GCE A LEVEL

1410U40-1

MONDAY, 19 JUNE 2023 – AFTERNOON

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.	13	
	9.	15	
	10.	15	
	11.	15	
	12.	12	
	Total	80	

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. Give the structure of an unsaturated aldehyde of molecular formula C_4H_6O

Space for working:

[1 mark]

2. State a group that will give a positive triiodomethane (iodoform) test and give the observation for a positive result.

_____

_____

[2 marks]

3. (a) **1, 2 – Diaminoethane reacts as a base.**

Explain how this compound acts as a base.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 3 continued

3. (b) Give the structure of the organic compound formed when 1 mole of 1, 2 – diaminoethane reacts with 2 moles of ethanoyl chloride.

Space for working:

[1 mark]

4. Look at the diagram for Question 4 in the separate Diagram Booklet.

The diagram shows the formula of the azo dye, Para Red.

Give the structure of the compound that couples with 4 – nitrobenzenediazonium chloride to give this dye.

Space for working:

[1 mark]

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

The diagram shows the structure of hexachlorocyclohexane.

Hexachlorocyclohexane can be used as an insecticide.

Deduce the empirical formula of this compound.

_____

[1 mark]

6. Look at the diagram for Question 6 in the separate Diagram Booklet.

On the diagram, give the structure of the organic product of the reaction shown.

[1 mark]

7. Look at the diagram for Question 7 in the separate Diagram Booklet.

The diagram shows a reaction sequence.

Study the reaction sequence shown and answer the TWO questions that follow.

(a) Reagent F is

_____

[1 mark]

(b) Give the structure of Compound G.

Space for working:

[1 mark]

(Total for SECTION A = 10 marks)

SECTION B

ANSWER ALL QUESTIONS.

8. (a) Look at the diagram for Question 8 (a) in the separate Diagram Booklet.
The diagram shows the structural formula of sorbic acid.

Sorbic acid was isolated in 1859 from mountain ash berry oil. It is a white solid that is slightly soluble in cold water.

continued on the next page . . .

Question 8 (a) continued

8. (a) (i) The solubility of sorbic acid in water is $1.6\ g\ dm^{-3}$ at $20^{\circ}C$ and $40.0\ g\ dm^{-3}$ at $100^{\circ}C$.

Calculate how much sorbic acid is precipitated from its aqueous solution if $200\ cm^3$ of a saturated solution at $100^{\circ}C$ is cooled to $20^{\circ}C$.

Give your answer to an appropriate number of significant figures.

Space for working:

_____ g

[2 marks]

continued on the next page . . .

Question 8 (a) continued

8. (a) (ii) Sorbic acid and its salts, for example sodium sorbate, have important uses as antimicrobial agents in food preservation.

Some moulds are, however, able to detoxify the action of these sorbates. An example is the decarboxylation of sodium sorbate.

I. State what is meant by 'decarboxylation'.

_____

_____

[1 mark]

continued on the next page . . .

Question 8 (a) (ii) continued

8. (a) (ii) II. In the laboratory sodium sorbate can be decarboxylated by heating it with soda lime.
The organic product of decarboxylation is
E **– penta – 1, 3 – diene.**

Write the equation for this decarboxylation of sodium sorbate with soda lime (which you should represent as NaOH in your equation), showing the structure of
E **– penta – 1, 3 – diene.**

Space for working:

[2 marks]

Question 8 (a) (ii) continued

8. (a) (ii) III. ***E*** **– penta – 1, 3 – diene can then react with hydrogen using platinum as a catalyst giving pentane.**

State the number of moles of hydrogen required to react with 0.2 mol of *E* – penta – 1, 3 – diene in this way.

_____

_____

[1 mark]

continued on the next page . . .

Question 8 continued

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

The diagram shows the structural formula of tartaric acid.

Tartaric acid (2, 3 – dihydroxybutanedioic acid) is used in the food industry.

(i) Indicate any chiral centre(s) present by means of an asterisk (*).

[1 mark]

continued on the next page . . .

Question 8 (b) continued

8. (b) (ii) This acid occurs in a number of optically active forms.
Complete the sentences below.

Forms of tartaric acid that rotate the plane of plane – polarised light are called

_____

[1 mark]

A solution containing an equimolar mixture of two forms of the acid that rotates the plane of plane – polarised light in equal and opposite directions is called a

_____

[1 mark]

continued on the next page . . .

Question 8 continued

8. (c) Both sorbic acid and tartaric acid are described as showing stereoisomerism.

Explain what is meant by the term stereoisomerism.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 8 continued

8. (d) Tartaric acid is formed when butenedioic acid reacts with a suitable oxidising agent.

Give the equation for this reaction, representing the oxidising agent as [O] and using water as a reactant.

Space for working:

[1 mark]

continued on the next page . . .

Question 8 continued

8. (e) Look at the table for Question 8 (e) in the separate Diagram Booklet.

The table indicates that the solubility of unsaturated carboxylic acids in water decreases as the chain length increases.

Suggest why this solubility decreases as the chain length increases.

[2 marks]

(Total for Question 8 = 13 marks)

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

The diagram shows the general reaction of an acid chloride with water.

1.598 g of an acid chloride, $RCOCl$, was added to water.

The aqueous solution contained hydrochloric acid and a carboxylic acid, $R — COOH$, where R is an alkyl group

(i) State the type of reaction occurring.

_____

_____

[1 mark]

continued on the next page . . .

Question 9 (a) continued

9. (a) (ii) **This acidic solution was titrated with $0.400\ mol\ dm^{-3}$ aqueous sodium hydroxide, using a suitable indicator. Both acids were just neutralised by $75.00\ cm^3$ of the sodium hydroxide solution.**

Use the results to calculate the relative molecular mass of the acid chloride.

Space for working:

M_r _____

[3 marks]

Question 9 (a) continued

9. (a) (iii) The low resolution ^{1}H NMR spectrum of the acid chloride showed two signals in the peak area ratio of **6:1**

Use this information and the relative molecular mass of the **RCOCl**, obtained in part (ii), to find the structure of the acid chloride.

Space for working:

[2 marks]

continued on the next page . . .

Question 9 continued

9. (b) (i) The acid chloride, benzene – 1, 4 – dicarbonyl dichloride, $ClOC-C_6H_4-COCl$ is made by reacting benzene – 1, 4 – dicarboxylic acid with phosphorus(V) chloride. The other products of this reaction are hydrogen chloride and phosphoryl trichloride, $POCl_3$

Give the equation for this reaction.

Space for working:

[1 mark]

continued on the next page . . .

Question 9 (b) continued

9. (b) (ii) Benzene – 1, 4 – dicarbonyl dichloride reacts with benzene – 1, 4 – diamine to give a polyamide.

Show the repeating unit for this polyamide.

Space for working:

[1 mark]

continued on the next page . . .

Question 9 continued

9. (c) Nylon polyamides that are produced from starting materials with a different number of carbon atoms are given numbers.

For example Nylon 4,5 has a 4 – carbon diamine fragment and a 5 – carbon dicarboxylic acid fragment.

Look at the equation for Question 9 (c) in the separate Diagram Booklet.

Butane – 1,4 – diamine can be used as a starting material for this polyamide. This can be produced in a two – stage reaction from butane – 1,4 – diol, as shown in the equation.

(i) State the name of reagent(s) A.

_____

_____

[1 mark]

continued on the next page . . .

Question 9 (c) continued

9. (c) (ii) State the name of reagent(s) B.

_____

_____

[1 mark]

(iii) State the type of mechanism occurring in Stage 2.

_____

_____

[1 mark]

continued on the next page . . .

Question 9 (c) continued

9. (c) (iv) Draw the SKELETAL formula of the 5 – carbon containing dicarboxylic acid used to produce Nylon 4, 5

Space for drawing:

[1 mark]

continued on the next page . . .

Question 9 continued

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

The depolymerisation of polyamides and polyesters present a number of difficult problems as these polymers are very stable and only slowly decompose in the environment.

Poly(ethyleneterephthalate) (PET) is very difficult to hydrolyse but a new process using specific enzymes is proving promising. In this process 90% of PET is depolymerised into benzene – 1, 4 – dicarboxylic acid.

The process is represented by the structural formulae equation shown in the diagram.

continued on the next page . . .

Question 9 (d) continued

Calculate the mass of benzene – 1, 4 – dicarboxylic acid produced from 75 kg of PET if the yield from this hydrolysis is 90%

Space for working:

mass of benzene – 1, 4 – dicarboxylic acid produced

= _____ kg

[3 marks]

(Total for Question 9 = 15 marks)

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10. (a) Benzene reacts with bromine in the presence of a catalyst.

Give the mechanism for this reaction and explain how the Br — Br bond becomes polarised during the reaction.

Suggest why, in the absence of this catalyst, there is very little reaction between benzene and bromine under normal conditions.

[6 marks QER]

continued on the next page . . .

Question 10 continued

10. (b) Look at the diagram for Question 10 (b) in the separate Diagram Booklet.
The diagram shows the structural formulae of eugenol and eugenyl ethanoate.

Eugenol is the main constituent of clove oil, together with smaller quantities of eugenyl ethanoate.

(i) Describe what is seen if a few drops of iron(III) chloride solution are added to a solution of eugenol.

_____

_____

[1 mark]

(ii) State the colour change that occurs if a few drops of aqueous bromine are added to a solution of eugenol.

_____

_____

[1 mark]

Question 10 (b) continued

10. (b) (iii) If an excess of bromine is added to eugenol, a new compound is formed that contains the following percentages by mass of each element.

C 24.9%

H 2.1%

O 6.6%, the remainder being the % of bromine

Use this information to calculate the empirical and molecular formulae of this brominated compound and suggest a possible structure for it.

Space for working:

[5 marks]

Question 10 (b) continued

10. (b) (iv) Explain how adding aqueous sodium hydroxide at room temperature to a solution of eugenol and eugenyl ethanoate dissolved in trichloromethane, enables the two compounds to be separated. Trichloromethane and water are immiscible.

[2 marks]

(Total for Question 10 = 15 marks)

11. (a) Aminoethanoic acid is the simplest α – amino acid.

$$H_2N — CH_2 — COOH$$

(i) Give the structure of the dipeptide formed from two molecules of aminoethanoic acid.

Space for working:

[1 mark]

(ii) Explain why aminoethanoic acid can only form one dipeptide.

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 11 continued

11. (b) Amino acids form esters in the usual way from the carboxylic acid group and an alcohol, in the presence of an acid catalyst. These esters can form a salt with the acid used in esterification.

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

The formula of one of these salts is shown in the diagram. Compound M is a white solid that is soluble in water, giving a colourless solution.

continued on the next page . . .

Question 11 (b) continued

11. (b) (i) I. Many amino acids exist as zwitterion forms in aqueous solution.

Give the zwitterion form of aminoethanoic acid.

Space for working:

[1 mark]

II. Explain why compound M cannot form a zwitterion in this way.

_____

_____

[1 mark]

continued on the next page . . .

Question 11 (b) continued

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

Under suitable conditions, aminoethanoic acid condenses to give diketopiperazine. The structural formula is shown in the diagram.

I. The mass spectrum of diketopiperazine shows a molecular ion at m/z 114 and two prominent fragments at m/z 43 and 71

Suggest a formula for the fragment at m/z 71

Space for working:

[1 mark]

continued on the next page . . .

Question 11 (b) (ii) continued

11. (b) (ii) II. Look at the diagram for Question 11 (b) (ii) II. In the separate Diagram Booklet.

The diagram shows an outline infrared absorption spectrum of diketopiperazine.
Use the formula shown and the data sheet to suggest an absorption value for the N — H and C ═ O bonds.

N — H _____ cm^{-1}

C ═ O _____ cm^{-1}

[1 mark]

continued on the next page . . .

Question 11 continued

11. (c) A mixture of α – amino acids can be separated and identified by thin layer chromatography.

(i) These amino acids are colourless and the chromatogram is sprayed with a solution of ninhydrin, so that the amino acids appear as purple dots. The colour is due to the dye Ruhemann's Purple.

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

The diagram shows a thin layer chromatogram of a mixture of α – amino acids.

continued on the next page . . .

Question 11 (c) (i) continued

Calculate the R_f value for threonine (spot B).

Space for working:

_____

[1 mark]

continued on the next page . . .

Question 11 (c) continued

11. (c) (ii) Ruhemann's Purple has a maximum absorption at 564 nm.

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

The information in the diagram indicates the colours absorbed at various wavelengths in the visible spectrum.
Use this to help you explain why the colour of the dye is purple.

_____

_____

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 11 (c) continued

11. (c) (iii) Calculate the energy (in $kJ\ mol^{-1}$) associated with this absorption at 564 nm.

Space for working:

energy = _____ $kJ\ mol^{-1}$

[3 marks]

continued on the next page . . .

Question 11 continued

11. (d) Look at the equation for Question 11 (d) in the separate diagram Booklet.

The equation shows how amino acids react with nitric(III) acid to produce nitrogen gas.

continued on the next page . . .

Question 11 (d) continued

11. (d) (i) **0.500 g of 2 – aminohexanoic acid, $CH_3(CH_2)_3CH(NH_2)COOH$, reacted with an excess of nitric(III) acid.**

Calculate the volume of nitrogen produced, assume the temperature was measured at 298 K and at 1 atmosphere pressure.

Space for working:

volume of nitrogen produced

= _____ cm^3

[2 marks]

continued on the next page . . .

Question 11 (d) continued

11. (d) (ii) The actual volume of nitrogen produced was $90.9\ cm^3$, which was less than the calculated volume in part (i).

Suggest TWO reasons for this low result, apart from errors in weighing and in measuring the volume of nitrogen produced.

1. _____

_____

_____

2. _____

_____

_____

[2 marks]

(Total for Question 11 = 15 marks)

12. (a) (i) Look at Diagram 1 for Question 12 (a) (i) in the separate Diagram Booklet.

2 – Methylpropenoic acid can be obtained from

2 – methylprop – 2 – en – 1 – ol.

The structural formula for

2 – methylprop – 2 – en – 1 – ol

is shown in the diagram.

The standard reagents used for the oxidation of a primary alcohol to a carboxylic acid may affect the C = C bond. To prevent this occurring the double bond is protected by bromination.

This reaction is shown in Diagram 2 for Question 12 (a) (i) in the separate Diagram Booklet.

continued on the next page . . .

Question 12 (a) (i) continued

The bromine atoms are removed in a later reaction to give the required acid.

State the type of mechanism occurring during the bromination.

_____

_____

[1 mark]

(ii) Suggest an oxidising agent used for the oxidation of the brominated alcohol.

The oxidation reaction is represented in the diagram for Question 12 (a) (ii) in the separate Diagram Booklet.

_____

_____

[1 mark]

continued on the next page . . .

Question 12 (a) continued

12. (a) (iii) **The dibromoacid produced in part (ii) is then reacted with zinc under suitable conditions to give 2 – methylpropenoic acid.**

The equation for this reaction is shown in the diagram for Question 12 (a) (iii) in the separate Diagram Booklet.

Complete the equation, showing zinc bromide as the co – product.

[1 mark]

continued on the next page . . .

Question 12 continued

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

The diagram shows how methyl *2* – methylpropenoate can be produced from propanone.

(i) STAGE 1 is a nucleophilic addition reaction.

Give the formula of the nucleophile taking part in this stage.

_____

_____

[1 mark]

(ii) State why STAGE 1 is described as an ADDITION reaction.

_____

_____

[1 mark]

continued on the next page . . .

Question 12 (b) continued

12. (b) (iii) State a reagent used for hydrolysis in STAGE 2.

_____

_____

[1 mark]

(iv) State the role of sulfuric acid in STAGE 3.

_____

_____

[1 mark]

continued on the next page . . .

Question 12 (b) continued

12. (b) (v) Addition polymerisation of methyl 2 – methylpropenoate gives ‘Perspex’.

Give the repeating unit of this polymer.

Space for working:

[1 mark]

continued on the next page . . .

Question 12 (b) continued

12. (b) (vi) Explain why the polymerisation in part (v) is described as addition polymerisation and not condensation polymerisation.

_____

_____

_____

_____

_____

_____

[1 mark]

continued on the next page . . .

Question 12 continued

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

The diagram shows the formula of a halogenoalkane.

(i) Give the systematic name of this halogenoalkane.

_____

_____

[1 mark]

continued on the next page . . .

Question 12 (c) continued

12. (c) (ii) **Look at the table for Question 12 (c) (ii) in the separate Diagram Booklet.**

Complete the table which describes the high resolution ^{1}H NMR spectrum of this compound.

[2 marks]

(Total for Question 12 = 12 marks)

END OF PAPER

TOTAL 80 MARKS

Question number	Additional pages, if required. Write the question number(s) in the left - hand margin.

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GCE A LEVEL

1410U40-1

MONDAY, 19 JUNE 2023 – AFTERNOON

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: _____

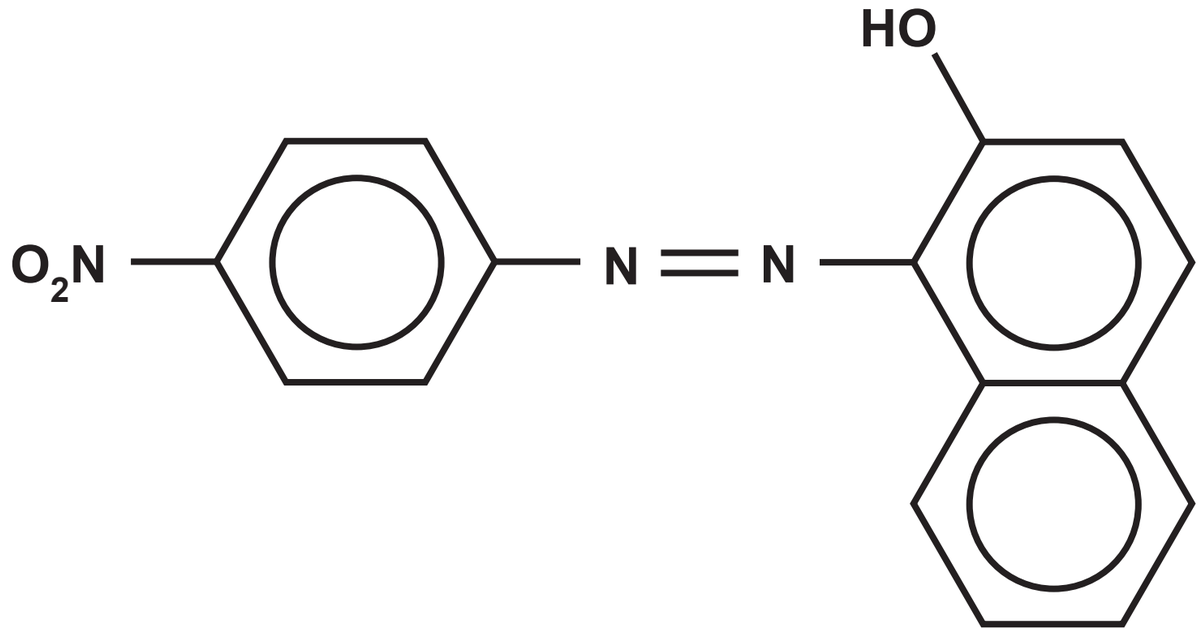
First name(s): _____

Centre Number: _____

Candidate Number: 2 _____

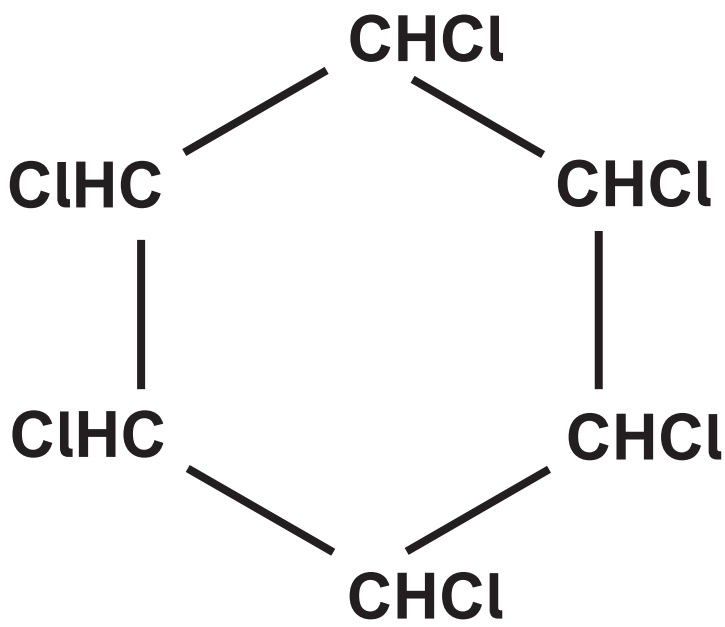
Question 4

Para Red

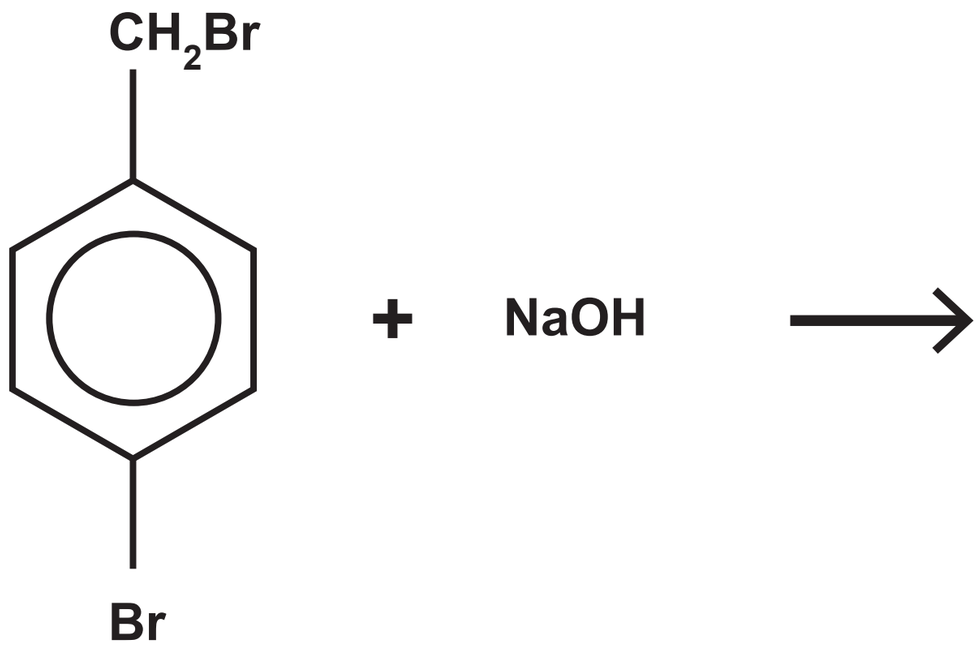


Question 5

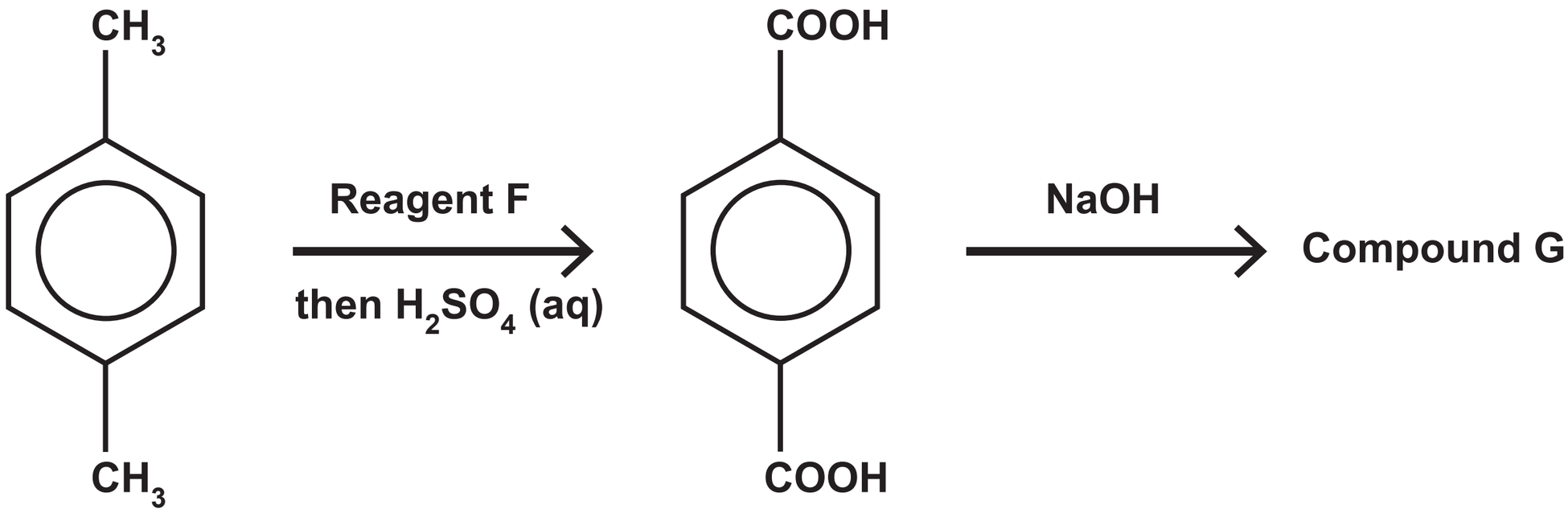
Hexachlorocyclohexane



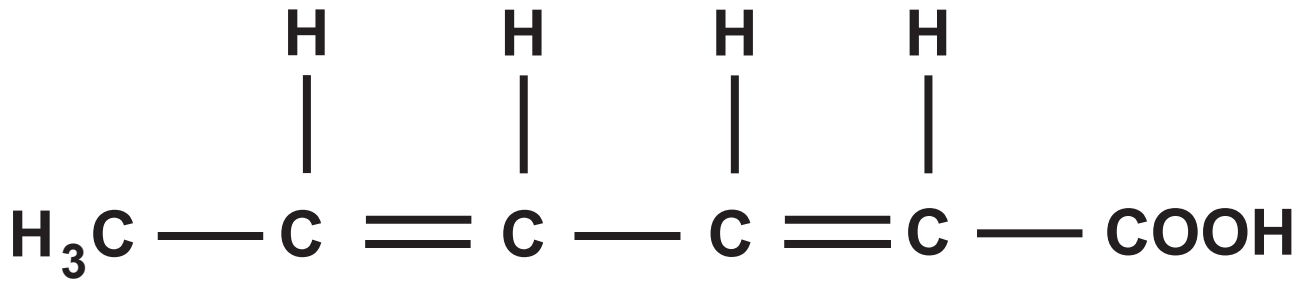
Question 6



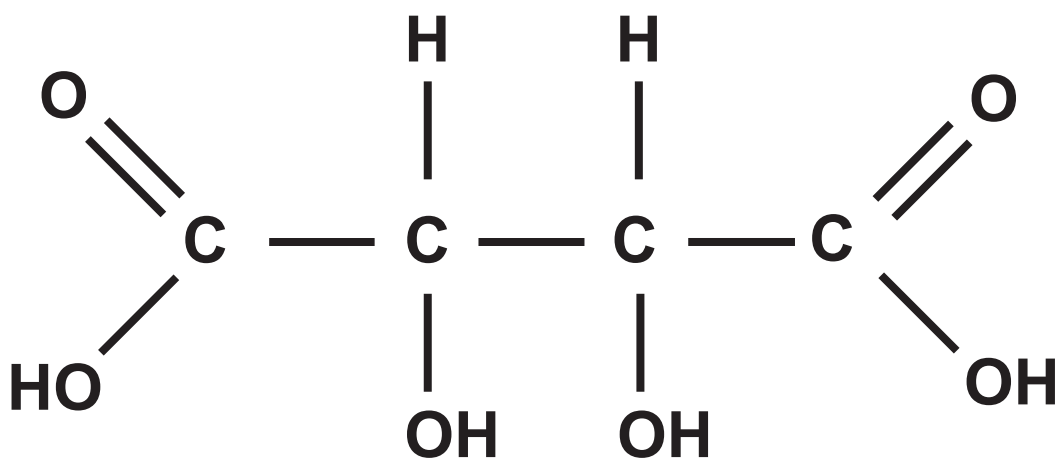
Question 7



Question 8 (a)



Question 8 (b)

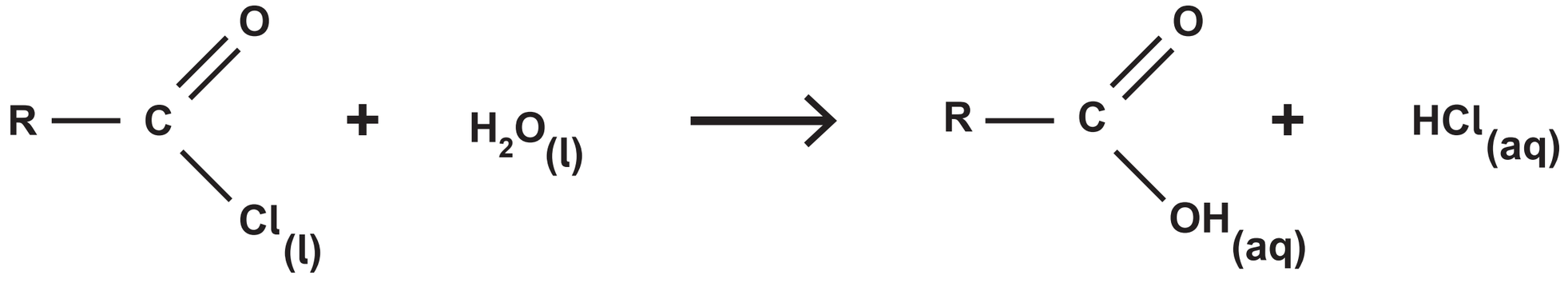


Question 8 (e)

Table

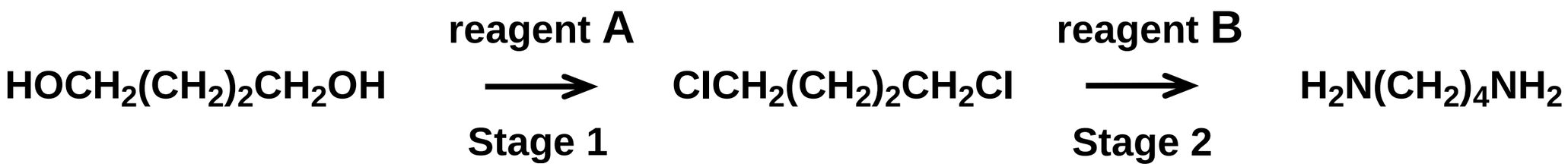
Number of carbon atoms in the alkyl chain	Solubility in water at 25°C / g dm^{-3}
3	94
5	1.6
7	0.7

Question 9 (a)

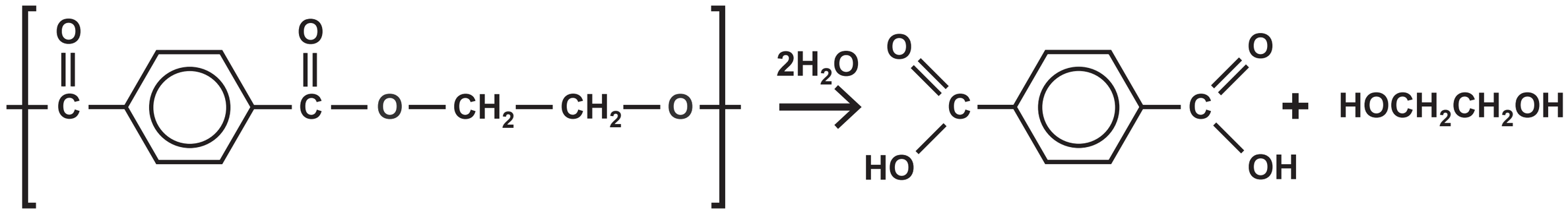


Question 9 (c)

Equation

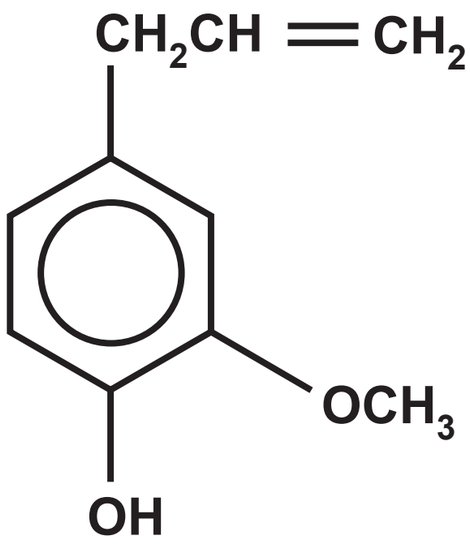


Question 9 (d)

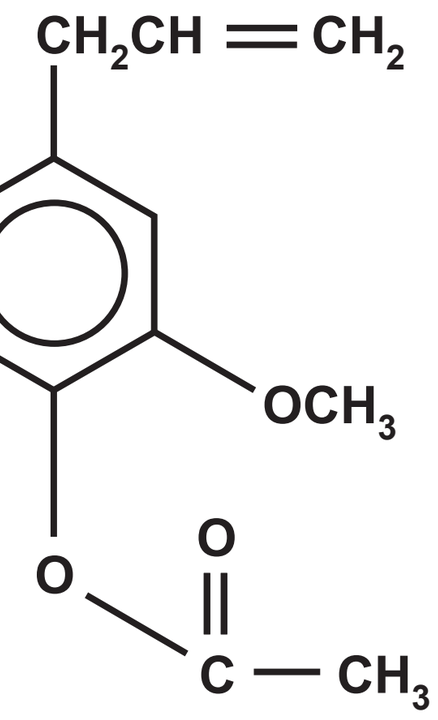


Question 10 (b)

Eugenol



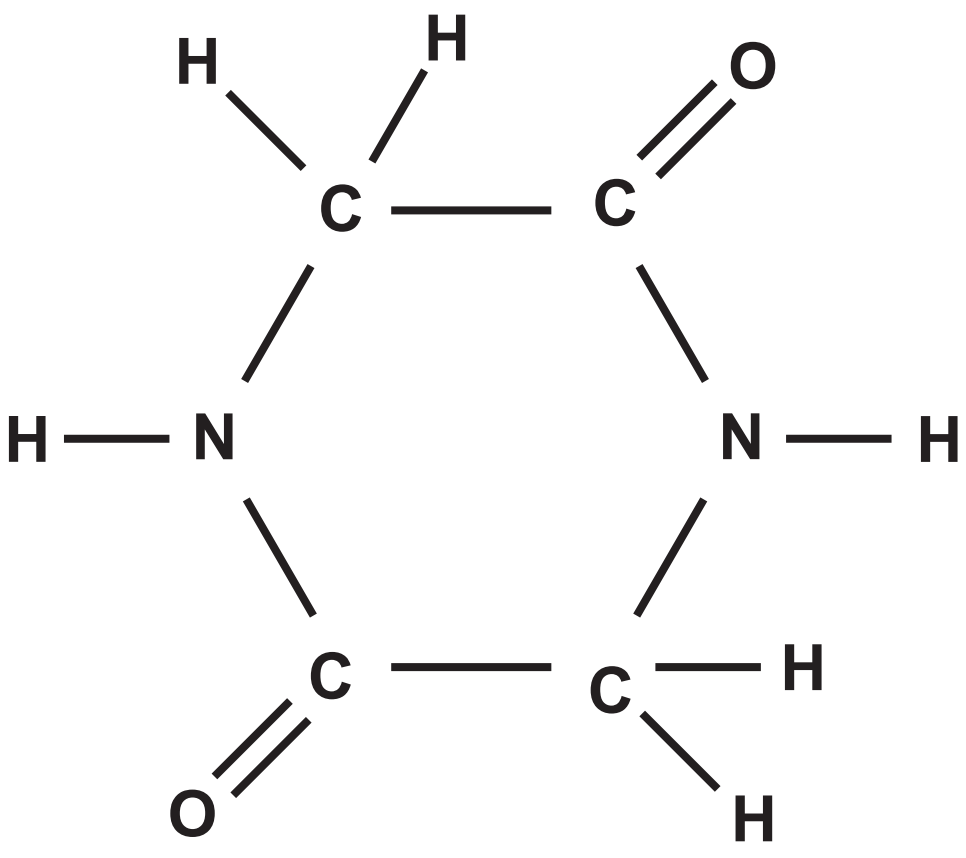
Eugenyl ethanoate



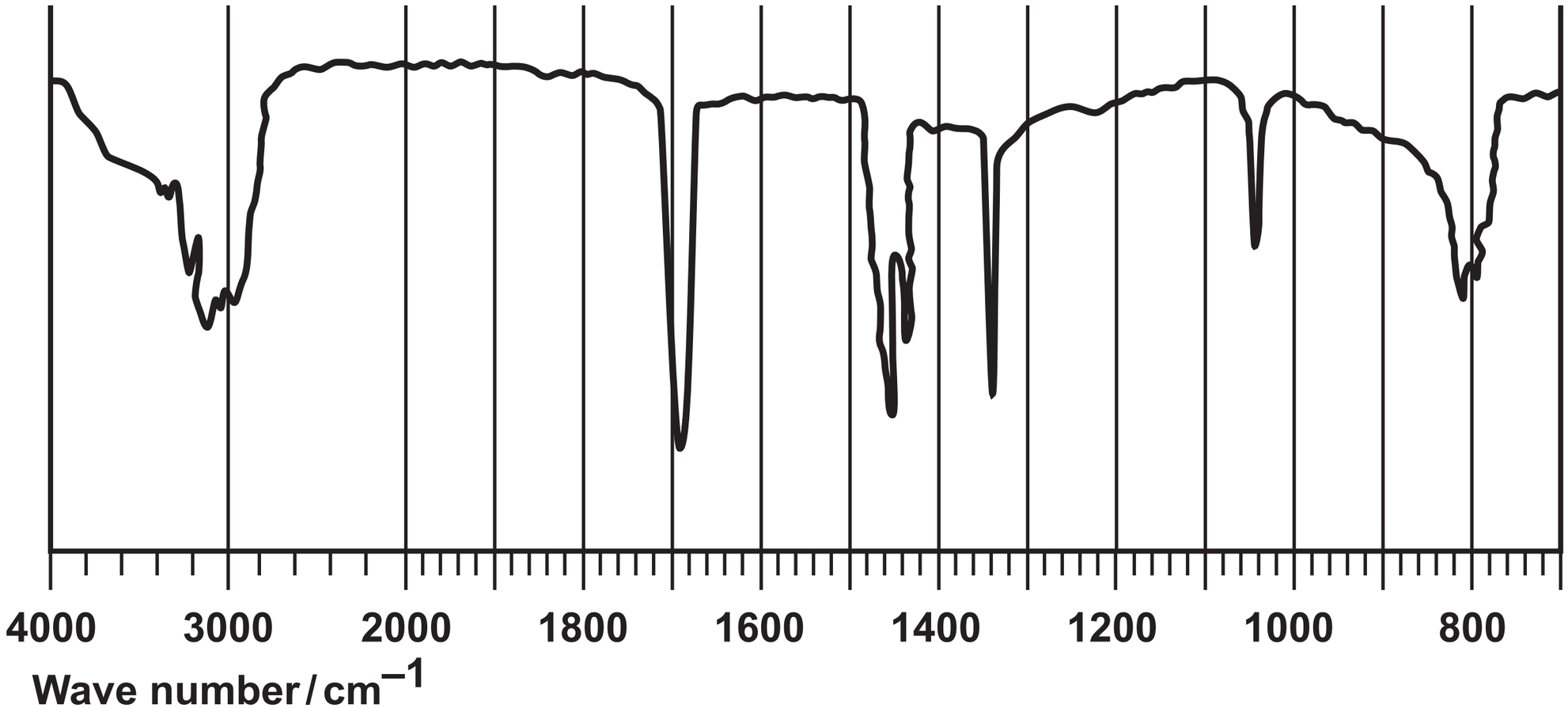
Question 11 (b)

Compound M

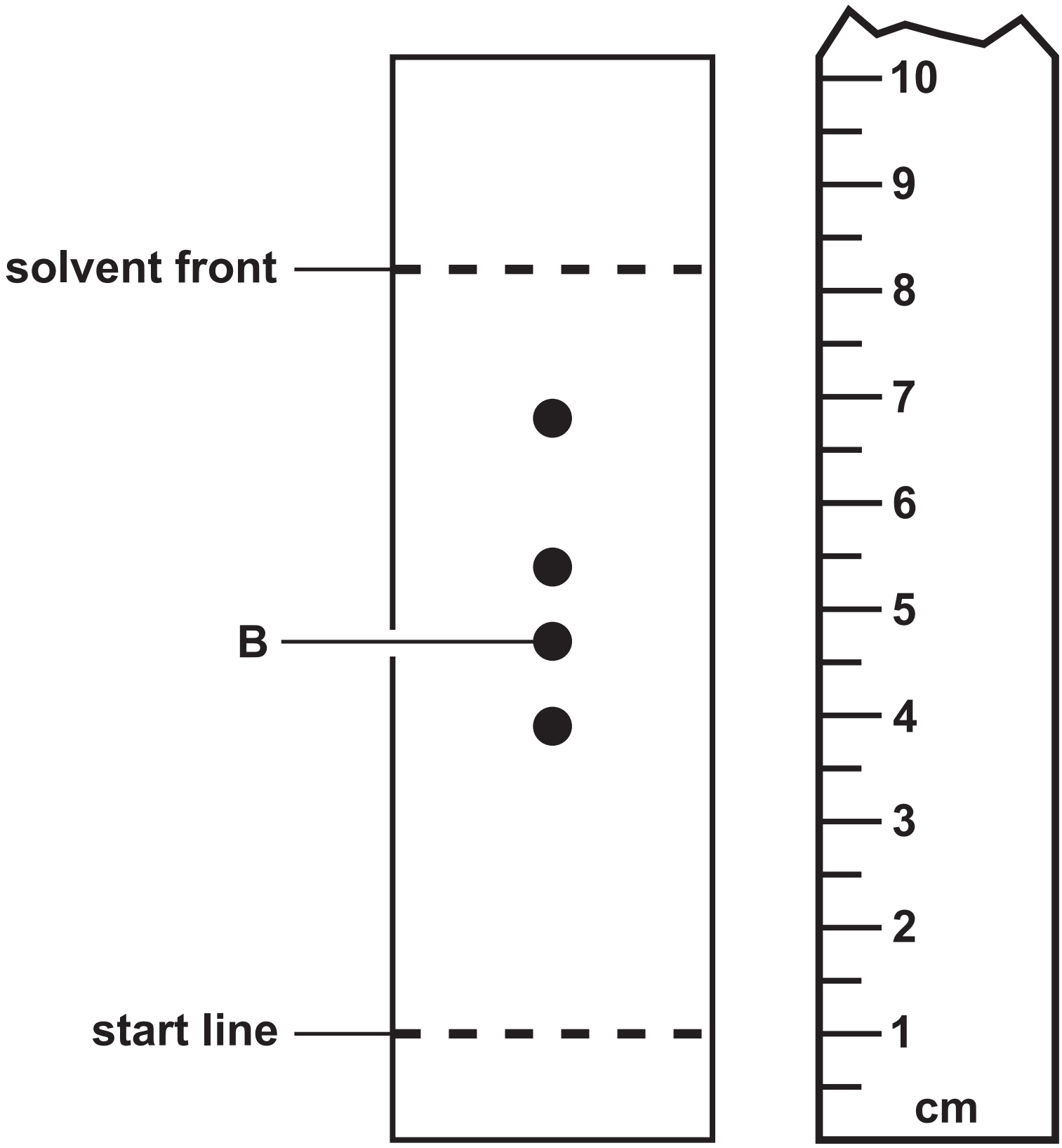
Question 11 (b) (ii)



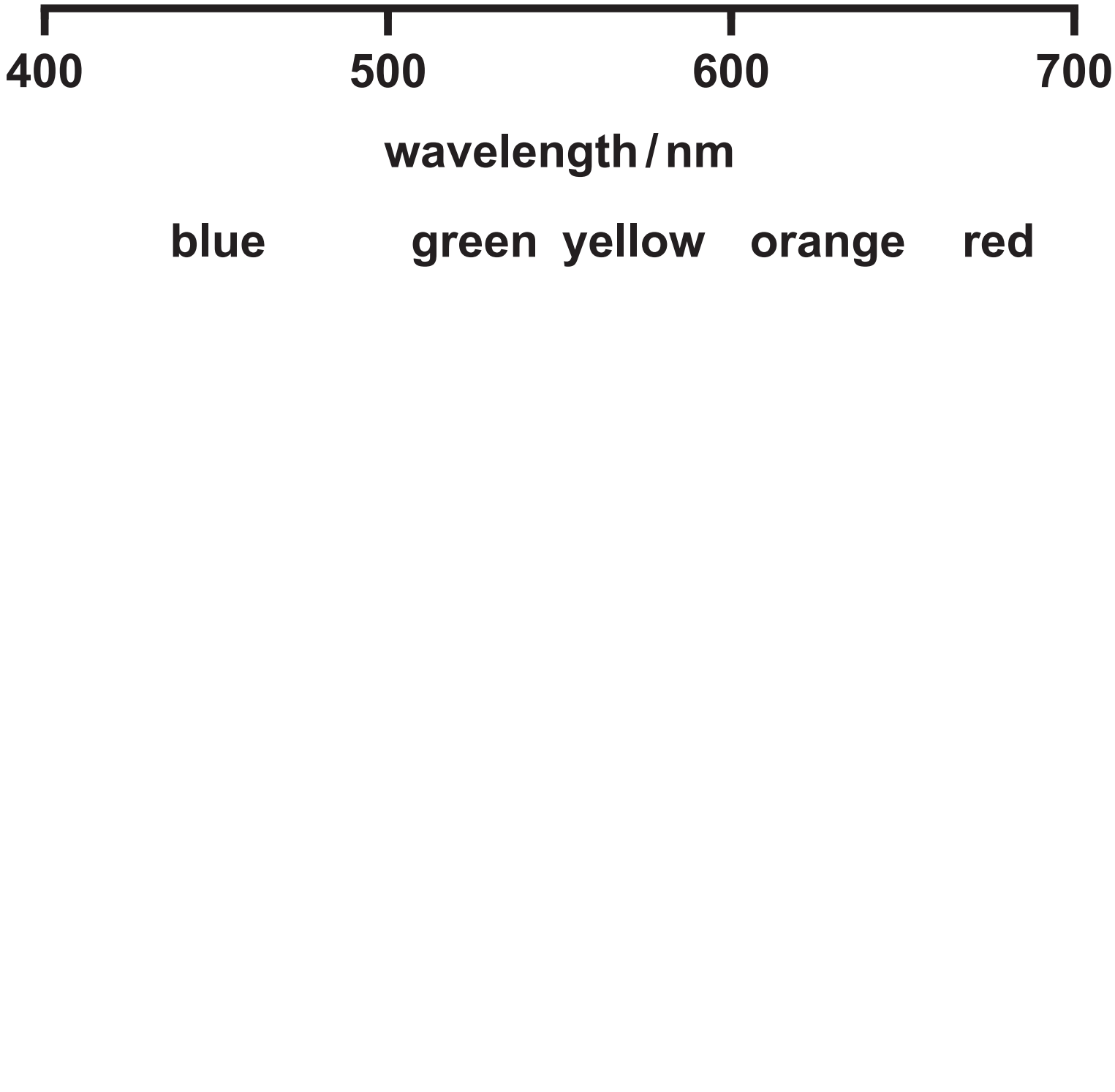
Question 11 (b) (ii) II.



Question 11 (c) (i)



Question 11 (c) (ii)



Question 11 (d)

Equation

Question 12 (a) (i)

DIAGRAM 1

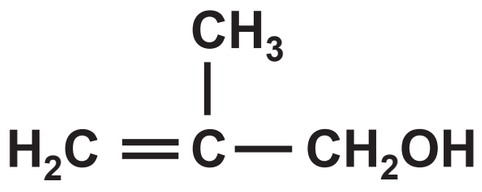
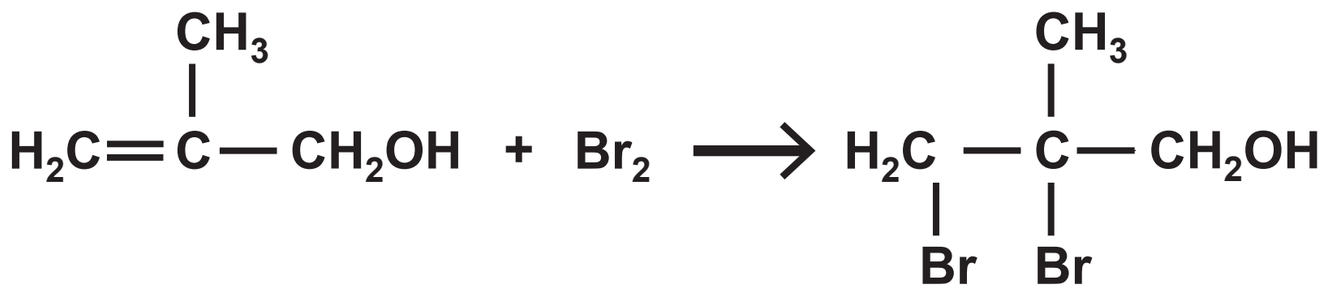
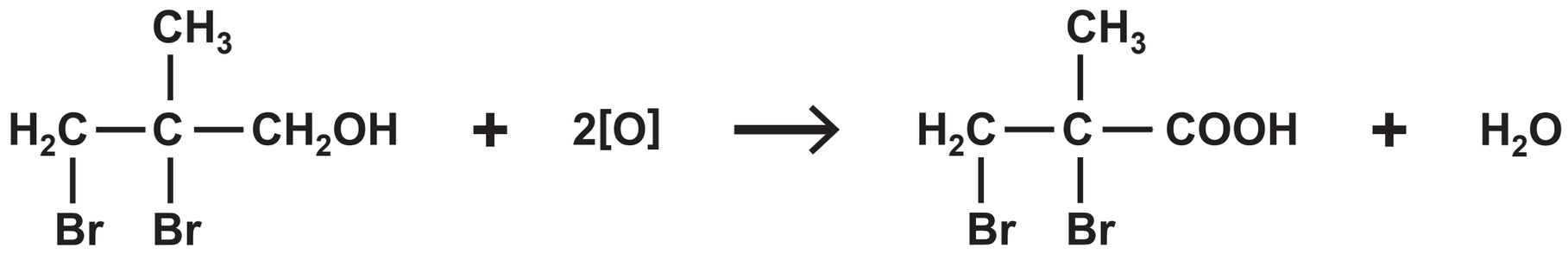


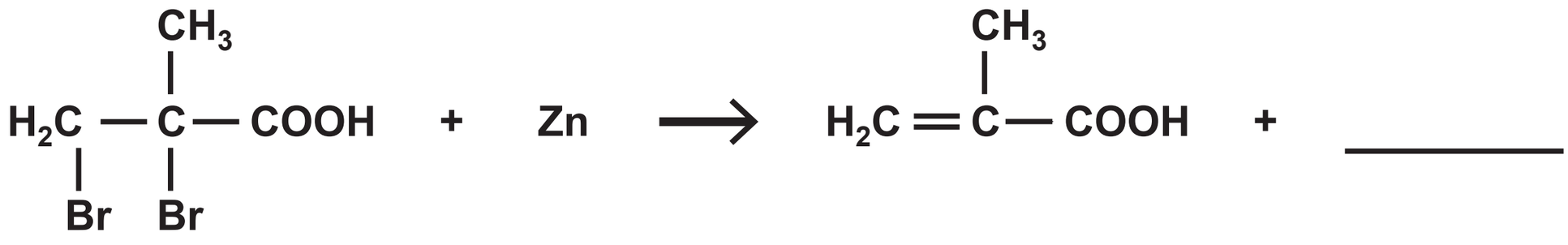
DIAGRAM 2



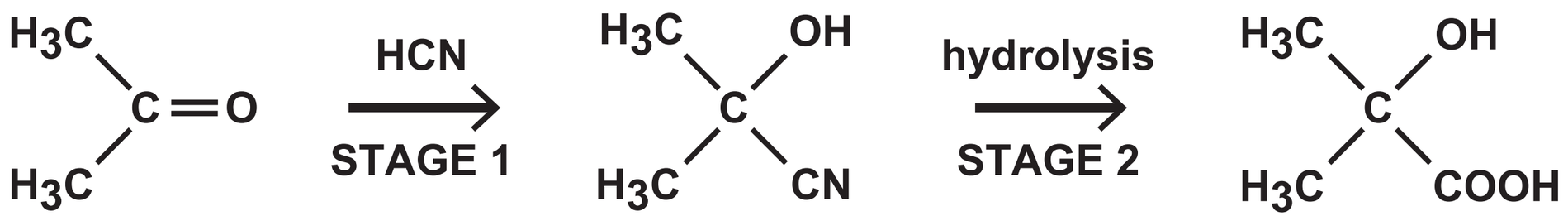
Question 12 (a) (ii)



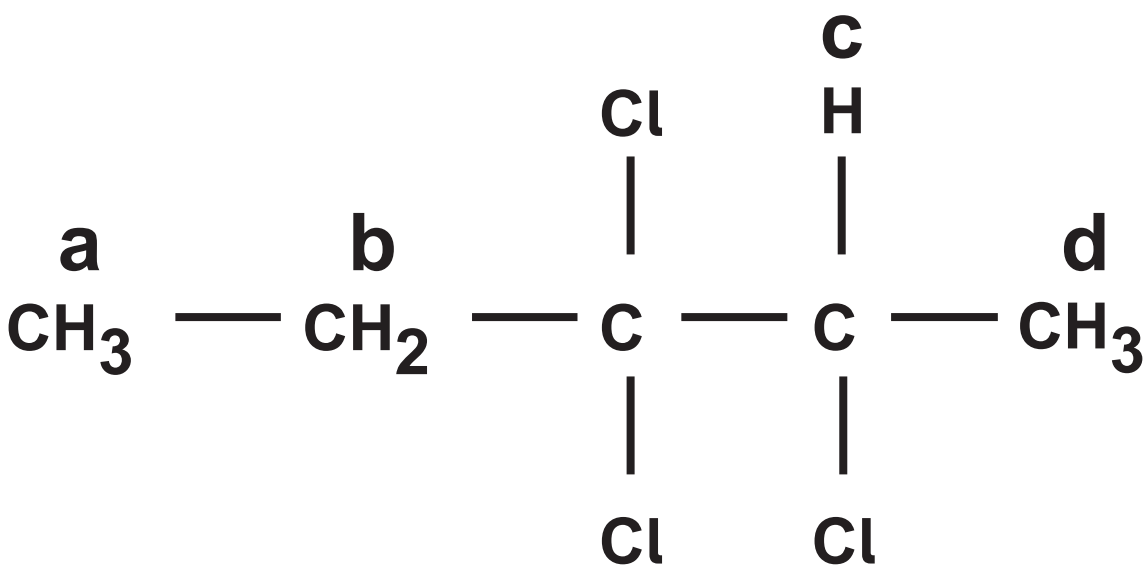
Question 12 (a) (iii)



Question 12 (b)



Question 12 (c)



Question 12 (c) (ii)

Table

Hydrogen proton	Splitting pattern
a	
b	
c	
d	