



GCE AS/A LEVEL

2410U20–1

TUESDAY, 20 MAY 2025 – MORNING

CHEMISTRY – AS UNIT 2

**ENERGY, RATE AND CHEMISTRY OF CARBON
COMPOUNDS**

**1 hour 30 minutes plus your additional time
allowance**

Surname: _____

First name(s): _____

Centre Number: _____

Candidate Number: 2 _____

Section A

Section B

FOR EXAMINER'S USE ONLY		
Question	Maximum Mark	Mark Awarded
1. to 6.	10	
7.	10	
8.	17	
9.	18	
10.	11	
11.	14	
Total	80	

ADDITIONAL MATERIALS

- A calculator and ruler
- 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.

(Turn over)

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.

SECTION A Answer ALL questions.

SECTION B Answer ALL questions.

Write your answers in the spaces provided. If you run out of space, use the additional pages at the back of this booklet, taking care to number the question(s) correctly.

(Turn over)

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 11 (b).

SECTION A

Answer ALL questions.

- 1. Draw the SKELETAL formula of pentane – 2,4 – diol in the space provided below.**

[1 mark]

(Turn over)

2. Give the NAME of the straight chain alkane that has the same molecular formula as 2, 2, 4 – trimethylpentane.
-

[1 mark]

3. (a) Refer to the diagram for Question 3 (a) in the separate Diagram Booklet. The diagram shows the Boltzmann energy distribution curve for a reaction at 298 K.

ON THE DIAGRAM, draw the curve for the same reaction at 288 K.

[1 mark]

- (b) State how a catalyst increases the rate of a reaction.
-
-
-

[1 mark]

(Turn over)

4. Refer to the diagram for Question 4 in the separate Diagram Booklet. Complete the diagram to show the mechanism for the nucleophilic substitution of bromoethane to form ethanol. You should include any relevant dipoles in the reactants.

[2 marks]

5. Refer to the diagram for Question 5 in the separate Diagram Booklet. Name the compound shown by the structure in the diagram.

[2 marks]

(Turn over)

6. Refer to the EQUATIONS for Question 6 in the separate Diagram Booklet. Use the information in the equations to answer parts (a) and (b).

Give ΔH^θ for the reactions shown below.



$\Delta H^\theta =$ _____ kJ mol^{-1}

[1 mark]



$\Delta H^\theta =$ _____ kJ mol^{-1}

[1 mark]

(Total for SECTION A = 10 marks)

(Turn over)

SECTION B

Answer ALL questions.

- 7. A reaction used to produce chloromethane is initiated by shining ultraviolet light into a mixture of methane gas and chlorine gas.**

(a) (i) Name the mechanism for this reaction.

[1 mark]

continued on the next page . . .

(Turn over)

Question 7 (a) continued

- 7. (a) (ii) Give the reaction mechanism for the production of chloromethane from methane and chlorine. Show the initiation and propagation stages.**

Initiation

Propagation

[3 marks]

continued on the next page . . .

(Turn over)

Question 7 continued

- 7. (b) (i) Explain why the mixture produced in this reaction could contain ethane.**

[1 mark]

- (ii) Explain why the mixture produced in this reaction could contain dichloromethane.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 7 continued

- 7. (c) Refer to DIAGRAM 1 and DIAGRAM 2 for Question 7 (c) in the separate Diagram Booklet. The original reaction to produce chloromethane was carried out in an aluminium – lined container. The gas mixture was exposed to ultraviolet light for a prolonged period of time. This method, represented in DIAGRAM 1, produced large quantities of side – products.**

A possible improvement to this method, designed to minimise the formation of side – products, involves passing the mixture of methane and chlorine through a narrow transparent tube wrapped around an ultraviolet light source. This is represented in DIAGRAM 2.

- (i) Suggest why this improvement could lead to fewer side – products in the mixture.**

[1 mark]

continued on the next page . . .

(Turn over)

Question 7 (c) continued

7. (c) (ii) This method was tested using different flow rates of the methane and chlorine mixture to find the best yield of chloromethane.

The composition of the product mixture was found and recorded in TABLE 1 provided separately in the Diagram Booklet.

Use this data to determine the optimum flow rate for the production of chloromethane.

Explain the results recorded at this flow rate.

[2 marks]

(Total for Question 7 = 10 marks)

(Turn over)

8. (a) Refer to the diagram for Question 8 (a) in the separate Diagram Booklet. The reaction between hydrated barium hydroxide and ammonium chloride is a rare example of an endothermic solid state – reaction.

Complete the reaction profile shown in the diagram to show the enthalpy change involved in an endothermic reaction. Label the enthalpy change clearly on the diagram.

[1 mark]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (b) The enthalpy change for this reaction can be calculated using standard enthalpy changes of formation.

(i) Give the meaning of the term standard enthalpy change of formation.

[2 marks]

continued on the next page . . .

(Turn over)

Question 8 (b) continued

8. (b) (ii) The standard enthalpy changes of formation, $\Delta_f H^\theta$, of the substances involved in this reaction are given in TABLE 2 provided separately in the Diagram Booklet.

Refer to the EQUATION for this reaction provided separately in the Diagram Booklet. Using a Hess cycle or otherwise, calculate the standard enthalpy change for the reaction.

Enthalpy change = _____ kJ mol^{-1}
[3 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

- 8. (c) (i) A student performed an experiment to determine the enthalpy change for this reaction.**

He weighed 31.5 g of hydrated barium hydroxide into a glass beaker and recorded its temperature. He started his stopwatch and recorded the temperature again after 30 seconds.

After 1 minute, he added excess ammonium chloride and thoroughly mixed the solids using a stirring rod. He then measured the temperature every 30 seconds for a further 4 minutes.

His results are shown in TABLE 3 provided separately in the Diagram Booklet.

continued on the next page . . .

Question 8 (c) (i) continued

Refer to the grid for Question 8 (c) (i) in the separate Diagram Booklet.

Plot the results from TABLE 3 on the grid.

Calculate the maximum temperature change and record it below your graph.

[4 marks]

continued on the next page . . .

(Turn over)

Question 8 (c) continued

8. (c) (ii) Refer to the EQUATION provided separately in the Diagram Booklet. Use this balanced equation to calculate the mass of water released during this reaction. Give your answer to an APPROPRIATE number of significant figures.

Mass of water = _____ g

[3 marks]

continued on the next page . . .

(Turn over)

Question 8 (c) continued

8. (c) (iii) Use the mass of water from part (ii) and the maximum temperature change from part (i) to calculate the enthalpy change of reaction per mole of hydrated barium hydroxide. Give your answer in kJ mol^{-1} .

Assume that the specific heat capacity of the reaction mixture is $1.13 \text{ J g}^{-1} \text{ K}^{-1}$.

Enthalpy change = _____ kJ mol^{-1}
[2 marks]

continued on the next page . . .

(Turn over)

Question 8 continued

8. (d) (i) Explain why the experimental value calculated in part (c)(iii) is much lower than the theoretical value calculated in part (b)(ii).

[1 mark]

- (ii) Suggest a possible change to the method that would improve the accuracy of the experimentally determined value.

[1 mark]

(Total for Question 8 = 17 marks)

(Turn over)

9. (a) Refer to the diagrams for Question 9 (a) in the separate Diagram Booklet. Compound **A** contains carbon, hydrogen and oxygen only.

Elemental analysis of compound **A** indicates that it is composed of **68.09%** carbon and **18.16%** oxygen by mass.

Simplified forms of the mass spectrum, infrared spectrum, ^1H NMR spectrum and ^{13}C NMR spectrum are shown in the diagrams.

Determine the identity of compound **A**.

Explain your answer using information from **ALL** of the data sources provided.

(Turn over)

[10 marks]

9. (b) Propan – 1 – ol can be oxidised to propanoic acid in the presence of sulfuric acid.

(i) Give a solution which acts as an oxidising agent for this reaction in acidic conditions.

[1 mark]

(ii) Refer to the incomplete EQUATION for this reaction in the separate Diagram Booklet. Complete the balanced equation for this reaction.

[1 mark]

continued on the next page . . .

(Turn over)

Question 9 (b) continued

9. (b) (iii) The oxidation of propan – 1 – ol requires the presence of a strong acid. Hydrochloric acid cannot be used in this reaction as the chloride ions would be oxidised.

Give the half equation for the oxidation of chloride ions.

[2 marks]

- (iv) Propanoic acid and ethanol react on heating in acidic conditions to form a sweet – smelling compound.

- I. Give the products of this reaction. Clearly show the structure of the sweet – smelling compound.

[2 marks]

continued on the next page . . .

(Turn over)

Question 9 (b) (iv) continued

9. (b) (iv) II. Name the sweet – smelling compound.

[1 mark]

III. State the purpose of adding an acid to the reaction mixture.

[1 mark]

(Total for Question 9 = 18 marks)

(Turn over)

10. **1 – Bromobutane can be converted into
2 – bromobutane using a two – step synthesis.**

**(a) The first step in this synthesis is an elimination
reaction between 1 – bromobutane and sodium
hydroxide to form but – 1 – ene.**

**(i) Give the conditions needed for this
elimination reaction.**

[2 marks]

**(ii) State the molecule ELIMINATED from
1 – bromobutane.**

[1 mark]

continued on the next page . . .

(Turn over)

Question 10 (a) continued

- 10. (a) (iii) The but – 1 – ene formed during this reaction is then used to form 2 – bromobutane by reaction with hydrogen bromide, HBr.**

Draw the mechanism for this reaction.

[3 marks]

continued on the next page . . .

(Turn over)

Question 10 continued

- 10. (b) A similar two – step synthesis was carried out starting from 2 – bromo – 2 – methylbutane.**

Refer to the diagram for Question 10 (b) in the separate Diagram Booklet. The diagram shows some of the details.

- (i) COMPLETE THE DIAGRAM by drawing the structures of the TWO possible alkene intermediates, Y and Z.**

[2 marks]

continued on the next page . . .

(Turn over)

Question 10 (b) continued

- 10. (b) (ii) Suggest which of the THREE possible products, A, B or C, would have the greatest yield.**

Explain your reasoning in terms of the stability of any carbocation intermediates formed.

[3 marks]

(Total for Question 10 = 11 marks)

(Turn over)

11. (a) Refer to the diagram for Question 11 (a) in the separate Diagram Booklet. A student was investigating the rate of hydrolysis of three different halogenoalkanes:

**1 – chlorobutane, 1 – bromobutane and
1 – iodobutane**

She added 2 cm^3 of the halogenoalkane to a mixture of 6 cm^3 of sodium hydroxide dissolved in ethanol and aqueous silver nitrate solution. She then used a light sensor to measure the amount of light transmitted through the reaction mixture over time.

The diagram shows the experimental set – up.

Refer to the GRAPH for Question 11 (a) in the separate Diagram Booklet. The student's results are shown.

continued on the next page . . .

Question 11 (a) continued

- 11. (a) (i) Explain why this method can be used to monitor the rate of these hydrolysis reactions.**

[2 marks]

- (ii) Identify which of graphs A – C shows the rate of hydrolysis for 1 – iodobutane.**

Explain your reasoning.

[3 marks]

continued on the next page . . .

(Turn over)

Question 11 (a) continued

11. (a) (iii) Calculate the mean rate of the reaction shown by graph B.

Give the appropriate unit.

Rate = _____

Unit _____

[2 marks]

(iv) Using the graphs, suggest why the results of this experiment could be considered to be NOT valid.

[1 mark]

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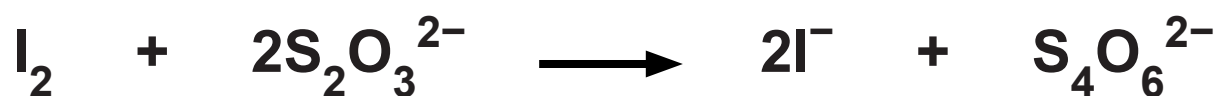
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Question 11 continued

11. (b) Another student investigated the effect of concentration on rate using an iodine clock reaction. This method uses a solution containing persulfate ions to oxidise iodide ions to generate iodine in a slow reaction.



Iodine is then reduced back to iodide by thiosulfate ions in a fast reaction.



When the thiosulfate has been consumed, excess iodine is formed which can then be identified using an appropriate indicator.

continued on the next page . . .

Question 11 (b) continued

Describe how the student could determine the effect of changing the concentration of persulfate ions on the rate of the reaction.

You should

- **give a brief method (specific quantities are NOT required)**
- **state how persulfate solutions of different concentrations are prepared from a stock solution**
- **state how the data collected is used to determine the rate of the reaction**

Space for working and answer continues on the next two pages.

Question 11 (b) continued

(Turn over)

[6 QER marks]

(Total for Question 11 = 14 marks)

END OF PAPER

TOTAL 80 MARKS

(Turn over)

[illegible]

(Turn over)

[illegible]

(Turn over)

[illegible]

(Turn over)



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Diagram Booklet

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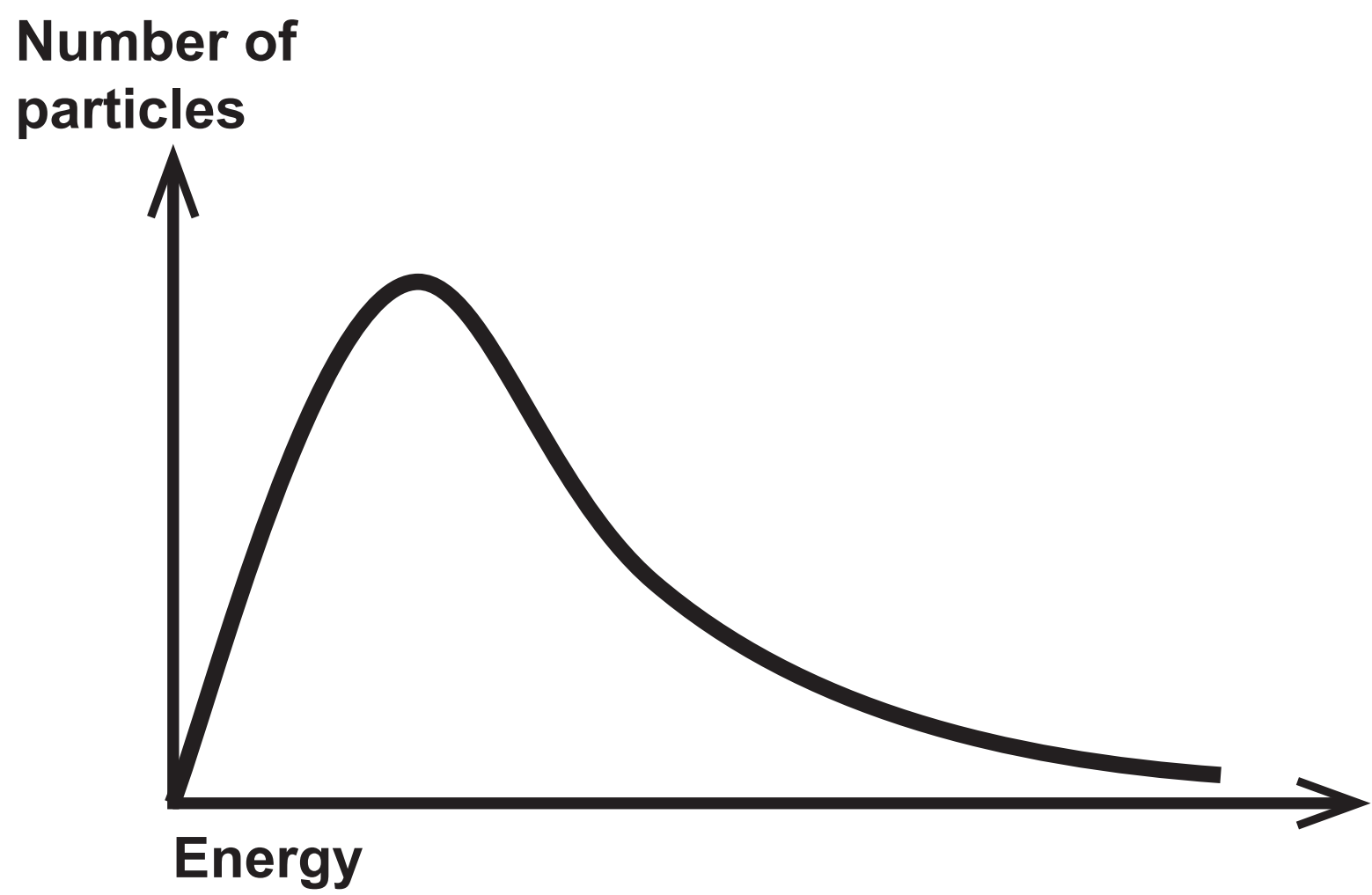
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First name(s): _____

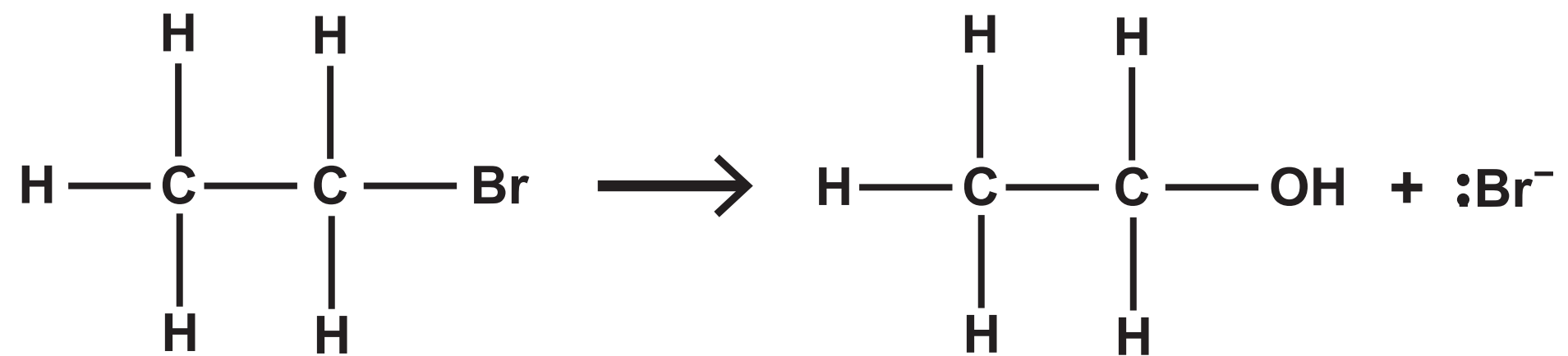
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Candidate Number: 2 _____

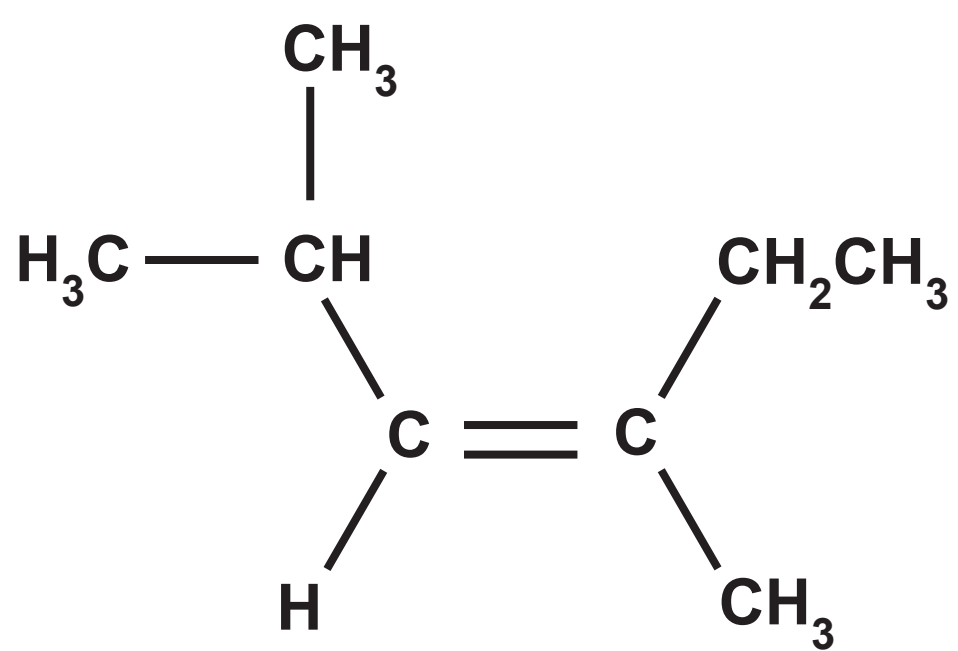
Question 3 (a)



Question 4



Question 5



Question 6

EQUATIONS



Question 7 (c)

DIAGRAM 1

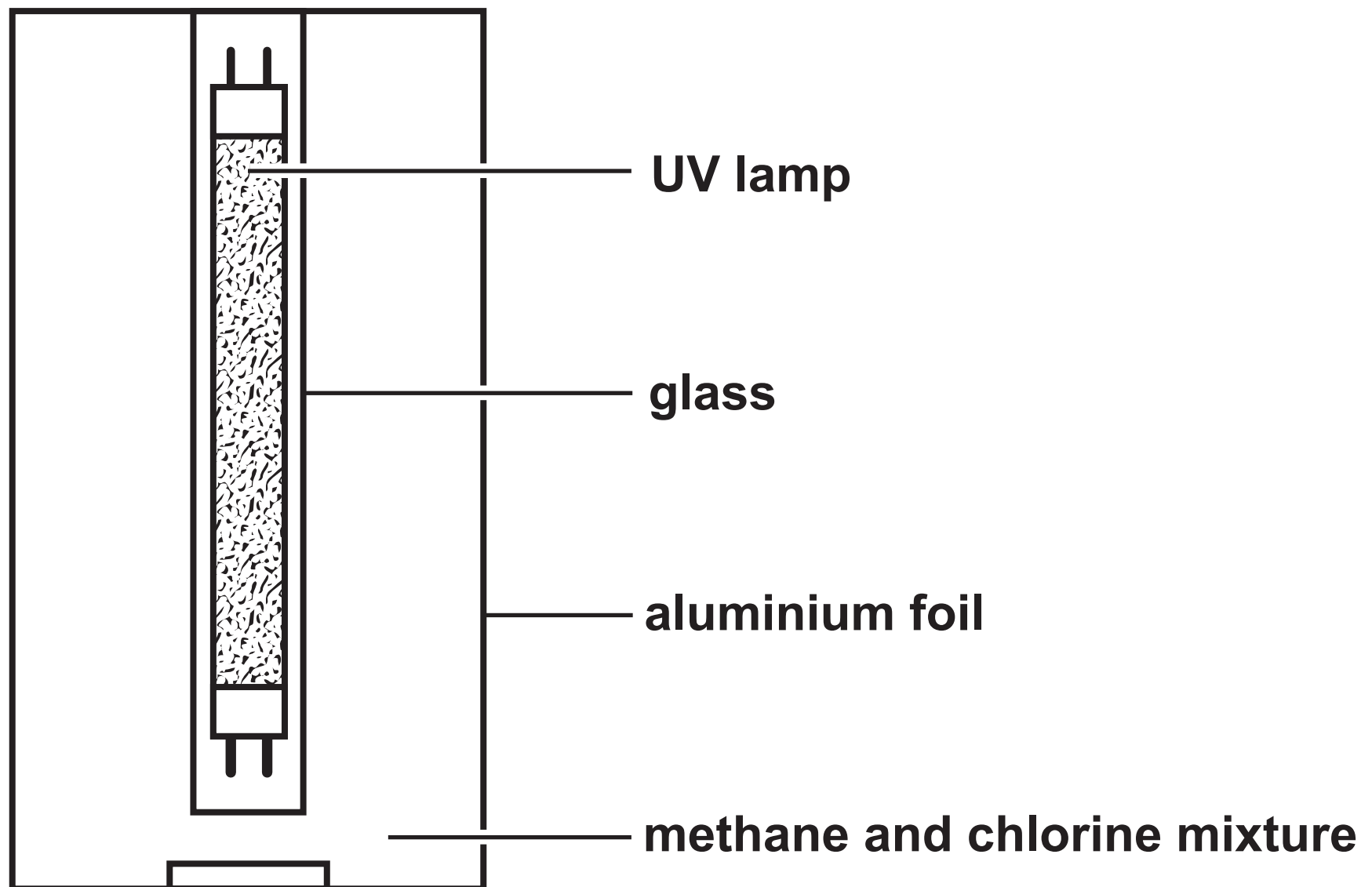
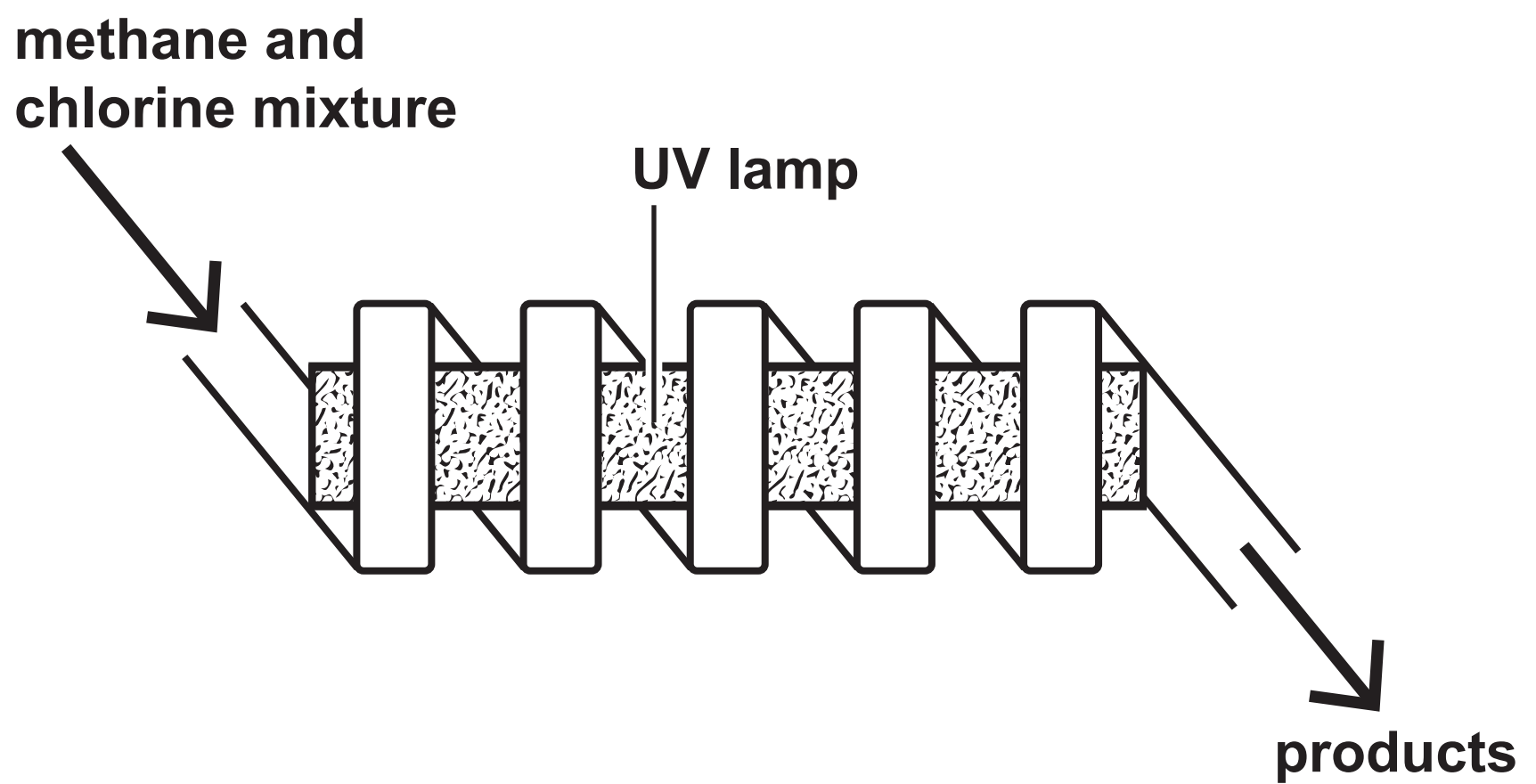


DIAGRAM 2

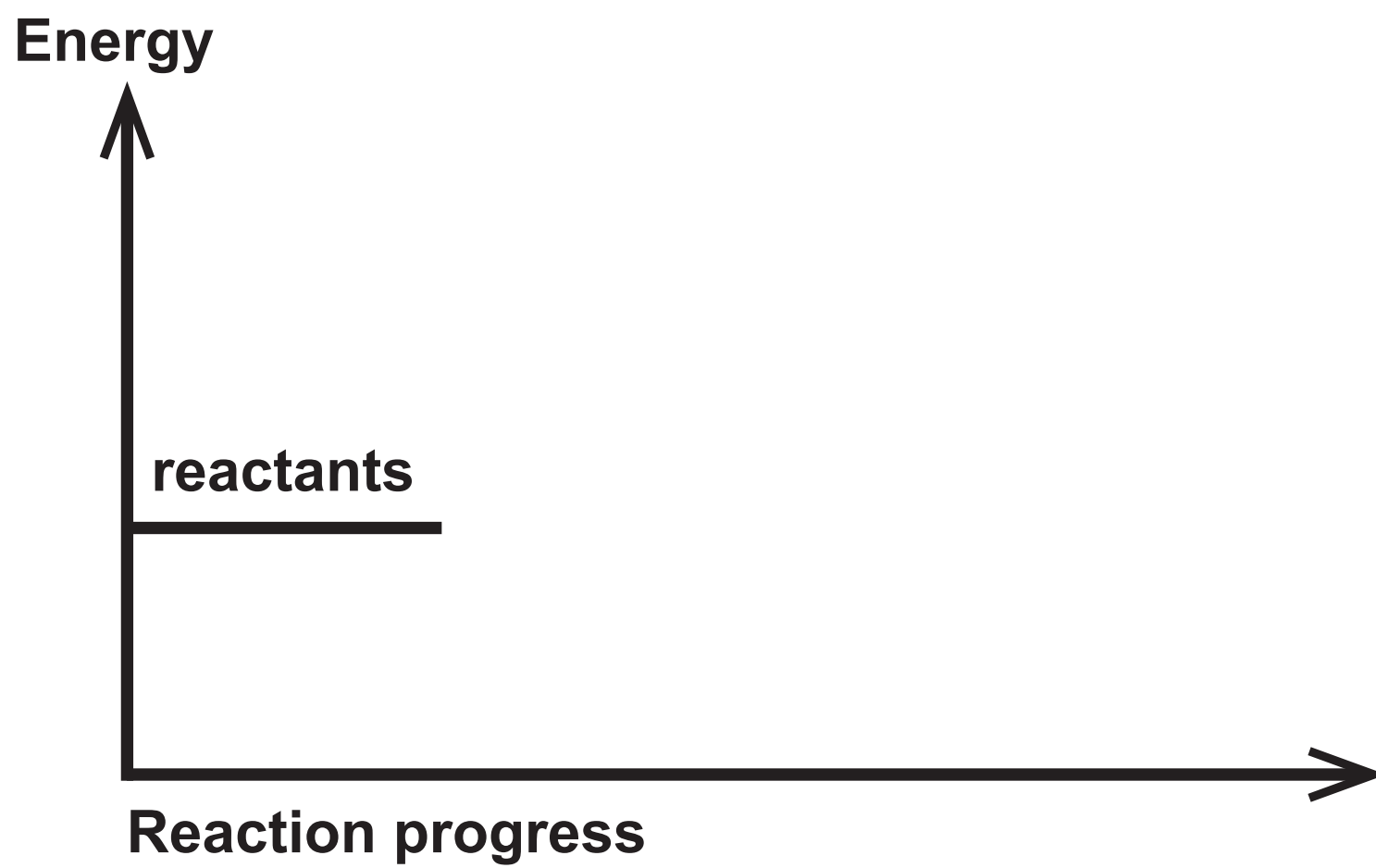


Question 7 (c) (ii)

TABLE 1

Flow rate (cm ³ s ⁻¹)	Percentage of product mixture				
	CH ₄	Cl ₂	CH ₃ Cl	CH ₂ Cl ₂	C ₂ H ₆
1	2	1	12	48	37
2	6	3	43	28	20
3	10	5	72	8	5
4	34	17	42	5	2
5	58	29	10	2	1

Question 8 (a)



Question 8 (b) (ii)

TABLE 2

Substance	$\Delta_f H^\theta$ (kJ mol ⁻¹)
H ₂ O	-286
NH ₃	-45.9
BaCl ₂ .2H ₂ O	-1460
Ba(OH) ₂ .8H ₂ O	-3350
NH ₄ Cl	-314

EQUATION

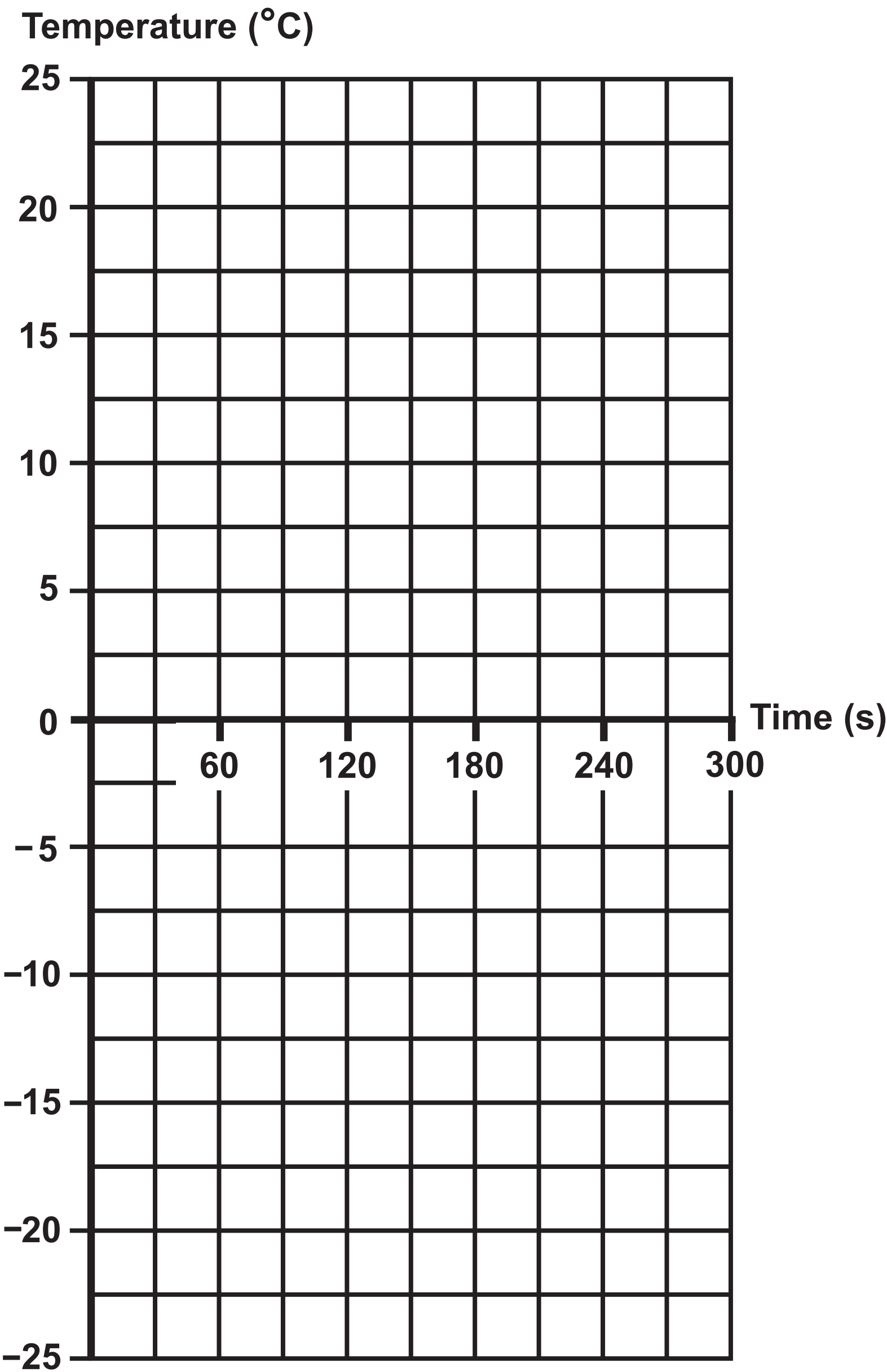


Question 8 (c) (i)

TABLE 3

Time (s)	Temperature (°C)
0	21
30	21
60	—
90	17
120	5
150	−8
180	−20
210	−19
240	−18
270	−17
300	−16

Question 8 (c) (i)



Maximum temperature change = _____ $^{\circ}\text{C}$

Question 8 (c) (ii)

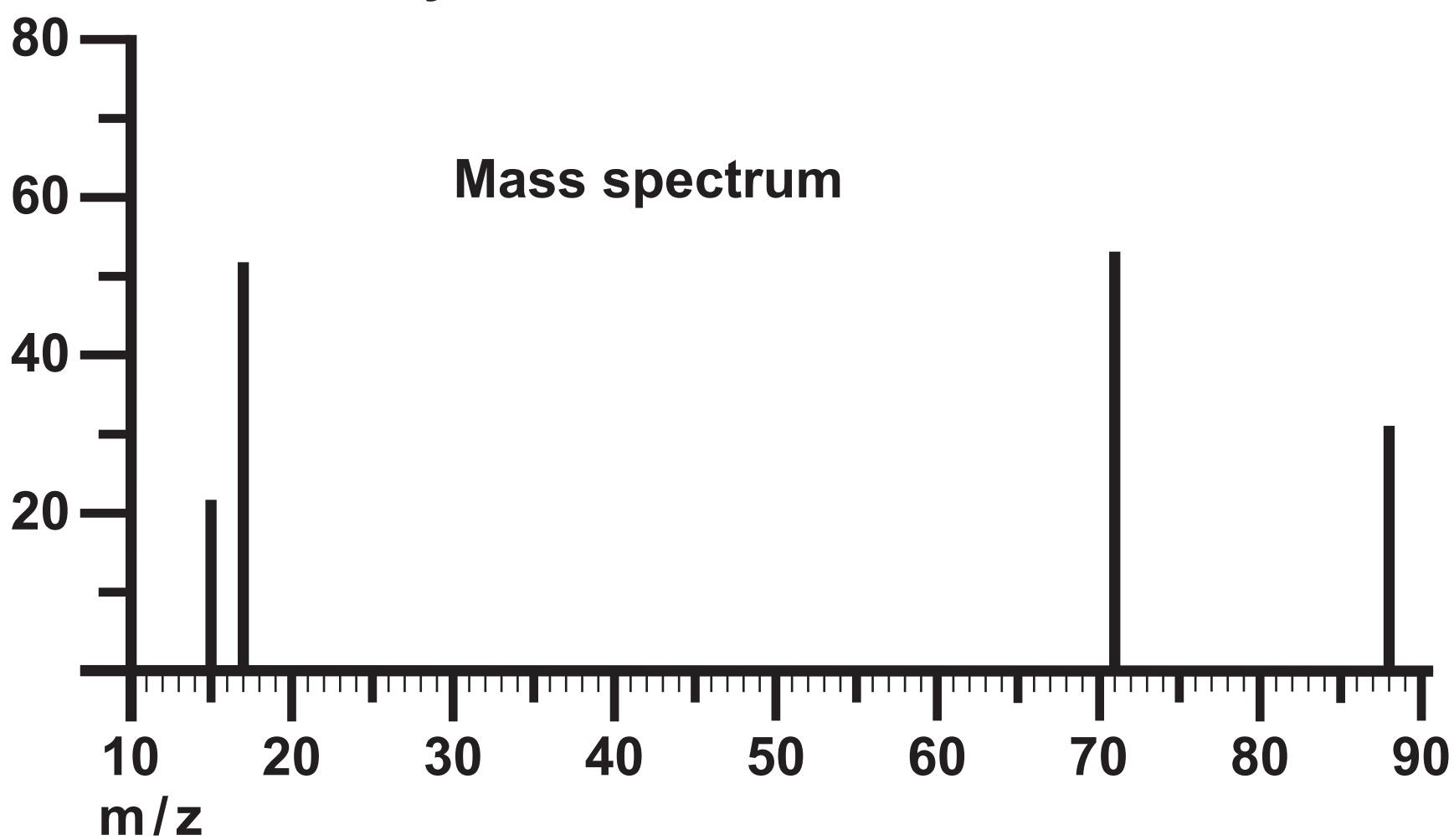
EQUATION



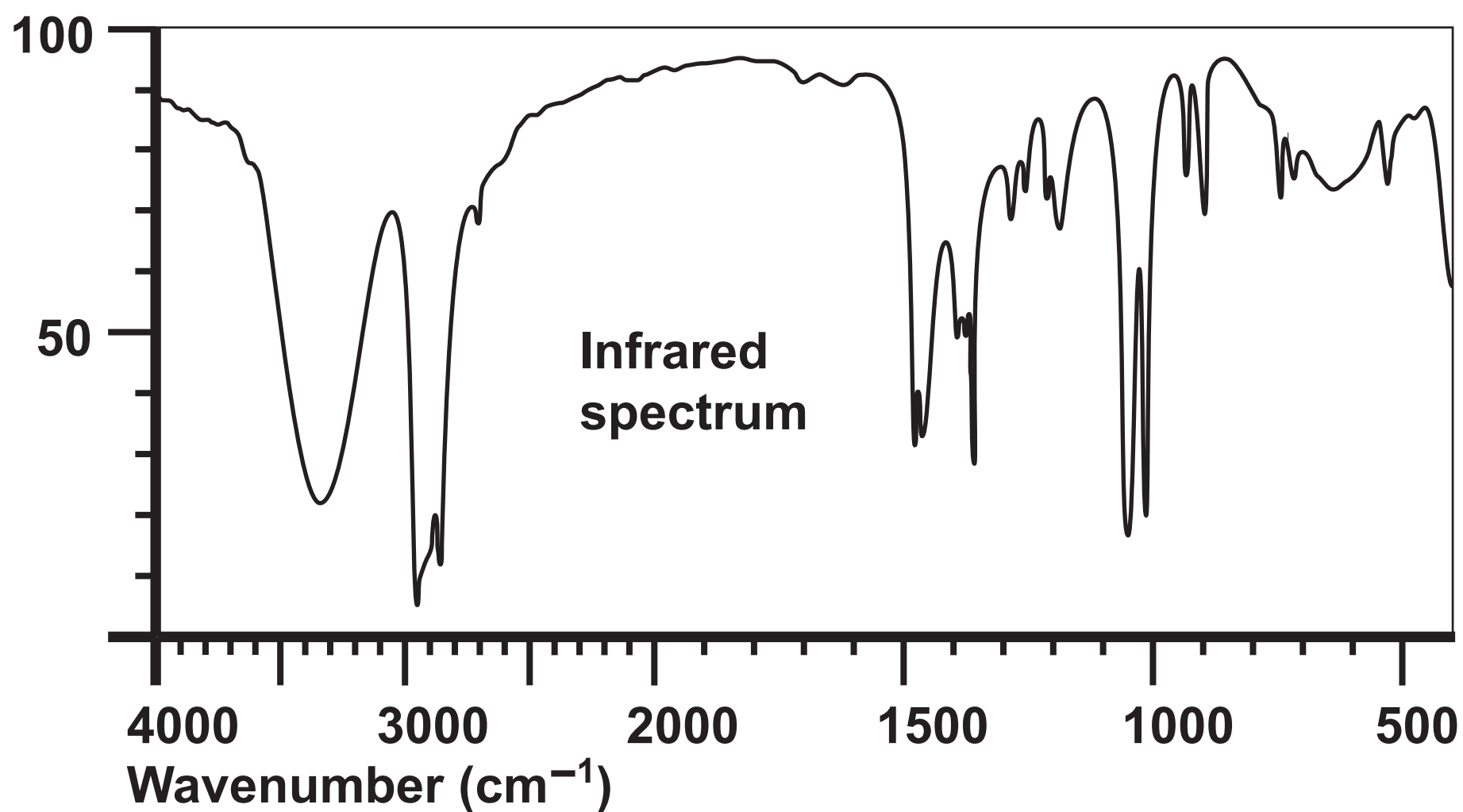
M_r 315

Question 9 (a)

Relative intensity



Transmittance (%)

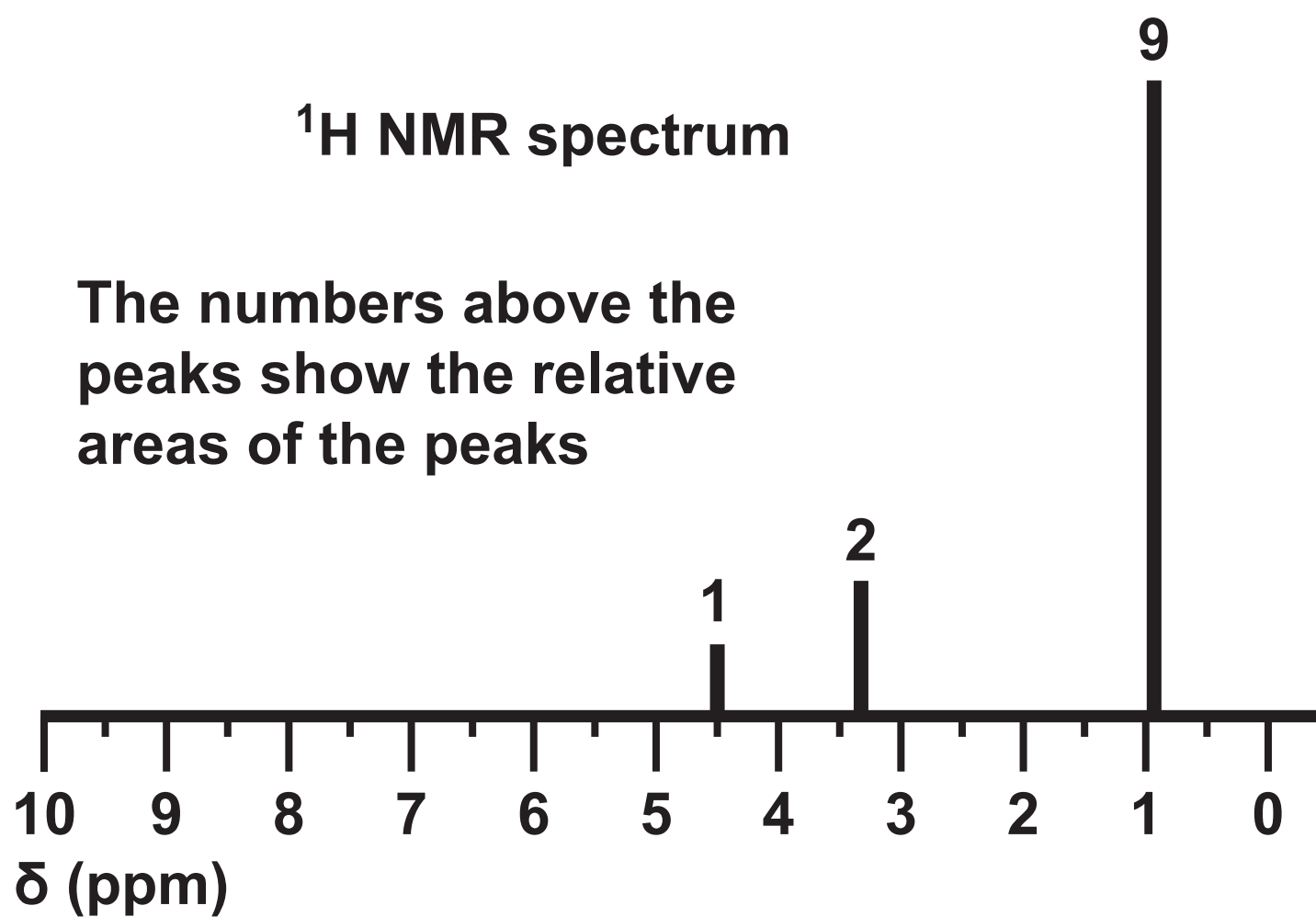


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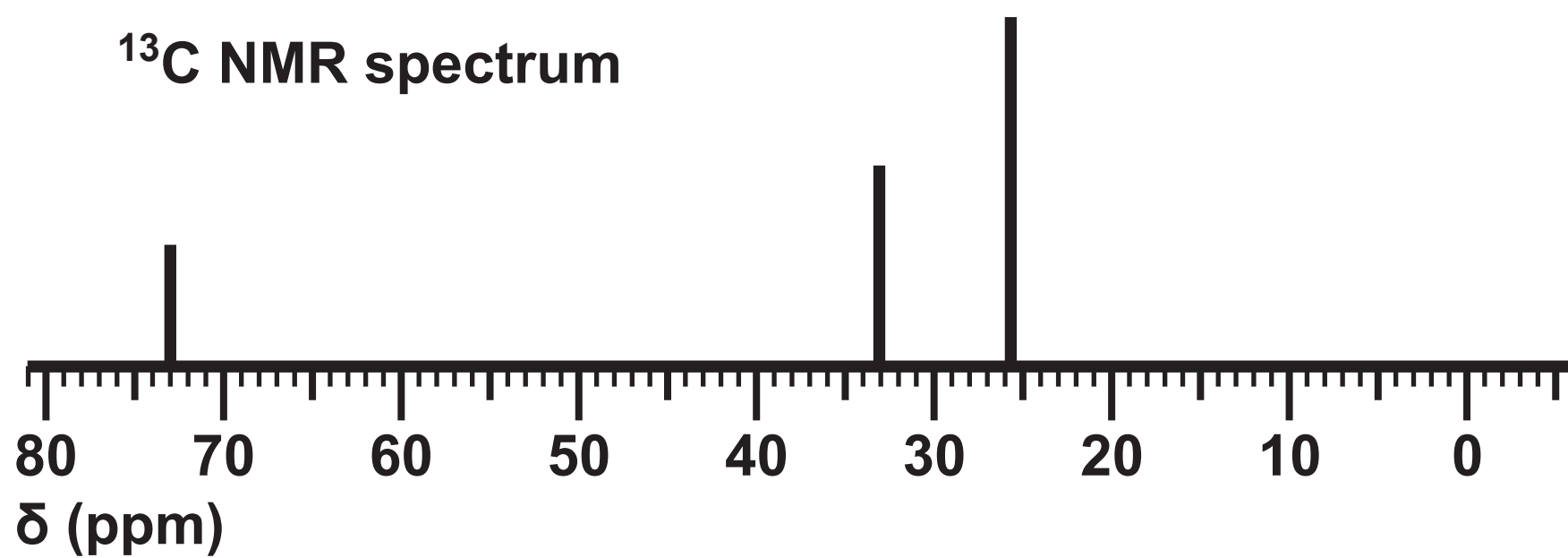
Question 9 (a)

^1H NMR spectrum

The numbers above the peaks show the relative areas of the peaks

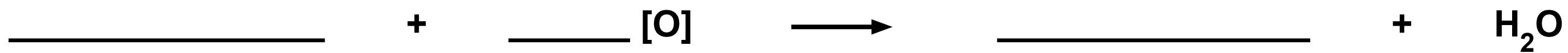


^{13}C NMR spectrum

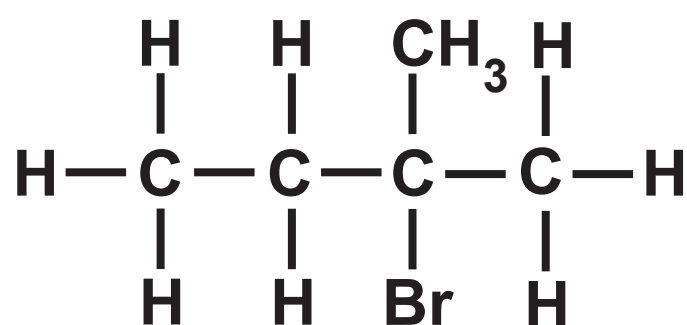


Question 9 (b) (ii)

EQUATION



Question 10 (b)



elimination



alkene intermediate Y



elimination



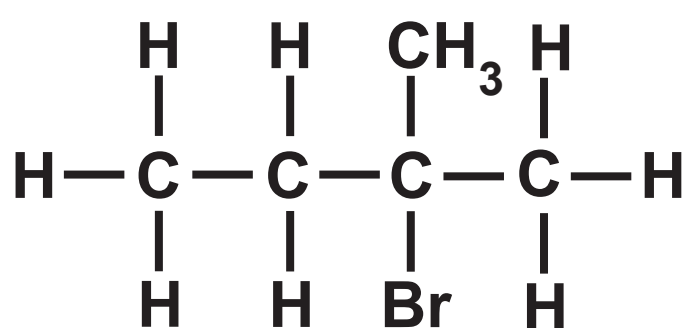
alkene intermediate Z



addition
of HBr



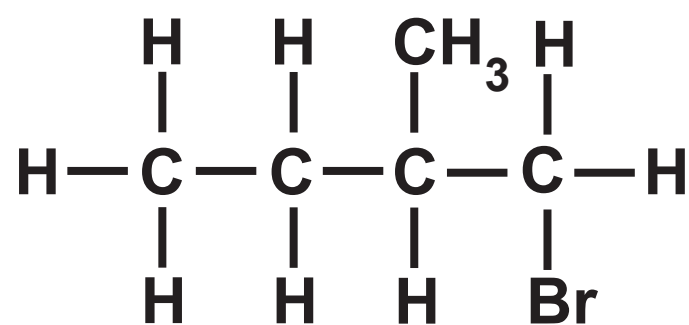
product B



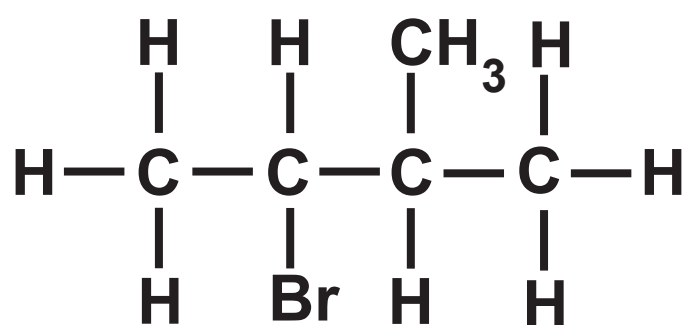
addition
of HBr



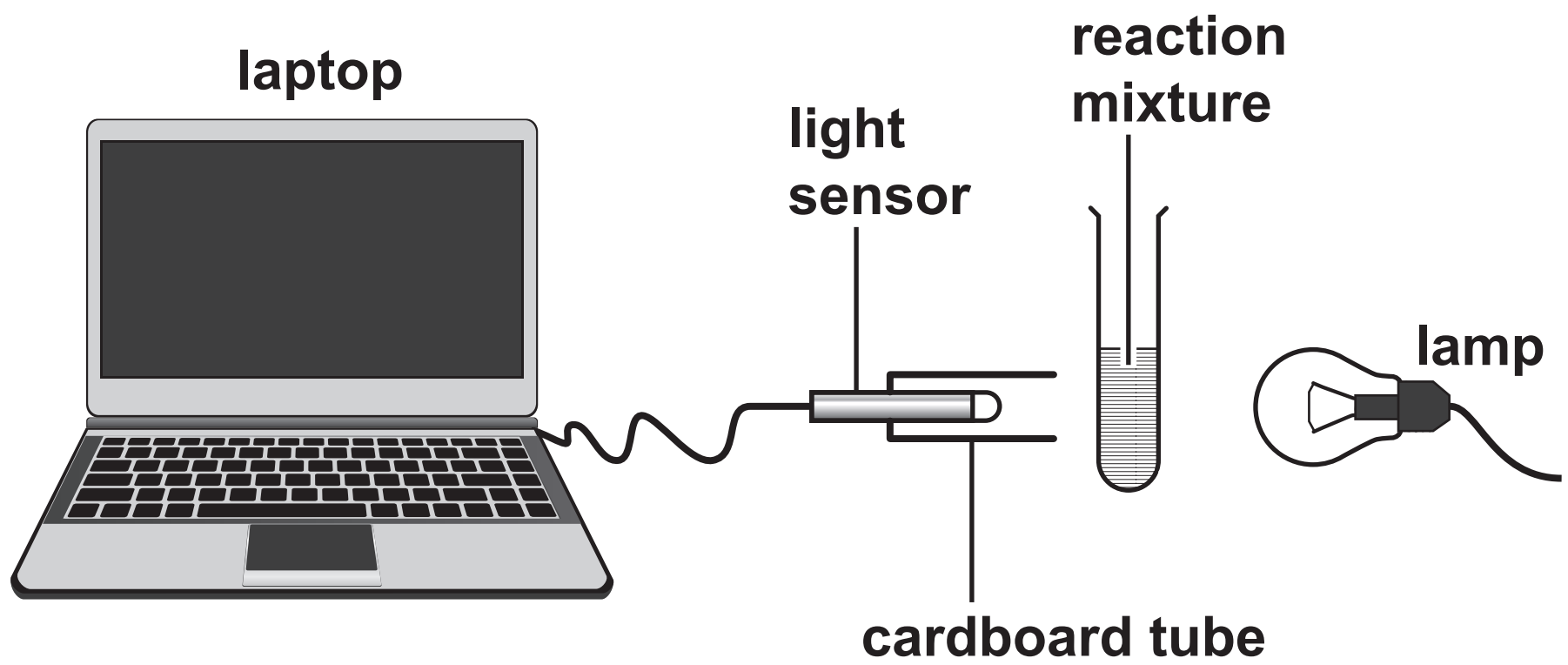
product C



product A



Question 11 (a)



GRAPH

