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EDEXCEL A LEVEL CHEMISTRY: QUESTIONS BY TOPIC

Organic Chemistry I (6)

A Level Chemistry Topic 6

34 questions · 373 marks · Mark schemes included

Pearson Edexcel A Level Chemistry (9CH0), June 2017 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any sub-topic heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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6(b) ALKANES		6 questions · 49 marks	6
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6(c) ALKENES		8 questions · 85 marks	19
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QUESTIONS

34 questions · 373 marks · grouped by sub-topic



SUB-TOPIC 6(a)

INTRODUCTION TO ORGANIC CHEMISTRY

1 question in this sub-topic · 4 marks · lowest tariff first



1 This question is about some organic compounds.

(a) Draw the **skeletal** formula of 1,3-dimethylcyclohexane.

(1)

(b) What is the general formula for a **cycloalkene**?

(1)

☐ A C_nH_{2n-2}

☐ B C_nH_{2n}

☐ C C_nH_{2n+1}

☐ D C_nH_{2n+2}

(c) A student is asked to devise a laboratory synthesis of 1,2-dichloroethane.
The student suggests reacting ethane with chlorine in the presence of
ultraviolet radiation.

Give **two** reasons why this is not a good method to prepare 1,2-dichloroethane.

(2)

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(Total for Question 1 = 4 marks)



SUB-TOPIC 6(b)

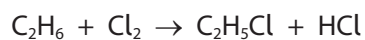
ALKANES

6 questions in this sub-topic · 49 marks · lowest tariff first



1 This question is about alkanes.

(a) The reaction of ethane and chlorine in UV radiation produces chloroethane.



This reaction is classified as

(1)

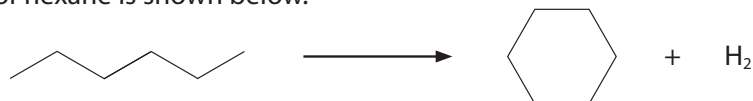
- ☐ A addition
- ☐ B elimination
- ☐ C initiation
- ☐ D substitution

(b) The black smoke produced from the incomplete combustion of alkane fuels is

(1)

- ☐ A carbon particulates
- ☐ B oxides of nitrogen
- ☐ C oxides of sulfur
- ☐ D unburnt hydrocarbons

(c) A reaction of hexane is shown below.

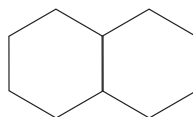


This is **best** described as

(1)

- ☐ A elimination
- ☐ B hydrogenation
- ☐ C isomerisation
- ☐ D reforming

(d) The skeletal formula of decalin is



The molecular formula of decalin is

(1)

- ☐ A $\text{C}_{10}\text{H}_{22}$
- ☐ B $\text{C}_{10}\text{H}_{20}$
- ☐ C $\text{C}_{10}\text{H}_{18}$
- ☐ D $\text{C}_{10}\text{H}_{16}$

(Total for Question 1 = 4 marks)

1 This is a question about alkanes.

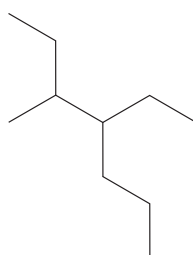
(a) What is the reaction mechanism when ethane and chlorine react in UV light?

(1)

- ☐ A electrophilic addition
- ☐ B electrophilic substitution
- ☐ C free radical addition
- ☐ D free radical substitution

(b) What is the name of this alkane?

(1)



- ☐ A 2-ethyl-3-propylpentane
- ☐ B 4-ethyl-3-methylheptane
- ☐ C 3-methyl-4-propylhexane
- ☐ D 4-methyl-3-propylhexane

(c) Alkanes are obtained by processing crude oil.

(i) Explain why different alkanes in crude oil can be separated by fractional distillation. (2)

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(ii) Complete the equation for the cracking of octane to produce ethene and only one other organic compound. State symbols are not required. (1)



(iii) Write the equation for the reforming of hexane into cyclohexane, using **displayed** formulae for the organic compounds. State symbols are not required. (1)

(Total for Question 1 = 6 marks)



1 Alkanes are often used as fuels.

- (a) Complete the equation for the complete combustion of hexane.
State symbols are not required.

(1)

- (b) Identify **two** pollutants produced from the **incomplete** combustion of a pure sample of pentane.

(2)

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- (c) Explain the problem which results from sulfur impurities in fuels.

(2)

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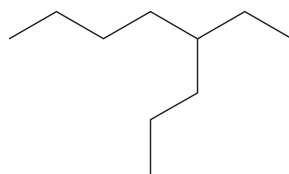
- (d) Adding cyclic hydrocarbons to fuels results in more efficient combustion.
These compounds can be made by reforming straight-chain alkanes.

Write an equation for the reforming of pentane into a cyclic hydrocarbon, using skeletal formulae for the organic compounds.
State symbols are not required.

(2)**(Total for Question 1 = 7 marks)**

2 This question is about alkanes and their reactions.

(a) What is the IUPAC name for this alkane?



(1)

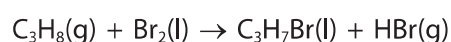
- ☐ A 4-ethyloctane
- ☐ B 5-ethyloctane
- ☐ C 3-propylheptane
- ☐ D 5-propylheptane

(b) What is the name of the process that could be used to produce propane, C_3H_8 , from decane, $C_{10}H_{22}$?

(1)

- ☐ A substitution
- ☐ B reforming
- ☐ C fractional distillation
- ☐ D cracking

(c) A student researched the reaction of propane with bromine and found that the reaction could be used to make 1-bromopropane.



(i) The first step of the reaction involves

(1)

- ☐ A heterolytic bond fission to form free radicals
- ☐ B heterolytic bond fission to form ions
- ☐ C homolytic bond fission to form free radicals
- ☐ D homolytic bond fission to form ions

(ii) Calculate the atom economy by mass for the formation of 1-bromopropane in the reaction in (c).

(2)

(iii) A source from the internet gave the percentage yield for this reaction as 31.0%. The best explanation for the low percentage yield of 1-bromopropane in this reaction is

(1)

- ☐ **A** bromine is very unreactive
- ☐ **B** a gaseous reactant always gives a low yield
- ☐ **C** the reaction is very slow
- ☐ **D** the reaction produces a mixture of organic products

(iv) Calculate the volume of propane, in dm^3 , measured at room temperature and pressure, that is needed to produce 14.7 g of 1-bromopropane, assuming a percentage yield of 31.0%.

Give your answer to an appropriate number of significant figures.

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

(3)

(Total for Question 2 = 9 marks)



4 Covalent bonds can break by either heterolytic fission or homolytic fission.

(a) The reaction of butane and chlorine involves homolytic bond fission of the chlorine molecule, using ultraviolet radiation.

(i) The energy of ultraviolet radiation can be calculated using the formula shown.

$$\text{Energy of one photon} = \frac{h \times c}{\lambda}$$

Planck constant, $h = 6.626 \times 10^{-34} \text{ J s}$

Speed of light, $c = 3.00 \times 10^8 \text{ m s}^{-1}$

Avogadro constant, $L = 6.02 \times 10^{23} \text{ mol}^{-1}$

Wavelength, λ in metres

The mean C—H bond energy is 413 kJ mol^{-1} compared to 243 kJ mol^{-1} for the Cl—Cl bond.

Show, by calculation, that ultraviolet radiation, with the wavelength 315 nm, can break the Cl—Cl bond but not the C—H bond.

(4)



- (ii) In the reaction of chlorine with butane, the propagation stage produces two different butyl radicals.

Write the structural formulae of these two radicals.

(2)

- (iii) The reaction of chlorine with butane produces 2-chlorobutane (72 %) and 1-chlorobutane (28 %).

Explain, by application of your knowledge of the stability of carbocations, why there is a higher yield of 2-chlorobutane.

(2)

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- (b) Water molecules can undergo either heterolytic fission to form a hydroxide ion or homolytic fission to form a hydroxyl radical.

Draw dot-and-cross diagrams of these two species.

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

(2)



hydroxide ion



hydroxyl radical

- (c) Which process does **not** involve heterolytic fission?

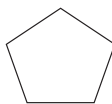
(1)

- ☐ A the formation of the cyanide nucleophile from KCN
- ☐ B the formation of propanenitrile from bromoethane
- ☐ C hydroxide ion attack on bromopropane in ethanol
- ☐ D aqueous silver nitrate in ethanol reacting with iodoethane

(Total for Question 4 = 11 marks)

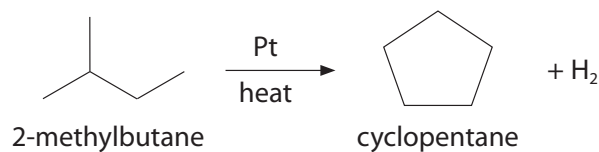
5 This question is about cyclic compounds.

- (a) The hydrocarbon cyclopentane is present in some fuels and is used in the manufacture of insulation for freezers.



cyclopentane

Cyclopentane can be synthesised by passing 2-methylbutane over a hot platinum catalyst.



Name the type of reaction that takes place in this synthesis.

(1)

- (b) The energy density of a fuel is defined as the energy released per dm^3 of the liquid fuel burned.

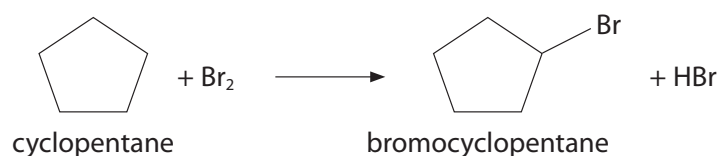
A sample of cyclopentane with a mass of 30.0 g releases 1.41 MJ of energy.

Calculate the energy density of cyclopentane.
Include units in your answer.

[Density of cyclopentane = 0.751 g cm^{-3}]

(2)

- (c) Under appropriate conditions, cyclopentane reacts with bromine to form bromocyclopentane.

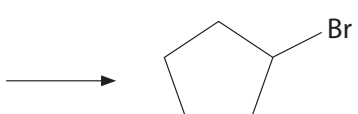


- (i) State the condition needed to initiate the reaction.

(1)

- (ii) Complete the table showing the steps of the mechanism of this reaction. Curly arrows are not required.

(3)

Step	Equation(s)
Initiation	
Propagation	1.  2.
Termination	

- (iii) Draw the structure of the organic product of an alternative termination step.

(1)

- (d) Bromocyclopentane forms cyclopentene when heated under reflux with a concentrated solution of potassium hydroxide in ethanol.



- (i) Explain why the solvent ethanol is treated with anhydrous sodium sulfate before use in this reaction.

(2)

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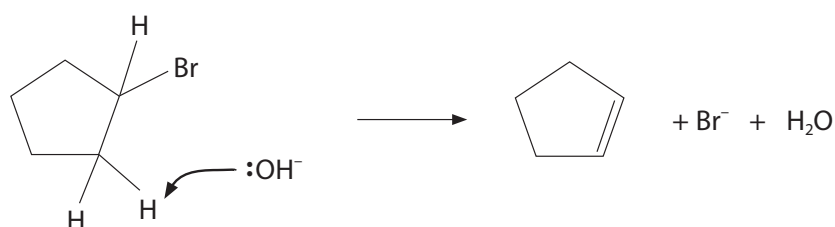
- (ii) Give the name of the reaction shown in the equation.

(1)

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- (iii) Predict the mechanism for the reaction by adding two curly arrows.

(1)



(Total for Question 5 = 12 marks)

SUB-TOPIC 6(c)

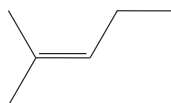
ALKENES

8 questions in this sub-topic · 85 marks · lowest tariff first



1 This is a question about polymers.

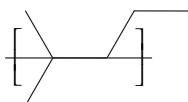
(a) An addition polymer is formed from 2-methylpent-2-ene.



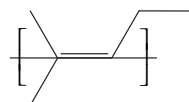
What is the repeat unit for poly(2-methylpent-2-ene)?

(1)

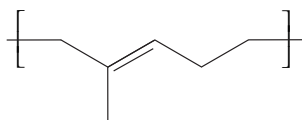
☒ A



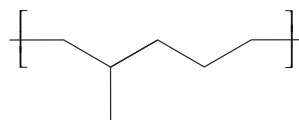
☒ B



☒ C



☒ D



(b) Which is **not** a use of waste poly(alkenes)?

(1)

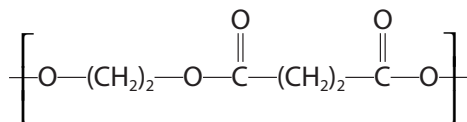
- ☒ A feedstock for cracking
- ☒ B generation of biodegradable materials
- ☒ C incineration to release energy
- ☒ D make new materials by recycling

(c) A condensation polymer can be made from ethane-1,2-diol and butanedioic acid.

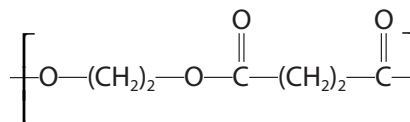
Which is the repeat unit for this polymer?

(1)

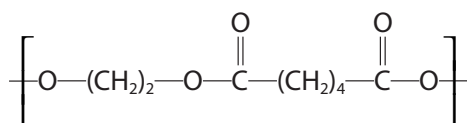
☒ **A**



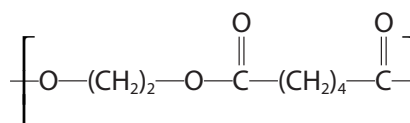
☒ **B**



☒ **C**



☒ **D**



(d) Which approach used by chemists would **not** contribute to a more sustainable use of materials over the life cycle of a polymer?

(1)

- ☒ **A** make more efficient use of energy
- ☒ **B** make more efficient use of resources
- ☒ **C** use catalysts for a faster reaction rate
- ☒ **D** use a higher temperature for a faster reaction rate

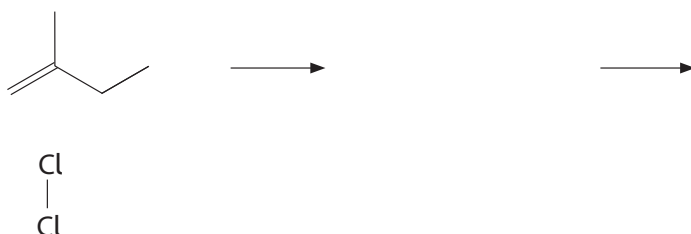
(Total for Question 1 = 4 marks)

3 This is a question about dihalogenoalkanes.

(a) Dihalogenoalkanes are formed when alkenes react with halogens.

- (i) Complete the mechanism for the production of a dihalogenoalkane from 2-methylbut-1-ene and chlorine. Include curly arrows and any relevant lone pairs.

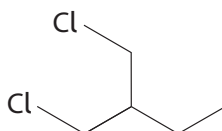
(3)



- (ii) Give the name of the dihalogenoalkane produced.

(1)

(b) What is the classification of the dihalogenoalkane shown?



(1)

- ☐ **A** primary
- ☐ **B** secondary
- ☐ **C** tertiary
- ☐ **D** primary and secondary

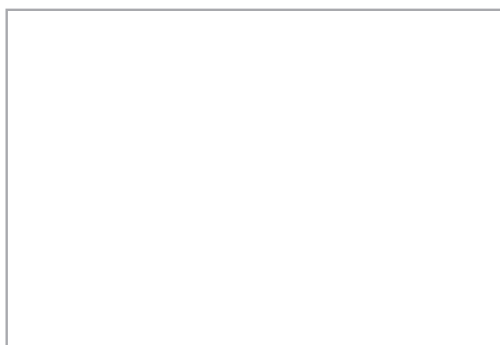
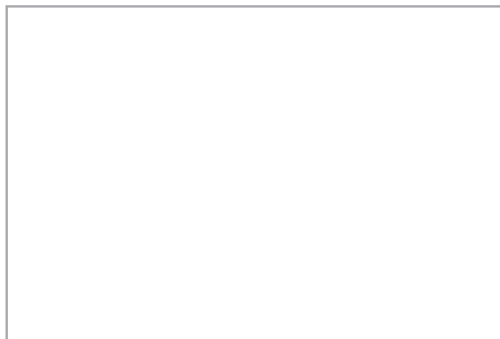
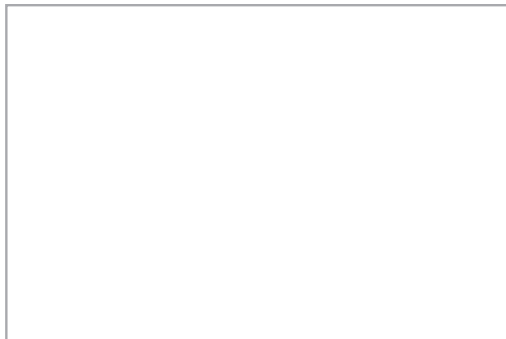
(Total for Question 3 = 5 marks)

(Total for Question 5 = 6 marks)

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, H_3PO_4 ?

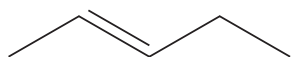
(1)

- ☐ **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.

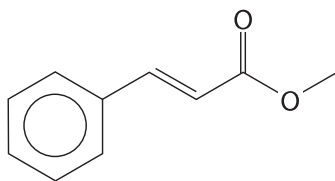
[Gas constant (R) = 8.31 J mol⁻¹ K⁻¹]

(4)

(Total for Question 4 = 12 marks)



4 Methyl cinnamate, $C_{10}H_{10}O_2$, is a white crystalline solid used in the perfume industry.



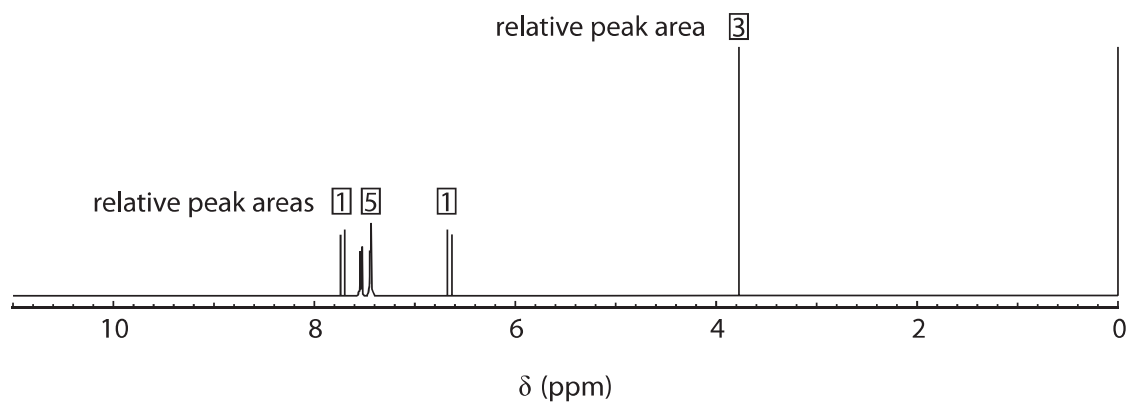
methyl cinnamate

(a) Calculate the mass of carbon in 2.34 g of methyl cinnamate.

(2)

(b) A sample of methyl cinnamate was analysed by high resolution proton NMR spectroscopy.

A simplified spectrum is shown.



(i) Name the compound responsible for the peak at a chemical shift of 0 ppm, stating its purpose.

(2)

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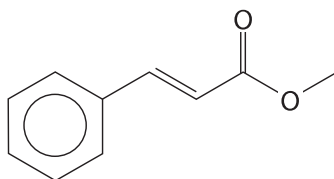
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- (ii) Identify the proton environment that causes the peak at a chemical shift of 3.8 ppm by circling it on the diagram shown. Fully justify your answer.

(3)



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- (c) Methyl cinnamate undergoes an addition reaction in the dark with bromine.

- (i) Draw the mechanism for the reaction between methyl cinnamate and bromine, Br₂.
Include curly arrows, and relevant lone pairs and dipoles.

(4)

- (ii) Deduce the number of optical isomers of the addition product that can exist.

(1)

- ☐ A 2
- ☐ B 3
- ☐ C 4
- ☐ D 8

- (iii) When plane-polarised light is passed through an optical isomer, the plane of polarisation is

(1)

- ☐ A diffracted
- ☐ B reflected
- ☐ C refracted
- ☐ D rotated

(Total for Question 4 = 13 marks)

8 This question is about isomerism in organic compounds.

(a) How many structural isomers are there with the formula C_5H_{12} ?

(1)

☐ **A** 2

☐ **B** 3

☐ **C** 4

☐ **D** 5

(b) Propene reacts with bromine to form 1,2-dibromopropane as the only product.

Draw the mechanism for the reaction between propene and bromine.
Include curly arrows and any relevant lone pairs and dipoles.

(3)



(c) When propene reacts with a mixture of bromine and sodium chloride, it forms 1,2-dibromopropane, 1-bromo-2-chloropropane and 2-bromo-1-chloropropane but no 1,2-dichloropropane.

(i) Explain, by reference to your mechanism in (b), why no 1,2-dichloropropane forms.

(2)

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(ii) Explain why far more 1-bromo-2-chloropropane forms than 2-bromo-1-chloropropane.

(2)

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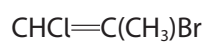
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*(d) Discuss the different types of stereoisomerism that occur in organic compounds. Use only molecules **A** and **B** as examples.

**A****B**

Include in your answer:

- how the different types of isomerism arise
- the naming of alkenes with the formula **A**
- the properties of isomers with the formula **B**
- diagrams of the different isomers.

(6)

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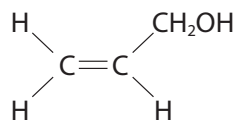
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(Total for Question 8 = 14 marks)

- 2 This question is about compounds that contain both an alkene and an alcohol functional group.

(a) Prop-2-en-1-ol, present in garlic, has the structure shown.



- (i) Describe a test, and the positive result, that confirms the presence of a $\text{C}=\text{C}$ group.

(2)

Test

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Result

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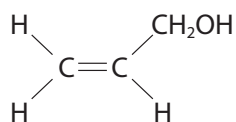
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- (ii) Prop-2-en-1-ol reacts with hydrogen bromide to form 3-bromopropan-1-ol as one of the products.

Draw a mechanism for this reaction.

Include curly arrows, and relevant lone pairs and dipoles.

(3)

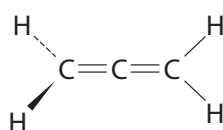


(b) Prop-2-en-1-ol can polymerise to form an addition polymer.

Write a balanced equation for this polymerisation.

(2)

(c) Prop-2-en-1-ol can form the alkene propadiene, which has two adjacent $C=C$ bonds, as shown.



propadiene

Explain why the CH_2 groups at each end of the molecule are at right angles to each other.

Use your knowledge of how orbitals overlap to form π -bonds.

(2)

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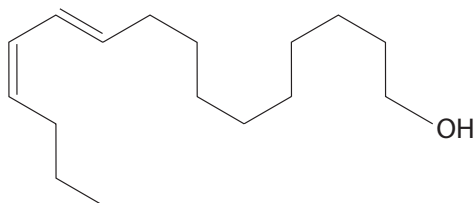
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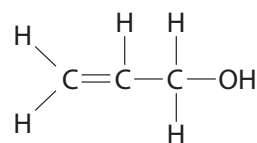
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- (d) The compound bombykol is a pheromone secreted by female silk moths. Like prop-2-en-1-ol, it can also be classified as both an alkene and an alcohol.



bombykol



prop-2-en-1-ol

Bombykol can exist as a number of geometric isomers.

- (i) Give the number of different geometric isomers of bombykol.

(1)

- (ii) Give the reason why prop-2-en-1-ol does **not** exhibit geometric isomerism.

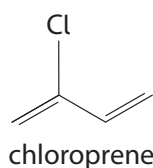
(1)

- (iii) Explain the expected solubilities in water of bombykol and prop-2-en-1-ol.

(3)

(Total for Question 2 = 14 marks)

- 7 This question is about polymers, an example of which is neoprene, a synthetic rubber material.
It is formed by the polymerisation of chloroprene.



- (a) What is the IUPAC name of chloroprene?

(1)

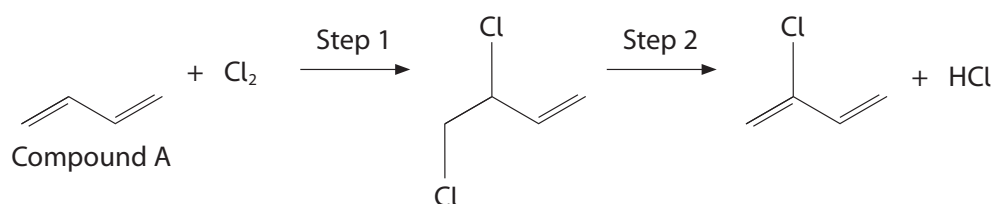
- ☐ A 3-chlorobuta-1,3-diene
☐ B 2-chlorobuta-2,4-diene
☐ C 3-chlorobuta-2,4-diene
☐ D 2-chlorobuta-1,3-diene

- (b) Calculate the volume, in cm^3 , occupied by 10.0 g of chloroprene in the gaseous phase, at 80.0°C and 205 kPa.
Give your answer to an appropriate number of significant figures.

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

(5)

- (c) Chloroprene is formed by first adding chlorine, Cl_2 , to Compound A and then removing hydrogen chloride from the product of this reaction.



- (i) Explain how chlorine, Cl_2 , can act as an electrophile in Step 1 even though a chlorine molecule is symmetrical.
You may find it helpful to include a diagram.

(2)

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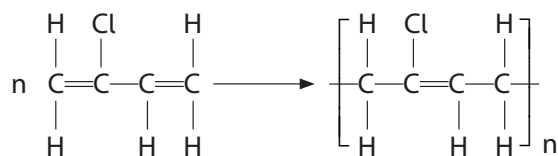
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- (ii) Draw the mechanism for Step 1.
Include curly arrows, and any relevant lone pairs and dipoles.

(3)



(iii) Chloroprene polymerises to form neoprene as shown.



Give the name of the type of reaction that occurs when chloroprene polymerises.

(1)

(d) Flexible and water-resistant materials can be made by combining neoprene with polyester fabric.

A polyester may be made by the reaction of benzene-1,4-dicarboxylic acid with ethane-1,2-diol.

(i) Explain why ethane-1,2-diol is soluble in water.
A detailed description of the forces involved is not required.

(2)



- (ii) The molar mass of a polyester is 8400 g mol^{-1} .

Calculate the number of polymer molecules in 4.25 mg of this polyester.

[Avogadro constant (L) = $6.02 \times 10^{23} \text{ mol}^{-1}$]

(2)

- (iii) A student spilled a small amount of 0.40 mol dm^{-3} sodium hydroxide solution onto a polyester laboratory coat. A hole formed in the laboratory coat as the result of a chemical reaction.

What type of reaction occurred?

(1)

- ☐ A dehydration
- ☐ B hydrolysis
- ☐ C neutralisation
- ☐ D redox

(Total for Question 7 = 17 marks)



SUB-TOPIC 6(d)

HALOGENOALKANES

6 questions in this sub-topic · 64 marks · lowest tariff first



- 8 The chemistry of organic compounds containing a chlorine atom is affected by the presence of other groups.

Consider the reaction of ammonia, NH_3 , with $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$ and with $\text{CH}_3\text{CH}_2\text{COCl}$.

- (a) Draw the mechanism for the reaction of $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$ with an **excess** of ammonia to form the primary amine. Include curly arrows and relevant lone pairs.

(3)

- (b) Predict the mechanism for the reaction of $\text{CH}_3\text{CH}_2\text{COCl}$ with ammonia. Include curly arrows and relevant lone pairs.

(3)

(Total for Question 8 = 6 marks)



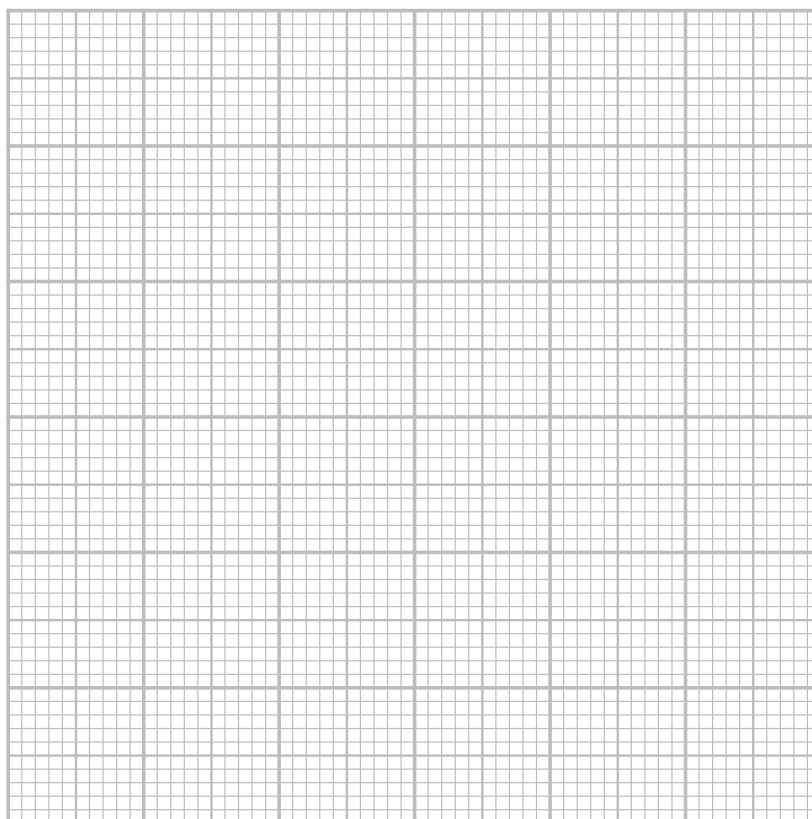
- 11** A series of experiments was carried out to determine the kinetics of the reaction between a chloroalkane, RCl , and potassium hydroxide in aqueous solution. A large excess of the chloroalkane was used.

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)



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

(2)

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

(2)

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

(1)

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(Total for Question 11 = 7 marks)



1 This question is about organic compounds that contain a halogen atom or a nitrogen atom.

- (a) Equal amounts of four bromoalkanes were added to separate test tubes containing 2 cm^3 of a silver nitrate solution. The mixtures were heated in a water bath.

Which bromoalkane would be the **first** to form a precipitate?

(1)

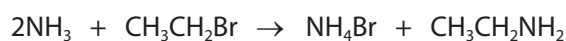
- ☐ A 1-bromobutane
- ☐ B 2-bromobutane
- ☐ C 1-bromo-2-methylpropane
- ☐ D 2-bromo-2-methylpropane

- (b) Which pair of reactants will form an *N*-substituted amide?

(1)

- ☐ A CH_3COCl and NH_3
- ☐ B $\text{CH}_3\text{CH}_2\text{OH}$ and NH_3
- ☐ C CH_3COCl and CH_3NH_2
- ☐ D $\text{CH}_3\text{CH}_2\text{OH}$ and CH_3NH_2

(c) Ammonia reacts with bromoethane as shown.



- (i) Explain, by referring to the reaction mechanism, the roles of ammonia in the formation of each of the products of this reaction.

(3)

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- (ii) What conditions are needed for this reaction?

(1)

	Method of heating	Solvent
☐ A	heat in a sealed tube	ethanol
☐ B	heat under reflux	ethanol
☐ C	heat in a sealed tube	water
☐ D	heat under reflux	water



- (d) The halogenoalkane, 1-bromobutane, can be formed by the reaction of butan-1-ol with sodium bromide and sulfuric acid.



Calculate the atom economy, by mass, for the formation of 1-bromobutane.
Give your answer to **one** decimal place.

[A_r values: H = 1.0 C = 12.0 O = 16.0 Na = 23.0 S = 32.1 Br = 79.9]

(2)

(Total for Question 1 = 8 marks)



- 6 A bromoalkane, RBr, reacts with aqueous hydroxide ions in a nucleophilic substitution reaction.



This reaction is first order with respect to the bromoalkane and the rate equation is

$$\text{rate} = k[\text{RBr}]^1[\text{OH}^-]^x$$

where x is the order of the reaction with respect to hydroxide ions.

In an experiment, a sample of the bromoalkane was added to a large excess of aqueous sodium hydroxide and the concentration of the bromoalkane was determined at regular time intervals.

Results

Time / s	[RBr] / mol dm ⁻³
0	0.100
30	0.065
60	0.042
90	0.028
120	0.019
150	0.014

- (a) This experiment is carried out using the bromoalkane dissolved in ethanol and the hydroxide ions dissolved in water.

Give a reason why a solution of hydroxide ions dissolved in pure ethanol should **not** be used.

(1)

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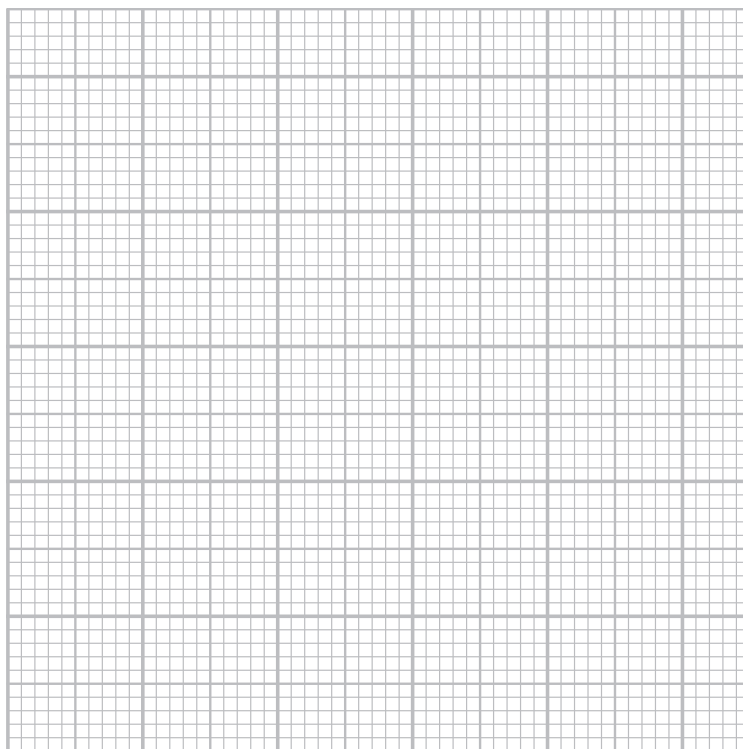
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(b) Plot a graph of $[RBr]$ against time.

(3)



(c) Explain how the graph shows that the reaction is first order with respect to RBr . Include the values of two consecutive half-lives.

You **must** show your working for the half-lives on the graph.

(2)

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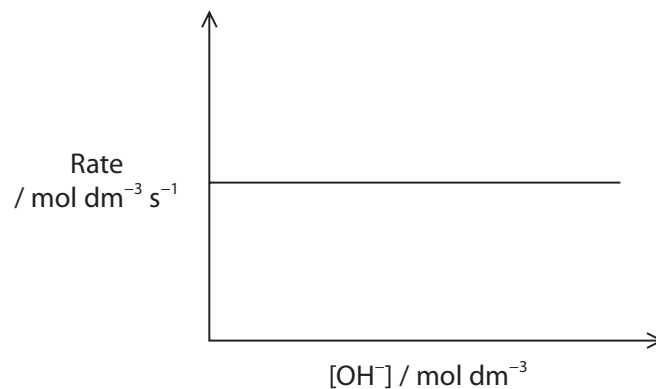
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- (d) The experiment was repeated using equal concentrations of RBr and varying the concentration of hydroxide ions.

A graph was plotted of the results.



- (i) Deduce the value of x in the rate equation.

$$\text{rate} = k[\text{RBr}]^1[\text{OH}^-]^x \quad (1)$$

-
- (ii) Give the mechanism for the reaction that is consistent with the orders of reaction with respect to R—Br and hydroxide ions.
Include curly arrows and relevant lone pairs.

(3)

(e) 2-bromobutane can react with aqueous hydroxide ions by an S_N1 mechanism.

Explain why the butan-2-ol produced from a single optical isomer of 2-bromobutane, using this mechanism, is **not** optically active.

(3)

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(Total for Question 6 = 13 marks)



3 This is a question about halogenoalkanes and related compounds.

- (a) Explain the trend in reactivity of the **primary** chloro-, bromo- and iodoalkanes with aqueous hydroxide ions.

(2)

- (b) In aqueous sodium hydroxide, 1-bromoethane reacts to produce ethanol.

- (i) Write the mechanism for this reaction, including all relevant curly arrows, lone pairs and dipoles. Include the transition state.

(4)

- (ii) Give the reagents that are used to test that bromide ions are formed in this reaction mixture. Include the result of the test.

(2)



- (c) The halogenoalkane 2-bromobutane reacts with ethanolic potassium hydroxide to produce a mixture of alkenes.

Draw the **skeletal** formulae of all the alkenes that could be produced.

(3)

- (d) Explain why ethene has a boiling temperature of -104°C , whereas ethanol has a boiling temperature of 78°C .

(3)

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(Total for Question 3 = 14 marks)



6 This is a question about the hydrolysis of halogenoalkanes.

(a) Devise an experiment, giving outline details only, that would enable the relative rates of hydrolysis of halogenoalkanes to be compared.

(5)

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(b) Explain the trend in the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane.

(2)



(c) The product of the hydrolysis of 2-bromobutane is butan-2-ol. Both molecules are chiral.

State what is meant by the term chiral, using three-dimensional diagrams of the enantiomers of butan-2-ol to illustrate your answer.

(3)

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*(d) Compare and contrast the mechanism of hydrolysis, using aqueous potassium hydroxide, of the primary halogenoalkane, RCH_2X , with that of the tertiary halogenoalkane, R_3CX . Include diagrams of any intermediate or transition state.

Curly arrows are not required.

(6)

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(Total for Question 6 = 16 marks)



SUB-TOPIC 6(e)

ALCOHOLS

5 questions in this sub-topic · 47 marks · lowest tariff first



1 This question is about some reactions of alcohols.

(a) (i) Which alcohol **cannot** be oxidised by acidified potassium dichromate(VI)?

(1)

- ☐ A hexan-2-ol
- ☐ B 2-methylpentan-2-ol
- ☐ C hexan-3-ol
- ☐ D 2-methylpentan-3-ol

(ii) Which alcohol reacts with iodine in the presence of alkali to form a yellow solid?

(1)

- ☐ A hexan-2-ol
- ☐ B 2-methylpentan-2-ol
- ☐ C hexan-3-ol
- ☐ D 2-methylpentan-3-ol

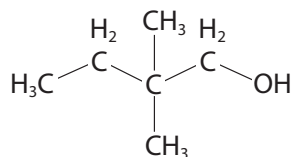
(b) Which reagent is used with iodine to prepare iodoalkanes from alcohols?

(1)

- ☐ A red phosphorus
- ☐ B concentrated phosphoric acid
- ☐ C sulfur
- ☐ D concentrated sulfuric acid

(Total for Question 1 = 3 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)



3 Ethanol can be dehydrated using concentrated phosphoric(V) acid, concentrated sulfuric acid or aluminium oxide.

- (a) Write the equation for the dehydration of ethanol using structural formulae. State symbols are not required.

(1)

- (b) Give the formula of phosphoric(V) acid.

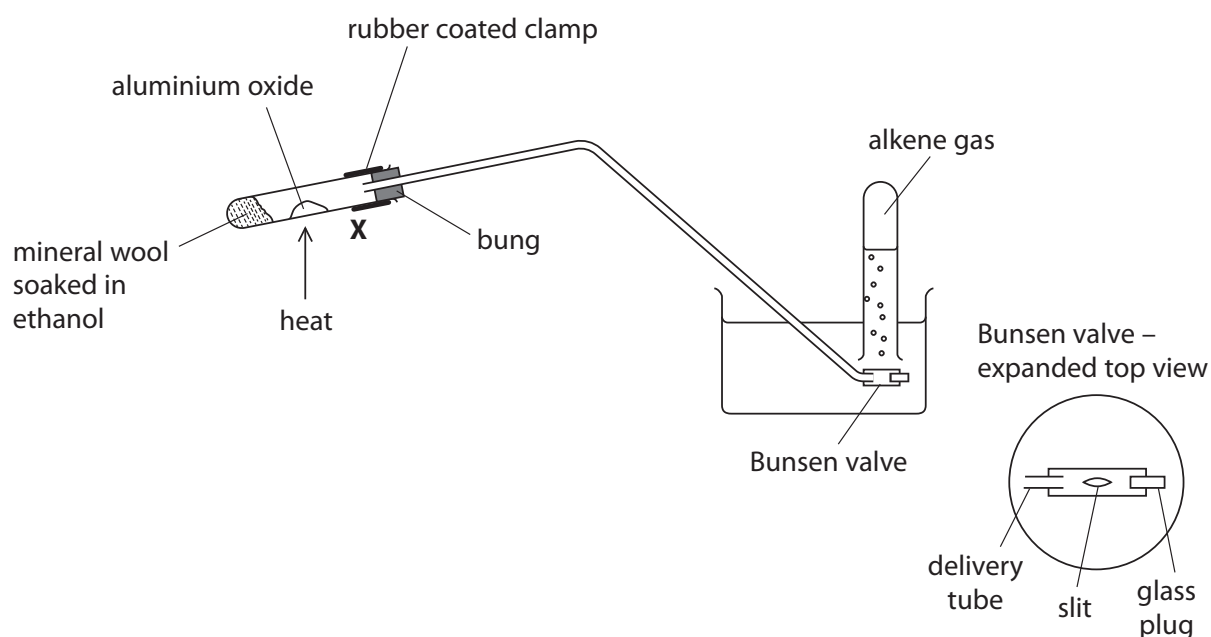
(1)

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- (c) Draw the dot-and-cross diagram of sulfuric acid, H_2SO_4 . Clearly differentiate between sulfur, oxygen and hydrogen electrons. Show outer shell electrons only.

(2)



- (d) Ethanol may be dehydrated using the catalyst aluminium oxide, Al_2O_3 . The apparatus is shown.



- (i) Give a possible reason for the boiling tube to be clamped at the angle shown.

(1)

- (ii) Describe the problem if the ethanol is heated instead of the catalyst.

(1)

- (iii) Identify a safety issue if the heat source was moved to the position labelled X on the diagram.

(1)

(iv) Give a possible reason for the use of the Bunsen valve in the apparatus.

(1)

(v) Describe a test, with the positive result, which would confirm the presence of an alkene in the test tube.

(1)

(vi) Calculate the volume of 2.759×10^{20} molecules of alkene gas at room temperature and pressure (r.t.p.).

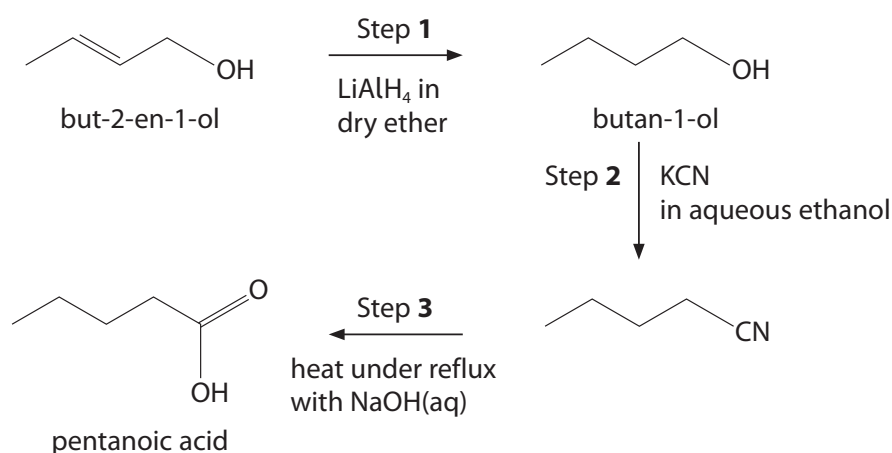
(2)

(Total for Question 3 = 11 marks)



7 This question is about the synthesis of organic compounds.

(a) A student suggested the following plan for the synthesis of pentanoic acid from but-2-en-1-ol.



(i) LiAlH_4 is a source of hydride ions, H^- .

Give a possible reason why LiAlH_4 cannot be used to reduce alkenes.

(1)

(ii) Give a suitable reagent and condition for Step 1.

(2)

(iii) Step 2 is incorrect because alcohols can only be converted to nitriles via an intermediate compound.

Identify a suitable intermediate compound by name or formula.

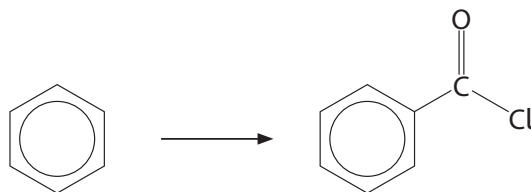
(1)

(iv) Step 3 involves the hydrolysis of a nitrile.

Give the additional reagent that should be added after heating under reflux with aqueous sodium hydroxide, to produce pentanoic acid.

(1)

- (b) Devise a four-step synthesis, involving the use of a Grignard reagent, to convert benzene into benzoyl chloride.

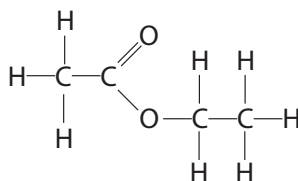


Include the reagents and conditions for each step in the synthesis and the structures of the intermediates.

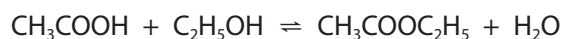
(7)

(Total for Question 7 = 12 marks)

10 Ethyl ethanoate is an ester.



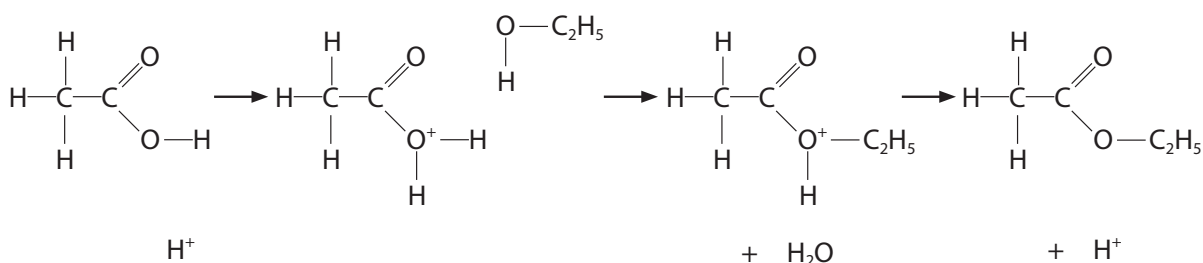
- (a) One method for the formation of ethyl ethanoate is the reaction between ethanol and ethanoic acid, which is catalysed by hydrogen ions.



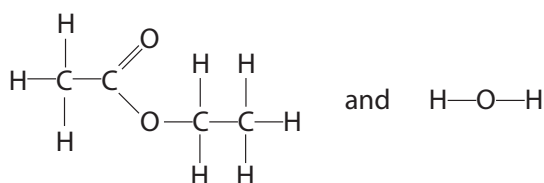
An incomplete simplified mechanism for this reaction is shown.

- (i) Add curly arrows and relevant lone pairs of electrons to complete the mechanism.

(4)



- (ii) In an experiment, the oxygen atom in ethanol is replaced by the oxygen-18 isotope, ^{18}O .
The products of the esterification are



Label the ^{18}O oxygen atom in one of the products.
Justify your answer.

(2)

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- (iii) Calculate the standard molar entropy of ethyl ethanoate using your knowledge of Gibbs free energy, ΔG , and the data in the table.

Include sign and units in your answer.

Use $\Delta G = -RT \ln K$ and other appropriate equations.

Quantity	Value
Gas constant, R	$8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
Temperature, T	298 K
Equilibrium constant of esterification reaction, K	4.0
Enthalpy change of esterification reaction, ΔH	-6.0 kJ mol^{-1}
Standard molar entropy of ethanoic acid, S°	$159.8 \text{ J K}^{-1} \text{ mol}^{-1}$
Standard molar entropy of ethanol, S°	$160.7 \text{ J K}^{-1} \text{ mol}^{-1}$
Standard molar entropy of water, S°	$69.9 \text{ J K}^{-1} \text{ mol}^{-1}$

(6)



(b) Ethyl ethanoate can also be formed by reacting ethanol with ethanoyl chloride, CH_3COCl .

Identify **three** differences in the esterification reaction when ethanoyl chloride is used instead of ethanoic acid.

(3)

(Total for Question 10 = 15 marks)



TOPIC 6

SYNOPTIC AND MIXED QUESTIONS

8 questions in this sub-topic · 124 marks · lowest tariff first



***5** Explain the difference in the reactivity of bromine with benzene and with phenol.

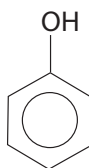
Include the type of reaction, the products that form, and any conditions required. Mechanisms for the reactions are **not** required.

(6)



(Total for Question 5 = 6 marks)

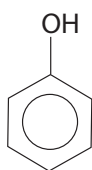
8 Phenol is a feedstock in the production of many organic molecules.



(a) Phenol reacts with bromine water.

- (i) Complete the equation for the reaction of phenol with excess bromine water, using the **skeletal** formula of the organic product.

(2)



- (ii) Compare and contrast the bromination of phenol with the bromination of benzene.

(3)

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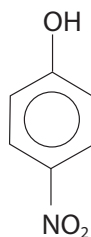
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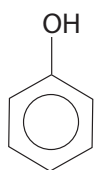
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(b) Phenol can be nitrated to produce 4-nitrophenol.



- (i) The mechanisms of the nitration of phenol and of benzene are similar. Complete the diagram, using curly arrows, to show a possible mechanism for the reaction between the electrophile, NO_2^+ , and phenol to produce 4-nitrophenol.

(3)



- (ii) What is the mass, in grams, of 4-nitrophenol produced from 0.94 g of phenol if the yield of this isomer is 15%?

(1)

- ☐ A 0.14
- ☐ B 0.21
- ☐ C 0.68
- ☐ D 1.39

- (iii) Draw **two** structural isomers of 4-nitrophenol which have a benzene ring.

(1)

(Total for Question 8 = 10 marks)

3 This question is about aluminium chloride.

(a) Complete the electronic configuration of an aluminium atom.

(1)

$1s^2$

(b) At high temperatures, aluminium chloride exists as $AlCl_3$ molecules.

(i) Draw a dot-and-cross diagram of an aluminium chloride molecule, $AlCl_3$.
Show the outer shell electrons only.

(1)

(ii) Predict the shape of an $AlCl_3$ molecule and the $Cl-Al-Cl$ bond angle.

(2)

Shape of $AlCl_3$	
$Cl-Al-Cl$ bond angle	

(iii) Aluminium chloride is used as a catalyst in the alkylation of benzene.

Draw the mechanism for the reaction between benzene and chloromethane using aluminium chloride as the catalyst.

Include an equation for the formation of the electrophile, and any relevant curly arrows.

(4)

(c) Aluminium chloride exists as a dimer, Al_2Cl_6 , just above its boiling temperature.

(i) Draw a diagram to show how two AlCl_3 molecules are joined together in the dimer.

(1)

(ii) State the type of bond that joins the two AlCl_3 molecules together.

(1)

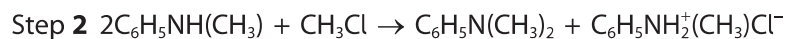
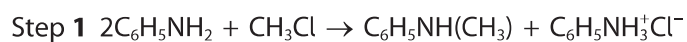
(Total for Question 3 = 10 marks)



8 Gentian violet is a purple crystalline solid used as an antifungal treatment.

It can be synthesised from dimethylphenylamine, $\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_2$.

(a) The dimethylphenylamine used in the synthesis can be made by the stepwise reaction of phenylamine with chloromethane.



The reaction mechanism for Step 1 between phenylamine and chloromethane is the same as that in the reaction between ammonia and chloromethane.

(i) What is the reaction type and mechanism in Step 1?

(1)

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

(ii) Draw the mechanism for the reaction in Step 1.
Include curly arrows, and relevant lone pairs and dipoles.

(4)

- (iii) Describe, in outline, how a sample of a solid, such as gentian violet, is purified by recrystallisation.
Specific details of the solvent used are not required.

(4)

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- (b) The rate constant for the reaction between a solution of gentian violet and aqueous sodium hydroxide was determined at different temperatures.

Temperature (<i>T</i>) / K	1 / Temperature (1/ <i>T</i>) / K ⁻¹	Rate constant, <i>k</i> / dm ³ mol ⁻¹ s ⁻¹	ln <i>k</i>
283.5	3.53 × 10 ⁻³	2.71 × 10 ⁻³	-5.91
287.5	3.48 × 10 ⁻³	3.55 × 10 ⁻³	
291.5		4.75 × 10 ⁻³	-5.35
295.0	3.39 × 10 ⁻³	6.10 × 10 ⁻³	-5.10
298.5	3.35 × 10 ⁻³	7.60 × 10 ⁻³	-4.88

- (i) Complete the data in the table.

(1)

- (ii) Plot a graph and use it to determine the activation energy for the reaction in kJ mol⁻¹.

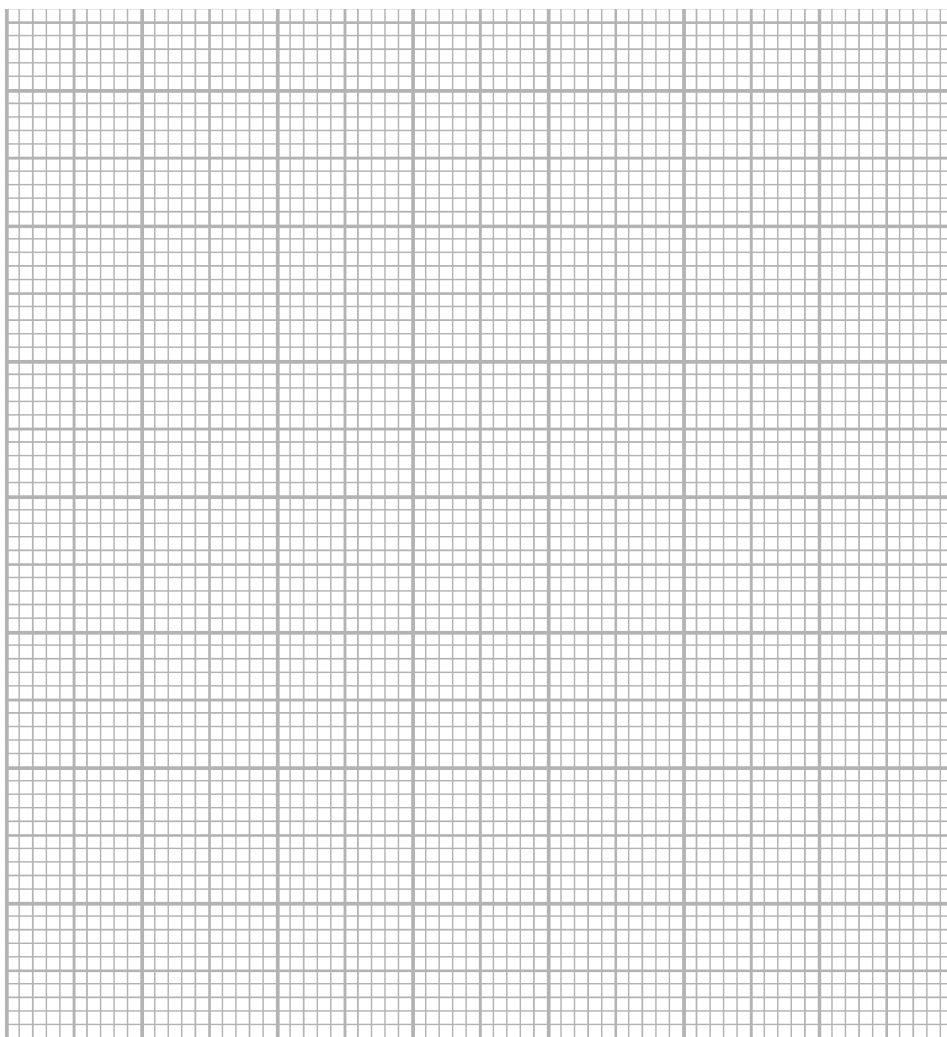
You should include the value and units of the gradient of the line.

The Arrhenius equation can be shown as

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

(6)





Gradient

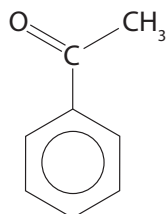
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Activation energy

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(Total for Question 8 = 16 marks)

- 8 Phenylethanone is an ingredient in many types of chewing gum.



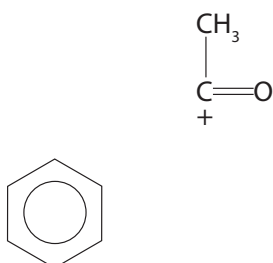
One method for the production of phenylethanone involves the reaction of benzene with ethanoyl chloride, CH_3COCl .

- (a) (i) Write the equation for the formation of the electrophile, CH_3CO^+ , from ethanoyl chloride using the catalyst aluminium chloride.

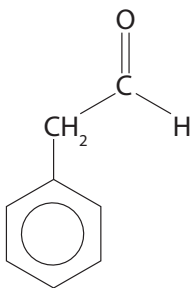
(1)

- (ii) Complete the diagram, including curly arrows, to show the mechanism for the reaction between this electrophile and benzene to produce phenylethanone. Include the regeneration of the catalyst.

(4)



- (b) Phenylethanone can be distinguished from its structural isomer, phenylethanal, in a number of different ways.



- (i) Which would react with phenylethanone but **not** with phenylethanal?

(1)

- ☒ **A** acidified sodium dichromate(VI)
- ☒ **B** alkaline iodine solution
- ☒ **C** Fehling's solution
- ☒ **D** Tollens' reagent

- (ii) Give the steps to show how 2,4-dinitrophenylhydrazine could be used to distinguish between phenylethanone and phenylethanal.

(4)

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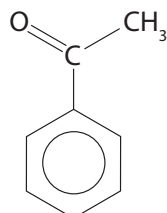
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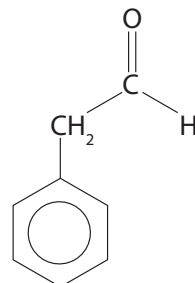
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*(iii) Compare and contrast the high resolution proton NMR spectra of phenylethanone and phenylethanal.

You should use the Data Booklet.



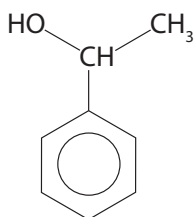
Phenylethanone



Phenylethanal

(6)

(c) The compound 1-phenylethanol can be formed from phenylethanone.



Give the reagent and conditions that would be used to form 1-phenylethanol.

(2)

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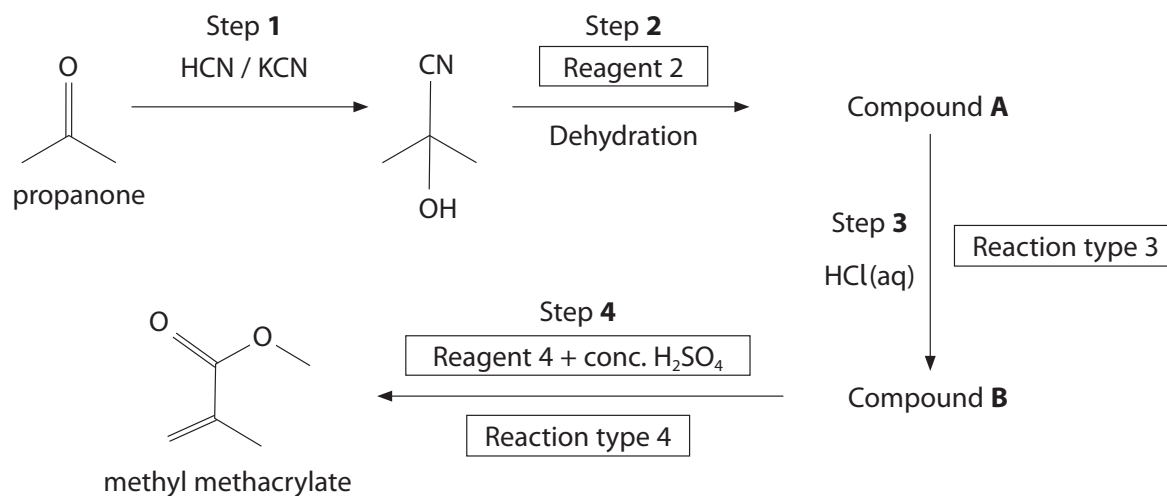
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(Total for Question 8 = 18 marks)

7 This question is about some reactions of carbonyl compounds.

- (a) Methyl methacrylate is the monomer used to make the polymer perspex. It can be synthesised from propanone using the reaction scheme shown.



- (i) Draw the mechanism for the reaction in Step 1. Include curly arrows and any relevant lone pairs and dipoles.

(4)

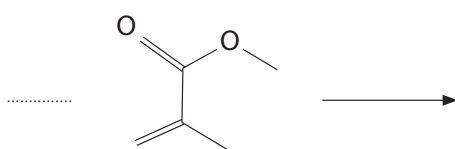
(ii) Complete the table to show the information missing from the reaction scheme.

(6)

Reagent 2	
Structure of compound A	
Reaction type 3	
Structure of compound B	
Reagent 4	
Reaction type 4	

(iii) Complete the equation for the formation of the polymer from methyl methacrylate.

(2)



- (b) Propanone can be formed from the fermentation of polysaccharides such as starch. The propanone can be separated from the fermentation mixture by distillation.

Draw the apparatus used in the laboratory for distillation of propanone from the reaction mixture.

(3)



- (c) Carbonyl compounds, such as propanone, react with 2,4-dinitrophenylhydrazine in solution (Brady's reagent) to form a precipitate which can be used to identify the compound.

The precipitate can be purified by recrystallisation.

Details of the recrystallisation process are shown.

Step 1 Dissolve the precipitate in the minimum volume of hot ethanol.

Step 2 Warm a filter paper and funnel in an oven for use in **Step 3**.

Step 3 Filter the solution whilst still warm to remove any undissolved solids, using gravity filtration.

Step 4 Allow the filtrate to cool and recrystallise.

Step 5 Filter the crystals under reduced pressure.

Step 6 Rinse the crystals with a small amount of ice-cold ethanol.

Step 7 Dry the crystals between filter papers and leave in a desiccator.

- (i) Explain why the filter paper and funnel are warmed in an oven before **Step 3**.

(2)

- (ii) Explain how **Steps 4** and **5** remove impurities from the crystalline product.

(2)



(iii) State how the purified crystals can be used to identify the carbonyl compound that reacts with 2,4-dinitrophenylhydrazine.

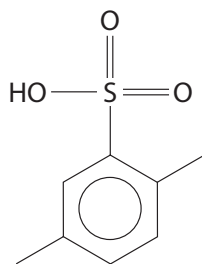
Detailed descriptions of practical procedures are not required.

(2)

(Total for Question 7 = 21 marks)



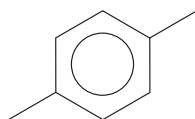
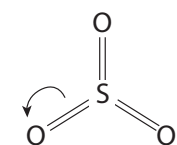
- 9 This question is about the compound 2,5-dimethylbenzenesulfonic acid, which has the structure shown.



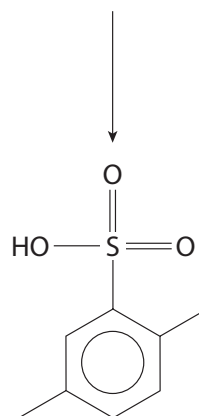
It is used to analyse levels of cholesterol in blood plasma. It can be synthesised by the reaction of 1,4-dimethylbenzene with concentrated sulfuric acid. The electrophile in this reaction is sulfur trioxide.

- (a) Complete a possible mechanism for this reaction by adding curly arrows, and any relevant dipoles, charges and lone pairs.

(3)



structure of intermediate



- (b) The 2,5-dimethylbenzenesulfonic acid formed can be purified by recrystallisation using hot water as a solvent.

Procedure

- Step 1** Dissolve impure 2,5-dimethylbenzenesulfonic acid in the minimum volume of hot water.
- Step 2** Allow the solution to cool until 2,5-dimethylbenzenesulfonic acid has crystallised.
- Step 3** Separate the 2,5-dimethylbenzenesulfonic acid by filtering under reduced pressure.
- Step 4** Rinse the 2,5-dimethylbenzenesulfonic acid using a small amount of ice-cold water.
- Step 5** Dry the 2,5-dimethylbenzenesulfonic acid between two pieces of filter paper.

- (i) Explain how recrystallisation reduces the amount of **soluble** impurities.

(3)

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- (ii) A student carrying out this procedure noticed some **insoluble** impurities in their sample.

Describe how the procedure should be amended to remove these insoluble impurities.

(2)

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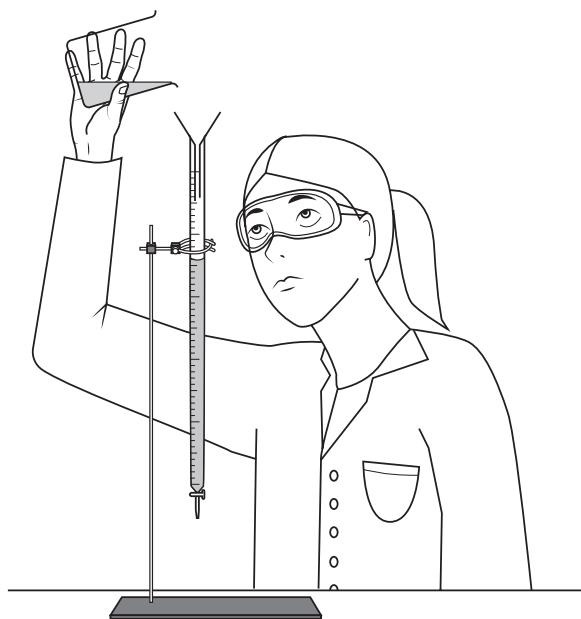


- (ii) Calculate the relative formula mass of hydrated 2,5-dimethylbenzenesulfonic acid and hence deduce the value of n .

(5)



- (d) A student carrying out this experiment used a funnel as shown to try to ensure the acid was added safely to the burette during the titration.



- (i) Give **one** change to this technique that would reduce the risk to this student.

(1)

- (ii) The student forgot to remove the funnel from the burette and during the titration five drops of acid from the funnel dripped into the burette.

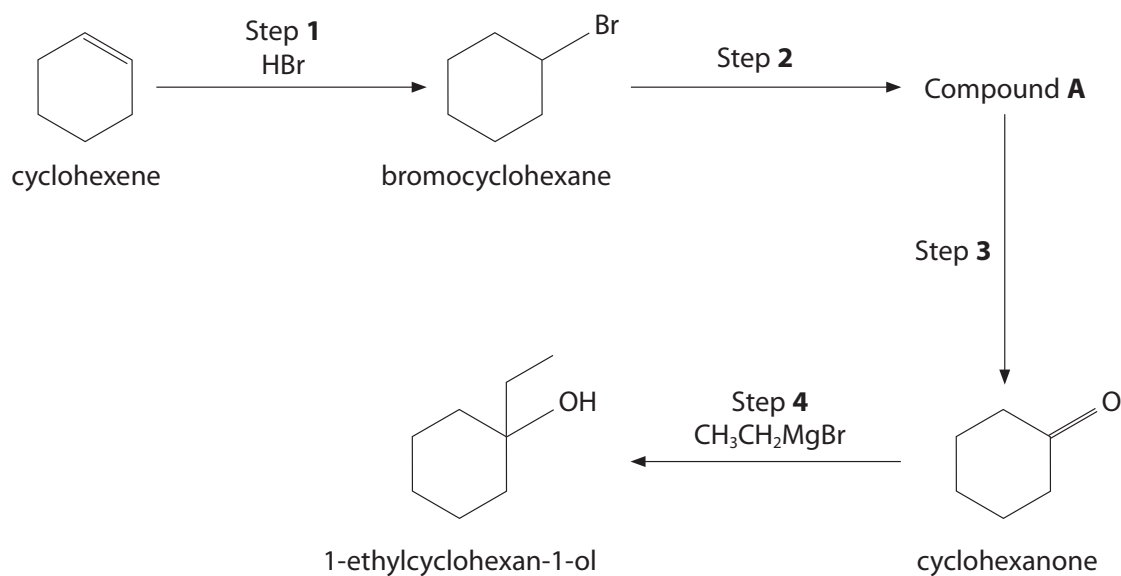
Explain what effect, if any, this error will have on the final value for n .

(3)

(Total for Question 9 = 21 marks)



- 7 The alcohol 1-ethylcyclohexan-1-ol can be synthesised from cyclohexene using the reaction scheme shown.



- (a) Draw the mechanism for Step 1.
Include curly arrows, and relevant lone pairs and dipoles.

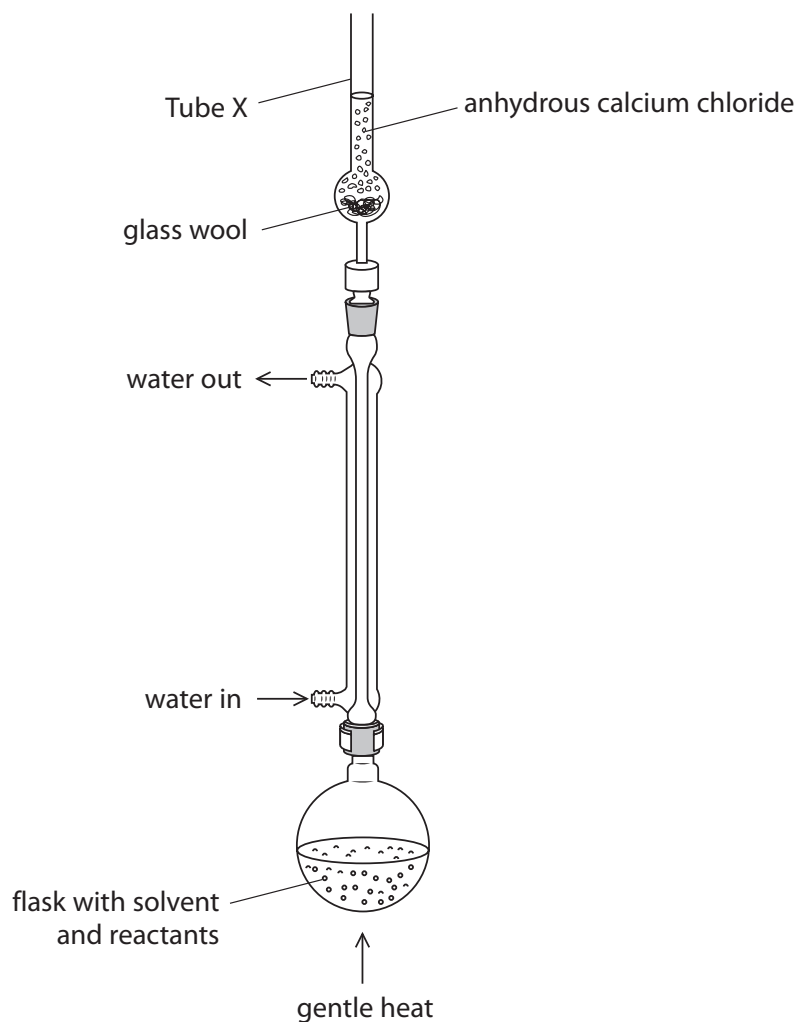
(4)

- (b) Devise a reaction scheme for Step **2** and Step **3** of the synthesis.
Include in your answer all reagents and conditions, the type of reaction in each step, and the structure of **A**.

(5)



- (c) The reaction to produce the $\text{CH}_3\text{CH}_2\text{MgBr}$ used in Step 4 requires bromoethane and magnesium to be warmed under reflux with a suitable solvent. The apparatus used for this reaction is shown.



- (i) Name the solvent used.

(1)

(ii) Explain why the anhydrous calcium chloride in Tube X is necessary.

(2)

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(iii) Give a reason why it is best practice for the water in the condenser to flow in the direction shown in the diagram.

(1)

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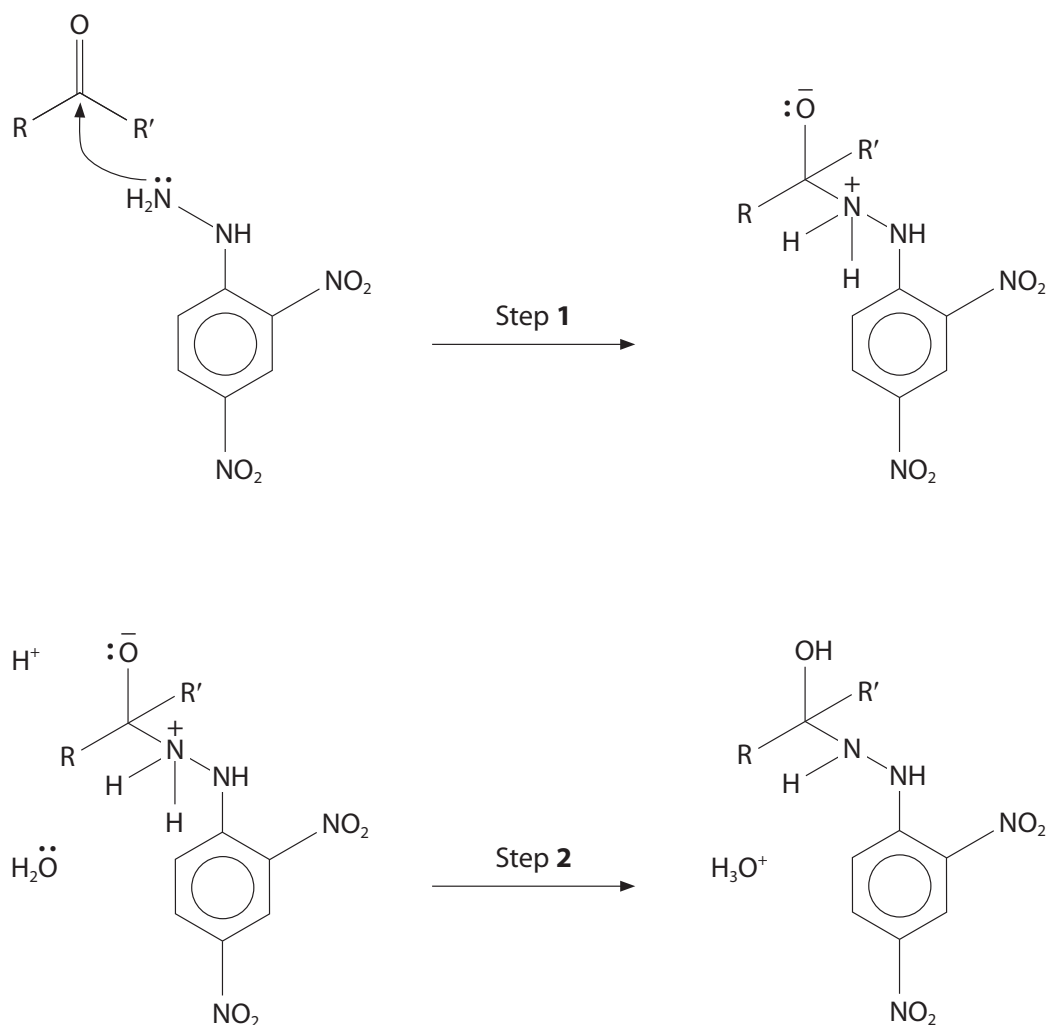
(d) Carbonyl compounds such as cyclohexanone can be identified by the reaction with 2,4-dinitrophenylhydrazine.

(i) Give the colour of the precipitate formed in this reaction.

(1)

(ii) Complete the simplified mechanism for the first two steps of this reaction by adding **four** curly arrows.

(4)



(iii) Describe how you would obtain pure dry crystals from the precipitate.

(4)

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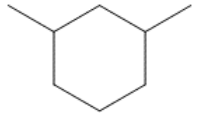
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(Total for Question 7 = 22 marks)

MARK SCHEMES

official Pearson Edexcel mark schemes



Question Number	Answer	Additional Guidance	Mark
1(a)	skeletal formula	<u>Example of skeletal formula</u>  Do not award displayed or structural formulae	(1)

Question number	Answer	Mark
1(b)	The only correct answer is A (C_nH_{2n-2}) <i>B is incorrect because C_nH_{2n} is the general formula of an alkene or a cycloalkane</i> <i>C is incorrect because C_nH_{2n+1} is the general formula of an alkyl group</i> <i>D is incorrect because C_nH_{2n+2} is the general formula of a straight chain or branched chain alkane</i>	(1)



Question Number	Answer	Additional Guidance	Mark
1(c)	An answer that makes reference to the following points: - you cannot control how many chlorine atoms will substitute or you cannot control the carbon atom on which the chlorine will substitute or a mixture of / side / unwanted / products will form (1) - need to separate the 1,2-dichloroethane from any other products made (1)	Allow names or formulae Allow a specific example of a correct unwanted product e.g. chloroethane, 1,1,1-trichloroethane, 1,1-dichloroethane, 1-chlorobutane, butane Do not award H₂ Ignore Low yield, waste products, damage to ozone, dangers of UV, chain reaction, HCl	(2)

(Total for Question 1 = 4 marks)



Question Number	Acceptable Answer	Mark
1(a)	The only correct answer is D <i>A is incorrect because it is not an addition reaction</i> <i>B is incorrect because no multiple bond is formed</i> <i>C is incorrect because initiation is only the first stage in the mechanism of the reaction</i>	(1)

Question Number	Acceptable Answer	Mark
1(b)	The only correct answer is A <i>B is incorrect because oxides of nitrogen are not black solids</i> <i>C is incorrect because oxides of sulfur are not black</i> <i>D is incorrect because unburnt hydrocarbons are not black solids</i>	(1)

Question Number	Acceptable Answer	Mark
1(c)	The only correct answer is D <i>A is incorrect because no alkenes are produced</i> <i>B is incorrect because hydrogen is formed</i> <i>C is incorrect because the molecular formulae of the organic compounds are not the same</i>	(1)



Question Number	Acceptable Answer	Mark
1(d)	The only correct answer is C <i>A is incorrect because there are not 22 hydrogen atoms</i> <i>B is incorrect because there are not 20 hydrogen atoms</i> <i>D is incorrect because there are not 16 hydrogen atoms</i>	(1)

(Total for Question 1 = 4 marks)



Question Number	Answer	Mark
1(a)	The only correct answer is D (free radical substitution) <i>A is not correct because electrophilic addition would be the reaction mechanism between alkenes, such as ethene, and chlorine but the substance in the question is the alkane, ethane</i> <i>B is not correct because electrophilic substitution involves the reactions of aromatic systems but this question refers to the reaction of the alkane, ethane</i> <i>C is not correct because the mechanism of reaction between an alkane such as ethane and chlorine involves substitution and not addition</i>	(1)

Question Number	Answer	Mark
1(b)	The only correct answer is B (4-ethyl-3-methylheptane) <i>A is not correct because the longest consecutive carbon chain involves the seven carbon atoms from the top left of the molecular drawing down to the bottom right which means that the stem of the name is not pentane but heptane, with the consequential effect on the numbering and length of side chains</i> <i>C is not correct because the longest consecutive carbon chain involves the seven carbon atoms from the top left of the molecular drawing down to the bottom right which means that the stem of the name is not hexane but heptane, with the consequential effect on the numbering and length of side chains</i> <i>D is not correct because the longest consecutive carbon chain involves the seven carbon atoms from the top left of the molecular drawing down to the bottom right which means that the stem of the name is not hexane but heptane, with the consequential effect on the numbering and length of side chains</i>	(1)

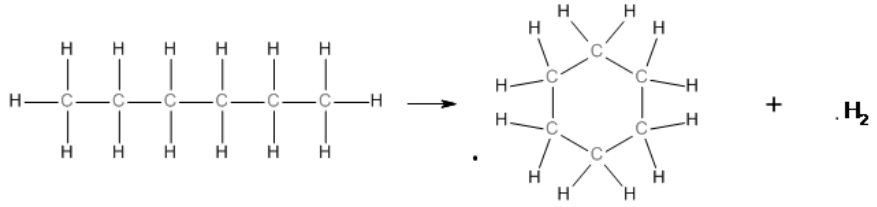
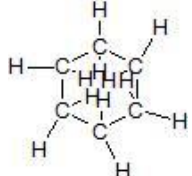
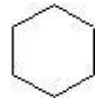


Question Number	Answer	Additional Guidance	Mark
1(c)(i)	An explanation that makes reference to the following points: - different alkanes have different boiling temperatures/points (1) - because of (different) chain length/molar mass /strength of intermolecular forces/ number of electrons (1)	Allow Volatility for boiling temperature Allow Different alkanes condense at different temperatures Ignore melting temperatures if given with boiling temperatures Ignore densities Accept London /dispersion /van der Waals forces Allow reference to size A comparison such as 'longer alkanes have higher boiling points' scores 2 Ignore any reference to surface area Do not award references to cracking Do not award reference to just weight/mass Do not award incorrect trend	(2)



Question Number	Answer	Additional Guidance	Mark
1(c)(ii)	Correct equation	<u>Example of equation:</u> $\text{C}_8\text{H}_{18} \rightarrow \text{C}_2\text{H}_4 + \text{C}_6\text{H}_{14}$ OR $\text{C}_8\text{H}_{18} \rightarrow 2\text{C}_2\text{H}_4 + \text{C}_4\text{H}_{10}$ OR $\text{C}_8\text{H}_{18} \rightarrow 3\text{C}_2\text{H}_4 + \text{C}_2\text{H}_6$ Allow $\text{CH}_2=\text{CH}_2$ for C_2H_4 Products can be given in either order Do not award equations forming H_2	(1)



Question Number	Answer	Additional Guidance	Mark
1(c)(iii)	Correct equation	<u>Example of equation:</u>  Accept bonds to hydrogen atoms inside the ring, e.g.  Allow skeletal or structural formulae for hexane  or $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$ and for cyclohexane  or $(\text{CH}_2)_6$ Ignore $\text{C}_6\text{H}_{14} \rightarrow \text{C}_6\text{H}_{12} + \text{H}_2$	(1)

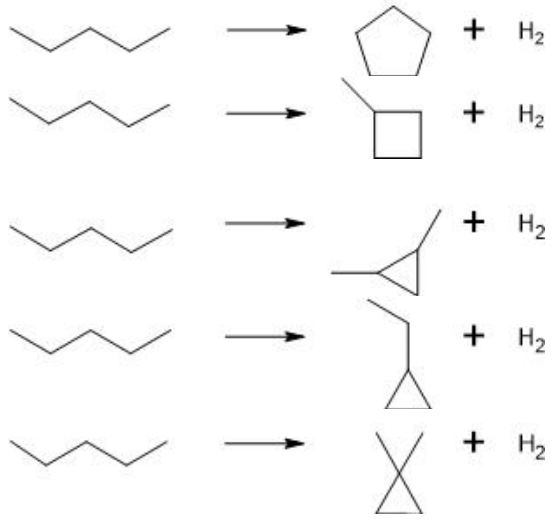
(Total for Question 1 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
1(a)	correct balancing	<u>Example of equation</u> $\text{C}_6\text{H}_{14} + 9\frac{1}{2}\text{O}_2 \rightarrow 6\text{CO}_2 + 7\text{H}_2\text{O}$ Accept decimals/improper fractions Allow multiples 2:19:12:14 Ignore state symbols even if incorrect	(1)

Question Number	Answer	Additional Guidance	Mark
1(b)	An answer that makes reference to two of the following points: - carbon / C (1) - carbon monoxide / CO (1) - nitrogen monoxide / NO / nitrogen dioxide / NO₂ / nitrogen oxides / NO_x / pentane / C₅H₁₂ (1)	Do not award hydrogen / H ₂ Allow particulates / soot Ignore carbon dioxide Ignore 'unburnt hydrocarbons'	(2)

Question Number	Answer	Additional Guidance	Mark
1(c)	An explanation that makes reference to the following points: - acid rain is formed (1) - because sulfur oxides / sulfur dioxide / SO₂ / sulfur trioxide / SO₃ (formed which dissolve in water) (1)	Causes respiratory difficulties/bronchitis Allow description of breathing difficulties Ignore just vague references to harm the environment Ignore reference to greenhouse effect/global warming Allow (formation of) sulfuric acid Allow SO _x but not SO	(2)



Question Number	Answer	Additional Guidance	Mark
1(d)	- skeletal formulae (1) - hydrogen molecule (product) to balance the equation (1)	<u>Examples of equations</u>  Award (1) for use of non-skeletal formulae in balanced equation Ignore state symbols even if incorrect Allow formation of cyclopentene with 2H₂ Do not award M2 if any other species is/are given in the equation but ignore any catalysts written above the arrow	(2)

(Total Question 1 = 7 marks)

Question Number	Answer	Mark
2(a)	The only correct answer is A (4-ethyloctane) <i>B is incorrect because the position of the ethyl group should be shown by counting in the direction that gives the lowest possible number</i> <i>C is incorrect because the longest carbon chain has 8 carbons</i> <i>D is incorrect because the longest carbon chain has 8 carbons and because the position of the alkyl group should be shown by counting in the direction that gives the lowest possible number</i>	(1)

Question Number	Answer	Mark
2(b)	The only correct answer is D (cracking) <i>A is incorrect because substitution would exchange atoms/groups in the reactant for other atoms/groups</i> <i>B is incorrect because reforming would produce branched/cyclic alkanes</i> <i>C is incorrect because fractional distillation would separate a mixture of alkanes</i>	(1)

Question Number	Answer	Mark
2(c)(i)	The only correct answer is C (homolytic bond fission to form free radicals) <i>A is incorrect because such bond fission would produce ions</i> <i>B is incorrect because the first step of the reaction produces free radicals by homolytic fission</i> <i>D is incorrect because the first step of the reaction produces free radicals</i>	(1)



Question Number	Answer	Additional Guidance	Mark
2(c)(ii)	$122.9 \div (122.9 + 80.9) \times 100$ or $122.9 \div (44.0 + (2 \times 79.9)) \times 100$ or $(122.9 \div 203.8) \times 100$ $= 60.304\%$	Allow $123 \div (123 + 81) = 60.29\%$ Award M1 only if final answer given as decimal 0.603 rather than % Allow TE for M2 for only one incorrect A_r value Ignore SF Correct answer with or without working scores (2)	(2)

Question Number	Answer	Mark
2(c)(iii)	The only correct answer is D (the reaction produces a mixture of organic products) <i>A is incorrect because bromine is very reactive</i> <i>B is incorrect because gaseous reactants do not necessarily give a poor yield</i> <i>C is incorrect because the kinetics of the reaction do not affect the yield</i>	(1)



Question Number	Answer	Additional Guidance	Mark
2(c)(iv)	Amount of 1-bromopropane (1)	$14.7/122.9 = 0.11961 \text{ (mol)}$	(3)
	So moles of propane required (1)	$(0.11961/31) \times 100 = 0.38584 \text{ (mol)}$	
	So volume of propane required to 2 or 3 SF (1)	$= 0.38584 \times 24.0 = 9.2601 \text{ (dm}^3\text{)}$ $= 9.3 / 9.26 \text{ (dm}^3\text{)}$ Allow $14.7/123 = 0.11951 \text{ (mol)}$ $(0.11951/31) \times 100 = 0.38552 \text{ (mol)}$ $= 0.38552 \times 24.0 = 9.2526 \text{ (dm}^3\text{)}$ $= 9.3 / 9.25 \text{ (dm}^3\text{)}$	
	Alternative route		
	Target mass of 1-bromopropane required to produce 14.7 g (with a 31.0% yield) (1)	$14.7 \times \frac{100}{31.0} = 47.4 \text{ g}$	
	Moles of propane required to produce the required mass of 1-bromopropane (1)	$\frac{47.4}{122.9} = 0.3857 \text{ (mol)}$	
	So volume of propane required to 2 or 3 SF (1)	$0.3857 \times 24.0 = 9.3 / 9.26 \text{ (dm}^3\text{)}$ Award (2) for a final answer of 0.890 / 0.89 (dm ³) (incorrect use of 31.0%) Answer assuming 100% yield scores (2) for final answer of 2.87 / 2.9 (dm ³) Penalise incorrect units in M3 Do not award M3 if Ideal Gas Eqtn used for propane volume Penalise incorrect rounding once only Correct answer to 2 or 3 SF with or without working scores (3)	

(Total Question 2 = 9 marks)

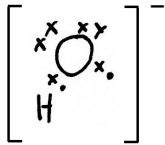
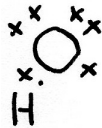


Question Number	Answer	Additional Guidance	Mark
4(a)(i)	- conversion of nanometres to metres - calculation of energy of one photon - calculation of energy per mol of photons - comparison to Cl–Cl bond and C–H bond stating that Cl–Cl bond can be broken but not C–H bond	<u>Example of calculation</u> (1) $\lambda = 3.15 \times 10^{-7} \text{ m}$ (1) $E = ((6.626 \times 10^{-34} \times 3.00 \times 10^8) \div 3.15 \times 10^{-7})$ $= 6.3105 \times 10^{-19} \text{ (J)}$ (1) $E = 6.3105 \times 10^{-19} \times 6.02 \times 10^{23}$ $= 379\,890 \text{ (J mol}^{-1}\text{)} / 379.890 \text{ (kJ mol}^{-1}\text{)}$ TE for M1 to M3 (1) $413 > 379.890$ (so) C–H (is not broken) but $379.890 > 243$ (so) Cl–Cl (is broken) Alternative approach for M3 Bond enthalpy for one C–H bond $E = (413 \times 1000) \div 6.02 \times 10^{23}$ $= 6.86 \times 10^{-19} \text{ (J)}$ Bond enthalpy for Cl–Cl bond $E = (243 \times 1000) \div 6.02 \times 10^{23}$ $= 4.04 \times 10^{-19} \text{ (J)}$	(4)

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	An answer that makes reference to the following points: - primary butyl radical - secondary butyl radical	‘dot’ must be on the correct carbon atom (1) $\text{CH}_3\text{CH}_2\text{CH}_2\dot{\text{C}}\text{H}_2$ Allow $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\bullet$ (1) $\text{CH}_3\dot{\text{C}}\text{HCH}_2\text{CH}_3$ Allow $\text{CH}_3\text{CH}\bullet\text{CH}_2\text{CH}_3$ Penalise missing ‘dot’/extra ‘dot’ once only Do not allow charged ions Do not allow chlorinated radicals Allow displayed formulae	(2)

Question Number	Answer	Additional Guidance	Mark
4(a)(iii)	An explanation that makes reference to the following points: 1-chlorobutane is produced from a primary radical and 2-chlorobutane is produced from a secondary radical - a secondary (radical) which is more stable (than a primary (radical))	(1) Penalise use of carbocation in M1 only (1) Allow (because) of the positive inductive effect / electron-releasing effect of the two alkyl groups (rather than one), providing linked to stability Do not allow reference to stability of halogenoalkanes	(2)



Question Number	Answer	Additional Guidance	Mark
4(b)	An answer that makes reference to the following points: - dot-and-cross diagram of hydroxide ion (1) - dot-and-cross diagram of hydroxyl radical (1)	<u>Example of diagrams</u>  Allow missing brackets, but do not award omission of negative charge Allow all of the non-bonded electrons to be crosses so long as the shared pair is a dot and a cross  Allow dots and crosses to be given the 'other way around' Allow use of other symbols as long as clearly different. Allow (1) for two 'correct' diagrams with all dots or all crosses	(2)

Question Number	Answer	Mark
4(c)	The only correct answer is A (the formation of the cyanide nucleophile from KCN) <i>B is not correct because the attack by the cyanide nucleophile to produce the nitrile does involve heterolytic fission of the C–Br bond</i> <i>C is not correct because the attack by the hydroxide nucleophile does involve heterolytic fission of the C–Br bond</i> <i>D is not correct because the attack by the water nucleophile does involve heterolytic fission of the C–I bond</i>	(1)

(Total for Question 4 = 11 marks)

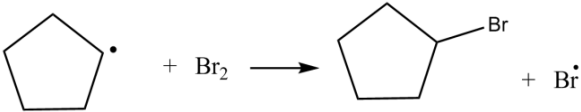
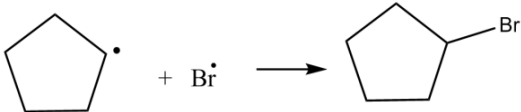
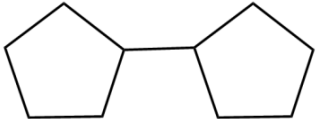


Question Number	Answer	Additional Guidance	Mark
5(a)	An answer that makes reference to the following point: reforming/reformation	Allow dehydrogenation / cyclisation Ignore oxidation / catalytic Do not award cracking / dehydration	(1)

Question Number	Answer	Additional Guidance	Mark
5(b)	- calculate volume of cyclopentane - calculate energy density of cyclopentane and appropriate units	<u>Example of calculation</u> (1) Volume = $30.0 \div 0.751 / 39.947 \text{ (cm}^3\text{)}$ Ignore units in M1 (1) $1.41 \div (39.947 \div 1000) = 35.297 \text{ MJ dm}^{-3}$ Ignore SF except 1 SF Allow TE from M1 Allow $3.5297 \times 10^4 \text{ kJ dm}^{-3}$ or $3.5297 \times 10^7 \text{ J dm}^{-3}$ $3.5297 \times 10^4 \text{ J cm}^{-3}$	(2)

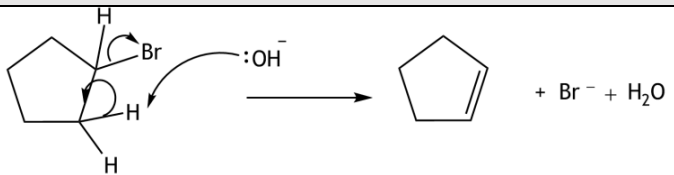
Question Number	Answer	Additional Guidance	Mark
5(c)(i)	An answer that makes reference to the following point: UV (light) / ultraviolet (light)	Allow sun(light) / temperature over 250°C Ignore heat under reflux Do not award high pressure	(1)



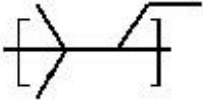
Question Number	Answer	Additional Guidance	Mark
5(c)(ii)	An answer that makes reference to the following points: - Initiation $\text{Br}_2 \rightarrow 2\text{Br}^\bullet$ (1) - Propagation  (1) - Termination  (1)	NOTE – penalise use of hexagons once only in 5(c)(ii) and 5(c)(iii) Penalise omission of unpaired electrons once only Curly-half arrows if shown must be in correct direction Do not award double-headed arrow(s) in M1 Penalise use of chlorine once only Ignore position of bromine relative to dot on free radical	(3)
5(c)(iii)		Allow displayed formulae Do not award 	(1)

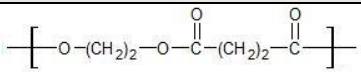
Question Number	Answer	Additional Guidance	Mark
5(d)(i)	An explanation that makes reference to the following points: - to dry the ethanol / solvent - as (presence of) water would result in formation of (some) cyclopentanol	(1) Allow remove water from the ethanol / solvent Allow to react with the ethanol to remove the water Allow to ensure the reaction conditions are not aqueous Ignore just 'it's a drying agent' Ignore to dry the reactants / removes water that forms in the reaction Do not allow 'to dehydrate' (1) Allow alcohol / hydroxycyclopentane for cyclopentanol Allow as (presence of) water would result in (some) (nucleophilic) substitution (by the hydroxide ion) Ignore hydrolysis	(2)

Question Number	Answer	Additional Guidance	Mark
5(d)(ii)	An answer that makes reference to the following point: elimination	Comment: Allow dehydrohalogenation Do not award nucleophilic / electrophilic / free-radical Ignore oxidation / reduction / basic	(1)

Question Number	Answer	Additional Guidance	Mark
5(d)(iii)	double-headed arrow from C-H bond to C-C bond and double-headed arrow from C-Br bond to Br	 Ignore any dipoles, even if incorrect	(1)

(Total for Question 5 = 12 marks)

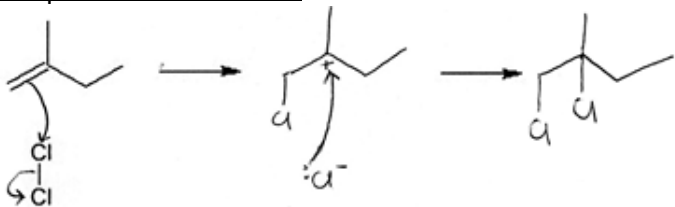
Question Number	Answer	Mark
1(a)	The only correct answer is A () B is not correct because there is no C=C in the repeat unit C is not correct because the extension bonds are not from the correct carbon atoms of the chain and there should not be a C=C in the repeat unit D is not correct because the extension bonds are not from the correct carbon atoms of the chain	(1)
Question Number	Answer	Mark
1(b)	The only correct answer is B (generation of biodegradable materials) A is not correct because some poly(alkenes) may be used as a feedstock for cracking C is not correct because some poly(alkenes) may be used for energy from incineration D is not correct because some poly(alkenes) may be used for recycling to make new materials	(1)

Question Number	Answer	Mark
1(c)	The only correct answer is B () <i>A is not correct because there is an additional oxygen atom in the repeat unit</i> <i>C is not correct because there is an incorrect number of CH₂ groups in one of the monomers and there is an additional oxygen atom in the repeat unit</i> <i>D is not correct because there is an incorrect number of CH₂ groups in one of the monomers</i>	(1)

Question Number	Answer	Mark
1(d)	The only correct answer is D (use a higher temperature for a faster reaction rate) <i>A is not correct because efficient use of energy does contribute to sustainability</i> <i>B is not correct because efficient use of resources does contribute to sustainability</i> <i>C is not correct because use of catalysts do contribute to sustainability</i>	(1)

(Total Question 1 = 4 marks)



Question Number	Answer	Additional Guidance	Mark
3(a)(i)	- curly arrow from C=C to chlorine and curly arrow from Cl-Cl to 'bottom' chlorine atom (1) - structure of carbocation intermediate and structure of final product (1) - chloride ion with lone pair and curly arrow from lone pair to C⁺ of carbocation (1)	<u>Example of mechanism:</u>  Ignore dipoles even if incorrect Allow correct structural/displayed formulae for intermediate and/or product Allow TE on incorrect primary carbocation	(3)

Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	1,2-dichloro-2-methylbutane	Allow name shown on mechanism Ignore missing hyphens and commas Do not allow 2-methyl-1,2-dichlorobutane TE on structure in (a)(i) Allow correct name even if incorrect structure in (i)	(1)

Question Number	Answer	Mark
3(b)	The only correct answer is A (primary) <i>B is not correct because there is no chlorine atom bonded to a carbon atom which is bonded to two other carbon atoms</i> <i>C is not correct because there is no chlorine atom bonded to a carbon atom which is bonded to three other carbon atoms</i> <i>D is not correct because both chlorine atoms are bonded to carbon atoms which are bonded to only one carbon atom</i>	(1)

(Total Question 3 = 5 marks)



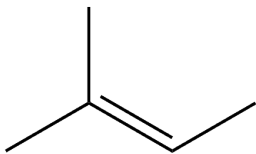
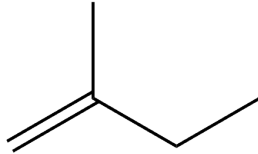
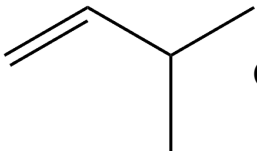
Question Number	Answer	Additional Guidance	Mark																				
*5	This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages).	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5-4	3																						
3-2	2																						
1	1																						
0	0																						
	Number of marks awarded for structure of answer and sustained lines of reasoning																						
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2																						
Answer is partially structured with some linkages and lines of reasoning	1																						
Answer has no linkages between points and is unstructured	0																						



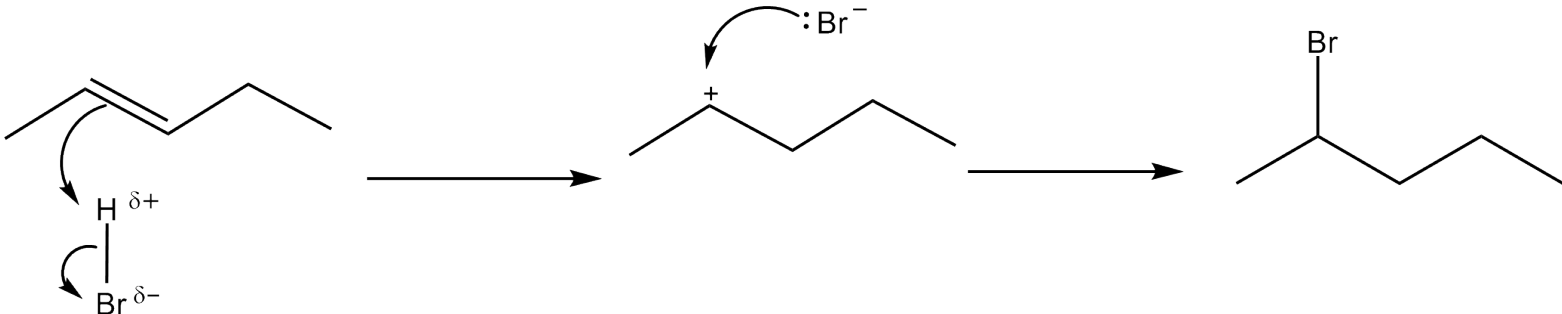
	Indicative content Similarity IP1 both reactions involve attack by an electrophile Differences IP2 benzene reaction is a substitution, cyclohexene reaction is an addition IP3 benzene forms 2 products, cyclohexene forms 1 product IP4 so benzene reaction requires a catalyst of FeBr₃ (to induce dipole in bromine) IP5 cyclohexene reacts at room temperature / with bromine water IP6 benzene is less reactive / more stable as (pi) electrons are delocalised (across the ring)	Benzene forms bromobenzene + HBr and cyclohexene forms just 1,2-dibromocyclohexane Allow equations for evidence of IP3 but not IP2 Ignore names if correct structures drawn Allow Fe/AlBr₃ as catalyst/halogen carrier Allow AlCl₃ Allow this shown by equation e.g. $\text{FeBr}_3 + \text{Br}_2 \rightarrow \text{FeBr}_4^- + \text{Br}^+$ Ignore reference to heat/reflux/room temperature Accept cyclohexene is more reactive due to high electron density of double bond / localised pi electrons Ignore just 'does not need a catalyst' Ignore just 'no special conditions'	
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(Total for Question 5 = 6 marks)



Question Number	Answer		Mark	
4(a)	 (1)	 (1)  (1)	Allow (2) for three correct displayed or structural formulae Allow (1) for any two correct displayed or structural formulae	(3)

Question Number	Answer	Mark
4(b)	The only correct answer is D $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$ only <i>A is not correct because it will not form pent-2-ene</i> <i>B is not correct because it will only form pent-1-ene</i> <i>C is not correct because $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_3$ will also form pent-1-ene</i>	(1)

Question Number	Answer	Additional Guidance	Mark
4(c)	• arrow from double bond to δ^+ H in HBr (1) • arrow from bond in HBr to $\text{Br}^{\delta-}$ (1) • structure of carbocation (1) • arrow from lone pair on Br^- to C^+ in carbocation and final products (1)	Penalise lack of dipole only once in M1 or M2 Do not award M1 if arrow from $\text{C}=\text{C}$ to C also shown Formation of 3-bromopropane can potentially score M1, M2 and M4 as a TE	(4)
			

Question Number	Answer	Additional Guidance	Mark
4(d)	- calculation of moles of pent-1-ene (1) - conversion of volume and temperature (1) - rearrangement of ideal gas equation and calculation of p (1) - final answer to 2 or 3 SF and units (1)	<u>Example of calculation</u> $1.33 / 70 = 0.019$ (mol) $500 \times 10^{-6} \text{ m}^3$ and 333 K Allow conversion of volume to 0.5 dm^3 if units for M3 and / or M4 shown as kPa $P = (nRT) / V = (0.019 \times 8.31 \times 333) / 500 \times 10^{-6}$ $= 105154.74$ $= 105000 \text{ Pa} / 1.05 \times 10^5 \text{ Pa} / 1.1 \times 10^5 \text{ Pa}$ Allow N m^{-2} for Pa Allow 105 kPa Allow TE at each stage Penalise rounding to 1SF in M1 but then allow TE Correct answer with units and no working scores (4)	(4)

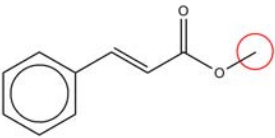
(Total Question 4 = 12 marks)



Question Number	Answer	Additional Guidance	Mark
4(a)	- calculation of molar mass of methyl cinnamate (1) - calculation of mass of carbon (1)	Example of calculation molar mass = 162 (g mol⁻¹) 2.34 x (120/162) = 1.73333 = 1.73 (g) TE on incorrect molar mass for M2 Correct answer with no working scores 2 marks Ignore SF except 1	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)(i)	An answer that makes reference to the following points: - peak due to tetramethylsilane (1) - so (chemical) shifts (due to other hydrogen atoms) can be compared (1)	Allow TMS / Si(CH₃)₄ Name must be correct if given Allow "a reference" / "a standard" "calibration" Ignore "to allow other molecules to be compared"	(2)



Question Number	Answer	Additional Guidance	Mark
4(b)(ii)	An answer that makes reference to the following points: • M1 circle around $-\text{CH}_3$ group in $-\text{OCH}_3$ (1) • M2 singlet as no neighbouring hydrogen atoms (1) • M3 peak area of 3 means there are 3 hydrogen atoms in this environment (1)	Allow 'protons' for hydrogen atoms  Award whole $-\text{OCH}_3$ circled Do not award if $\text{C}=\text{O}$ included in circle M1 is a stand alone mark Award "has no adjacent hydrogen atoms" Award "no hydrogens on adjacent carbon" Ignore "there is no adjacent C atom" Award "(relative) peak area of three for a $-\text{CH}_3$ group" For M3 must relate to (relative) peak area / integral Ignore references to chemical shift value for ester $\delta = 3.0$ to 4.0 (ppm) Ignore references to relative heights of peaks Comment M2 and / or M3 dependent on $-\text{CH}_3$ group being included in the circled group	(3)

Question Number	Answer	Additional Guidance	Mark
4(c)(i)	M1 arrow from double bond to (δ^+)Br in Br₂ (1) M2 arrow from bond in Br₂ to Brδ^- (1) M3 structure of carbocation (1) M4 arrow from lone pair on Br$^-$ to C$^+$ in carbocation and final product (1)	<u>Example of mechanism</u> See below Penalise lack of dipole only once in M1 and M2 Award C$^+$ in intermediate on either C from the double bond Do not award M3 if four bonds are shown on carbocation Br atoms can be shown either upwards or downwards in final product Award (0) if just electrophilic substitution mechanism given. If both electrophilic substitution and addition shown allow 2 max Penalise errors in structure of methyl cinnamate once only in either M3 or M4 Do not award M4 if the two Br atoms have been added to the same carbon atom in the addition product Penalise use of half arrows once only	(4)



Question Number	Answer	Mark
4(c)(ii)	The only correct answer is C (4) <i>A is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms</i> <i>B is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms</i> <i>D is not correct because 2 chiral centres form in reaction, so 4 possible combinations of +/- forms</i>	(1)

Question Number	Answer	Mark
4(c)(iii)	The only correct answer is D (rotated) <i>A is not correct because diffracted is the wrong term</i> <i>B is not correct because reflected is the wrong term</i> <i>C is not correct because refracted is the wrong term</i>	(1)

(Total Question 4 = 13 marks)

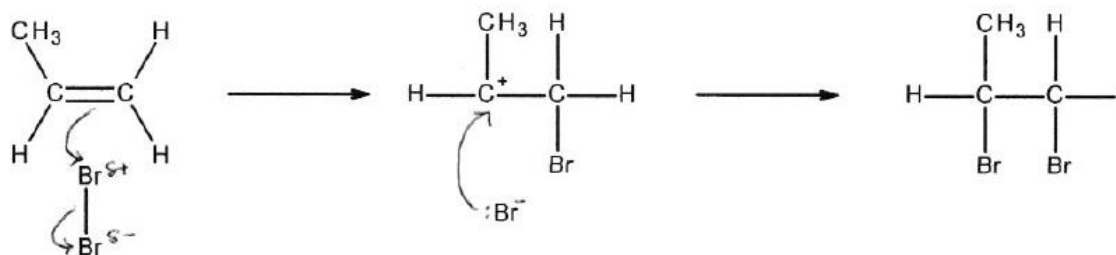


Question number	Answer	Mark
8(a)	The only correct answer is B (3) <i>A is incorrect because pentane, 2-methylbutane and 2,2-dimethylpropane are the isomers of C_5H_{12}</i> <i>C is incorrect because pentane, 2-methylbutane and 2,2-dimethylpropane are the isomers of C_5H_{12}</i> <i>D is incorrect because pentane, 2-methylbutane and 2,2-dimethylpropane are the isomers of C_5H_{12}</i>	(1)



Question Number	Answer	Additional Guidance	Mark
8(b)	An answer that makes reference to the following points: • curly arrow from C=C towards top Br • dipole on Br₂ • curly arrow from Br–Br bond to, or just beyond, lower Br • intermediate • lone pair on Br[–] • curly arrow from lone pair towards C⁺	Allow skeletal formulae throughout. Allow + on carbon 1 and Br on carbon 2 Do not award Br^{δ–} 6 points awarded 3 marks 4 or 5 awarded 2 marks 2 or 3 awarded 1 mark 1 or 0 awarded 0 marks	(3)

Example of mechanism



Question Number	Answer	Additional Guidance	Mark
8(c)(i)	An explanation that makes reference to the following points: - because sodium chloride (only) contains Cl^- ions and the initial attack is by an electrophile (1) $\text{Br}^{\delta+}$ / bromine must attack first (so no dichloro-product can form) (1)	Allow these points shown on a labelled mechanism Allow (the first step involves an electrophile but) Cl^- is a nucleophile / not an electrophile / there is no Cl^+ / $\text{Cl}^{\delta+}$ Allow Cl^- only reacts when a carbocation has been formed Do not award Br^- Do not award Br^+ must attack first.	(2)

Question Number	Answer	Additional Guidance	Mark
8(c)(ii)	An explanation that makes reference to the following points: - because a secondary carbocation (intermediate) is formed (1) - more stable than a primary (carbocation intermediate) (1)	Allow answers referring to the mechanism Allow a correct diagram or description of the secondary carbocation Allow a correct diagram or description of the primary and/or the secondary carbocation with a comment about it being less stable / secondary being more stable for 2 marks	(2)

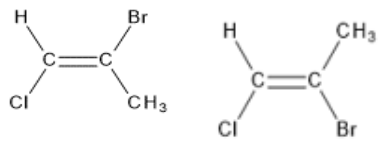


Question Number	Acceptable Answers	Additional Guidance	Mark												
8(d)*	This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning.	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5–4	3	3–2	2	1	1	0	0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5–4	3														
3–2	2														
1	1														
0	0														



		Number of marks awarded for structure of answer and sustained line of reasoning		In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.	
	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2			
	Answer is partially structured with some linkages and lines of reasoning.	1			
	Answer has no linkages between points and is unstructured.	0			
	Comment: Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning			General points to note If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). e.g.	



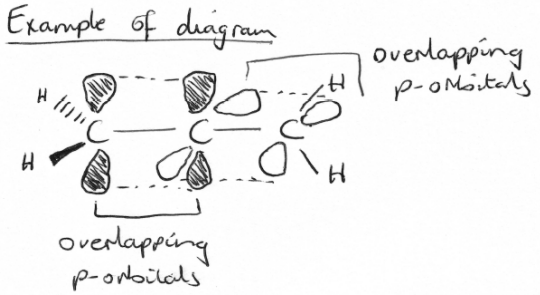
Indicative content IP1 – C=C restricted rotation around C=C / double bond / pi bond IP2 – Attached atoms the higher the atomic number of the attached atom, the higher the priority of the group and in the <i>E</i> isomer the highest priority atom on each carbon are on opposite sides of the double bond / in the <i>Z</i> isomer the highest priority atom on each carbon atom are on the same side of the double bond IP3 – Example of <i>E/Z</i> Example of <i>E</i> isomer and <i>Z</i> isomer as labelled diagram IP4 – Optical isomerism a non-superimposable mirror image / cannot be superimposed / contain a chiral centre / do not have a plane of symmetry IP5 – Example of optical isomers Two 3-dimensional structures that are mirror images IP6 – Property (optical isomers) rotate the plane of (plane-) polarised light (by equal amounts) in opposite directions	Ignore cis-trans Allow 'no rotation about C=C' Allow atomic mass / mass of group / heaviest  <i>E</i> isomer <i>Z</i> isomer Ignore chemical names even if incorrect Allow diagrams without labels but clearly identified in their explanation Allow have four different atoms or groups attached to a carbon atom  Do not award images that are not in 3D	
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Question Number	Answer	Additional Guidance	Mark
2(a)(i)	An answer that makes reference to the following points: Test - add bromine water / bromine Result - which decolourises / (turns) colourless or Test - add acidified KMnO_4 / acidified potassium manganate(VII) / acidified potassium permanganate Result - which decolourises / (turns) colourless	Only award M2 if linked to the correct test (1) Allow Br_2 or $\text{Br}_2(\text{aq})$ Do not award if Br^- or bromide used (1) Allow if near miss on reagent e.g. Br Allow initial colours of orange, yellow, brown or brown-red Ignore references to heating Do not award incorrect initial colour e.g. red to colourless Do not award clear (1) Allow initial colours of purple or pink If formula is given it must be correct Do not award incorrect initial colour e.g. red to colourless Do not award incorrect initial colour e.g. red to colourless Do not award clear Allow if near miss on reagent e.g. omission of acidified or name / formula recognisable but incorrect Ignore references to heating	(2)



Question Number	Answer	Additional Guidance	Mark
2(a)(ii)	An answer that makes reference to the following points: - dipole on HBr - curly arrow from C=C bond to H (δ^+) - curly arrow from H-Br bond to Br or just beyond - correct intermediate - lone pair and negative charge on Br⁻ - curly arrow from lone pair (if shown) on Br⁻ to C⁺	Do not award partial charge on C=C Allow structural, skeletal or hybrid formulae Penalise half arrows once only Penalise additional arrows once only Penalise use of Br₂ or other incorrect reactant once only All 6 points scores 3 4 or 5 points scores 2 2 or 3 points scores 1	(3)

Question Number	Answer	Additional Guidance	Mark
2(b)	An answer that makes reference to the following points: - correct structure of monomer and n on both sides of equation - correct structure of repeating unit with extension bonds	(1) (1) Allow placement of 'n' anywhere vertically if it is in front of the reactant and after the product $ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ n \text{ C} = \text{C} \\ \quad \\ \text{H} \quad \text{CH}_2\text{OH} \end{array} \longrightarrow \left[\begin{array}{cc} \text{H} & \text{H} \\ & \\ -\text{C} & -\text{C}- \\ & \\ \text{H} & \text{CH}_2\text{OH} \end{array} \right]_n $ Allow structural or skeletal formulae throughout Do not award molecular formulae Examples $n \text{ CH}_2\text{CHCH}_2\text{OH} \longrightarrow \text{---} \left[\text{CH}_2\text{CHCH}_2\text{OH} \right]_n \text{---}$ $ n \text{ } \begin{array}{c} \diagup \quad \diagdown \\ \text{CH}_2 \quad \text{CH} \end{array} \text{CH}_2\text{OH} \longrightarrow \left[\begin{array}{c} \diagup \quad \diagdown \\ \text{CH}_2 \quad \text{CH} \end{array} \text{CH}_2\text{OH} \right]_n $ Vertical connectivity must be to C of CH₂OH; penalise once only Ignore conditions / catalysts on the arrow even if incorrect Ignore brackets	(2)

Question Number	Answer	Additional Guidance	Mark
2(c)	An explanation that makes reference to the following points: - pi bonds form by sideways overlap of (p) orbitals - so two (p) orbitals are at right angles / perpendicular (to each other) / π bonds are at right angles / perpendicular (to each other)	(1) Do not award 'head-on' overlap Ignore references to 's' orbitals May be shown on a (labelled) diagram (1) Allow 'one orbital on central C is P_y, the other is P_z' (any pair of x, y and z orbitals will suffice) May be shown on a (labelled) diagram Example of diagram  Ignore repulsion between electrons / bonds etc	(2)

Question Number	Answer	Additional Guidance	Mark
2(d)(i)	An answer that makes reference to the following point: four / 4		(1)

Question Number	Answer	Additional Guidance	Mark
2(d)(ii)	An answer that makes reference to the following point: has two hydrogen (atoms) on (first) carbon (atom) of double bond / has same group on (first) carbon (atom) of double bond	Allow doesn't have different groups at the end of the (one of the) C=C bonds Do not award molecules Allow 'hydrogen groups'	(1)

Question Number	Answer	Additional Guidance	Mark
2(d)(iii)	An explanation that makes reference to the following points: - prop-2-en-1-ol is more soluble than bombykol (1) - both (have OH / alcohol group that) can form hydrogen bonds (with water) (1) - bombykol has a (very) long (hydro)carbon chain or forms stronger London forces (1)	Allow prop-2-en-1-ol is soluble and bombykol is insoluble Allow as bombykol has a (very) long hydrophobic / non-polar hydrocarbon chain	(3)

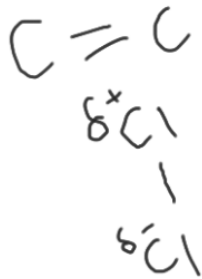
(Total for Question 2 = 14 marks)

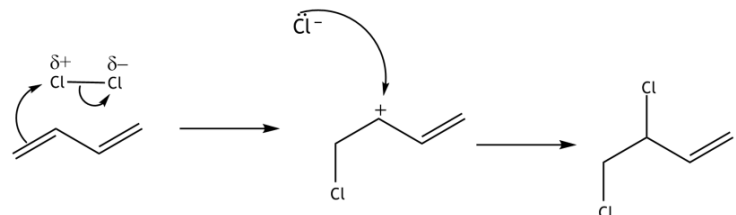


Question Number	Answer	Mark
7(a)	The only correct answer is D (2-chlorobuta-1,3-diene) <i>A is not correct as the position of chlorine is incorrectly numbered</i> <i>B is not correct as the position of double bonds are incorrectly numbered</i> <i>C is not correct as the position of double bonds and chlorine are incorrectly numbered</i>	(1)

Question Number	Answer	Additional Guidance	Mark
7(b)	• calculation of M_r of chloroprene (1) • calculation of amount of chloroprene in mol (1) • conversion of °C to K and kPa to Pa (1) • re-arrangement of $pV = nRT$ and calculation of V (1) • conversion to cm^3 and rounding to 2 or 3 SF (1)	<u>Example of calculation</u> 88.5 $10.0 \div 88.5 = 0.11299$ (mol) 353 (K) and $205 \times 10^3 / 205000$ (Pa) M3 may be subsumed in M4 Allow pressure in kPa if volume is clearly shown as dm^3 in M4 $V = (nRT) \div p$ $= (0.11299 \times 8.31 \times 353) \div 205000 = 1.6169 \times 10^{-3}$ (m^3) M4 may be subsumed in M5 Ignore units in M4 1600 / 1620 (cm^3) 1620 with no working scores 5 Comments Allow use of correctly rounded values carried forward Take care with awarding 5 for 1600, as it may be the result of an incorrect value from M4, correctly rounded	(5)



Question Number	Answer	Additional Guidance	Mark
7(c)(i)	An explanation that makes reference to the following points: - chlorine (molecule) moves close to (electron rich) double bond / pi bond (1) - which induces partial positive charge on chlorine (atom) (nearest to double bond / pi bond) (1)	 M1 via diagram e.g Allow C=C bond has a high electron density Accept repulsion between the electrons of chlorine and the pi electrons results in partial positive charge on chlorine (atom) Allow polarises the chlorine forming a δ^+ Cl Note M2 must have idea that the partial charge is induced / brought about / produced so a diagram alone does not score M2	(2)

Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	An answer that makes reference to the following points: - curly arrow from one double bond to chlorine or just beyond (1) - correct dipole on chlorine molecule (1) - curly arrow from Cl-Cl bond to Cl (1) - carbocation intermediate (1) - lone pair on chloride ion (1) - curly arrow from chloride ion to carbocation and correct final product (1) 6 bullet points scores 3 marks, 4/5 bullet points scores 2 marks, 2/3 bullet points scores 1 mark, 0/1 bullet points scores 0 marks	Do not award if arrow shown to partial negative / negative Cl Do not award primary carbocation Do not award Cl / Cl^{δ-}, but allow TE into BP6 If lone pair evident, curly arrow must originate from it  Note – correct dipole discussed in (c)(i) can be awarded as part of M1 if not shown on the diagram	(3)

Question Number	Answer	Additional Guidance	Mark
7(c)(iii)	An answer that makes reference to the following point: addition (polymerisation)	Do not award condensation	(1)

Question Number	Answer	Additional Guidance	Mark
7(d)(i)	An explanation that makes reference to the following points: - both compounds have hydrogen bonds (1) - so the intermolecular forces / hydrogen bonds they form together will be similar in strength (to the intermolecular forces / hydrogen bonds they have before mixing) (1)	Allow can hydrogen bond to each other Allow H-bond for hydrogen bond Allow correct diagram for M1 Allow 'they break strong H bonds but then form strong H bonds together' Allow the new hydrogen bonds are stronger than the ones between water molecules / ethane-1-2-diol	(2)

Question Number	Answer	Additional Guidance	Mark
7(d)(ii)	- calculation of mass and moles of polyester (1) - calculation of number of molecules of polyester (1)	<u>Example of calculation</u> $4.25 \times 10^{-3} \div 8400 = 5.0595 \times 10^{-7} \text{ (mol)}$ $5.0595 \times 10^{-7} \times 6.02 \times 10^{23} = 3.0458 \times 10^{17} \text{ (molecules)}$ Ignore SF Allow TE from M1 If incorrect units given in M1 and M2, penalise only once Correct answer with or without working scores 2 marks	(2)



Question Number	Answer	Mark
7(d)(iii)	The only correct answer is B (hydrolysis) <i>A is not correct as the reaction as dehydration is the removal of water</i> <i>C is not correct as the reaction as neutralisation is a reaction between an acid and a base</i> <i>D is not correct as the reaction as redox is oxidation and reduction</i>	(1)

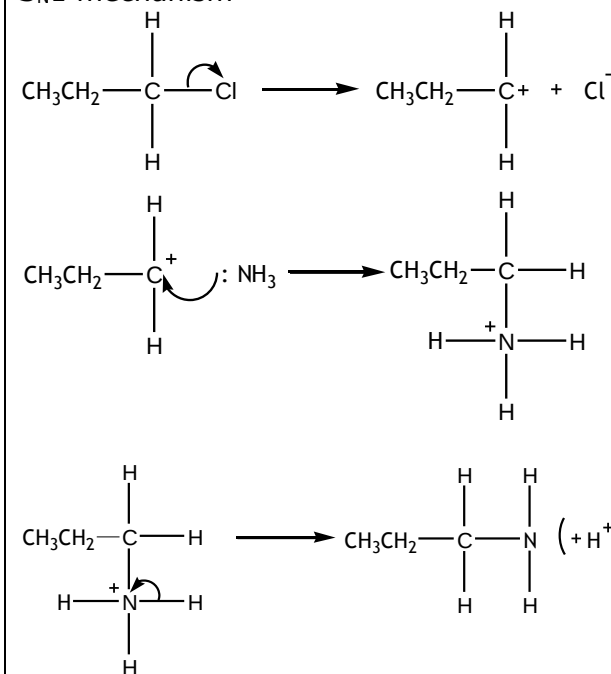
(Total for Question 7 = 17 marks)



8(a)	- first two curly arrows and lone pair shown on the nitrogen - structure of intermediate including positive charge - third curly arrow and formation of final organic product	Ignore correct dipoles Allow non-displayed NH_3^+ for MP2 Ignore involvement of Cl^- / NH_3 or wrong inorganic products for MP3 EITHER $\text{CH}_3\text{CH}_2-\text{C}(\text{H})_2-\text{Cl} \xrightarrow{\text{NH}_3} \text{CH}_3\text{CH}_2-\text{C}(\text{H})_2-\text{NH}_3^+ + \text{Cl}^-$ $\text{CH}_3\text{CH}_2-\text{C}(\text{H})_2-\text{NH}_3^+ \xrightarrow{\text{H}_2\text{O}} \text{CH}_3\text{CH}_2-\text{C}(\text{H})_2-\text{NH}_2 + \text{H}^+$ Ignore depiction of transition state e.g. $\left[\begin{array}{c} \text{H} \quad \text{CH}_2\text{CH}_3 \\ \quad \\ \text{H}-\text{N} \cdots \text{C} \cdots \text{Cl} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \end{array} \right]$	(3)
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OR

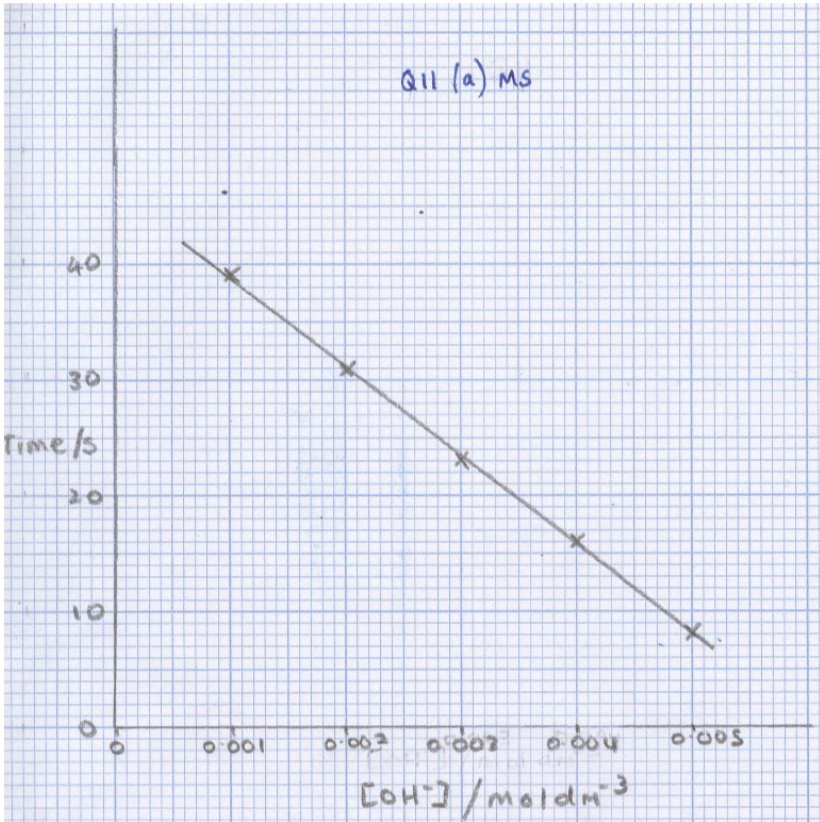
- fission of C-Cl bond curly arrow **and** curly arrow from nitrogen in NH_3 with lone pair shown on N atom to correct carbocation (1)
- structure of resulting nitrogen-containing intermediate including positive charge (1)
- curly arrow resulting in breaking of an N-H bond and structure of the final organic product (1)

OR AWARD
 $\text{S}_{\text{N}}1$ mechanism

Question Number	Acceptable Answers	Additional Guidance	Mark
8(b)	- first two curly arrows and lone pair shown on the nitrogen (1) - structure of intermediate including both charges (1) - three curly arrows and structure of final organic product (1)	(+ HCl)	(3)

(Total for Question 8 = 6 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
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Question Number	Answer	Additional Guidance	Mark
11(a)	M1 axes labelled with units on axes, suitable uniform scale with points covering at least half the available space in both directions (1) M2 all points plotted correctly with straight line of best fit (1)	<u>Example of graph</u>  Allow variables on either axis	(2)

Question Number	Answer	Additional Guidance	Mark
11(b)	An answer that makes reference to the following points - zero order with respect to hydroxide ions (1) - The graph is a straight line so the rate of reaction is independent of the concentration of the hydroxide ions (1)	M2 dependent on M1	(2)

Question Number	Answer	Additional Guidance	Mark
11(c)	An answer that makes reference to the following points - S_N1 (1) - as there is only one reactant in the rate determining step / as the hydroxide ions do not affect the rate (1)	Mark consequentially on order Allow TE from (b) e.g. if first order in (b) allow S_N2	(2)

Question Number	Answer	Additional Guidance	Mark
11(d)	the chloroalkane is tertiary	Allow TE from first order in (b) and/or S_N2 in (c) e.g. if S_N2 in (c) allow primary NOTE if first order wrt hydroxide ions in (b) but S_N1 given in (c) can score 1 mark in (d) for tertiary	(1)

(Total for Question 11 = 7 marks)

Question Number	Answer	Mark
1(a)	The only correct answer is D (2-bromo-2-methylpropane) <i>A is not correct because 1-bromobutane is a primary halogenoalkane so hydrolyses more slowly than the tertiary halogenoalkane</i> <i>B is not correct because 2-bromobutane is a secondary halogenoalkane so hydrolyses more slowly than the tertiary halogenoalkane</i> <i>C is not correct because 1-bromo-2-methylpropane is a primary halogenoalkane so hydrolyses more slowly than the tertiary halogenoalkane</i>	(1)

Question Number	Answer	Mark
1(b)	The only correct answer is C (CH_3COCl and CH_3NH_2) <i>A is not correct because the reactants will form a primary amide</i> <i>B is not correct because the reactants will not form an N-substituted amide as there is no reaction</i> <i>D is not correct because the reactants will not form an N-substituted amide as there is no reaction</i>	(1)



Question Number	Answer	Additional Guidance	Mark
1(c)(i)	An explanation that makes reference to three of the following points: - one (molecule of) ammonia acts as a nucleophile (1) - to attack the carbon with a (partial) positive charge (1) - a (second) molecule (of ammonia) acts as a base (1) - to remove a H^+ / H ion / proton from the intermediate (1)	Correctly drawn mechanism with no reference to nucleophile and base scores 2 max (see diagram) Allow 'ammonia donates its lone pair' / 'ammonia reacts in a nucleophilic substitution reaction' Allow 'attacks the carbocation' Do not award NH_3 acting as a base in an incorrect context (e.g. with Br^-) If intermediate drawn then this must be correct Allow ammonia gains a H^+ (ion) / proton from the intermediate Ignore comments related to oxidation and reduction	(3)

1 mark for left hand side, including dipole, curly arrow from lone pair on N and arrow from bond to Br

1 mark for right hand side including structure of intermediate with charge, arrow from lone pair on NH_3 to H, and arrow from bond to N^+

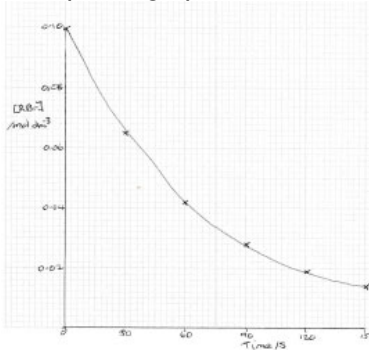
Question Number	Answer	Mark
1(c)(ii)	The only correct answer is A (heat in a sealed tube, ethanol) <i>B is not correct as the reaction is carried out in a closed system</i> <i>C is not correct as the bromoethane is not soluble in water</i> <i>D is not correct as the reaction is carried out in a closed system and bromoethane is not soluble in water</i>	(1)

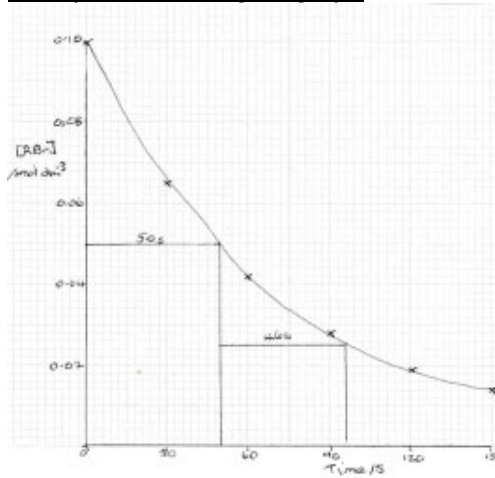
Question Number	Answer	Additional Guidance	Mark
1(d)	- calculation of total relative mass of all reactants or calculation of total relative mass of all products (1) - calculation of atom economy to 1 dp (1)	<u>Example of calculation</u> $74 + 102.9 + 98.1 / = 275$ or $136.9 + 120.1 + 18 / = 275$ $(136.9 \div 275) \times 100 = 49.782 (\%) = 49.8 (\%)$ Correct answer with no working scores 2 TE from M1 to M2 Incorrect rounding for final answer does not score M2	(2)

(Total for Question 1 = 8 marks)

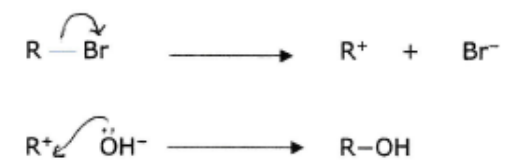


Question Number	Answer	Additional Guidance	Mark
6(a)	An answer that makes reference to the following point: (hydroxide ions in ethanol would give an) elimination reaction	Allow an alkene would form Ignore references to solubility in ethanol / ethanol is a (co-)solvent Ignore just 'causes another reaction'	(1)

Question Number	Answer	Additional Guidance	Mark
6(b)	- both axes labelled, including units (1) - suitable scales and points taking up at least half the graph paper in both directions (1) - points plotted correctly and smooth curve through the points (1)	<u>Example of graph</u>  Allow T / t for time with units Allow just 'concentration' with units Do not award RBr without square brackets Allow ± half square Do not award point-to-point straight lines	(3)

Question Number	Answer	Additional Guidance	Mark
6(c)	- first half-life 50 s and second half-life 50 s - reaction is first order because the half-lives are (almost) the same	<u>Example of working on graph</u>  Allow ± 6 s for both half-lives Do not award M1 if no working is shown on the graph Allow $\text{rate} \propto [\text{RBr}]$ / $\text{rate} = k[\text{RBr}]$ for first order Conditional on 2 half-lives within 12 s or the second half-life is (about) twice the first half-life	(2)

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	zero (order) / 0 (order)	Allow $x = 0$ / rate is proportional to $[\text{OH}^-]^0$ / rate = $k[\text{R-Br}][\text{OH}^-]^0$	(1)

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	- curly arrow from R-Br bond to, or just beyond, Br (1) R^+ and Br^- (1) - lone pair on O of OH^- and curly arrow from lone pair to R^+ (1)	<u>Example of mechanism</u>  Ignore dipole on RBr	(3)

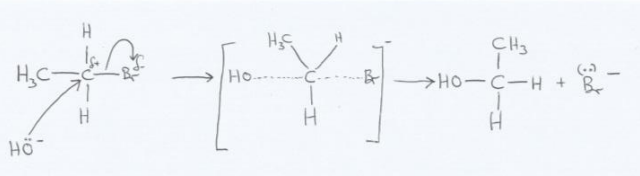
Question Number	Answer	Additional Guidance	Mark
6(e)	An explanation that makes reference to the following points: - a racemic mixture / racemate is formed or equal amounts / an equimolar mixture of both optical isomers forms (1) - intermediate / carbocation is (trigonal) planar around the reaction site / C^+ / central carbon (1) (equal probability of) attack (by nucleophile / hydroxide ions) from either side / above and below / both sides / opposite sides (of the plane) (1)	Allow enantiomers / D-L isomers / (+) and (-) isomers Allow the two isomers rotate the plane of plane-polarised light in opposite directions and cancel out Ignore just 'mixture is not optically active' / 'mixture does not rotate the plane of plane-polarised light' Allow the intermediate / carbocation is planar (around the reaction site) Do not award 'the molecule is planar'	(3)

(Total for Question 6 = 13 marks)

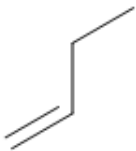
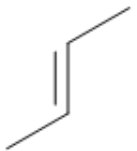
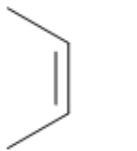


Question Number	Answer	Additional Guidance	Mark
3(a)	An explanation that makes reference to the following points: • reactivity increases down Group (7) (1) • because (C—X) bond enthalpy decreases / because (C—X) bond gets weaker down Group 7 (1)	Accept reverse argument References to halogen reactivity scores (0) Do not award references to ions/halides Do not award explanation in terms of just electronegativity or C—X dipoles Ignore references to atom size, shielding etc and references to intermolecular forces No TE on incorrect reactivity trend	(2)



Question Number	Answer	Additional Guidance	Mark
3(b)(i)	- dipole on C—Br bond and curly arrow from C-Br bond to Br or just beyond (1) - curly arrow from lone pair on oxygen of hydroxide ion to carbon bonded to Br (1) - formula of transition state with correct charge, partial bonding (1) - correct final products (1)	 Dipole and curly arrow may be shown on transition state Allow curly arrow to C⁺ of carbocation Do not award if carbocation formed as intermediate Square brackets are not essential Allow charge on Br or OH of transition state Allow longer bonds for partial bonding Ignore geometry of transition state Allow NaBr product if mechanism starts with NaOH Only penalise horizontal bond from the H of OH to C in the product e.g. OH—CH₂CH₃ Use of incorrect halogenoalkane loses this mark One mark max deducted for omission of charge on ions, including transition state S_N1 mechanism can score M1, M2 and M4 but not M3. M2 can be awarded for curly arrow from the lone pair on the oxygen of the hydroxide ion to the C⁺ of the carbocation intermediate	(4)

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	Reagents: nitric acid / HNO_3 and silver nitrate (solution) / AgNO_3 (1) (Result) cream/off-white precipitate (1)	Use of hydrochloric acid/HCl OR sulfuric acid/ H_2SO_4 scores (0) Do not award acidified silver nitrate If name and formula given then both must be correct Allow (very) pale yellow Do not award just white or just yellow Ignore subsequent additions of ammonia even if incorrect Result mark dependent on reagents mark or 'near miss' such as omitting to add nitric acid, using ethanolic silver nitrate, incorrect formulae	(2)

Question Number	Answer			Additional Guidance	Mark
3(c)	 (1)	 (1)	 (1)	Accept formulae in any order Award 2 if 3 correct displayed/structural formulae given Award 1 if 2 correct displayed/structural formulae given If more than 3 skeletal formulae drawn then deduct one mark for each additional formula 2-methylpropene negates a correct formula only if four formulae given View any formulae given with skeletal formula as working and ignore Ignore names even if incorrect Penalise any other alkenes such as pentenes, once only	(3)

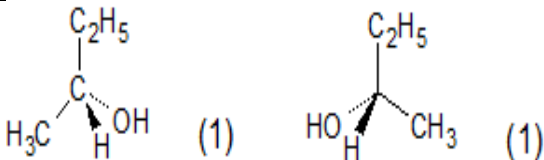
Question Number	Answer	Additional Guidance	Mark
3(d)	An explanation that makes reference to the following points: (only) ethanol has hydrogen bonding (and dipole-dipole and London forces) (1) - ethene (only) has (weaker) London/ instantaneous dipole –induced dipole forces (1) - more energy required to break the (stronger) intermolecular forces/hydrogen bonds in alcohols (1)	Ignore references to ethanol having stronger London forces Accept dispersion /van der Waals forces A comparison is needed Allow overcome for break Allow 'heat' for energy Accept reverse argument Do not award if the more energy required is given in response to just breaking stronger London forces for ethanol Do not award M3 for covalent bonds breaking	(3)

(Total for Question 3 = 14 marks)

Question Number	Acceptable Answer	Additional guidance	Mark
6(a)	An answer that gives reference to the following • (M1) use of ethanol (as a solvent) (1) • (M2) use of silver nitrate (solution) (1) • (M3) equal amounts used of each halogenoalkane (1) • (M4) measure the time taken for precipitate to form (1) • (M5) use a water bath (to control a raised temperature) (1)	Allow "alcohol" Do not award ammoniacal silver nitrate Ignore use of nitric acid Allow equal volumes/equal stated volumes Allow "time for cross to disappear" Do not award for a colour to form. M4 dependent on M2 or near miss. If hydroxide (ions) used for hydrolysis then measuring the reaction is too quick, so no M4. The solution would need to be acidified before the addition of silver nitrate if M2 is to be awarded. If hydrochloric acid is used, then only M1, M3 and M5 can be scored	(5)

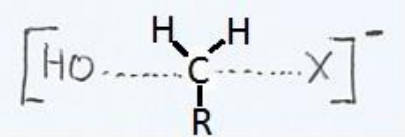
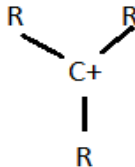


Question Number	Acceptable Answer	Additional guidance	Mark
6(b)	An explanation that makes reference to the following - the reaction rate is in the order 1-chlorobutane < 1-bromobutane < 1-iodobutane (1) - because the C-Cl bond is stronger than the C-Br bond which is stronger than the C-I bond (1)	Accept reverse arguments Incorrect trend scores (0) Allow 'the C-Cl bond is the strongest' Ignore any reasoning given Do not award if reference is made to the bonding of the halide (ion)	(2)

Question Number	Acceptable Answer	Additional guidance	Mark
6(c)	 Forms (two) isomers which are non-superimposable (1)	Diagram must be 3-dimensional, i.e. include 'wedges'. Allow Br instead of OH Ignore attachment of -OH, CH₃ and C₂H₅ groups Standalone mark Allow a chiral carbon has four different groups attached (so they are non-superimposable) Do not award has four different 'molecules' attached	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark																				
6(d)	This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5-4	3																						
3-2	2																						
1	1																						
0	0																						
	Number of marks awarded for structure of answer and sustained lines of reasoning																						
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2																						
Answer is partially structured with some linkages and lines of reasoning	1																						
Answer has no linkages between points and is unstructured	0																						



	Indicative content • (similarity)(both) are nucleophilic substitution (1) • Hydrolysis mechanism for RCH_2X/primary is $\text{S}_{\text{N}}2$ via a transition state and R_3CX/tertiary is $\text{S}_{\text{N}}1$ via a carbocation/intermediate (1) • RCH_2X and OH^- in the RDS (1) • R_3CX only in the RDS (1) • (RCH_2X forms a transition state with OH^-) diagram, including dotted lines and charge (1) • (R_3CX forms a carbocation / intermediate) diagram, including charge (1)	More than one indicative marking point may be made within the same comment or explanation Words needed at least once provided $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$ are given Allow "both/two species in the RDS" Allow correct rate equations for IP3 and IP4  Allow "-" either on the "OH" or the "X" Ignore point of attachment of OH Ignore dipoles within structure  Ignore shape Ignore references to comparative rates of reaction between 1° and 3° even if incorrect Ignore references to optical activity.	
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(Total for Question 6 = 16 marks)

Question Number	Answer	Mark
1(a)(i)	The only correct answer is B (2-methylpentan-2-ol) A is not correct because it is a secondary alcohol C is not correct because it is a secondary alcohol D is not correct because it is a secondary alcohol	(1)

Question Number	Answer	Mark
1(a)(ii)	The only correct answer is A (hexan-2-ol) B is not correct because it is a tertiary alcohol C is not correct because it does not contain a CH_3CHOH group D is not correct because it does not contain a CH_3CHOH group	(1)

Question Number	Answer	Mark
1(b)	The only correct answer is A (red phosphorus) B is not correct because it will not form iodoalkanes with iodine and alcohols C is not correct because it will not form iodoalkanes with iodine and alcohols D is not correct because it will not form iodoalkanes with iodine and alcohols	(1)

(Total Question 1 = 3 marks)

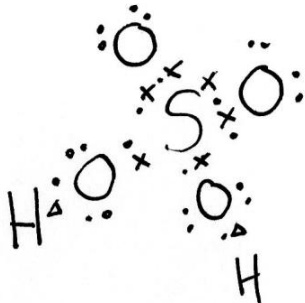
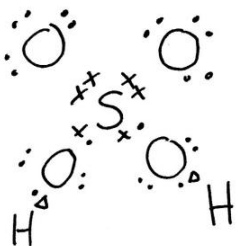


Question Number	Answer	Additional Guidance	Mark
12	2-bromo-2-methylbutane reacts with Mg (1) - Dry ether (1) $\text{CH}_3\text{CH}_2\text{C}(\text{MgBr})(\text{CH}_3)\text{CH}_3$ (1) - react Grignard reagent with HCHO (1) $\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)_2\text{CH}_2\text{OMgBr}$ (1) (hydrolyse) with (dilute) acid (1) OR 2-bromo-2-methylbutane reacts with KCN (1) - ethanol (as solvent) (1) $\text{CH}_3\text{CH}_2\text{C}(\text{CN})(\text{CH}_3)\text{CH}_3$ (1) - nitrile (hydrolysed) with (dilute) acid (1) $\text{CH}_3\text{CH}_2\text{C}(\text{COOH})(\text{CH}_3)\text{CH}_3$ (1) - carboxylic acid (reduced) with LiAlH_4 (in dry ether) (1)	Note – award of reagent or solvent marks must be in context of attempt to carry out an appropriate reaction e.g. use of ethanolic KCN to react with a ketone would not score OR M2 do not award HCOH Allow with water / H^+ Ignore HCN Allow methanol Allow H^+	(6)

(Total for Question 12 = 6 marks)
 TOTAL FOR PAPER = 60 MARKS



Question Number	Answer	Additional Guidance	Mark
3(a)	equation	<u>Example of equation</u> $\text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{CH}_2\text{CH}_2 + \text{H}_2\text{O}$ Allow displayed, semi-displayed, skeletal formulae and $\text{C}_2\text{H}_5\text{OH}$ and C_2H_4 Ignore any catalyst, even if incorrect, written above the arrow Ignore state symbols even if incorrect Do not award use of molecular formula for ethanol Do not award inclusion of catalyst on both sides of the equation Do not award reversible arrow	(1)
Question Number	Answer	Additional Guidance	Mark
3(b)	H_3PO_4	Ignore any state symbols even if incorrect Ignore (V) written after the correct formula	(1)

Question Number	Answer	Additional Guidance	Mark
3(c)	2 double bonds and 2 single bonds for sulfur (1) - rest of diagram correct (1)	<u>Example of diagram</u>  Allow  2 dative covalent bonds and 2 single bonds for sulfur scores (1) rest of diagram correct scores (1) Allow bond pairs to be show horizontally Ignore lines drawn between atoms to show covalent bonds Ignore arrows drawn between atoms to show coordinate bonds Allow (1) for diagram with all dots/crosses	(2)

Question Number	Answer	Additional Guidance	Mark
3(d)(i)	An answer that makes reference to the following point: (excess liquid) ethanol could 'run'/leak down the tube (to the catalyst)	Allow if test tube is horizontal then liquid ethanol would run down the tube Allow 'to keep the ethanol where it is' which implies movement otherwise Allow to prevent ethanol/ (mineral) wool and catalyst mixing Allow reactant for ethanol Allow the catalyst could slide (towards the ethanol) Ignore any reference to heating	(1)

Question Number	Answer	Additional Guidance	Mark
3(d)(ii)	An answer that makes reference to the following point: ethanol (would evaporate) and pass over the catalyst without reaction	Ignore references to combustion and flammability of ethanol Ignore references to the mineral wool	(1)

Question Number	Answer	Additional Guidance	Mark
3(d)(iii)	An answer that makes reference to the following point: the clamp may burn	Allow the bung may burn / be set on fire / rubber may melt	(1)



Question Number	Answer	Additional Guidance	Mark
3(d)(iv)	An answer that makes reference to the following point: (the valve) prevents the flow of water / suck-back (up the delivery tube)	Allow prevents water entering the delivery tube	(1)

Question Number	Answer	Additional Guidance	Mark
3(d)(v)	An answer that makes reference to the following point: bromine (water/solution) and decolourisation or (orange / brown / yellow / red) to colourless	Ignore clear Allow any combination of stated colours Allow Acidified potassium manganate(VII) and decolourisation / purple to colourless	(1)



Question Number	Answer	Additional Guidance	Mark
3(d)(vi)	- calculation of number of moles of ethene - calculation of the volume of ethene	<u>Example of calculation</u> (1) $n(\text{Ethene}) = (2.759 \times 10^{20} \div 6.02 \times 10^{23})$ $= 4.5831 \times 10^{-4} \text{ (mol)}$ (1) $V(\text{Ethene}) = (4.5831 \times 10^{-4} \times 24\,000)$ $= 10.999 / 11.0 / 11 \text{ (cm}^3\text{)}$ or $V(\text{Ethene}) = (4.5831 \times 10^{-4} \times 24 =)$ $= 0.010999 / 0.011 \text{ (dm}^3\text{)}$ Ignore SF except 1SF Correct answer without working scores (2) TE for the volume from number of moles Allow (1) for no. of molecules x 24(000) Allow use of $pV=nRT$ for both marks 298 K gives 11.349 (cm³) 293 K gives 11.159 (cm³)	(2)

(Total Question 3 = 11 marks)



Question Number	Answer	Additional Guidance	Mark
7(a)(i)	An answer that makes reference to the following point: the hydride ion will not attack / will be repelled by regions of high electron density	Allow the reduction by LiAlH_4 is a nucleophilic addition / alkenes do not undergo nucleophilic reactions / H^- is a nucleophile Allow alkenes react with H^+ / $\text{H}^{\delta+}$ / $\text{H}\cdot$ Allow the hydride ion will not attack a pi-bond / $\text{C}=\text{C}$ Allow like charges repel Ignore hydride ions cannot reduce alkenes Ignore hydride ions can only reduce carbonyl compounds	(1)

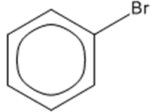
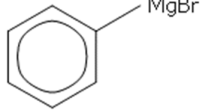
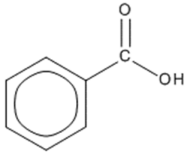
Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	An answer that makes reference to the following points: - hydrogen / H_2 (1) - nickel / Ni or platinum / Pt / palladium / Pd (1)	Mark independently Ignore reference to temperature	(2)



Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	1-bromobutane / $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$	If name and formula are given, both must be correct Allow Cl or I instead of Br Allow skeletal or displayed formulae	(1)

Question Number	Answer	Additional Guidance	Mark
7(a)(iv)	hydrochloric acid / HCl / H^+	Allow any (dilute) strong acid Ignore concentration of acid Do not award any weak acid	(1)



Question Number	Answer	Additional Guidance	Mark
7(b)	Step 1 • bromine and iron / iron(III) bromide or chlorine and aluminium chloride (1) •  (1) Step 2 • magnesium and dry ether (1) •  (1) Step 3 • carbon dioxide followed by a dilute acid (1) •  (1) Step 4 • phosphorus(V) chloride / phosphorus pentachloride (1)	Allow names or formulae for reagents but if both are given, both must be correct Allow these drawn as a reaction scheme with reagents and conditions on arrows and intermediates in unbalanced equations The marks for the intermediate structures are stand-alone Allow carbon dioxide and dilute acid Ignore just carbon dioxide and water	(7)

(Total for Question 7 = 12 marks)



Question Number	Answer	Additional Guidance	Mark
10(a)(i)	- oxygen lone pair and curly arrow to the H^+ (1) - curly arrow from oxygen lone pair on the ethanol to the carbon of the $\text{C}=\text{O}$ (1) - curly arrow from $\text{C}-\text{O}$ bond to oxygen of water molecule (1) - curly arrow from $\text{O}-\text{H}$ bond back to the O^+ oxygen (1)	Penalise additional curly arrows for each marking point Penalise missing lone pair on oxygen once only in M1 and M2	

Question Number	Answer	Additional Guidance	Mark
10(a)(ii)	correct oxygen identified (1) or the oxygen in ethanol acts as the nucleophile (to attack the carbon of the carboxylic acid group and so ends up in the ester) (1)	Allow 'loss of OH from the carboxylic acid'	(2)

Question Number	Answer	Additional Guidance	Mark
10(a)(iii)	(M1) calculation of ΔG (1) (M2) correct equation (1) (M3) rearrangement of equation (1) (M4) calculation of ΔS_{system} (1) (M5) rearrangement of equation so $S_{\text{(ethyl ethanoate)}}$ = (1) (M6) calculation of $S_{\text{(ethyl ethanoate)}}$ with sign and units (1)	<u>Example of calculation</u> $\Delta G = -RT \ln K = -8.31 \times 298 \times \ln 4.0$ $= -3433 \text{ (J mol}^{-1}\text{)}$ $\Delta G = \Delta H - T\Delta S_{\text{system}}$ $\Delta S_{\text{system}} = (\Delta H - \Delta G) \div T$ $\Delta S_{\text{system}} = (-6.0 \times 10^3 - (-3433)) \div 298$ $= -8.614 \dots \text{ (J mol}^{-1} \text{ K}^{-1}\text{)}$ $(\Delta S_{\text{system}} = \Sigma S_{\text{(products)}} - \Sigma S_{\text{(reactants)}})$ $S_{\text{(ethyl ethanoate)}} = \Delta S + \Sigma S_{\text{(reactants)}} - S_{\text{(water)}}$ $S_{\text{(ethyl ethanoate)}} = (-8.614 + (159.8 + 160.7)) - 69.9$ $= +242/240 \text{ J mol}^{-1} \text{ K}^{-1}$ Ignore SF except 1SF Correct final answer without working scores (6) TE throughout	(6)



Question Number	Answer	Additional Guidance	Mark
10(b)	A comparison that makes reference to: (with ethanoyl chloride) - the reaction is irreversible compared to reversible (1) - hydrogen chloride is the by-product rather than water (1) - the reaction is very fast/occurs at room temperature so an acid catalyst is not needed (1)	Accept reverse arguments Allow steamy fumes for 'HCl'	(3)

(Total Question 10 = 15 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark												
5*	This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning.	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5–4	3	3–2	2	1	1	0	0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 5 marks (3 marks for indicative content and 2 marks for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5–4	3														
3–2	2														
1	1														
0	0														



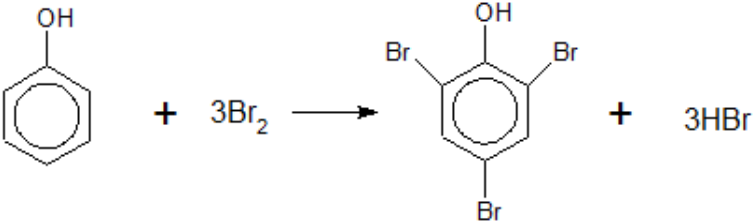
		Number of marks awarded for structure of answer and sustained line of reasoning		
	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2		
	Answer is partially structured with some linkages and lines of reasoning.	1		
	Answer has no linkages between points and is unstructured.	0		
	Comment: Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning			In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning. General points to note If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).



	Indicative content • IP1 Type of reaction Both reactions are (examples of) electrophilic substitution • IP2 Products Benzene forms bromobenzene and phenol forms 2,4,6-tribromophenol • IP3 Comparison of reactivity Benzene is less reactive (than phenol) / phenol is more reactive (than benzene) • IP4 Conditions Benzene requires (a catalyst of) FeBr₃ and phenol does not require a catalyst / can react with just bromine water • IP5 Lone pair (Phenol is more susceptible to electrophilic attack) because the lone pair on the oxygen (atom in phenol) delocalises into the ring / π system • IP6 Electron density Increasing the electron density of the ring / π system	If names and formulae are given, both must be correct Do not award addition-elimination for substitution Allow these products shown as structures in equations, even if equations are not fully correct Allow any feasible dibromophenol / tribromophenol Ignore dibromobenzene / tribromobenzene Allow Fe / FeCl₃ / AlBr₃ / AlCl₃ / Lewis Acid catalyst Allow Friedel-Crafts catalyst / halogen carrier Can be shown in equation Allow phenol reacts at room temperature Ignore reference to heat / mechanism Allow IP4 if stated that only benzene requires a catalyst Allow lone pair on oxygen is donated into the ring Allow OH for oxygen Allow activates the ring Do not award increases the electronegativity / charge density of the ring Penalise omission of 'the ring / π system' once only in IP5 and 6	
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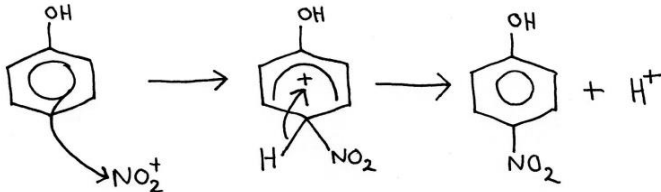
(Total for Question 5 = 6 marks)



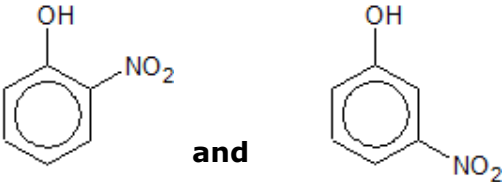
Question Number		Additional Guidance	Mark
8(a)(i)	 • Structure of 2,4,6-tribromophenol (1) • Balanced equation (1)	Ignore state symbols even if incorrect Do not award C₆H₃OBr₃ M2 dependent on M1	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
8(a)(ii)	An answer that makes reference to the following: Similarity - Both electrophilic substitution (1) Any two from: Contrast - No need of a halogen carrier with phenol (1) - oxygen's lone pair of electrons interacts with the benzene ring of delocalised electrons so electrophilic attack more likely (1) - Tri-substitution of phenol compared to mono for benzene (1) - Bromination of phenol requires bromine in aqueous solution but benzene requires liquid bromine (1) - Bromination of phenol requires room temperature but benzene requires heating (under reflux) / reflux (1)	Ignore comments of ease of reaction Should be stated clearly as a similarity Accept reverse argument Allow Fe/FeBr₃/AlBr₃ with benzene Do not award just 'catalyst' Allow reference to OH group Allow 'bromine' for 'electrophilic' Do not award for nucleophilic attack Allow "multiple-" for "tri-"	(3)



Question Number	Acceptable Answer	Additional Guidance	Mark
8(b)(i)	An answer that makes reference to - Electron pair movement from ring to electrophile (1) - Formula of intermediate ion (1) - Curly arrow from C-H bond to reform delocalised ring and correct final structure with H^+ also formed (1)	Allow arrow that starts from anywhere within the hexagon but it must go to the nitrogen of the ion 'Horseshoe' to cover at least three carbon atoms, facing the tetrahedral carbon and part of the + sign to be inside the 'horseshoe' Do not award '+' charge on the tetrahedral carbon Do not award dotted bonds unless part of a 3D structure Curly arrow to go from the bond to anywhere inside the ring Accept the drawing of HSO_4^- to remove the H from the ring as long as H_2SO_4 is given as the product instead of H^+ Exemplar mechanism  Do not penalise attachment of OH/NO_2 to benzene ring Penalise incorrect product: 1 mark	(3)

Question Number	Acceptable Answer	Mark
8(b)(ii)	The only correct answer is B <i>A is incorrect because this is 15% of the mass of the starting material</i> <i>C is incorrect because this is the percentage of the starting mass over the max mass of product</i> <i>D is incorrect because this is 100% yield and not 15%</i>	(1)

Question Number		Additional Guidance	Mark
8(b)(iii)	 and	Ignore connectivity of OH/NO ₂	(1)

(Total for Question 8 = 10 marks)

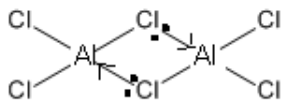
Question Number	Answer	Additional Guidance	Mark
3(a)	$(1s^2)2s^22p^63s^23p^1$	Allow numbers of electrons as subscripts or large numbers Allow p orbitals designated as x, y and z Ignore $1s^2$ repeated	(1)

Question Number	Answer	Additional Guidance	Mark
3(b)(i)	dot-and-cross diagram	<u>Example of diagram</u> Allow electrons in overlapping circles Allow all dots / all crosses Ignore inner shell electrons, even if incorrect Ignore lines as bonds e.g. $\begin{array}{c} \times \\ \cdot \end{array}$ Do not award diagram with lone pair on Al	(1)

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	An answer that makes reference to the following points: • shape – trigonal planar (1) • bond angle - 120° (1)	Mark independently Both words needed Allow triangular for trigonal – but not just tri Allow marks for labelled diagram Note If shape is pyramidal, no mark for M1 but allow (1) for 107° No TE for any other shape	(2)



Question Number	Answer	Additional Guidance	Mark
3(b)(iii)	- equation for the formation of the electrophile - curly arrow from on or within the circle to CH_3^+ - structure of intermediate including charge with some part of the charge within the horseshoe and horseshoe covering at least 3 carbon atoms and facing the tetrahedral carbon - curly arrow from C-H bond to anywhere in the hexagon reforming the delocalised structure	<u>Example of mechanism</u> $\text{CH}_3\text{Cl} + \text{AlCl}_3 \rightarrow \text{CH}_3^+ + [\text{AlCl}_4]^-$ Allow $\text{AlCl}_4^- / \delta^+ \text{CH}_3 - \text{AlCl}_4^{\delta-}$ Allow curly arrow from anywhere within the hexagon Allow curly arrow to any part of CH_3^+, including the + charge Do not award curly arrow from outside the hexagon Allow dotted / dashed lines for horseshoe Do not award dotted bonds to H and CH_3 unless clearly part of a 3D structure Ignore any involvement of AlCl_4^- in the final step /HCl Note Correct Kekulé structures score full marks	(4)

Question Number	Answer	Additional Guidance	Mark
3(c)(i)	diagram showing two AlCl_3 molecules joined through two chlorine atoms	Example of diagram  Allow dot-and-cross diagram Ignore missing arrows / direction of arrows Ignore missing lone pairs	(1)
3(c)(ii)	dative (covalent) bonds or coordinate bonds	Allow this labelled on diagram in (i) Do not award this mark if dative bonds shown as arrows starting from aluminium in (c)(i)	(1)

(Total for Question 3 = 10 marks)



Question Number	Answer	Mark
8(ai)	The only correct answer is D (nucleophilic substitution) A is not correct because it is not electrophilic or addition B is not correct because it is not electrophilic C is not correct because it is not addition	(1)

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	M1 arrow from lone pair on nitrogen atom to carbon atom (1) M2 dipole shown and arrow from C–Cl bond to Cl or just beyond (1) M3 formula of intermediate including the + charge on the N atom (1) M4 arrow from N–H bond to N⁺ and formula of organic product (1)	<u>Example of mechanism</u> (+ H⁺ / HCl) Comment M2 is a stand alone mark Allow access to full marks for correct use of other halogenomethanes Ignore any SN2 transition states Ignore use of a second molecule of phenylamine behaving as a base	(4)

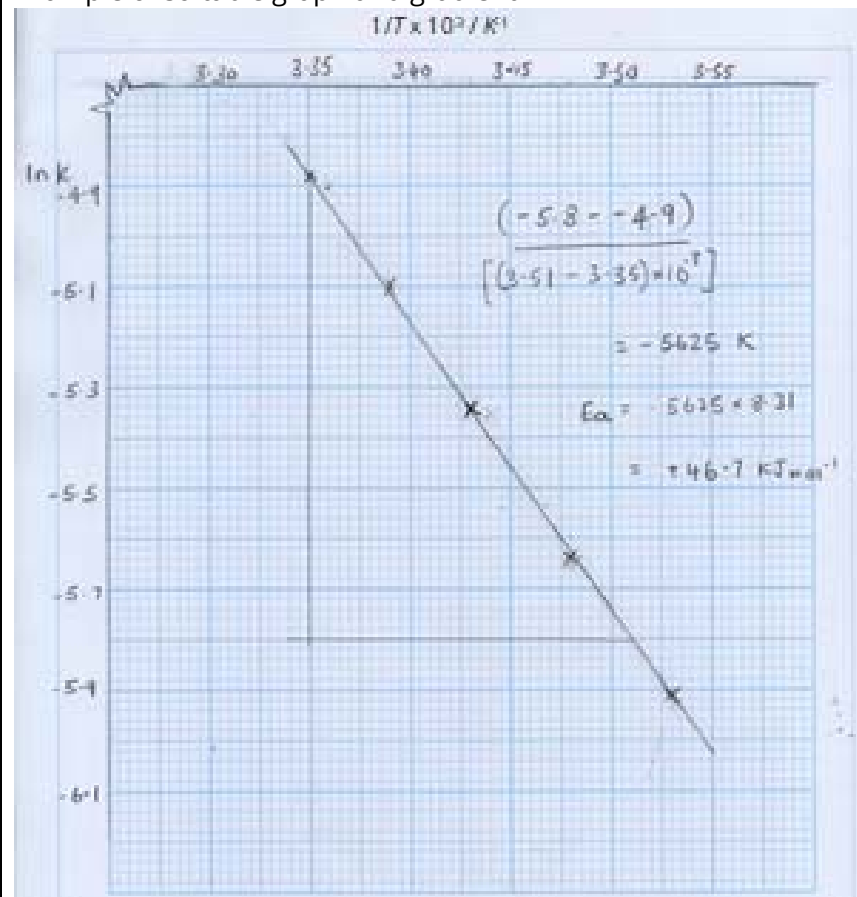
Question Number	Answer	Additional Guidance	Mark
8(a)(iii)	An answer that makes reference to the following points: • M1 dissolve (impure product) in a minimum volume of hot solvent (1) • M2 cool (in ice) or leave to recrystallise (1) • M3 filter using vacuum filtration / Buchner filtration / filter under suction (1) • M4 dry solid in desiccator / between filter papers (1)	Allow any named solvent Ignore hot filtration after M1 Allow dry in a warm oven Ignore references to rinsing Do not award M4 if drying agent added to the crystals / solution	(4)

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	• calculation of missing $1/T$ value and • calculation of missing $\ln k$ value	<u>Example of calculation</u> 3.43×10^{-3} -5.64 Ignore SF	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	M1 axes correct way round and labelled with units on x-axis (1) M2 suitable scale, must be uniform (1) M3 all points plotted correctly, with straight line of best fit (1) M4 calculation of gradient, including minus sign (1) M5 units of gradient (1) M6 calculation of activation energy with units (1) Comment If $\ln k$ plotted with most negative value at the top or $-\ln k$, then all marks can still be scored, but gradient should still be negative	<u>Example of calculation and graph</u> award $1/T \times 10^3 / K^{-1}$ or $1/T / 10^{-3} K^{-1}$ or $1/T / K^{-1} (10^{-3})$ Do not award $1/T \times 10^{-3} / K^{-1}$ Do not award M1 if units given for $\ln k$ on y-axis Do not award small "t" for "T" Points must cover at least half the graph paper in each direction -5775 (± 400) Award gradient value between -5375 to -6175 K (+)48.0 / (+)48 kJ mol^{-1}; allow TE for gradient outside range Award E_a values (+)44.7 to (+)51.3 kJ mol^{-1} Award E_a if correct in J mol^{-1} Do not award M6 if given in just "kJ" or "J" Ignore SF Do not award M6 if final answer is a negative E_a value See next page for graph Comment If $1/T$ (y-axis) plotted against $\ln k$ (x-axis) Can only award M2, M3 and TE for M4 If either or both variables incorrect, then only M2 can be scored	(6)

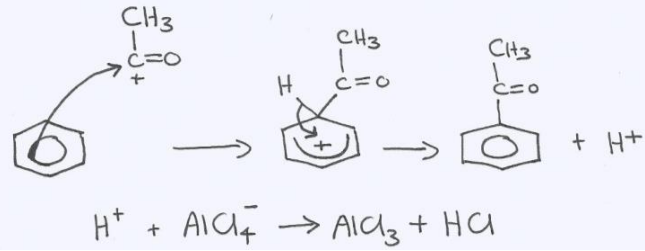


Example of suitable graph and gradient



(Total Question 8 = 16 marks)
TOTAL FOR PAPER = 90 MARKS

Question Number	Answer	Additional Guidance	Mark
8(a)(i)	$\text{CH}_3\text{COCl} + \text{AlCl}_3 \rightarrow \text{CH}_3\text{CO}^+ + \text{AlCl}_4^-$	Accept use of $\text{FeCl}_3/\text{Fe} + \text{Cl}_2$ Allow displayed formulae Do not award $\text{C}_2\text{H}_3\text{OCl}$ Ignore state symbols even if incorrect	(1)

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	- electron pair movement from ring to electrophile - formula of intermediate ion - curly arrow from C–H bond to reform delocalised ring - correct product and equation to show regeneration of catalyst and HCl	 Do not award curly arrow that ends at the CH_3 Allow arrow starting anywhere within the hexagon 'Horseshoe' to cover at least three carbon atoms and face the tetrahedral carbon and with some part of the plus sign inside 'horseshoe' Allow Kekulé diagrams Do not award dotted bonds unless part of a 3D structure Could be shown in reaction mechanism Ignore curly arrows	(4)

Question Number	Answer	Mark
8(b)(i)	The only correct answer is B (alkaline iodine solution) <i>A is not correct because this oxidising agent would react with phenylethanal and not with phenylethanone which is the wrong way round</i> <i>C is not correct because test is for aldehydes and so would react with phenylethanal and not with phenylethanone which is the wrong way round</i> <i>D is not correct because test is for aldehydes and so would react with phenylethanal and not with phenylethanone which is the wrong way round</i>	(1)

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An answer that makes reference to the following points: - formation of yellow/orange/red (crystalline) precipitate (1) (Filter then) recrystallisation of products (1) - determination of melting temperature (1) - comparison (and hence identification) from use of database/known values (1)	Colour and state are both required Allow solid for ppt Ignore any conditions given with the use of 2,4-DNPH Penalise M3 if any reference to boiling temperature Award only in the context of melting temperature of the hydrazones or as a TE of boiling temperature Max 3 out of 4 if test is only carried out with one of the carbonyls	(4)

Question Number	Answer	Additional Guidance	Mark																				
*8(b)(iii)	This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). If there is no mention of protons/hydrogens in the response then deduct one structure and reasoning mark	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5-4	3																						
3-2	2																						
1	1																						
0	0																						
	Number of marks awarded for structure of answer and sustained lines of reasoning																						
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2																						
Answer is partially structured with some linkages and lines of reasoning	1																						
Answer has no linkages between points and is unstructured	0																						



	Indicative content Similarities IP1: aromatic hydrogens will give similar/same peaks IP2: both have a peak in the range 1.7-3.0 (ppm) (due to the hydrogen of the H-C-C=O type) Differences IP3 (Hydrogen environments): Phenylethanone has one less peak/hydrogen environment than phenylethanal IP4 (Splitting patterns): a singlet for phenylethanone but a doublet and a triplet in phenylethanal IP5 (Peak area ratios): relative peak (area) ratio in phenylethanone is 3 but in phenylethanal the peak (area) ratio is 2 to 1 IP6 (Chemical shifts): (Only) phenylethanal has an aldehyde (hydrogen) peak in the range 9 – 10.1 (ppm)	Ignore references to C^{13} nmr Accept annotations on a structure towards crediting the following IPs Allow either a single chemical shift value or a range within the stated values Penalise incorrect chemical shifts Both have peaks in the range 6.5-8.4 (ppm) Ignore any splitting description Ignore any splitting pattern given for this peak to award this mark Allow any difference of one in the number of peaks stated All these splitting patterns required for this IP Ignore the splitting pattern for this IP and ignore any peak areas given for the aryl hydrogens Ignore the splitting pattern for this IP	
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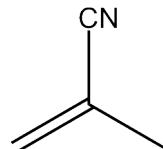
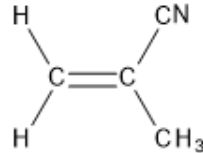
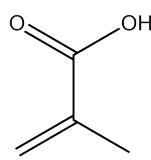
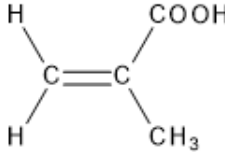
Question Number	Answer	Additional Guidance	Mark
8(c)	Reagent: lithium tetrahydridoaluminate(III) /LiAlH₄ (1)	Allow lithium aluminium hydride Accept sodium tetrahydridoborate /sodium borohydride/ NaBH ₄ In water/alcohol for 2 marks Ignore reference to addition of acid after use of LiAlH ₄ in dry ether Do not award with additional reagents	(2)
	Conditions: (dry) ether/ethoxyethane (1)	Ignore heat The mark for conditions is dependent on correct reagent or near miss such as incorrect formula LiAlH ₃ /LiAlH/LiAl	

(Total Question 8 = 18 marks)

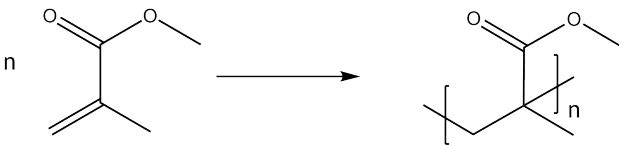
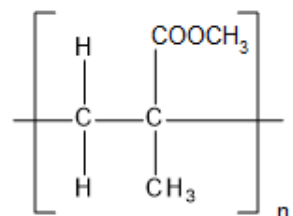
Question Number	Answer	Additional Guidance	Mark
		<u>Example of calculation:</u>	(1)

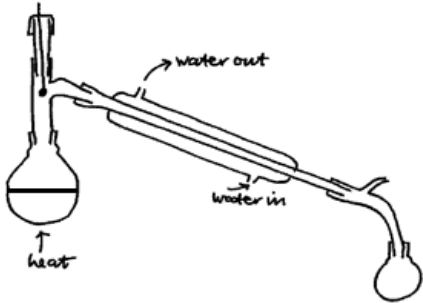


Question Number	Answer	Additional Guidance	Mark
7(a)(i)	- curly arrow from lone pair on C of CN^- ion to C of C=O (1) - dipole on C=O and curly arrow from C=O bond to or just beyond O (1) - intermediate structure (1) - curly arrow from lone pair on O to H of HCN and curly arrow from H-C bond to anywhere on CN (1)	Penalise omission of lone pair once in M1 and M4 Penalise use of single-headed arrows only once Penalise use of incorrect nucleophile once only in M1 e.g. OH^- Allow skeletal, displayed or structural formulae Allow CN^- to attack from any angle Allow CN triple bond displayed Do not award curly arrow from lone pair on N Do not award $\text{CN}^{\delta-}$ Ignore missing lone pair on O Ignore connectivity for vertical CN group if M1 awarded Do not award $\text{O}^{\delta-}$ Allow curly arrow from lone pair on O^- to H^+ Ignore dipole on HCN Ignore products, even if incorrect	(4)
Example of mechanism Allow straight arrows Curly arrows in M1 and M4 must start from, or close to, at least 1 of the electrons in the lone pair, but penalise this once only If candidate shows dipole on C=O and curly arrow first, allow M2 but if CN^- then attacks C^+, do not allow M1. M3 can score for the correct intermediate and M4 as per MS			

Question Number	Answer		Additional Guidance	Mark
7(a)(ii)	Reagent 2	(conc) phosphoric acid / H_3PO_4 (conc) sulfuric acid/ H_2SO_4 aluminium oxide / Al_2O_3 (1)	Ignore connectivity of groups All marks are stand alone Allow 'alumina' Do not award steam / water Do not award dilute for either acid Allow structural, displayed or any combination of structural, displayed or skeletal for Compounds A and B Do not award hydration / halogenation for M3 Allow TE for M4 based on incorrect M2 structure provided the nitrile group has been hydrolysed correctly and no other changes Allow addition-elimination for condensation in M6	(6)
	Structure of compound A	 (1) 		
	Reaction type 3	(acid) Hydrolysis (1)		
	Structure of compound B	 (1) 		
	Reagent 4	CH_3OH / methanol (1)		
	Reaction type 4	Esterification / condensation (1)		



Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	- correct repeat unit shown (1) - equation balanced (1)	 Allow displayed or structural formulae or a combination of these e.g.  Do not award 2 as the balancing number	(2)

Question Number		Additional guidance	Mark
7(b)	A diagram that shows the following points: Left-hand side - heat source, flask with reaction mixture and anti-bumping granules, still head and thermometer opposite 'exit' (1) Centre - downward angled condenser with separated water jacket and with correct water flow (1) Right-hand side - collection vessel (1)	<u>Example of diagram</u>  Allow pear shaped flask Do not allow one-piece apparatus for flask and still head Ignore missing thermometer / reaction mixture in flask / anti-bumping granules Ignore fractionating column Do not award conical flask Do not award M1 if noticeable gaps at joints / still head open at top Note – if thermometer is present, it must be within the still head Allow M2 if condenser is horizontal but not vertical Allow beaker / any type of flask Do not award M3 if apparatus is sealed Notes: Diagram of heat under reflux scores (0) Ignore lines across joints as part of Quickfit apparatus	(3)

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	An explanation that makes reference to any two of the following points: - to make sure the solution doesn't cool down (significantly) (1) - to prevent (premature) crystallization taking place (in funnel / on filter paper) (1) - which would reduce yield (of product) (1)	Ignore general references to removing impurities Allow crystals / solid / precipitate forming for crystallisation Allow to keep the solution warm Accept to prevent crystals forming during filtration Allow to make sure the substance stays in solution	(2)

Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	An explanation that makes reference to any two of the following points: - Step 4: product less soluble in cooler solvent (than hot solvent, so product crystallises out) (1) - Step 4 : (soluble) impurities present (in small amount so) stay in solution / remain dissolved (while product crystallises) (1) - Step 5: filtering under reduced pressure removes more of the soluble impurities / removes the soluble impurities faster / produces a drier product (1)	Allow crystals / solid / precipitate for product Allow product is insoluble in cold solvent Allow filtration removes the solution containing the impurities / separates the crystals from the soluble impurities Allow filtering under reduced pressure is faster (than gravity filtration) Ignore just 'use a Buchner funnel'	(2)



Question Number	Answer	Additional Guidance	Mark
7(c)(iii)	An answer that makes reference to the following points: • (measure) melting temperature (of purified crystals) (1) • compare to literature value (matched to original carbonyl compound) (1)	Allow compare to data book value / compare to value from (credible) internet source / compare to known melting temperature / compare to values in a database	(2)

(Total for Question 7 = 21 marks)



Question Number	Answer	Additional Guidance	Mark
9(a)	An answer that makes reference to the following points: - arrow from inside the hexagon to sulfur atom - partial charges on S and O - basic structure of intermediate, including both methyl groups, and broken circle covering at least three carbons, facing the tetrahedral carbon, and containing (some part of) positive charge - lone pair and negative charge on O of intermediate - arrow from (lone pair on) oxygen to H on ring - return of C–H bond pair towards/ inside (broken) ring	structure of intermediate In point 2 allow δ^- on all O atoms In point 5 allow arrow from lone pair on O to H^+, or hydrogen on H_2O, H_3O^+, or H_2SO_4 6 points scores 3 marks 4 or 5 points scores 2 marks 2 or 3 points scores 1 mark 0 or 1 point scores 0 marks	(3)

Question Number	Answer	Additional Guidance	Mark
9(b)(i)	An explanation that makes reference to the following points: - both 2,5-dimethylbenzenesulfonic acid and (soluble) impurities dissolve in hot water / hot solvent (1) - impurities are soluble in cold solvent or 2,5-dimethylbenzenesulfonic acid is (much) less soluble / insoluble in cold solvent (1) - so impurities remain in solution (as the solvent cools) / impurities remain in the filtrate and 2,5-dimethylbenzenesulfonic acid recrystallises / solid remains (on filter paper) (1)	Allow impurities are present in small amounts (and so do not crystallise in cold solvent) Do not award the ice-cold water (in step 4) dissolves the soluble impurities Allow the ice-cold water washes off any surface impurities	(3)



Question Number	Answer	Additional Guidance	Mark
9(b)(ii)	A description that makes reference to the following points: - filter when still hot / filter funnel and / or paper are heated (1) (filtration) carried out after step 1 / before step 2 (to remove insoluble impurities) (1)	Allow redissolve in a different solvent If no other credit awarded, allow 1 mark for decant (off from the impurities) whilst still hot	(2)
Question Number	Answer	Additional Guidance	Mark
9(c)(i)	A description that makes reference to the following points: (add the solution formed) to a 100 cm³ volumetric flask (1) (rinse remaining solution from conical flask) with distilled / deionised water and add washings to volumetric flask (1) - add distilled / deionised water (1) - make up to the line / mark and (1) (add stopper) then invert / mix (to ensure solution is homogenous)	Ignore starting with just the acid and omitting the alkali Do not award shake	(4)



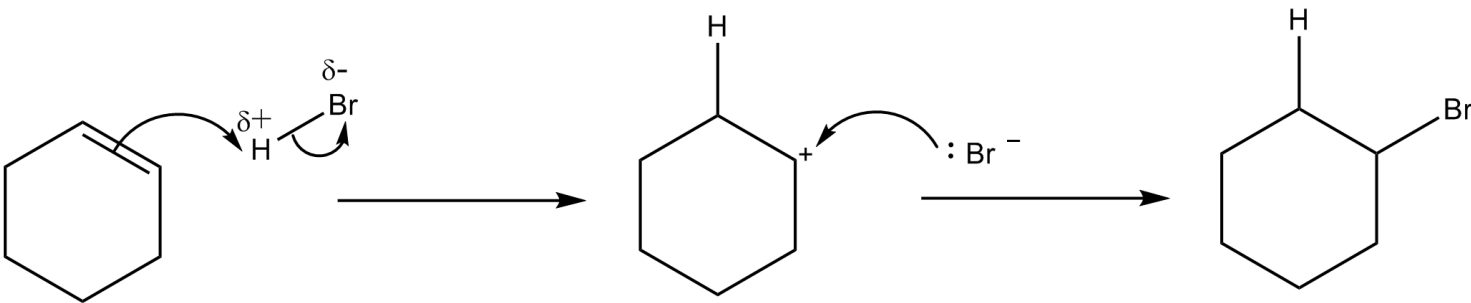
Question Number	Answer	Additional Guidance	Mark
9(c)(ii)	- calculation of moles of HCl(aq) (1) - calculation of moles of NaOH in in small conical flask (1) - calculation of moles of 2,5-dimethylbenzenesulfonic acid (1) - calculation of M_r of 2,5-dimethylbenzenesulfonic acid (1) - deduction of value for n (must be an integer) (1)	<u>Example of calculation</u> $(22.4/1000) \times 0.0250 = 5.6 \times 10^{-4} \text{ (mol)}$ $5.6 \times 10^{-4} \times 5 = 2.8 \times 10^{-3} \text{ (mol)}$ $(10/1000) - 2.8 \times 10^{-3} = 7.2 \times 10^{-3}$ $1.60 / 7.2 \times 10^{-3} = 222.2 \text{ (g mol}^{-1}\text{)}$ $222.2 - 186.1 = 36.1$ so $n = 2$ Allow TE throughout Correct answer with no working scores M5 only If you see 222.2 for the M_r this will score M1-M4 as the other steps will have been carried out correctly. Do not award negative value of n	(5)

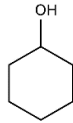
Question Number	Answer	Additional Guidance	Mark
9(d)(i)	An answer that makes reference to the following point: lower burette so pouring in acid below eye-level / place stand in sink / on (stable) stool / on floor	Allow alternative methods of height reduction Ignore just an observation that the top of the burette is too high Ignore just lower the burette / stand Do not award student raises themselves e.g. standing on a stool	(1)

Question Number	Answer	Additional Guidance	Mark
9(d)(ii)	An explanation that makes reference to the following points: - reduce the value of the titre (1) - smaller (calculated) value of excess NaOH / greater (calculated) moles of 2,5-dimethylsulfonic acid that reacted (1) - so smaller M_r, hence smaller (calculated value of) n (1)	M3 dependent on M2 Allow smaller M_r but negligible effect on (calculated value) of n If M1 is answered as 'increase the value of the titre' then allow reverse arguments for M2 and M3	(3)

(Total for Question 9 = 21 marks)



Question Number	Answer	Additional Guidance	Mark
7(a)	An answer that makes reference to the following points: • curly arrow from C=C to δ^+ H in HBr • dipole on HBr • curly arrow from H-Br bond to, or just beyond, $\text{Br}^{\delta-}$ • structure of carbocation • lone pair on Br^- • curly arrow (from lone pair on) Br^- to C^+	Penalise use of half arrows once only in points 1, 3 and 6 Ignore drawing of hydrogen atoms on carbocation unless the number of hydrogen atoms is too many 6 points scores (4) 5 points scores (3) 3 or 4 points scores (2) 2 points scores (1) 1 point scores (0)	(4)
			

Question Number	Answer	Additional Guidance	Mark
7(b)	An answer that makes reference to the following points: • (reaction of) bromocyclohexane with KOH(aq) / NaOH(aq) (1) • (nucleophilic) substitution (1) • structure of A (cyclohexanol) (1) • reflux / heat with sulfuric acid and sodium dichromate ((VI)) (1) • oxidation (1)	Each mark is standalone Accept aqueous ethanolic for (aq) or aqueous Ignore reference to reflux / heating Do not award just ethanolic KOH/ NaOH Accept hydrolysis (1)  Accept displayed formula Ignore name of A, even if incorrect Allow acidified dichromate ((VI)) / H⁺ and Cr₂O₇²⁻ Accept K₂Cr₂O₇ for Na₂Cr₂O₇ Ignore concentration Allow distillation/distil for reflux/heat Do not award HCl for sulfuric acid Allow reference to oxidising agent/oxidised Ignore redox	(5)

Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	An explanation that makes reference to the following points: - to prevent moist air entering (1) - as Grignard reagent will not form in presence of water (1)	Allow to keep the reactants dry Allow reference to absorbing water Ignore just drying agent Do not award to remove water from the solution or coming out from the solution Allow 'to ensure Grignard Reagent doesn't break down (to an alkane)' / Grignard reagents react with water / avoid hydrolysis of Grignard reagents Allow reference to ethane/alkane forming Ignore reference to just reacting with the reactants	(2)

Question Number	Answer	Additional Guidance	Mark
7(c)(iii)	An answer that makes reference to the following point: to ensure efficient cooling / prevent air bubbles forming in condenser	Allow to fill the condenser with water	(1)

Question Number	Answer	Additional Guidance	Mark
7(d)(i)	An answer that makes reference to the following point: orange / yellow	Allow red Allow any combination of these 3 colours Ignore any shades	(1)

Question Number	Answer	Additional Guidance	Mark
7(d)(ii)	An answer that makes reference to the following points: - arrow from C=O bond to O (1) - arrow from lone pair on O⁻ to H⁺ (1) - arrow from lone pair in O in H₂O to H in NH₂ (1) - arrow from N-H bond to N⁺ (1)	Accept arrow to either of the two hydrogen atoms Allow M2 to M4 to be drawn on the product of Step 1 if not drawn in Step 2 Ignore any dipoles added, even if incorrect Penalise any additional incorrect curly arrows over four	(4)
Exemplar diagram	The diagram illustrates the mechanism of reductive amination in two steps: Step 1: Nucleophilic attack of the amine (R-NH₂) on the carbonyl carbon of 3,5-dinitrobenzaldehyde. A curly arrow goes from a lone pair on the nitrogen to the carbonyl carbon. Another curly arrow goes from the C=O double bond to the oxygen. This is followed by a proton transfer from the nitrogen to the oxygen, resulting in a protonated intermediate. Step 2: Proton transfer from the hydroxyl group to another water molecule (H₂O). A curly arrow goes from a lone pair on the oxygen of H₂O to a hydrogen atom of the OH group. Another curly arrow goes from the N-H bond to the nitrogen. This leads to the formation of the imine product and a hydronium ion (H₃O⁺).		

Question Number	Answer	Additional Guidance	Mark
7(d)(iii)	An answer that makes reference to the following points: - solid dissolved in minimum amount of hot solvent (1) (hot filtration then) solution allowed to cool and (re)crystallise/precipitate (1) - solid filtered under reduced pressure (1) - rinsed with (cold) solvent and dried between (sheets of) filter paper (1)	Allow any named solvents M2 dependent on M1 or near miss Allow solid for crystal/ppt Allow 'Buchner filtration' / suction filtration Cooling and recrystallising follows M1 so M2 dependent M3 and M4 must apply to crystals/solid being present however derived Filtering and drying of dissolved solid is nonsense so M3 and M4 would both be lost Allow desiccator / warm oven as alternative for (sheets of) filter paper Allow drying with paper towels	(4)

(Total for Question 7 = 22 marks)

