

**Paper Reference(s) WCH04/01**

**Pearson Edexcel  
International Advanced Level**

## **Chemistry**

**Advanced**

**Unit 4: General Principles of Chemistry I – Rates,  
Equilibria and Further Organic Chemistry  
(including synoptic assessment)**

**Thursday 10 January 2019 – Afternoon**

**Time: 1 hour 40 minutes plus your additional time  
allowance**

### **INSTRUCTIONS TO CANDIDATES**

**Write your centre number, candidate number,  
surname, other names and your signature in the  
boxes below. Check that you have the correct  
question paper.**

<b>Centre No.</b>							
<b>Candidate No.</b>							
<b>Surname</b>							
<b>Other names</b>							
<b>Signature</b>							
<b>Paper Reference</b>	<b>W</b>	<b>C</b>	<b>H</b>	<b>0</b>	<b>4</b>	<b>/</b>	<b>0 1</b>



- Use **BLACK** ink or **BLACK** ball-point pen.
- Answer **ALL** questions.
- Answer the questions in the spaces provided – there may be more space than you need.

## **MATERIALS REQUIRED FOR EXAMINATION**

**Scientific calculator, Data Booklet**

## **ITEMS INCLUDED WITH QUESTION PAPERS**

**Periodic Table**

## **INFORMATION FOR CANDIDATES**

- The total mark for this paper is 90.
- The marks for **EACH** question are shown in brackets – use this as a guide as to how much time to spend on each question.
- Questions labelled with an **ASTERISK (\*)** are ones where the quality of your written communication will be assessed – you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.
- A Periodic Table is provided.

## **ADVICE TO CANDIDATES**

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

**(Turn over)**

## SECTION A

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box ☐. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☐.

- 1 Propanone reacts with iodine in acidic solution according to the equation



Which method would NOT be suitable for obtaining the rate of this reaction?

- ☐ A Colorimetry.
- ☐ B Measuring the increase in pH of the solution.
- ☐ C Measuring the increase in the infrared absorption for the C–I bond.
- ☐ D Quenching followed by titrating with sodium thiosulfate.

(TOTAL FOR QUESTION 1 = 1 MARK)

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(Questions continue on next page)

(Turn over)

2 For the reaction



the rate equation is

$$\text{rate} = k[\text{HgCl}_2(\text{aq})][\text{C}_2\text{O}_4^{2-}(\text{aq})]^2$$

The concentrations of both  $\text{HgCl}_2$  and  $\text{C}_2\text{O}_4^{2-}$  are increased by a factor of three.

The rate of reaction increases by a factor of

☐ A 3

☐ B 9

☐ C 12

☐ D 27

(TOTAL FOR QUESTION 2 = 1 MARK)

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(Questions continue on next page)

(Turn over)

- 3 To determine the activation energy,  $E_a$ , for a reaction, a graph was plotted of  $\ln k$  against  $1/T$ , where  $k$  is the rate constant.

The Arrhenius equation is

$$\ln k = -\frac{E_a}{RT} + \text{constant}$$

The gradient of the graph is equal to

☐ A  $-E_a$

☐ B  $-\frac{E_a}{R}$

☐ C  $-\frac{E_a}{T}$

☐ D  $-\frac{E_a}{RT}$

(TOTAL FOR QUESTION 3 = 1 MARK)

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(Questions continue on next page)

(Turn over)

4 Which is correct for standard molar entropy?

	Highest entropy	Medium entropy	Lowest entropy
<input type="checkbox"/> A	Hydrogen	Nitrogen	Iron
<input type="checkbox"/> B	Nitrogen	Iron	Hydrogen
<input type="checkbox"/> C	Nitrogen	Hydrogen	Iron
<input type="checkbox"/> D	Iron	Nitrogen	Hydrogen

(TOTAL FOR QUESTION 4 = 1 MARK)

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(Questions continue on next page)

(Turn over)

- 5 The Haber process is used to make ammonia from nitrogen and hydrogen at 450 °C.



When the temperature of the system is increased,

- ☐ A  $K_p$  decreases.
- ☐ B  $K_p$  increases.
- ☐ C  $K_p$  stays the same.
- ☐ D  $K_p$  increases and then decreases.

(TOTAL FOR QUESTION 5 = 1 MARK)

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(Questions continue on next page)

- 6 When magnesium hydroxide dissolves in water, the following equilibrium is established.



The expression for the equilibrium constant,  $K_c$ , is

☐ A  $[\text{Mg}^{2+}(\text{aq})] \times 2[\text{OH}^{-}(\text{aq})]$

☐ B  $[\text{Mg}^{2+}(\text{aq})] \times [\text{OH}^{-}(\text{aq})]^2$

☐ C  $\frac{[\text{Mg}^{2+}(\text{aq})] \times 2[\text{OH}^{-}(\text{aq})]}{[\text{Mg(OH)}_2(\text{s})]}$

☐ D  $\frac{[\text{Mg}^{2+}(\text{aq})] \times [\text{OH}^{-}(\text{aq})]^2}{[\text{Mg(OH)}_2(\text{s})]}$

(TOTAL FOR QUESTION 6 = 1 MARK)

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(Questions continue on next page)



- 7 Energy is given out when one mole of gaseous magnesium ions is hydrated.



This is more exothermic than the corresponding value for barium ions,  $\text{Ba}^{2+}$ , because the

- ☐ A ionic radius of  $\text{Mg}^{2+}$  is less than that of  $\text{Ba}^{2+}$ .
- ☐ B ionisation energy of magnesium is greater than that of barium.
- ☐ C lattice energy of magnesium oxide is more exothermic than that of barium oxide.
- ☐ D solubility of magnesium hydroxide in water is less than that of barium hydroxide.

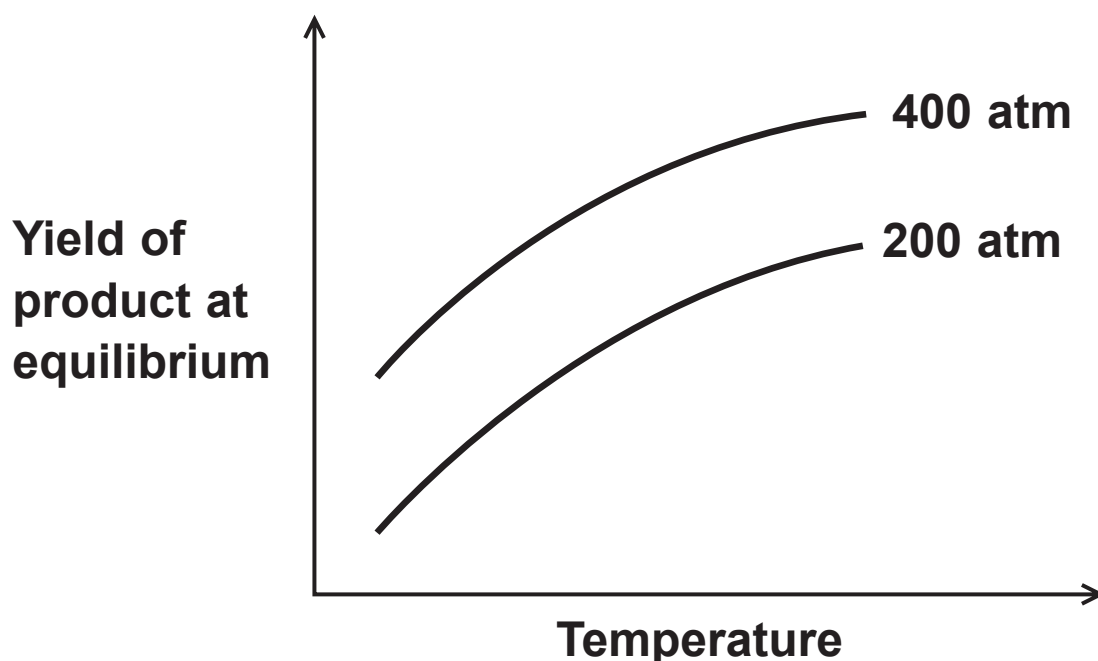
(TOTAL FOR QUESTION 7 = 1 MARK)

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(Questions continue on next page)

(Turn over)

- 8 The graph shows the yield of product in a gaseous equilibrium at different temperatures and pressures.



The forward reaction is

- ☐ A exothermic, and there are more moles of gas on the right-hand side.
- ☐ B endothermic, and there are more moles of gas on the right-hand side.
- ☐ C exothermic, and there are fewer moles of gas on the right-hand side.
- ☐ D endothermic, and there are fewer moles of gas on the right-hand side.

(TOTAL FOR QUESTION 8 = 1 MARK)

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(Questions continue on next page)

(Turn over)

- 9 An aqueous solution contains 4.0 g of sodium hydroxide in 250 cm<sup>3</sup> of solution.

$$[K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}]$$

$$\text{Molar mass of NaOH} = 40 \text{ g mol}^{-1}]$$

The pH of the solution is

☐ A 13.0

☐ B 13.4

☐ C 13.6

☐ D 13.9

(TOTAL FOR QUESTION 9 = 1 MARK)

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(Questions continue on next page)

(Turn over)

10 A solution containing HCN and KCN is a buffer. When a small amount of acid is added, the solution acts as a buffer because

- ☐ A hydrogen ions in the acid combine with cyanide ions to make HCN.
- ☐ B hydrogen ions in the acid combine with HCN to make  $\text{H}_2\text{CN}^+$ .
- ☐ C HCN dissociates to make more  $\text{CN}^-$  ions.
- ☐ D the hydrogen ions in the acid prevent dissociation of the HCN.

(TOTAL FOR QUESTION 10 = 1 MARK)

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(Questions continue on next page)

- 11 When 0.1 mol of hydrogen and 0.1 mol of iodine were allowed to react according to the equation



30% of the hydrogen was found to have been converted at equilibrium.

The number of moles of each gas present at equilibrium is

	Hydrogen	Iodine	Hydrogen iodide
<input type="checkbox"/> A	0.03	0.03	0.07
<input type="checkbox"/> B	0.03	0.03	0.14
<input type="checkbox"/> C	0.07	0.07	0.03
<input type="checkbox"/> D	0.07	0.07	0.06

(TOTAL FOR QUESTION 11 = 1 MARK)

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(Questions continue on next page)

(Turn over)

12 Which compound can show both geometric AND optical isomerism?

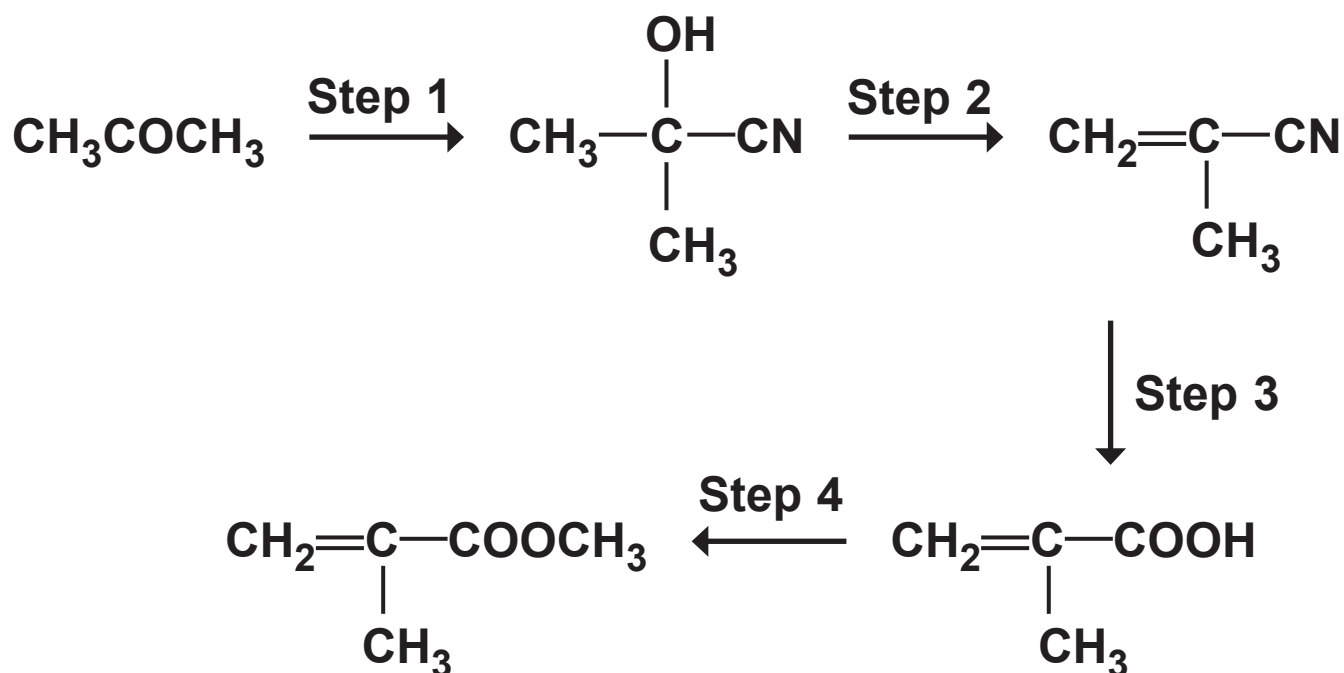
- ☐ A  $(\text{CH}_3)_2\text{C}=\text{CHCH}(\text{CH}_3)\text{CH}_2\text{CH}_3$
- ☐ B  $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}(\text{CH}_3)\text{CH}_2\text{CH}_3$
- ☐ C  $(\text{CH}_3)_2\text{C}=\text{C}(\text{CH}_2\text{CH}_3)_2$
- ☐ D  $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}(\text{CH}_3)_2$

(TOTAL FOR QUESTION 12 = 1 MARK)

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(Questions continue on next page)

13 Which set of reagents is NOT suitable for the step indicated?



- ☐ A Step 1: HCN and KCN
- ☐ B Step 2: hot ethanolic KOH
- ☐ C Step 3: warm aqueous  $\text{H}_2\text{SO}_4$
- ☐ D Step 4:  $\text{CH}_3\text{OH}$  with an acid catalyst

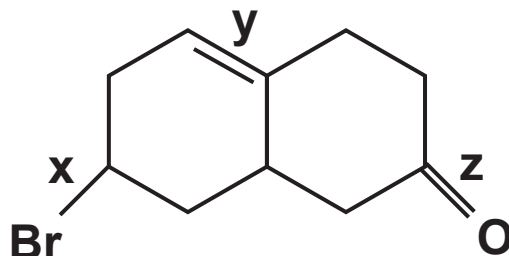
(TOTAL FOR QUESTION 13 = 1 MARK)

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(Questions continue on next page)

(Turn over)

- 14 The molecule shown has three functional groups labelled x, y and z.



Which of the functional groups can undergo nucleophilic attack?

- ☐ A x, y and z
- ☐ B x and z only
- ☐ C x only
- ☐ D z only

(TOTAL FOR QUESTION 14 = 1 MARK)

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(Questions continue on next page)

(Turn over)



15 What is the formula of the pale yellow solid formed when propanone reacts with iodine in the presence of sodium hydroxide?

- ☐ A  $\text{NaI}$
- ☐ B  $\text{CH}_3\text{COCH}_2\text{I}$
- ☐ C  $\text{CH}_3\text{I}$
- ☐ D  $\text{CHI}_3$

(TOTAL FOR QUESTION 15 = 1 MARK)

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16 Butanone can be distinguished from butanoic acid by the addition of

- ☐ A Fehling's solution and warming.
- ☐ B Tollens' reagent and warming.
- ☐ C 2,4-dinitrophenylhydrazine solution.
- ☐ D acidified potassium dichromate(VI) solution and refluxing.

(TOTAL FOR QUESTION 16 = 1 MARK)

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(Questions continue on next page)

(Turn over)

17 Which could be used to make  $\text{CH}_3\text{CONHCH}_3$ ?

- ☐ A  $\text{CH}_3\text{COOCH}_3$  and  $\text{NH}_3$
- ☐ B  $\text{CH}_3\text{CONH}_2$  and  $\text{CH}_3\text{NH}_2$
- ☐ C  $\text{CH}_3\text{COO}^-\text{Na}^+$  and  $\text{CH}_3\text{NH}_2$
- ☐ D  $\text{CH}_3\text{COCl}$  and  $\text{CH}_3\text{NH}_2$

(TOTAL FOR QUESTION 17 = 1 MARK)

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18 Which reaction may be used to make a carboxylic acid in a single step?

- ☐ A Hydrolysis of an ester with hydrochloric acid.
- ☐ B Hydrolysis of an ester with sodium hydroxide.
- ☐ C Reaction of acidified potassium manganate(VII) with an alkene.
- ☐ D Reaction of an acyl chloride with ammonia.

(TOTAL FOR QUESTION 18 = 1 MARK)

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(Questions continue on next page)

(Turn over)

19 The mass spectrum of ethanoyl chloride would NOT be expected to have a peak at the  $m/e$  value of

☐ A 35.5

☐ B 37

☐ C 43

☐ D 78

(TOTAL FOR QUESTION 19 = 1 MARK)

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20 A ketone which would not be expected to have a peak in its mass spectrum at  $m/e = 57$  is

☐ A butanone,  $\text{CH}_3\text{CH}_2\text{COCH}_3$

☐ B 3-methylbutanone,  $(\text{CH}_3)_2\text{CHCOCH}_3$

☐ C pentan-3-one,  $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$

☐ D hexan-3-one,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COCH}_2\text{CH}_3$

(TOTAL FOR QUESTION 20 = 1 MARK)

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TOTAL FOR SECTION A = 20 MARKS

(Section B begins on next page)

(Turn over)

## SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

- 21 Methanol has been proposed as a carbon-neutral fuel because it can be synthesised from carbon dioxide, as shown in the equation



- (a) Standard enthalpy change of formation and standard molar entropy data for the reactants and products are shown in the table.

	$\text{CO}_2(\text{g})$	$\text{H}_2(\text{g})$	$\text{CH}_3\text{OH}(\text{g})$	$\text{H}_2\text{O}(\text{g})$
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-394	0	-201	-242
$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$	214	131	238	189

(Question continues on next page)

(i) Calculate the standard enthalpy change for this reaction. (2 marks)

(ii) Calculate the standard entropy change in the system,  $\Delta S_{\text{system}}$ , for this reaction. (2 marks)

- (iii) Calculate the total entropy change,  $\Delta S_{\text{total}}$ , for this reaction at 298K. (3 marks)

(Question continues on next page)

**(iv) Calculate the highest temperature at which the reaction is feasible. (2 marks)**

**(v) State why the industrial process is carried out at a higher temperature than you have calculated. (1 mark)**

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- (b) (i) Write the equation for the complete combustion of methanol in the gas phase. State symbols are not required. (1 mark)**

- \*(ii) Suggest why this combustion reaction in the gas phase is likely to be thermodynamically feasible at ALL temperatures. Calculations are not required. (3 marks)**

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**(Continue your answer on next page)**

**(Turn over)**



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**(Question continues on next page)**

- (c) Give TWO reasons why methanol, synthesised from carbon dioxide and hydrogen, may NOT be a completely carbon-neutral fuel. (2 marks)

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**(TOTAL FOR QUESTION 21 = 16 MARKS)**

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**(Questions continue on next page)**

**(Turn over)**

**22 This question is about three colourless liquids butanal, pentane and propenoic acid. The bottles have lost their labels.**

**(a) Propenoic acid is the simplest carboxylic acid containing a carbon to carbon double bond.**

**(i) Draw the DISPLAYED formula of propenoic acid showing ALL the bonds.  
(1 mark)**

**(Question continues on next page)**

**(Turn over)**

- (ii) Propenoic acid reacts with methanol at a temperature of  $100^{\circ}\text{C}$  in the presence of an acid catalyst.

Name the product of this reaction and draw its SKELETAL formula. (2 marks)

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(Question continues on next page)

- (iii) Under appropriate conditions, propenoic acid will react with lithium tetrahydridoaluminate(III) ( $\text{LiAlH}_4$ ).

Identify the conditions necessary for this reaction and give the **STRUCTURAL** formula of the expected product. (2 marks)

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- (iv) The polymerisation of propenoic acid forms poly(propenoic acid), which is used in the manufacture of superabsorbents.

Draw the structure of poly(propenoic acid) showing two repeat units. (1 mark)

(Question continues on next page)

(Turn over)

(b) The three liquids can be identified by their boiling temperatures.

- (i) Complete the table with the boiling temperatures of butanal and pentane in  $^{\circ}\text{C}$  and the number of electrons in propenoic acid. Use the Data Booklet where necessary. (2 marks)

	butanal	pentane	propenoic acid
Boiling temperature / $^{\circ}\text{C}$			141
Number of electrons	40	42	

- \*(ii) Explain the differences in boiling temperature of these three compounds using the information in the table and their structures. A detailed explanation of the forces involved is NOT required. (3 marks)

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(Continue your answer on next page)

(Turn over)

**(Turn over)**

- (c) Chemical tests can also be used to identify two of the liquids, and hence, by elimination, the third.

**Give TWO chemical tests and the expected positive results. The use of indicators will NOT be accepted as a chemical test. (4 marks)**

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**(Continue your answer on next page)**

**(Turn over)**

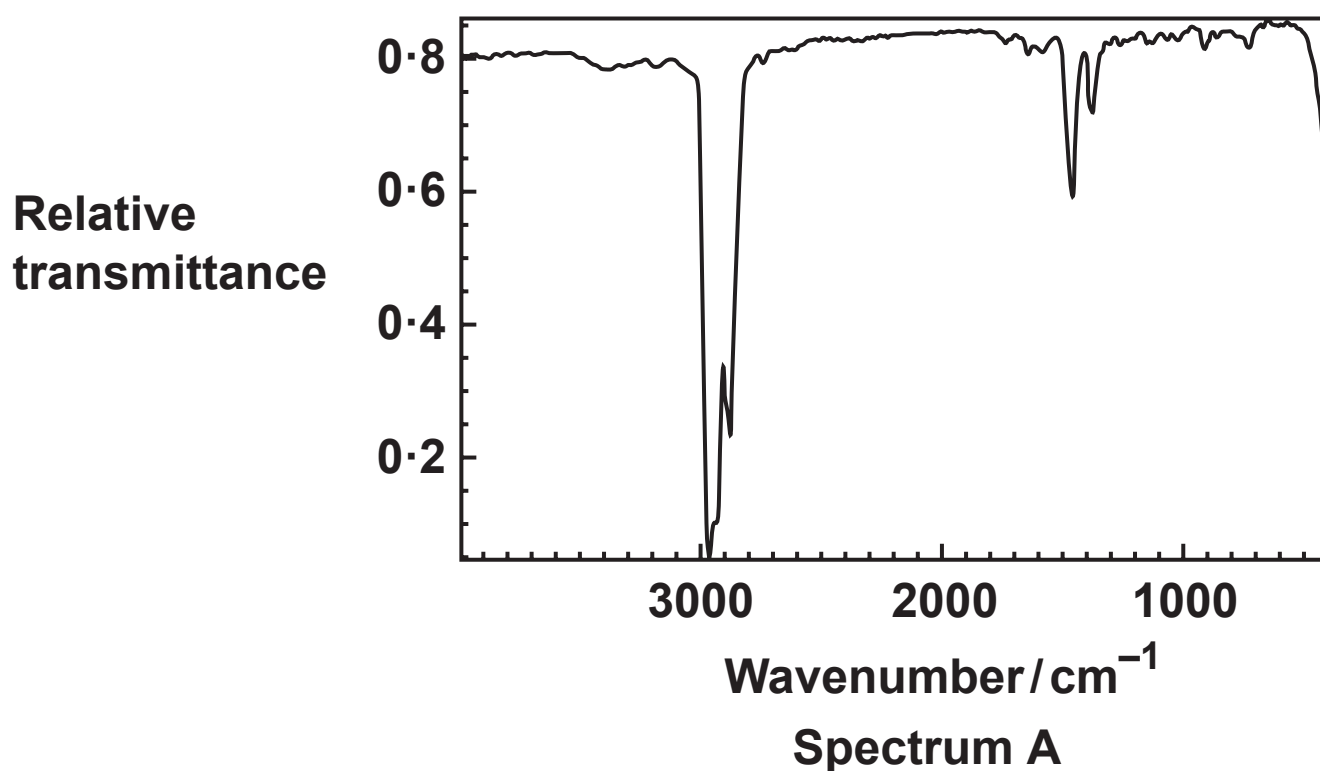


**(Turn over)**

(d) The three liquids can also be identified using infrared spectroscopy.

(i) Spectrum A contains very few peaks.

Identify which of the three liquids gives this spectrum and explain why it has fewer peaks than the other spectra. (2 marks)



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(Continue your answer on next page)

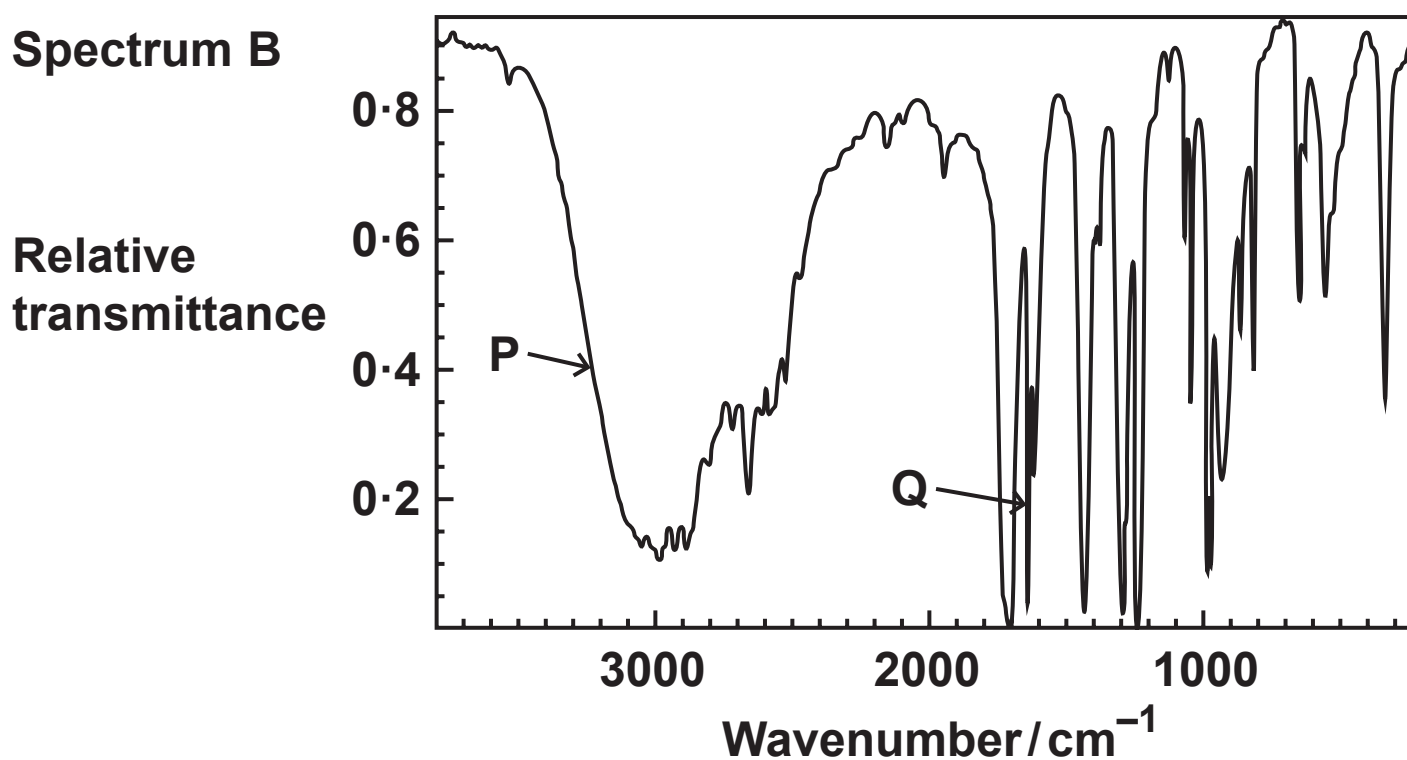
(Turn over)

- (ii) Spectra B and C are the infrared spectra of the other two liquids.

Using information from the Data Booklet, identify the **BONDS** responsible for the peaks labelled P, Q and R.

Hence state which spectrum is given by which liquid. (3 marks)

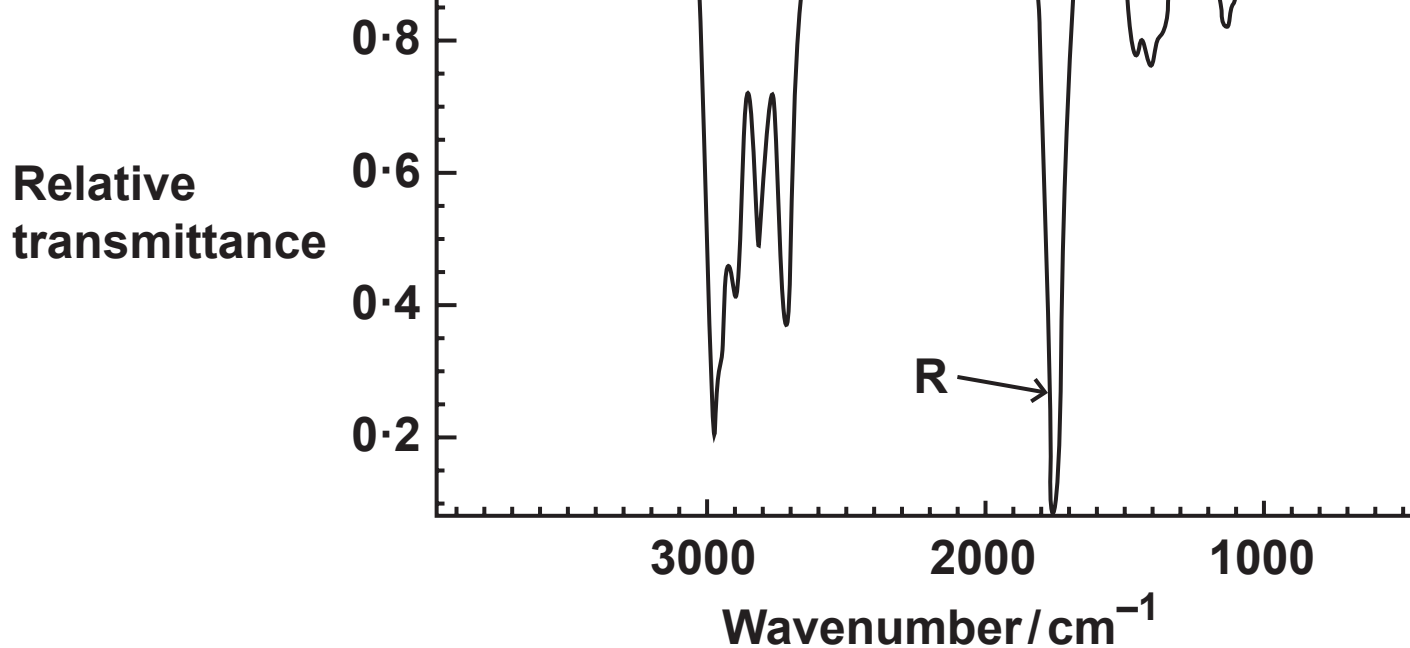
**Spectrum B**



(Question continues on next page)

(Turn over)

Spectrum C



P \_\_\_\_\_

Q \_\_\_\_\_

R \_\_\_\_\_

Spectrum B \_\_\_\_\_

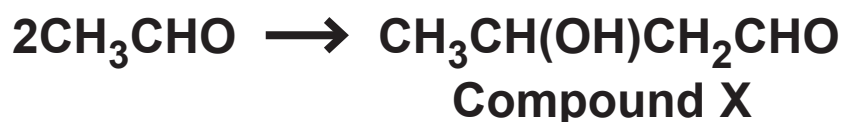
Spectrum C \_\_\_\_\_

(TOTAL FOR QUESTION 22 = 20 MARKS)

(Questions continue on next page)

(Turn over)

- 23 Compound X can be formed by a dimerisation reaction where two molecules of ethanal link together, as shown in the equation.

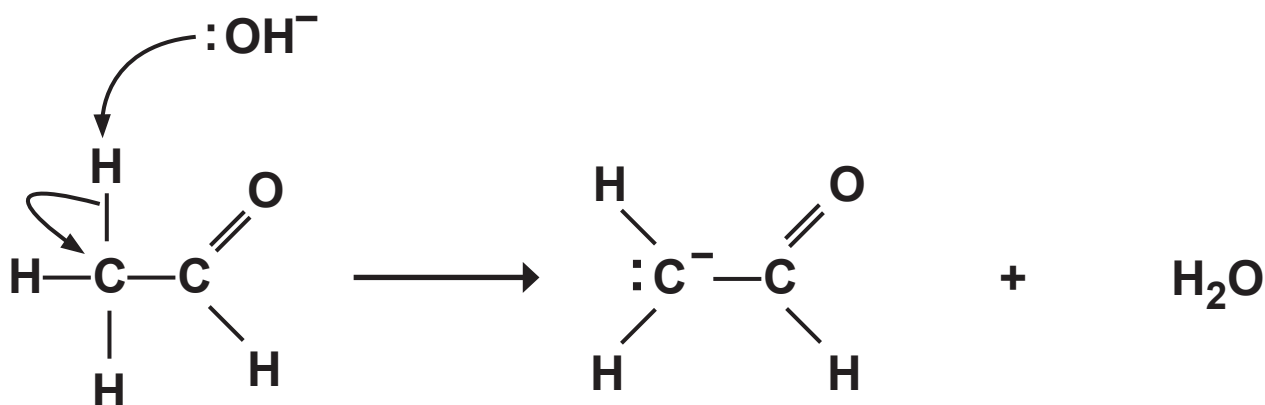


- (a) Give the name of compound X. (1 mark)
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- (b) The following three-step mechanism has been suggested for this reaction.

Steps 2 and 3 of this mechanism have some similarities to the reaction of aldehydes with hydrogen cyanide in the presence of potassium cyanide.

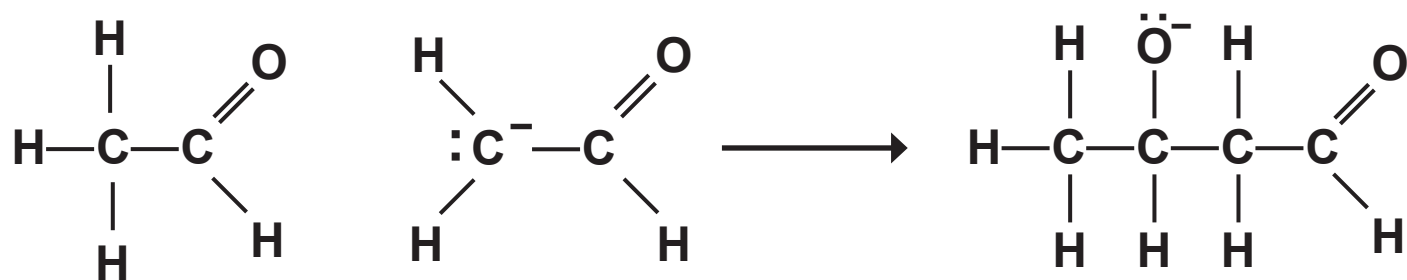
Step 1



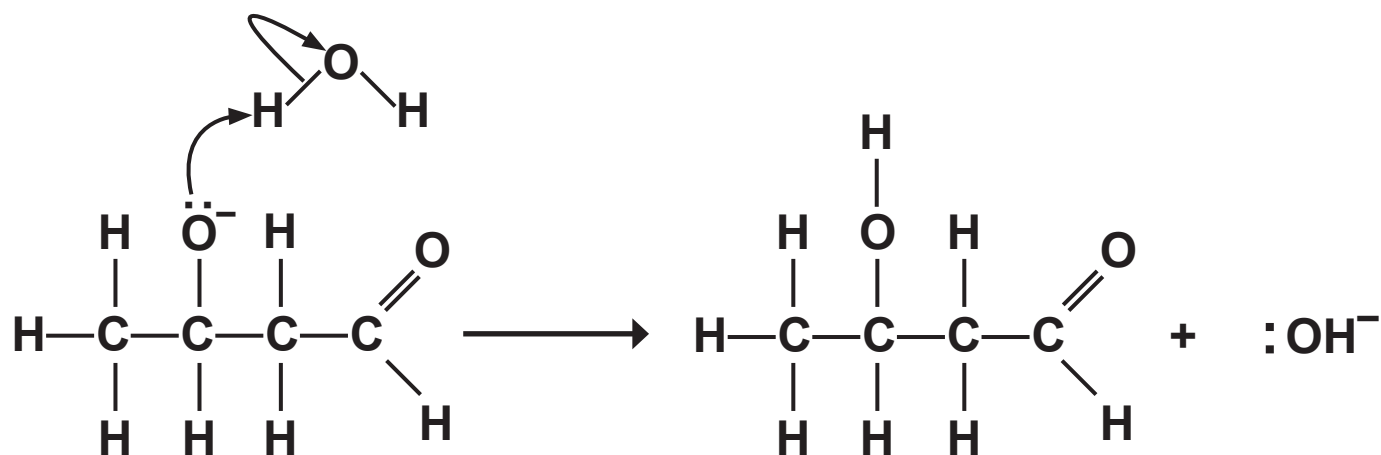
(Question continues on next page)

(Turn over)

## Step 2



## Step 3



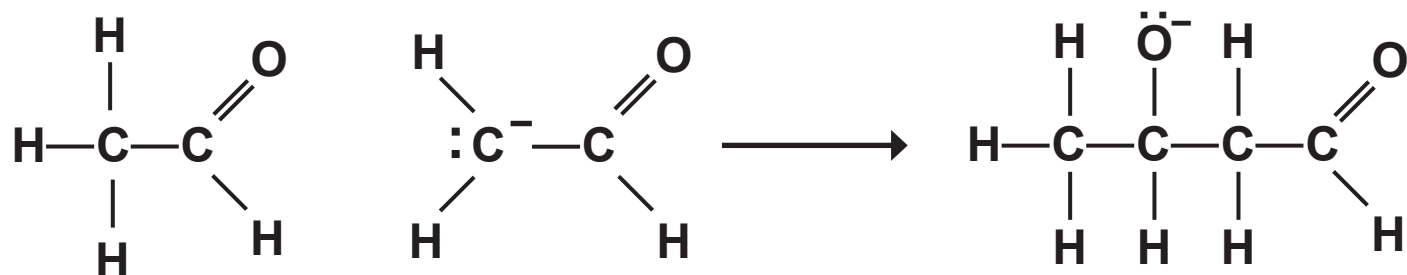
(i) Deduce the role of ethanal in Step 1. (1 mark)

(Question continues on next page)

(Turn over)

- (ii) Complete Step 2 of the mechanism showing the relevant curly arrows. (2 marks)

Step 2



- (iii) Deduce the type and mechanism of the OVERALL reaction. (2 marks)

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- (iv) State the overall role of the hydroxide ion,  $\text{OH}^-$ , in the suggested mechanism. Justify your answer. (2 marks)

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(Continue your answer on next page)

(Turn over)

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- (v) Explain why the sample of X produced by the reaction in (b) does NOT rotate the plane of plane-polarised light. (2 marks)

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(Question continues on next page)

(Turn over)



- (c) At low concentrations of hydroxide ions,  $\text{OH}^-$ , the rate equation for this reaction is

$$\text{rate} = k[\text{CH}_3\text{CHO}][\text{OH}^-]$$

When the concentration of ethanal was  $0.20 \text{ mol dm}^{-3}$  and the concentration of sodium hydroxide was  $0.040 \text{ mol dm}^{-3}$ , the rate of the reaction at  $298 \text{ K}$  was  $8.8 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$ .

- (i) Calculate a value for the rate constant at this temperature. Include units in your answer.  
(2 marks)

(Question continues on next page)

(Turn over)

- (ii) Give a reason why the rate equation suggests that Step 1 is the rate-determining step for this reaction. (1 mark)

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**(TOTAL FOR QUESTION 23 = 13 MARKS)**

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**TOTAL FOR SECTION B = 49 MARKS**

**(Section C begins on next page)**

**(Turn over)**

**SECTION C**

**Answer ALL the questions. Write your answers in the spaces provided.**

**24 Ammonia is manufactured from nitrogen and hydrogen.**



- \*(a) (i) In an experiment, 1 mol of nitrogen and 3 mol of hydrogen were placed in a sealed vessel.**

**At a temperature of 450 K and a pressure of 2 atm, the system reached equilibrium when 20% of the nitrogen had been converted into ammonia.**

**Calculate the value of the equilibrium constant  $K_p$  for this reaction at 450 K, giving units in your answer. (6 marks)**

**(Continue your answer on next page)**

**(Turn over)**

**(Question continues on next page)**

**(Turn over)**

- (ii) Give the equation that relates  $K_p$  to  $\Delta S_{\text{total}}$  and use your equation and your answer to (a)(i) to calculate the total entropy change for the reaction at 450 K. (2 marks)

$$[R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}]$$

- (b) Ammonia is a weak base which reacts with hydrochloric acid according to the equation



25.0 cm<sup>3</sup> of aqueous ammonia with a concentration of 1.00 mol dm<sup>-3</sup> was placed in a conical flask.

It was titrated with hydrochloric acid with a concentration of 0.625 mol dm<sup>-3</sup>.

(Question continues on next page)

(Turn over)

- (i) Calculate the volume of the acid required to react exactly with the aqueous ammonia.  
(2 marks)

(Question continues on next page)

(Turn over)

- (ii) Aqueous ammonium chloride is acidic.  
Write an ionic equation to show the acidic behaviour of the ammonium ion.  
State symbols are not required. (1 mark)

- (iii) Write an expression for  $K_a$  for this dissociation. (1 mark)

(Question continues on next page)

(Turn over)

- (iv) When all of the ammonia has just reacted with hydrochloric acid the concentration of the ammonium chloride solution is  $0.385 \text{ mol dm}^{-3}$ . Calculate the pH of this solution. (3 marks)

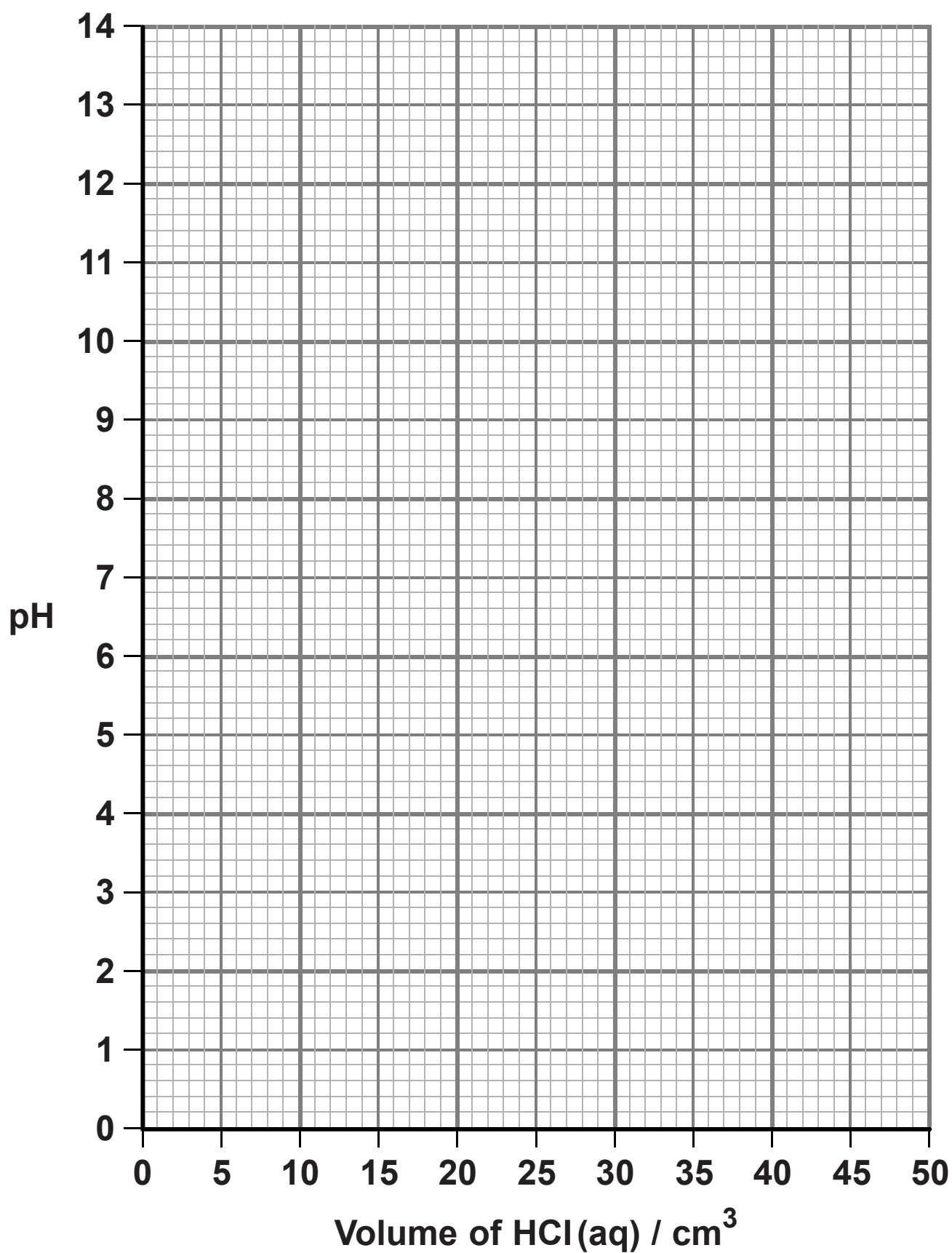
$$[K_a = 5.6 \times 10^{-10} \text{ mol dm}^{-3}]$$



- (v) Using your answers to (b)(i) and (b)(iv), draw the titration curve on page 50, showing the change in pH when  $50.0 \text{ cm}^3$  of  $0.625 \text{ mol dm}^{-3}$  hydrochloric acid solution is added to  $25.0 \text{ cm}^3$  of  $1.00 \text{ mol dm}^{-3}$  ammonia solution.

The pH of  $1.00 \text{ mol dm}^{-3}$  ammonia solution is 11.6. (4 marks)

(Question continues on next page)



(Question continues on next page)

(Turn over)

- (vi) Explain, by referring to the Data Booklet, whether or not thymol blue (base) would be a suitable indicator for this titration. (2 marks)

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**(TOTAL FOR QUESTION 24 = 21 MARKS)**

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**TOTAL FOR SECTION C = 21 MARKS**  
**TOTAL FOR PAPER = 90 MARKS**  
**END**