

Please check the examination details below before entering your candidate information

Candidate surname		Other names	
<b>Pearson Edexcel</b>		Centre Number	Candidate Number
<b>Level 3 GCE</b>		<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>
Time 1 hour 45 minutes	Paper reference	<b>9CH0/02</b>	
<b>Chemistry</b> <b>Advanced</b> <b>PAPER 2: Advanced Organic and Physical Chemistry</b>			
Candidates must have: <b>Scientific calculator</b> <b>Data Booklet</b> <b>Ruler</b>			Total Marks

## Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided  
– *there may be more space than you need.*
- Show all your working in calculations and include units where appropriate.

## Information

- 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.*
- For the question marked with an asterisk (\*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

## Advice

- Read each question carefully before you start to answer it.
- Check your answers if you have time at the end.
- Good luck with your examination.

Turn over ►

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Answer ALL questions.

Some questions must be answered with a cross in a box ☐.  
If you change your mind about an answer, put a line through the box ☒  
and then mark your new answer with a cross ☐.

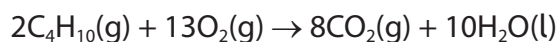
- 1 What is the total number of **ions** in 26.4 g of ammonium sulfate,  $(\text{NH}_4)_2\text{SO}_4$ ?

[Molar mass of  $(\text{NH}_4)_2\text{SO}_4 = 132 \text{ g mol}^{-1}$       Avogadro constant =  $6.0 \times 10^{23} \text{ mol}^{-1}$ ]

- ☐ A  $4.0 \times 10^{22}$   
☐ B  $1.2 \times 10^{23}$   
☐ C  $2.4 \times 10^{23}$   
☐ D  $3.6 \times 10^{23}$

(Total for Question 1 = 1 mark)

- 2 The equation for the complete combustion of butane is



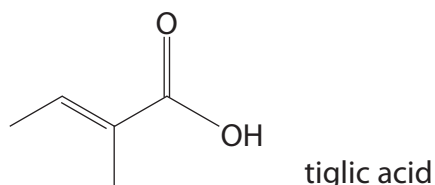
What is the minimum volume of oxygen, at room temperature and pressure (r.t.p.),  
needed for the complete combustion of 0.200 mol of butane?

[Molar volume of a gas at r.t.p. =  $24.0 \text{ dm}^3 \text{ mol}^{-1}$ ]

- ☐ A  $4.8 \text{ dm}^3$   
☐ B  $9.6 \text{ dm}^3$   
☐ C  $31.2 \text{ dm}^3$   
☐ D  $62.4 \text{ dm}^3$

(Total for Question 2 = 1 mark)

- 3 What is the systematic name for tiglic acid?



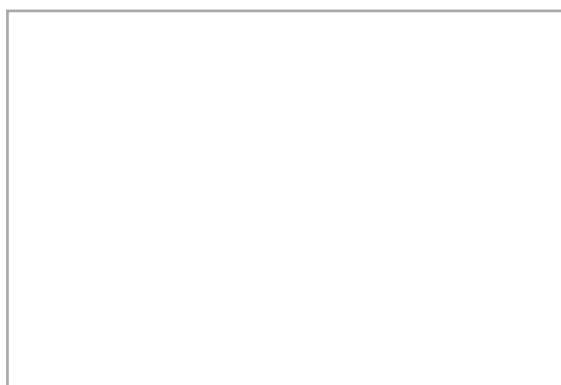
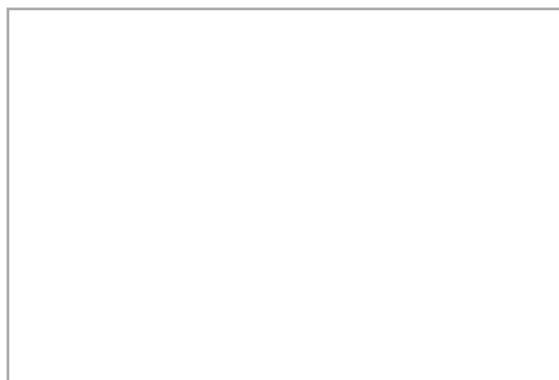
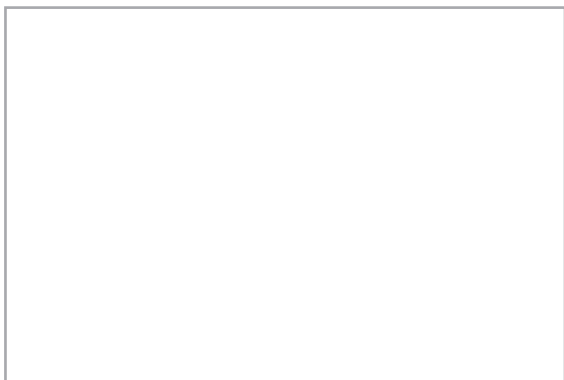
- ☐ A E-2-methylbut-2-enoic acid  
☐ B Z-2-methylbut-2-enoic acid  
☐ C E-3-methylbut-2-enoic acid  
☐ D Z-3-methylbut-2-enoic acid

(Total for Question 3 = 1 mark)

4 This question is about alkenes with the molecular formula  $C_5H_{10}$ .

- (a) Draw the **skeletal** formulae of three **branched** chain alkenes with the molecular formula  $C_5H_{10}$ .

(3)



(b) Which of these compounds would form pent-2-ene **only**, when reacted with concentrated phosphoric acid,  $\text{H}_3\text{PO}_4$ ?

(1)

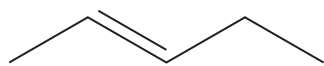
- ☐ A  $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{CH}_3)_2$
- ☐ B  $\text{CH}_2(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
- ☐ C  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$
- ☐ D  $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$

(c) Pent-2-ene reacts with hydrogen bromide,  $\text{HBr}$ , to form two bromoalkanes.

Complete the diagram to show the mechanism for the formation of 2-bromopentane in this reaction.

Include curly arrows, and relevant lone pairs and dipoles.

(4)



- (d) A sample of pent-1-ene, with a mass of 1.33 g, is warmed to 60 °C in a sealed container. The volume of the container is 500 cm<sup>3</sup>.

Calculate the pressure inside the container.

Include units and give your answer to an appropriate number of significant figures.

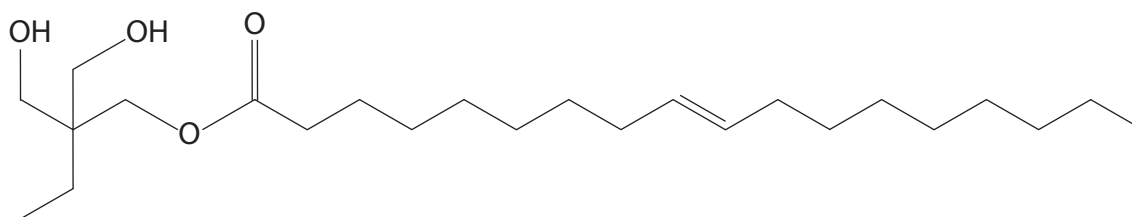
[Gas constant ( $R$ ) = 8.31 J mol<sup>-1</sup> K<sup>-1</sup>]

(4)

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(Total for Question 4 = 12 marks)

- 5 Compound **X** is a component of synthetic oils used as lubricants, for instance in the gearboxes of ships.



compound **X**

- (a) Name the **three** functional groups present in compound **X**.

(2)

- (b) The effectiveness of this synthetic oil is much reduced if it is contaminated with water.

Give, in terms of a chemical reaction, a possible reason for this.

(1)

(c) An alternative to synthetic oil is known as mineral oil and consists solely of hydrocarbons separated from crude oil.

(i) What is the name of the process used to separate different hydrocarbons from crude oil?

(1)

- ☐ **A** cracking
- ☐ **B** reforming
- ☐ **C** fractional distillation
- ☐ **D** heating under reflux

(ii) Explain why compound **X** is likely to have a higher boiling temperature than hydrocarbons of a similar molecular mass and shape.

A detailed description of how the intermolecular forces arise is not required.

(2)

(Total for Question 5 = 6 marks)

- 6 This question is about carbon monoxide, CO, which is a toxic and colourless gas used widely in the chemical industry.

(a) Draw a dot-and-cross diagram of a molecule of carbon monoxide.

Use dots (•) for the carbon electrons and crosses (×) for the oxygen electrons.

(2)

(b) Carbon monoxide can be made by the thermal decomposition of sodium ethanedioate.

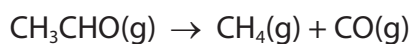


Calculate the atom economy, by mass, for the production of carbon monoxide in this reaction.

(2)



- (c) Carbon monoxide can also be made by the thermal decomposition of ethanal,  $\text{CH}_3\text{CHO}$ , in the gas phase.



This reaction was carried out at two different temperatures, and all other variables were kept constant.

Temperature / K	Rate / $\text{mol dm}^{-3} \text{s}^{-1}$	1/Temperature (1/T) / $\text{K}^{-1}$	ln rate
700	0.0108	$1.43 \times 10^{-3}$	
850	4.90		1.59

- (i) Complete the data in the table. (1)
- (ii) Calculate the activation energy,  $E_a$ , for the reaction without plotting a graph. Include a sign and units in your answer.

The Arrhenius equation may be written as

$$\ln \text{rate} = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant} \quad [R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}] \quad (3)$$

- (d) Haemoglobin (Hb) found in red blood cells reacts almost irreversibly with carbon monoxide.

Initial rate experiments were carried out to investigate the effect of the concentrations of Hb and CO on the rate of this reaction.

Experiment	[Hb] / mol dm <sup>-3</sup>	[CO] / mol dm <sup>-3</sup>	Rate / mol dm <sup>-3</sup> s <sup>-1</sup>
1	$2.09 \times 10^{-6}$	$1.40 \times 10^{-6}$	$8.20 \times 10^{-7}$
2	$4.18 \times 10^{-6}$	$1.40 \times 10^{-6}$	$1.64 \times 10^{-6}$
3	$3.26 \times 10^{-6}$	$2.80 \times 10^{-6}$	$2.56 \times 10^{-6}$

- (i) Deduce the order of reaction with respect to haemoglobin. (1)

- (ii) Determine the order with respect to carbon monoxide using your answer to (d)(i) and the data in the table. Justify your answer. (2)

- (iii) Write the rate equation for this reaction using your answers to (d)(i) and (d)(ii). (1)

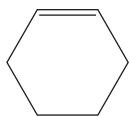
- (iv) Calculate the rate constant,  $k$ , for the reaction, using the data from Experiment 1 and the rate equation from (d)(iii).  
Include units in your answer.

(3)

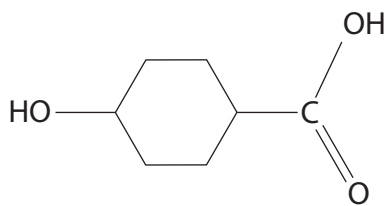
(Total for Question 6 = 15 marks)

**\*7** This question is about polymers.

(a) Compare and contrast how each of these monomers forms a polymer.



cyclohexene



4-hydroxycyclohexanecarboxylic acid

Include equations, showing the formation of a single repeat unit for each polymer.

(6)

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- (b) Give three ways in which waste polymers can be utilised to improve their sustainability.

(3)

(Total for Question 7 = 9 marks)

8 This question is about a dicarboxylic acid **Y** which is present in some citrus fruits. **Y** contains only the elements carbon, hydrogen and oxygen.

- (a) A sample of **Y** with a mass of 1.98 g was burned completely in excess oxygen. The reaction formed 2.51 g of carbon dioxide,  $\text{CO}_2$ , and 0.69 g of water,  $\text{H}_2\text{O}$ .

Use these data to calculate the empirical formula of **Y**.

(4)

- (b) A solution was prepared using 4.34 g of the dicarboxylic acid **Y** made up to a volume of  $250\text{ cm}^3$  with distilled water.

A  $25.0\text{ cm}^3$  sample of this solution was then titrated using sodium hydroxide solution,  $\text{NaOH(aq)}$ , of concentration  $0.320\text{ mol dm}^{-3}$ .

The mean titre of sodium hydroxide solution was  $26.10\text{ cm}^3$ .

Calculate the molar mass of **Y** using the titration data, and hence deduce its structure. You must show your working.

(5)

- (c) Which of these is used to convert a dicarboxylic acid into a diol?

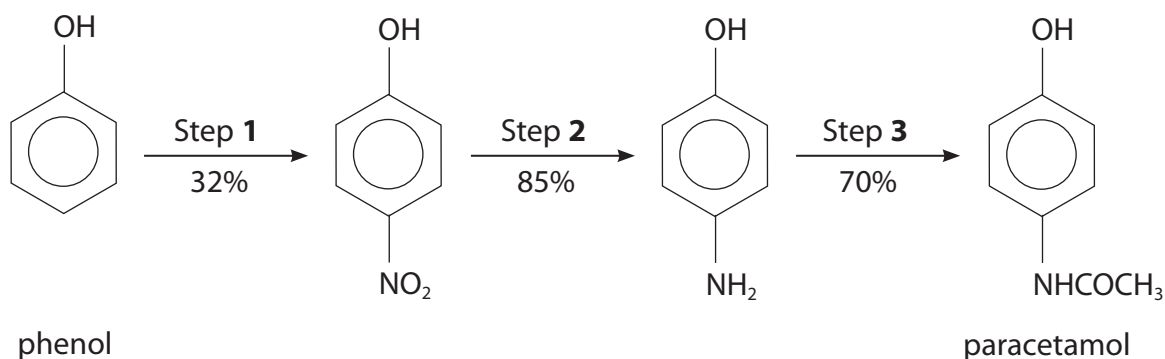
(1)

- ☐ **A**  $\text{LiAlH}_4$  and ether
- ☐ **B**  $\text{KMnO}_4$  and  $\text{H}_2\text{SO}_4$
- ☐ **C** Sn and HCl
- ☐ **D**  $\text{Na}_2\text{Cr}_2\text{O}_7$  and  $\text{H}_2\text{SO}_4$

(Total for Question 8 = 10 marks)



- 9 The painkiller paracetamol can be synthesised from phenol in three steps. The percentage yield for each step is shown.



- (a) In Step 1 another product also forms. The two products can be distinguished using their  $^{13}\text{C}$  NMR spectra.

Complete the table to show the number of peaks in each  $^{13}\text{C}$  NMR spectrum.

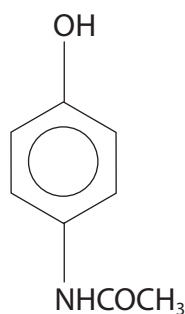
(2)

Product		
Number of peaks in the $^{13}\text{C}$ NMR spectrum		

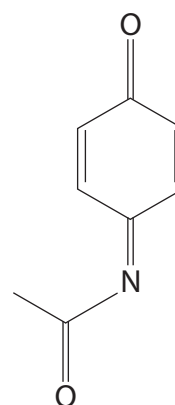
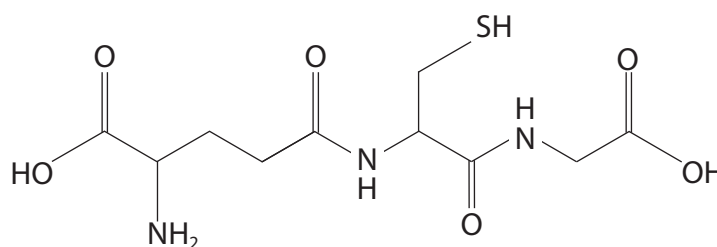
- (b) Calculate the minimum mass of phenol needed to synthesise 1.00 kg of paracetamol. [ $M_r$  values: paracetamol = 151.0 phenol = 94.0]

(3)

- (c) When metabolised in the body, paracetamol forms a toxic compound **Z**. This is then removed in the liver by a reaction with the tripeptide glutathione.



paracetamol

compound **Z**

glutathione

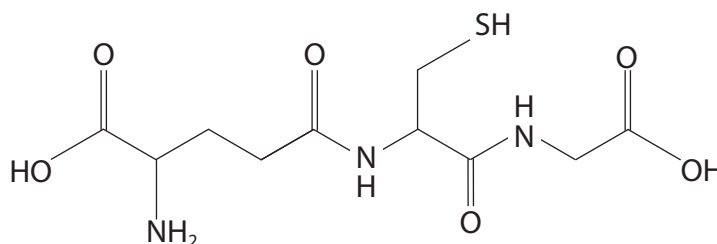
- (i) The conversion of paracetamol to compound **Z** is

(1)

- ☐ **A** addition  
☐ **B** hydrolysis  
☐ **C** oxidation  
☐ **D** reduction

- (ii) Draw a circle around each of the chiral carbon atoms in glutathione.

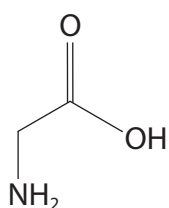
(1)



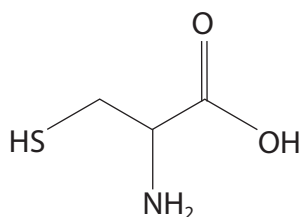
(iii) Glutathione is formed from glycine and two other amino acids.

Which two amino acids combine with glycine to form glutathione?

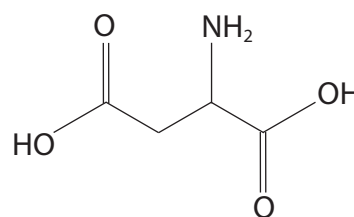
(1)



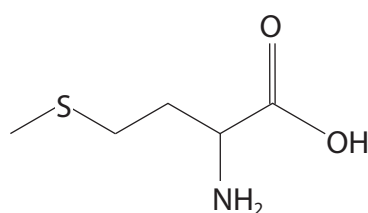
glycine



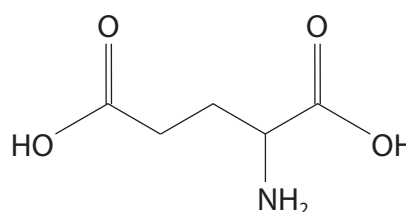
cysteine



aspartic acid



methionine



glutamic acid

- ☐ **A** aspartic acid and cysteine
- ☐ **B** glutamic acid and cysteine
- ☐ **C** glutamic acid and methionine
- ☐ **D** aspartic acid and methionine

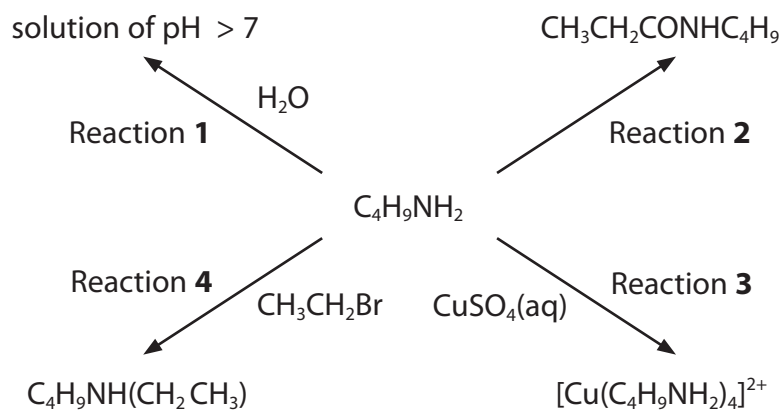
(d) Explain why amino acids such as glycine are crystalline solids at room temperature.

(2)

(Total for Question 9 = 10 marks)

**10** This question is about the amines butylamine,  $\text{C}_4\text{H}_9\text{NH}_2$ , and phenylamine,  $\text{C}_6\text{H}_5\text{NH}_2$ .

The reaction scheme shows some reactions of butylamine, a primary amine.



- (a) (i) Write the equation for Reaction 1 to show why the pH of the solution is greater than 7. State symbols are not required.

(1)

- (ii) Explain why phenylamine is a weaker base than butylamine.

(3)

- (b) Give the name and structural formula of the compound needed to react with butylamine in Reaction 2.

(2)

Name

Structural formula

(c) What is seen when excess butylamine is used in Reaction 3?

(1)

- ☐ A blue solution
- ☐ B blue precipitate
- ☐ C yellow solution
- ☐ D yellow precipitate

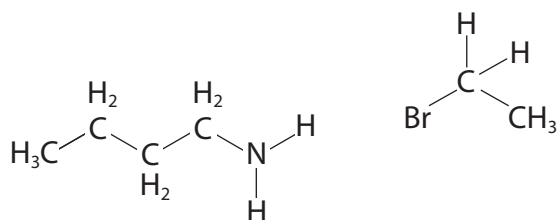
(d) (i) What is the type and mechanism of the reaction in Reaction 4?

(1)

- ☐ A electrophilic addition
- ☐ B electrophilic substitution
- ☐ C nucleophilic addition
- ☐ D nucleophilic substitution

(ii) Complete the diagram to show the mechanism for Reaction 4.  
Include curly arrows, and relevant lone pairs and dipoles.

(4)



(Total for Question 10 = 12 marks)

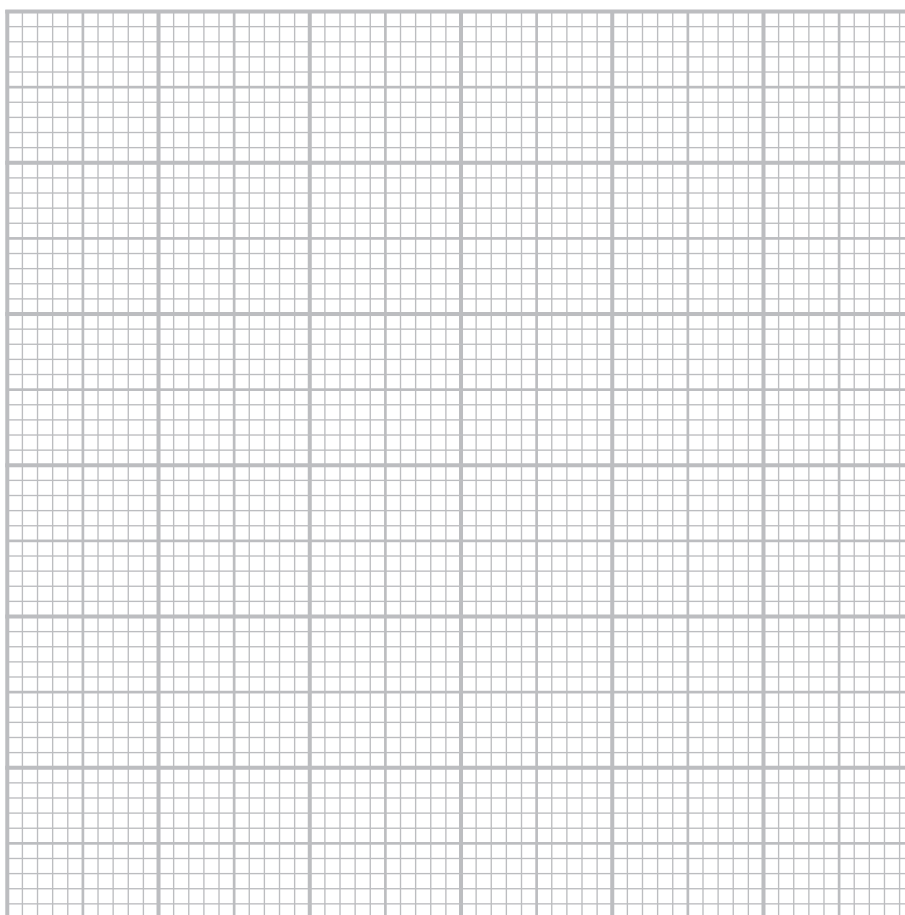
- 11** A series of experiments was carried out to determine the kinetics of the reaction between a chloroalkane,  $\text{RCl}$ , and potassium hydroxide in aqueous solution. A large excess of the chloroalkane was used.

The data obtained are shown.

$[\text{OH}^-] / \text{mol dm}^{-3}$	Time / s
0.00100	39
0.00200	31
0.00300	23
0.00400	16
0.00500	8

- (a) Plot a graph of the concentration of the hydroxide ions against time.

(2)



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- (b) State the order with respect to hydroxide ions.  
Justify your answer by reference to your graph in (a).

(2)

- (c) Deduce the type of mechanism occurring.  
Justify your answer.

(2)

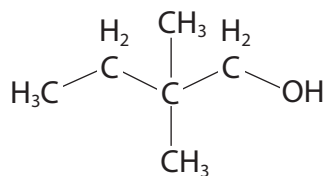
- (d) Give the classification of the chloroalkane in this reaction.

(1)

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**(Total for Question 11 = 7 marks)**

12 The alcohol 2,2-dimethylbutan-1-ol has the structure



Devise a reaction scheme for a synthesis of this alcohol starting from 2-bromo-2-methylbutane.

Include in your answer all reagents and conditions and the structures of any intermediate compounds.

(6)

(Total for Question 12 = 6 marks)

TOTAL FOR PAPER = 90 MARKS

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# The Periodic Table of Elements

1		2												3	4	5	6	7	0 (8)																
																				0 (8) (18)															
																				4.0 He helium 2															
(1)		(2)		Key										(13)		(14)		(15)		(16)		(17)													
6.9 Li lithium 3		9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number										10.8 B boron 5		12.0 C carbon 6		14.0 N nitrogen 7		16.0 O oxygen 8		19.0 F fluorine 9		20.2 Ne neon 10											
23.0 Na sodium 11		24.3 Mg magnesium 12												27.0 Al aluminium 13		28.1 Si silicon 14		31.0 P phosphorus 15		32.1 S sulfur 16		35.5 Cl chlorine 17		39.9 Ar argon 18											
39.1 K potassium 19		40.1 Ca calcium 20		45.0 Sc scandium 21		47.9 Ti titanium 22		50.9 V vanadium 23		52.0 Cr chromium 24		54.9 Mn manganese 25		55.8 Fe iron 26		58.9 Co cobalt 27		58.7 Ni nickel 28		63.5 Cu copper 29		65.4 Zn zinc 30		69.7 Ga gallium 31		72.6 Ge germanium 32		74.9 As arsenic 33		79.0 Se selenium 34		79.9 Br bromine 35		83.8 Kr krypton 36	
85.5 Rb rubidium 37		87.6 Sr strontium 38		88.9 Y yttrium 39		91.2 Zr zirconium 40		92.9 Nb niobium 41		95.9 Mo molybdenum 42		[98] Tc technetium 43		101.1 Ru ruthenium 44		102.9 Rh rhodium 45		106.4 Pd palladium 46		107.9 Ag silver 47		112.4 Cd cadmium 48		114.8 In indium 49		118.7 Sn tin 50		121.8 Sb antimony 51		127.6 Te tellurium 52		126.9 I iodine 53		131.3 Xe xenon 54	
132.9 Cs caesium 55		137.3 Ba barium 56		138.9 La* lanthanum 57		178.5 Hf hafnium 72		180.9 Ta tantalum 73		183.8 W tungsten 74		186.2 Re rhenium 75		190.2 Os osmium 76		192.2 Ir iridium 77		195.1 Pt platinum 78		197.0 Au gold 79		200.6 Hg mercury 80		204.4 Tl thallium 81		207.2 Pb lead 82		209.0 Bi bismuth 83		[209] Po polonium 84		[210] At astatine 85		[222] Rn radon 86	
[223] Fr francium 87		[226] Ra radium 88		[227] Ac* actinium 89		[261] Rf rutherfordium 104		[262] Db dubnium 105		[266] Sg seaborgium 106		[264] Bh bohrium 107		[277] Hs hassium 108		[268] Mt meitnerium 109		[271] Ds darmstadtium 110		[272] Rg roentgenium 111		Elements with atomic numbers 112-116 have been reported but not fully authenticated													
* Lanthanide series				140 Ce cerium 58		141 Pr praseodymium 59		144 Nd neodymium 60		[147] Pm promethium 61		150 Sm samarium 62		152 Eu europium 63		157 Gd gadolinium 64		159 Tb terbium 65		163 Dy dysprosium 66		165 Ho holmium 67		167 Er erbium 68		169 Tm thulium 69		173 Yb ytterbium 70		175 Lu lutetium 71					
* Actinide series				232 Th thorium 90		[231] Pa protactinium 91		238 U uranium 92		[237] Np neptunium 93		[242] Pu plutonium 94		[243] Am americium 95		[247] Cm curium 96		[245] Bk berkelium 97		[251] Cf californium 98		[254] Es einsteinium 99		[253] Fm fermium 100		[256] Md mendelevium 101		[254] No nobelium 102		[257] Lr lawrencium 103					