

Please check the examination details below before entering your candidate information

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

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 ►



Answer ALL questions.

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

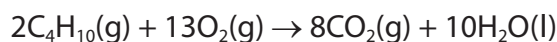
1 What is the total number of **ions** in 26.4 g of ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$?

[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 4.0×10^{22}
 B 1.2×10^{23}
 C 2.4×10^{23}
 D 3.6×10^{23}

(Total for Question 1 = 1 mark)

2 The equation for the complete combustion of butane is



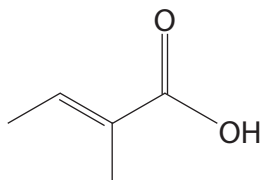
What is the minimum volume of oxygen, at room temperature and pressure (r.t.p.), needed for the complete combustion of 0.200 mol of butane?

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

- A 4.8 dm^3
 B 9.6 dm^3
 C 31.2 dm^3
 D 62.4 dm^3

(Total for Question 2 = 1 mark)

3 What is the systematic name for tiglic acid?



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

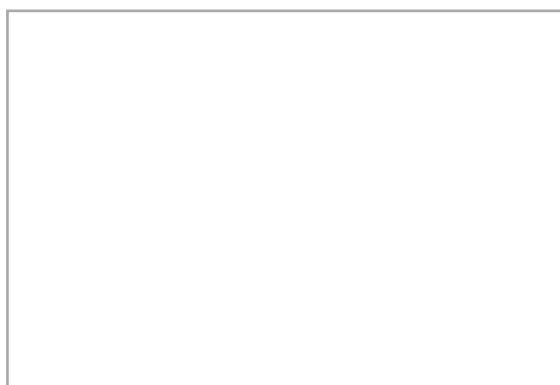
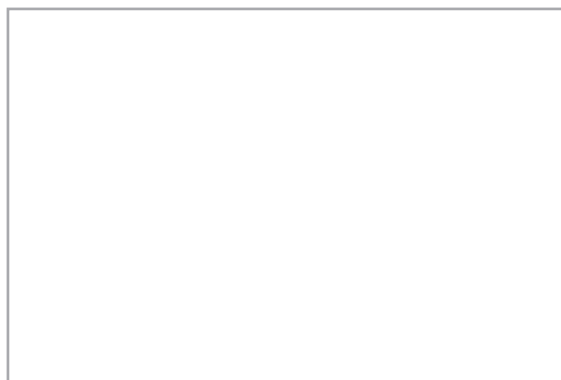
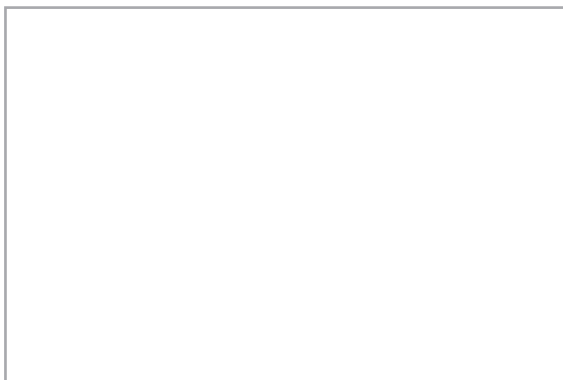
(Total for Question 3 = 1 mark)



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)



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(b) Which of these compounds would form pent-2-ene **only**, when reacted with concentrated phosphoric acid, H_3PO_4 ?

(1)

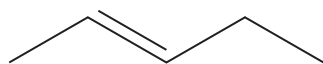
- A $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{CH}_3)_2$
- B $\text{CH}_2(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
- C $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$
- D $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$

(c) Pent-2-ene reacts with hydrogen bromide, 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 cm³.

Calculate the pressure inside the container.

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

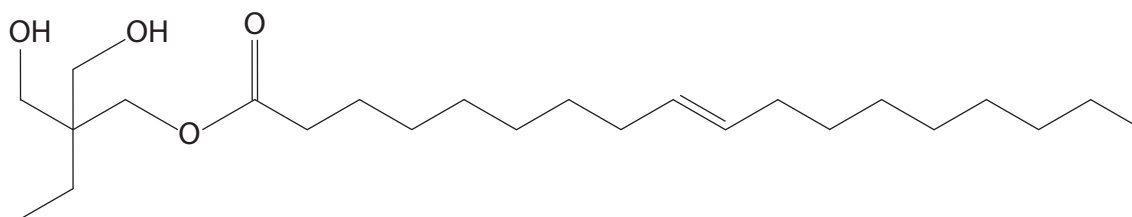
[Gas constant (R) = 8.31 J mol⁻¹ K⁻¹]

(4)

(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)

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- (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)

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(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)

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(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)

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

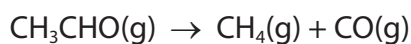


Calculate the atom economy, by mass, for the production of carbon monoxide in this reaction.

(2)



- (c) Carbon monoxide can also be made by the thermal decomposition of ethanal, CH_3CHO , 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) / K^{-1}	ln rate
700	0.0108	1.43×10^{-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 ⁻³	[CO] / mol dm ⁻³	Rate / mol dm ⁻³ s ⁻¹
1	2.09×10^{-6}	1.40×10^{-6}	8.20×10^{-7}
2	4.18×10^{-6}	1.40×10^{-6}	1.64×10^{-6}
3	3.26×10^{-6}	2.80×10^{-6}	2.56×10^{-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)

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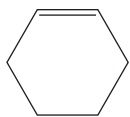
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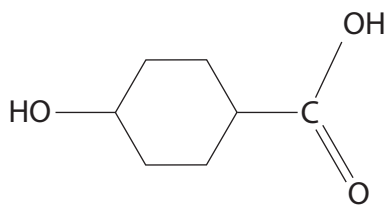
P 6 5 4 6 4 A 0 1 1 2 8

*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)

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(Total for Question 7 = 9 marks)

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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, CO_2 , and 0.69 g of water, H_2O .

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

(4)

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P 6 5 4 6 4 A 0 1 5 2 8

(b) A solution was prepared using 4.34 g of the dicarboxylic acid **Y** made up to a volume of 250 cm³ with distilled water.

A 25.0 cm³ sample of this solution was then titrated using sodium hydroxide solution, NaOH(aq), of concentration 0.320 mol dm⁻³.

The mean titre of sodium hydroxide solution was 26.10 cm³.

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?

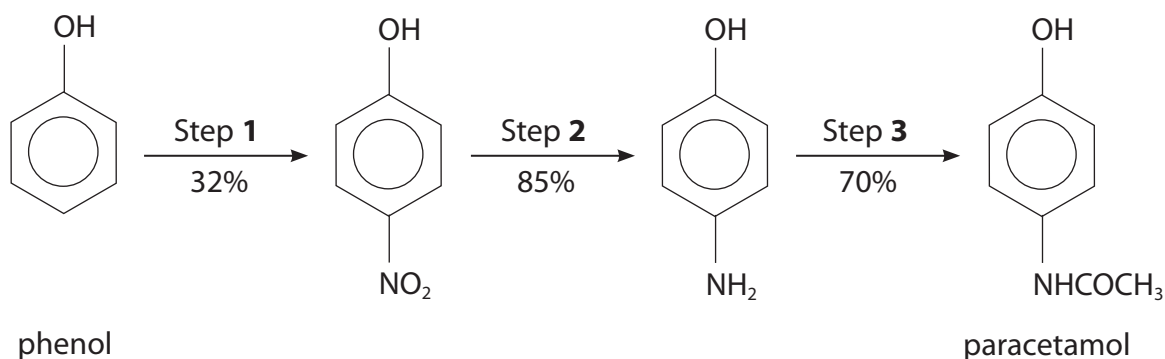
(1)

- A** LiAlH₄ and ether
- B** KMnO₄ and H₂SO₄
- C** Sn and HCl
- D** Na₂Cr₂O₇ and H₂SO₄

(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}C NMR spectra.

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

(2)

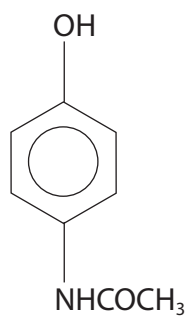
Product		
Number of peaks in the ^{13}C NMR spectrum		

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

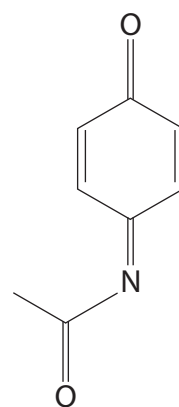
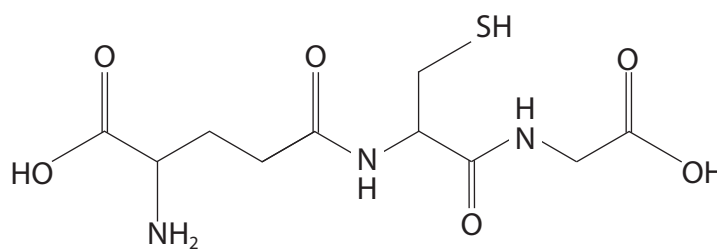
(3)



- (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

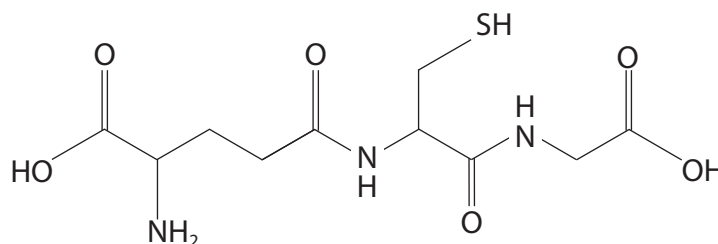
- (i) The conversion of paracetamol to compound **Z** is

(1)

- A** addition
 B hydrolysis
 C oxidation
 D reduction

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

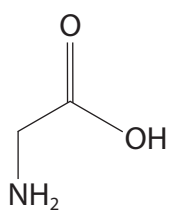
(1)



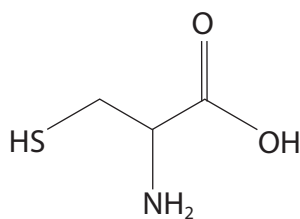
(iii) Glutathione is formed from glycine and two other amino acids.

Which two amino acids combine with glycine to form glutathione?

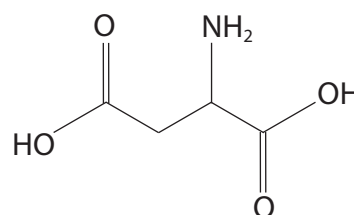
(1)



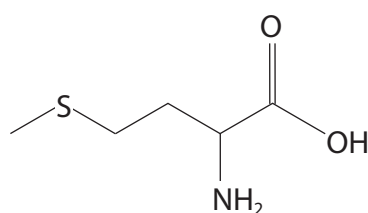
glycine



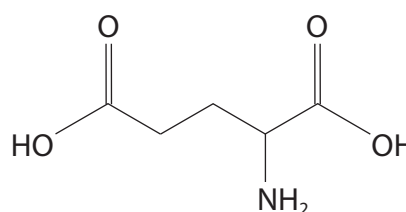
cysteine



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)

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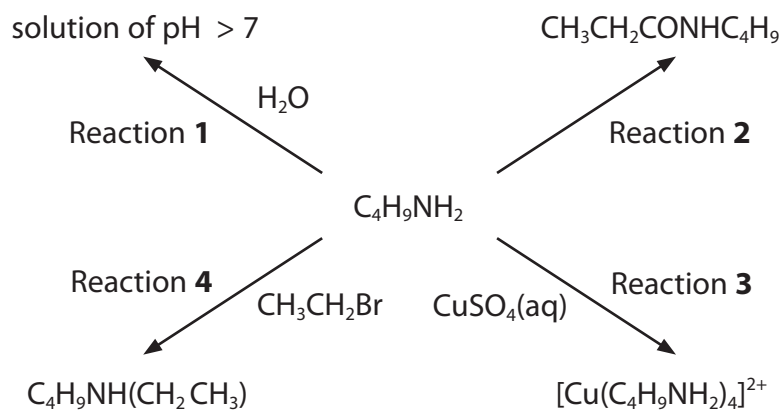
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(Total for Question 9 = 10 marks)



10 This question is about the amines butylamine, $C_4H_9NH_2$, and phenylamine, $C_6H_5NH_2$.

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)

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(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

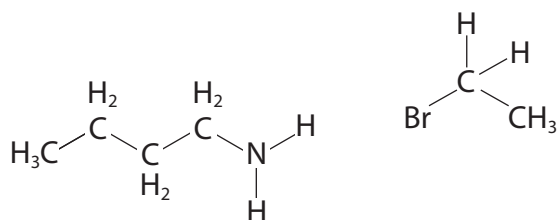
(d) (i) What is the type and mechanism of the reaction in Reaction 4?

(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)



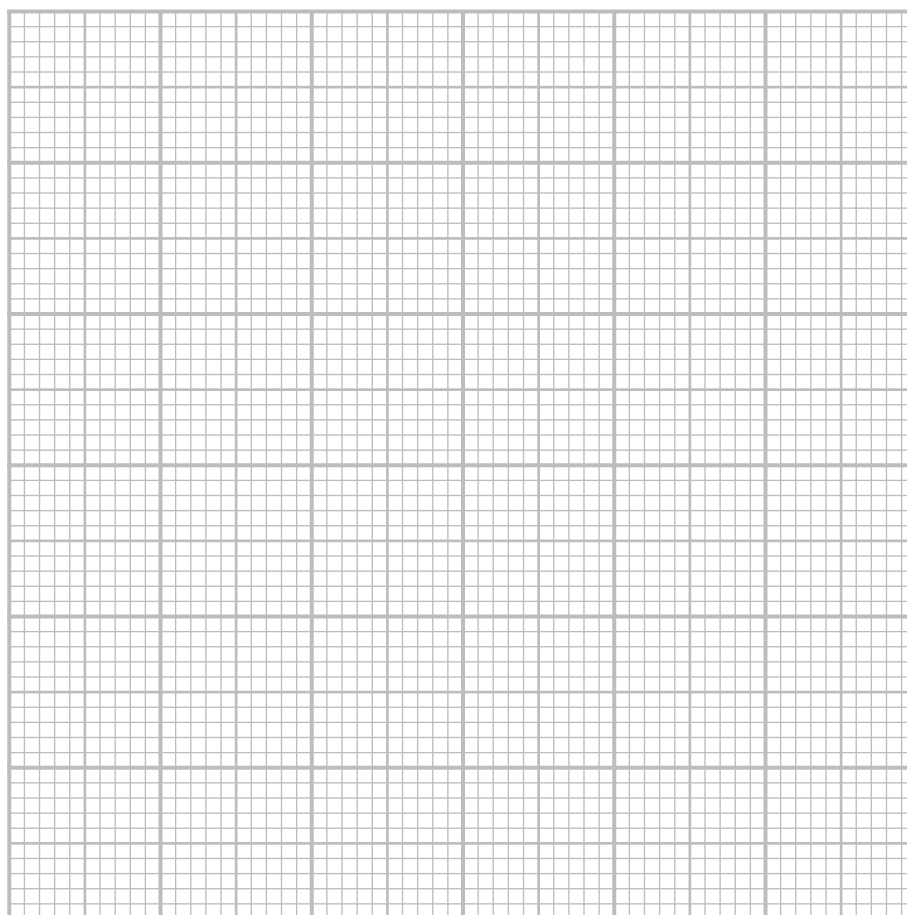
- 11 A series of experiments was carried out to determine the kinetics of the reaction between a chloroalkane, RCl , and potassium hydroxide in aqueous solution. A large excess of the chloroalkane was used.

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.

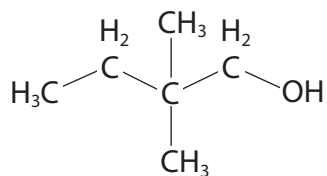
(1)

(Total for Question 11 = 7 marks)



P 6 5 4 6 4 A 0 2 3 2 8

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)

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(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) (18)

1.0	H	hydrogen	1
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Key

relative atomic mass
atomic symbol
name
atomic (proton) number

(1) (2)

6.9	Li	lithium	3	9.0	Be	beryllium	4
23.0	Na	sodium	11	24.3	Mg	magnesium	12
39.1	K	potassium	19	40.1	Ca	calcium	20
85.5	Rb	rubidium	37	87.6	Sr	strontium	38
132.9	Cs	caesium	55	137.3	Ba	barium	56
[223]	Fr	francium	87	[226]	Ra	radium	88

(13)

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
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
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
114.8	In	indium	49	112.4	Cd	cadmium	48	107.9	Ag	silver	47	106.4	Pd	palladium	46	102.9	Rh	rhodium	45	101.1	Ru	ruthenium	44
204.4	Tl	thallium	81	200.6	Hg	mercury	80	197.0	Au	gold	79	195.1	Pt	platinum	78	192.2	Ir	iridium	77	190.2	Os	osmium	76
207.2	Pb	lead	82	204.4	Tl	thallium	81	200.6	Hg	mercury	80	197.0	Au	gold	79	195.1	Pt	platinum	78	192.2	Ir	iridium	77
[222]	Rn	radon	86	[209]	Po	polonium	84	[210]	At	astatine	85	[222]	Rn	radon	86								

(14)

118.7	Sn	tin	50	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
207.2	Pb	lead	82	204.4	Tl	thallium	81	200.6	Hg	mercury	80	207.2	Pb	lead	82	209.0	Po	polonium	84	[222]	Rn	radon	86

(15)

121.8	Sb	antimony	51	127.6	Te	tellurium	52	126.9	I	iodine	53	131.3	Xe	xenon	54
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(16)

126.9	I	iodine	53	131.3	Xe	xenon	54
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(17)

[222]	Rn	radon	86
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Elements with atomic numbers 112-116 have been reported but not fully authenticated

140	Ce	cerium	58	141	Pr	praseodymium	59	144	Nd	neodymium	60	150	Sm	samarium	62	152	Eu	europium	63	157	Gd	gadolinium	64	163	Dy	dysprosium	66	165	Ho	holmium	67	167	Er	erbium	68	169	Tm	thulium	69	173	Yb	ytterbium	70	175	Lu	lutetium	71
232	Th	thorium	90	231	Pa	protactinium	91	238	U	uranium	92	237	Np	neptunium	93	243	Am	americium	95	247	Cm	curium	96	251	Cf	californium	98	254	Es	einsteinium	99	253	Fm	fermium	100	256	Md	mendelevium	101	254	No	nobelium	102	257	Lr	lawrencium	103

* Lanthanide series

* Actinide series

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