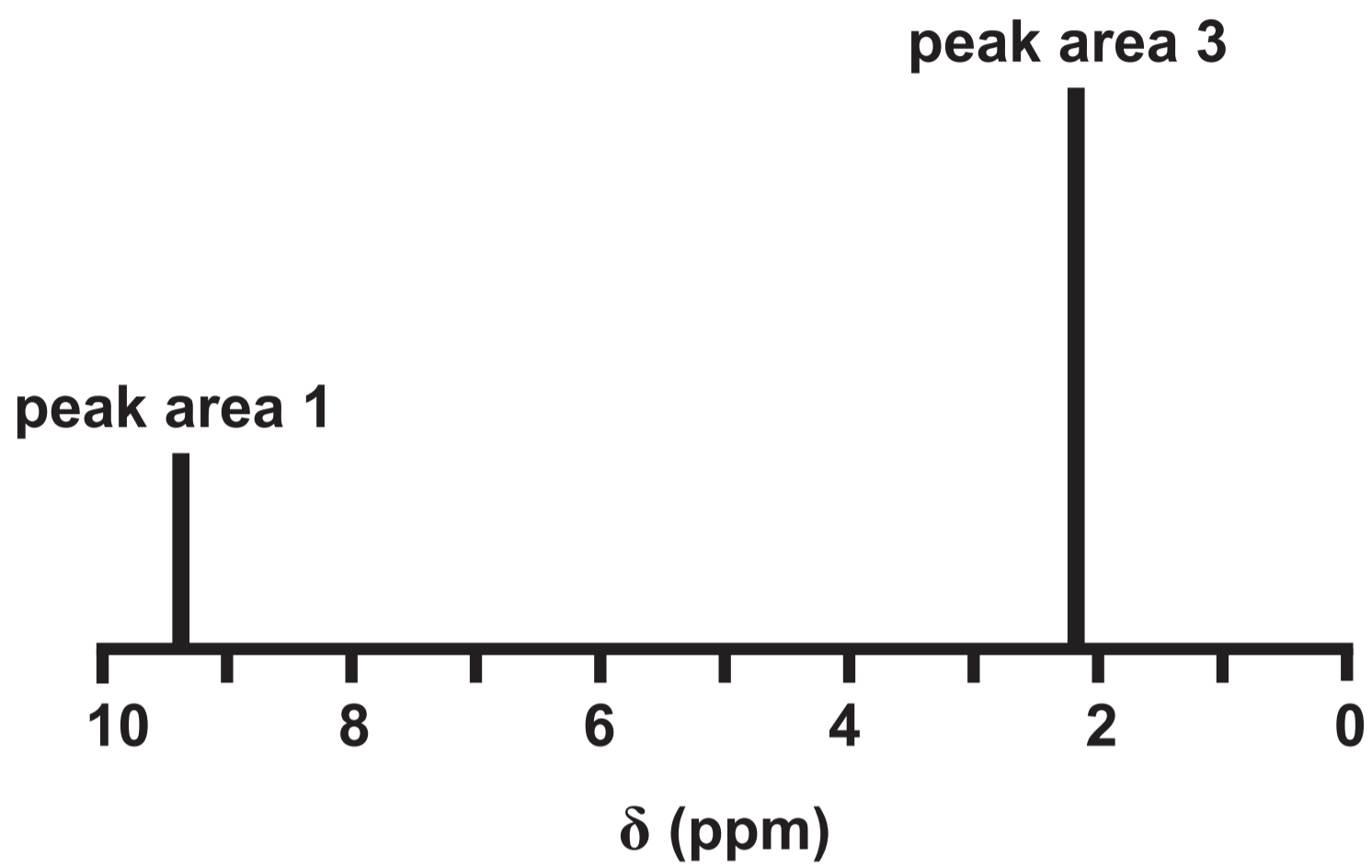


Question 9 (f) (iii)

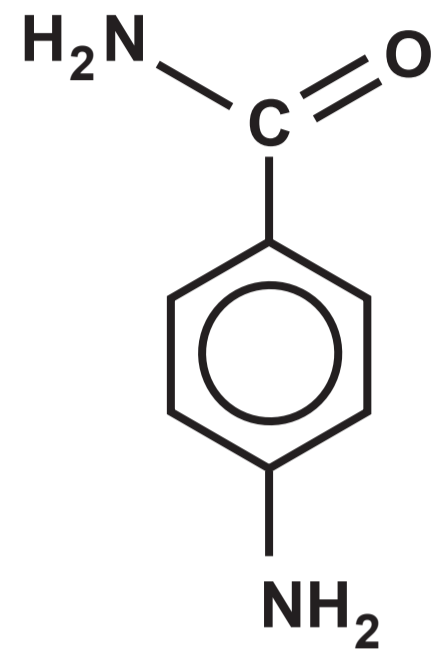
pyridine



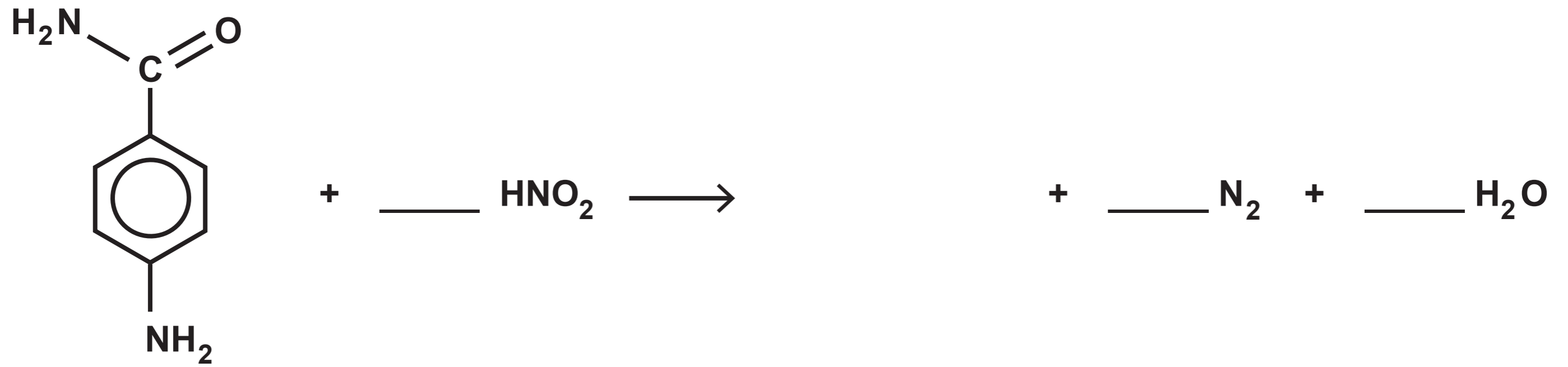
Question 10 (a)



Question 10 (c)

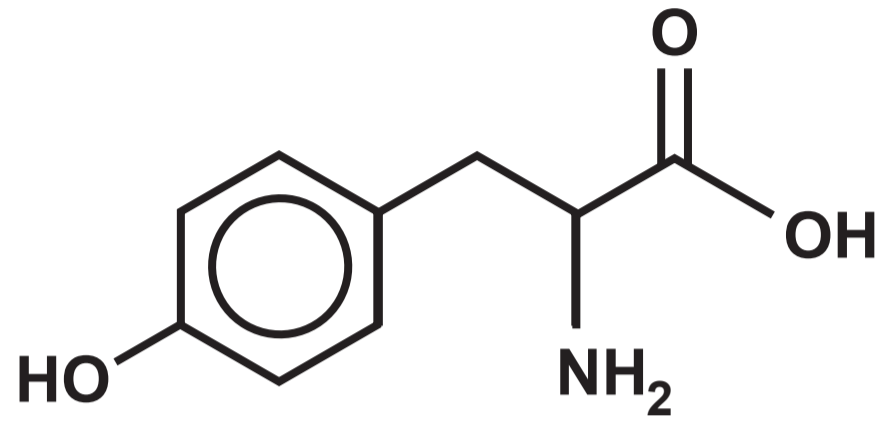


Question 10 (c) (ii)



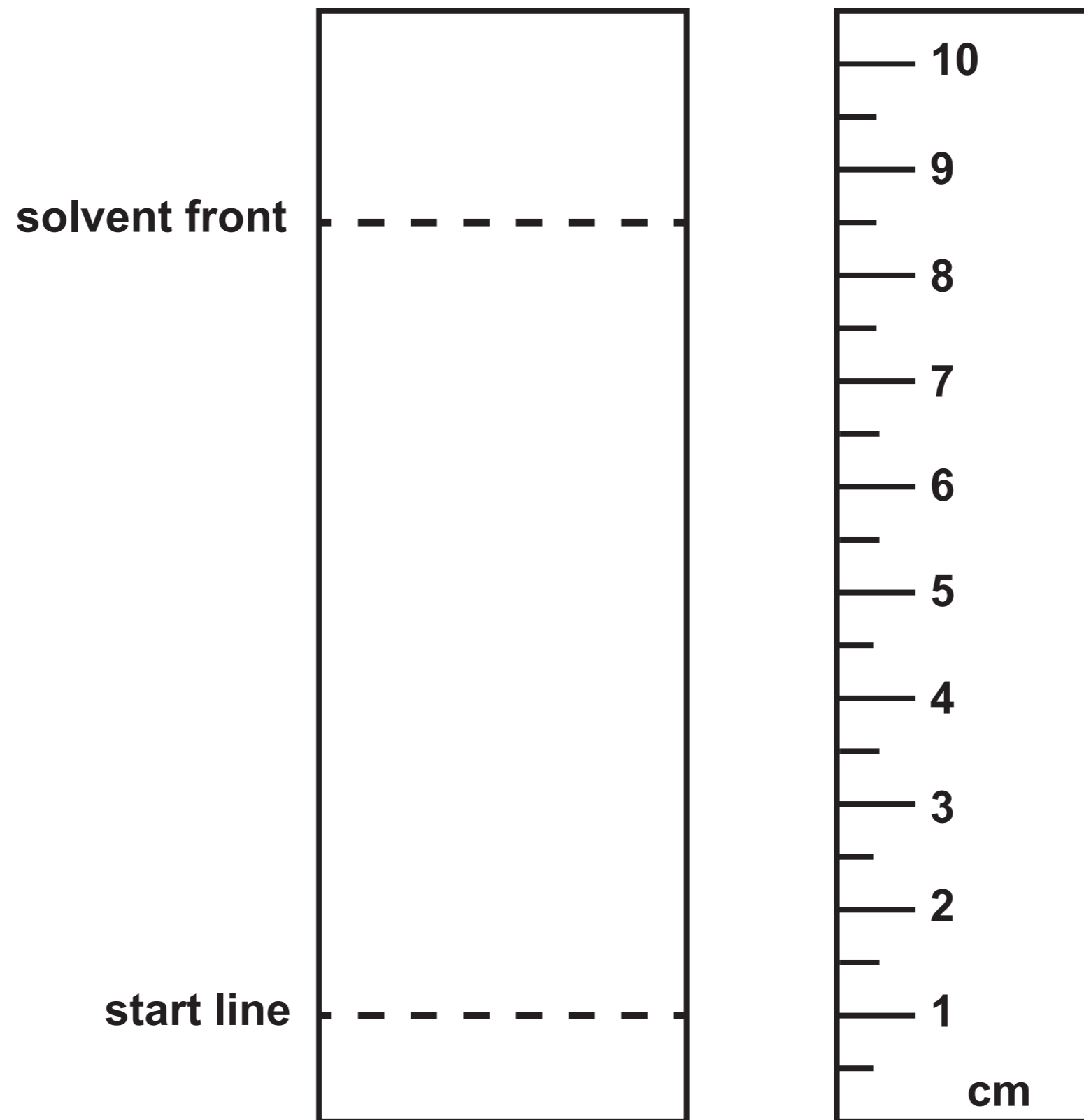
Question 11 (a)

tyrosine



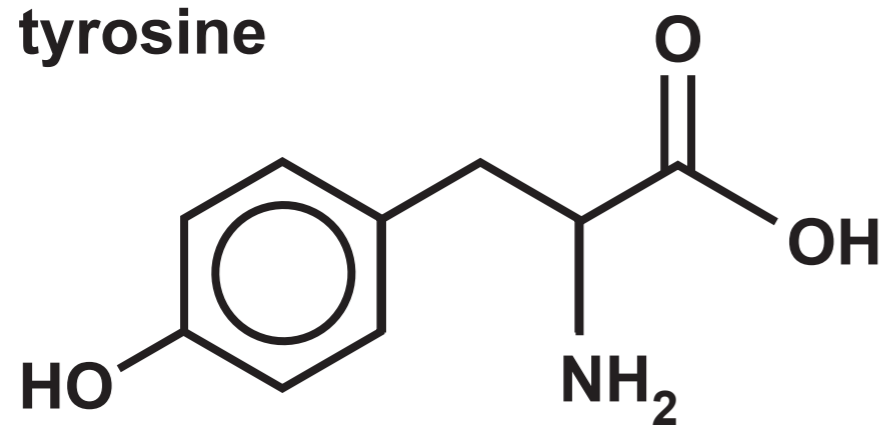
Question 11 (a) (i)

Diagram NOT drawn to scale

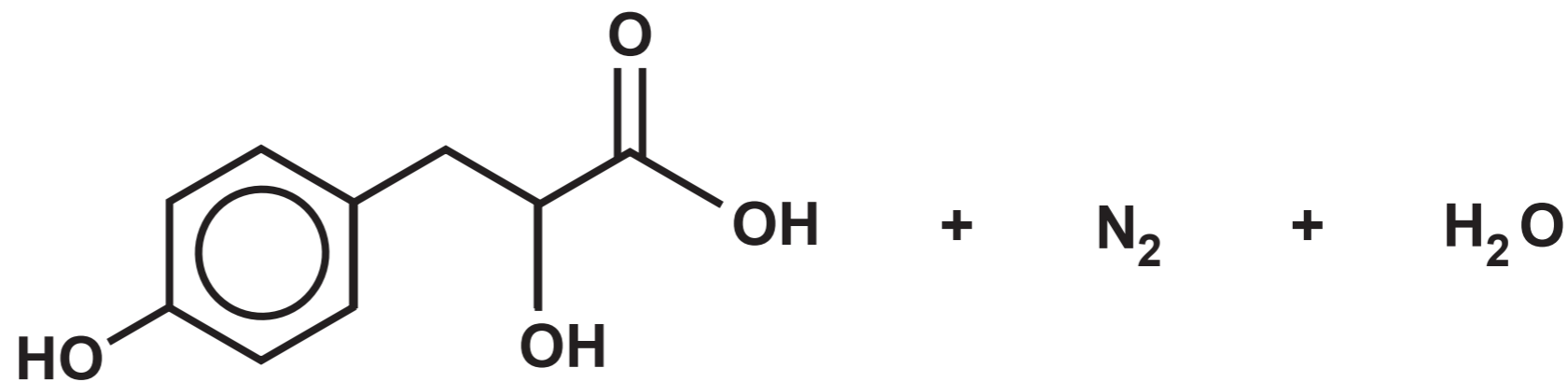
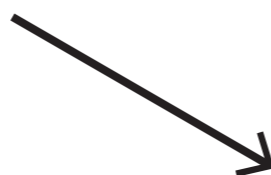


Question 11 (a) (iv)

tyrosine

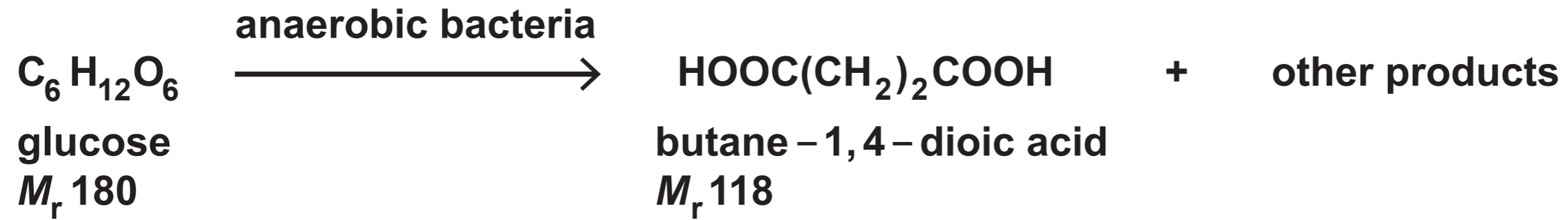


M_r 181

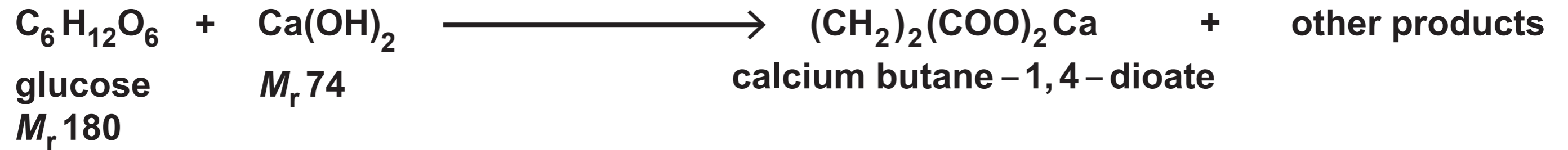


Question 11 (b)

Equation 1



Equation 2

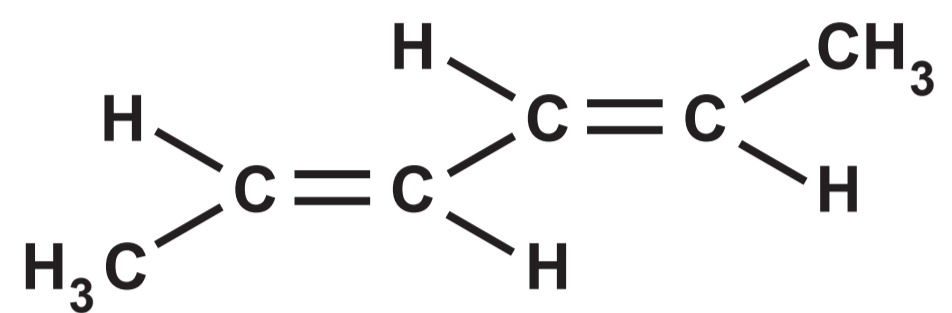


Question 11 (b) (ii)



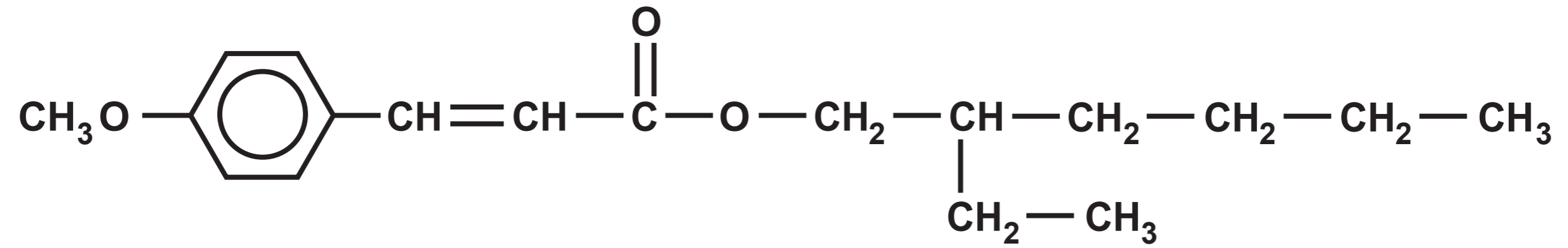
Question 11 (c)

hexa - 2, 4 - diene

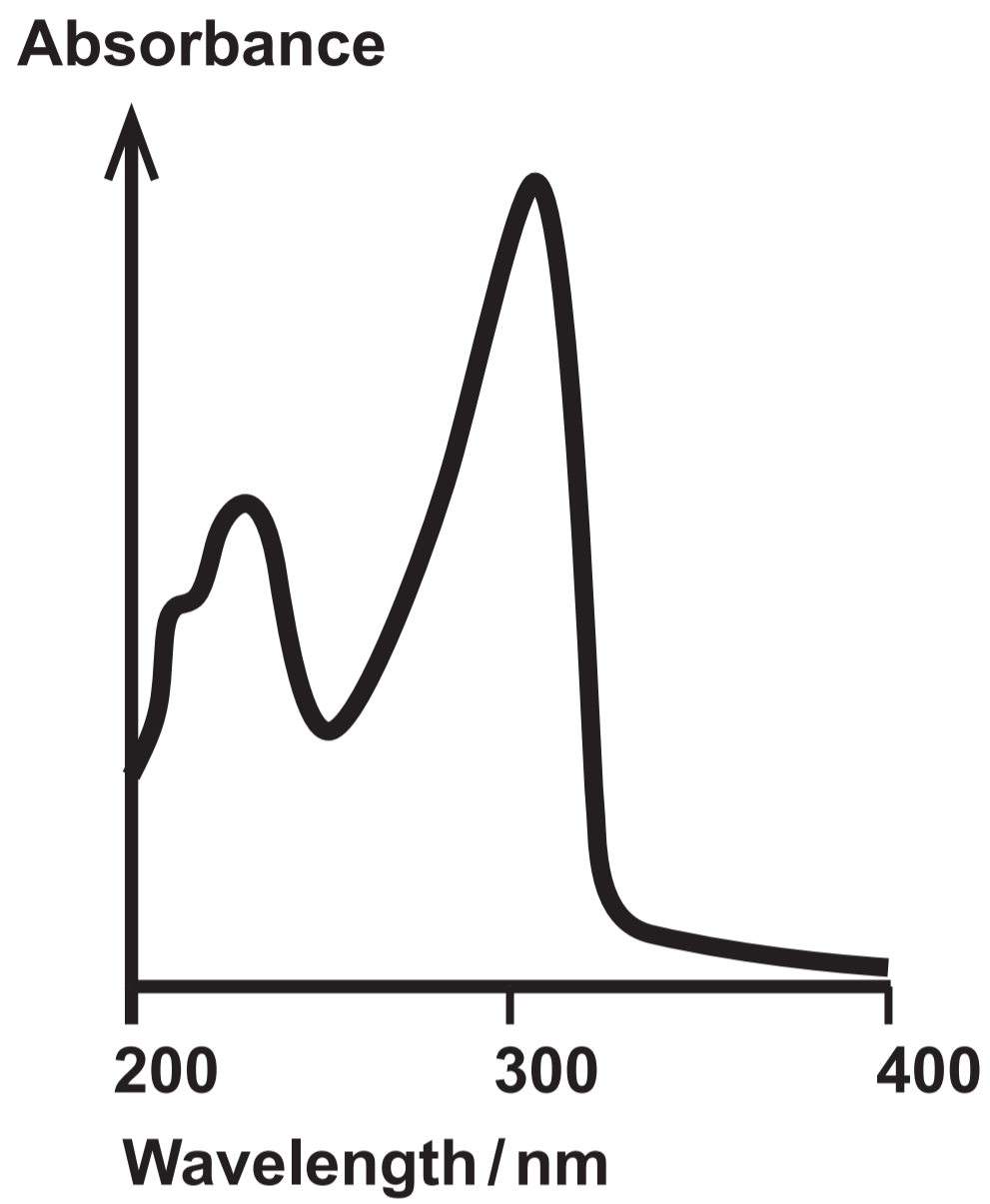


Question 12 (a)

compound A



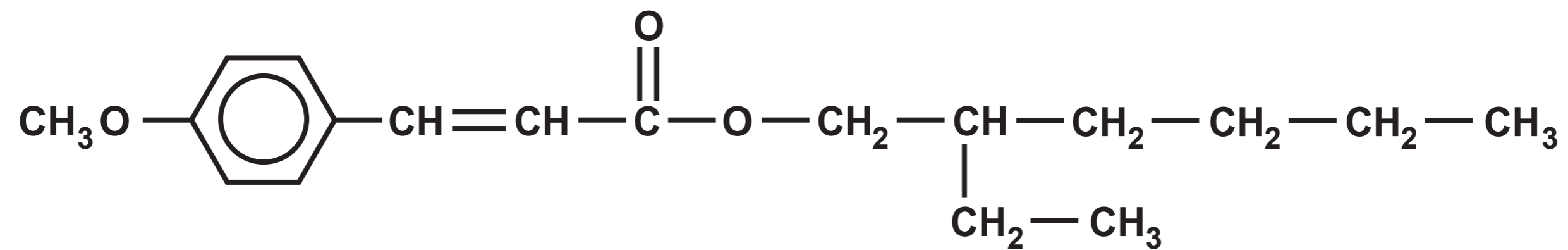
Question 12 (a) (i)



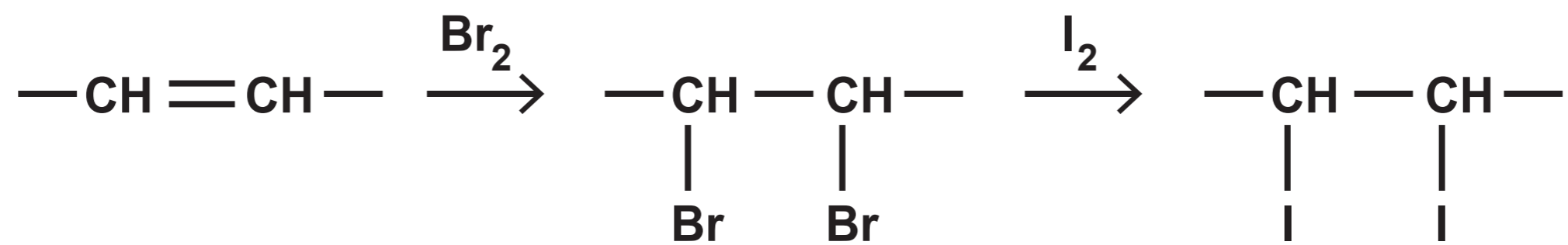
Question 12 (a) (iii) II



compound A



Question 12 (b) (ii)



Question 12 (b) (iii)

