PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 2: HALOGENOALKANES

SCORE	PERCENTAGE
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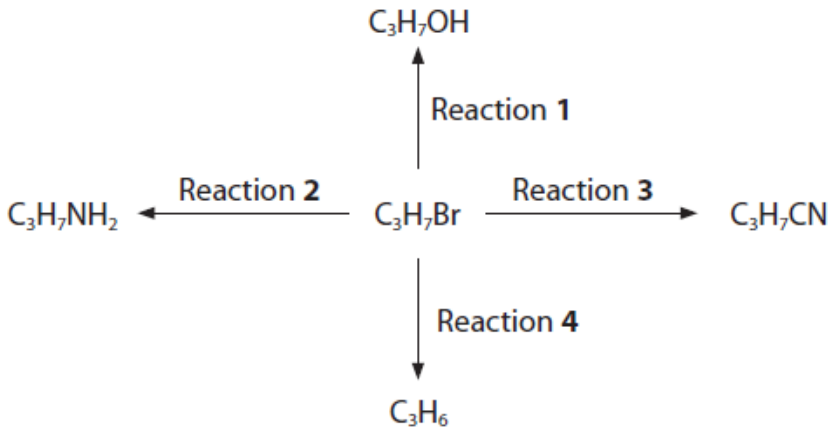
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Q1.

Halogenoalkanes are useful reagents in organic synthesis.

Some reactions of 1-bromopropane are shown.



(a) Complete the table about these reactions.

(4)

Reaction	Reagent	Solvent	Type of reaction
1	potassium hydroxide		
2	ammonia		
3		ethanol	
4			elimination

(b) Give the IUPAC name of the product of Reaction **3**.

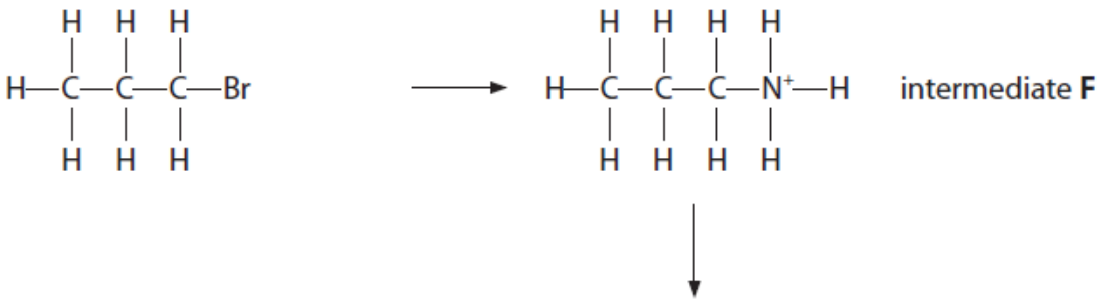
(1)

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(c) Complete the mechanism for Reaction **2**.

Show the formation of the intermediate **F** and of the product.
Include curly arrows, and any relevant lone pairs and dipoles.

(3)



*(d) The relative rates of hydrolysis of a series of halogenoalkanes were determined

using the following method:

- five test tubes, each containing 2 cm^3 of ethanol and 2 cm^3 of aqueous silver nitrate, were placed in a water bath at 50 °C
- four drops of a different halogenoalkane were added to each test tube
- the time taken for a precipitate to appear in each test tube was recorded.

The results are shown.

Halogenoalkane	Time for ppt to appear / s
2-bromobutane	29
2-chlorobutane	75
2-iodobutane	<1
1-bromobutane	41
2-bromo-2-methylbutane	13

Explain these results by considering:

- the chemical reaction occurring
- the structures of the halogenoalkanes
- the strengths of the carbon-halogen bonds.

(6)

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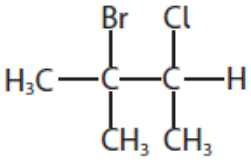
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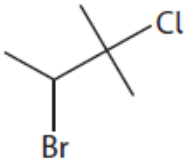
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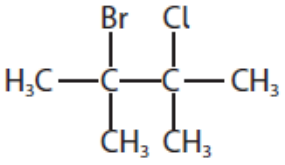
Q2.

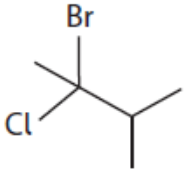
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

What is the structure of 2-bromo-3-chloro-2-methylbutane?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for question = 1 mark)

Q3.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Part of a reaction mechanism is shown.



Which curly arrow in the mechanism is **not** correct?

☒ **A** arrow 1

☒ **B** arrow 2

☒ **C** arrow 3

☒

D arrow 4

(Total for question = 1 mark)

Q4.

1-bromopropane is used for spot removal when 'dry cleaning' clothes.

(a) 1-bromopropane does not occur naturally but can be made from propan-1-ol.

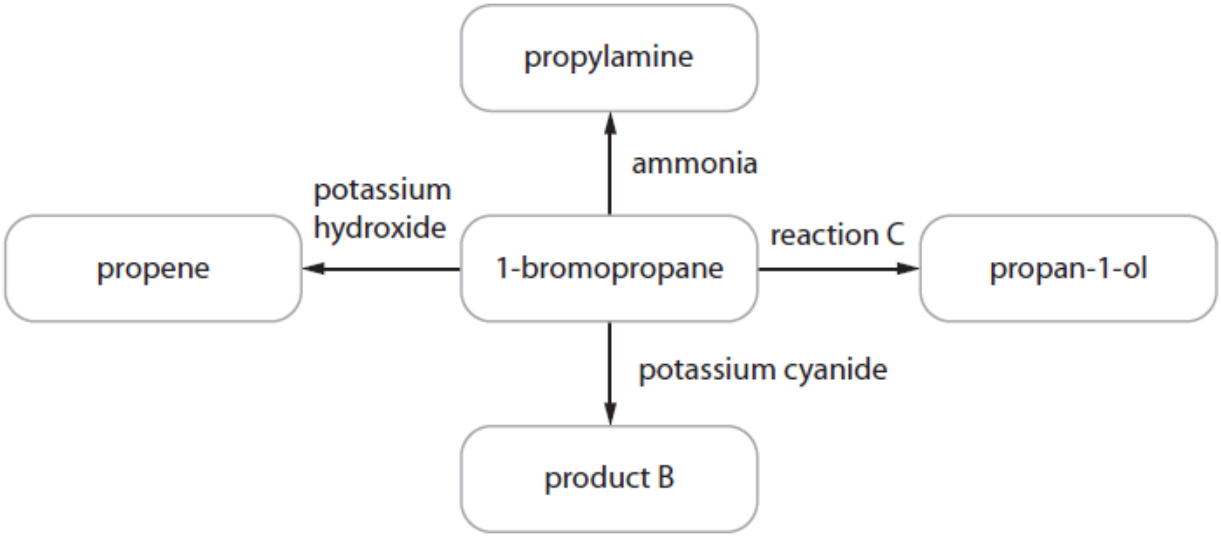
Identify the reagent or reagents you would use to make 1-bromopropane from propan-1-ol.

(1)

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(b) Some reactions of 1-bromopropane are shown.



(i) Give the conditions for the formation of propene.

(1)

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(ii) Give the **molecular** formula of product B.

(1)

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(iii) Name the type and mechanism of the reaction taking place in reaction C.

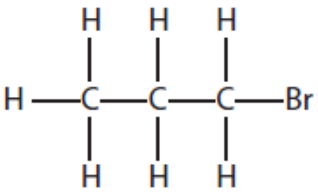
(2)

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(iv) Complete the mechanism for the reaction that occurs between ammonia and 1-bromopropane to form propylamine,
$CH_3CH_2CH_2NH_2$.

Include curly arrows, and relevant lone pairs and dipoles.

(4)



(Total for question = 9 marks)

Q5.

This question is about bicycles.

Bicycle frames have been made from steel and aluminium for many years but more recently titanium has been used.

Titanium is a metal that is extracted from its ore, impure titanium oxide (TiO_2), in a two-step process.

Step **1**

The titanium oxide reacts with chlorine in the presence of carbon to form titanium(IV) chloride ($TiCl_4$) and carbon monoxide.

Step **2**

The titanium(IV) chloride reacts with magnesium.

$$TiCl_4 + 2Mg \rightarrow Ti + 2MgCl_2$$

(a) (i) Write the equation for Step **1**.

State symbols are not required.

(1)

(ii) Explain why Step **2** is a redox reaction.

Refer to relevant oxidation numbers in your answer.

(2)

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.....

.....

(b) Titanium(IV) chloride is a liquid that reacts violently with water, producing white smoke. This reaction has been used to produce naval smoke screens to hide ships.

Suggest the type of reaction taking place **and** the compound producing the white smoke.

(2)

Type of reaction

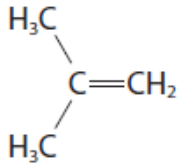
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Compound

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(c) Many bicycles use an inner tube inside the tyre.

A common material used for inner tubes is the addition polymer formed from 2-methylpropene.

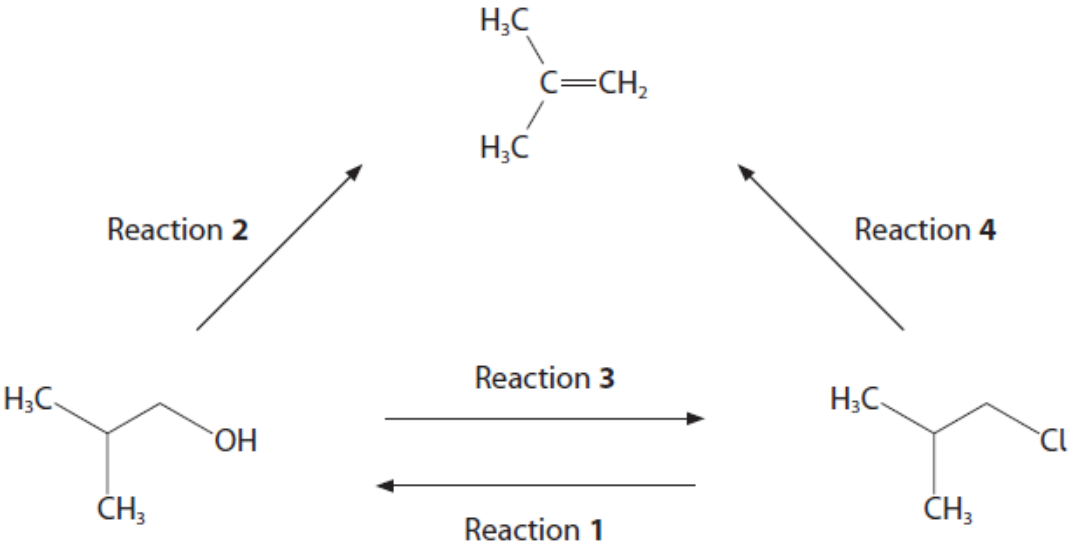


2-methylpropene

Draw a section of the polymer showing two repeat units.

(2)

(d) A reaction scheme involving 2-methylpropene is shown.



(i) For Reaction **1**, give the name or formula of a suitable reagent, stating the conditions for the reaction.

(2)

Reagent

.....

Conditions

.....

(ii) For Reaction **2**, give the name or formula of a suitable reagent, stating the type of reaction taking place.

(2)

Reagent

.....

Type of reaction

.....

(iii) For Reaction **3**, give the name or formula of a suitable reagent, writing an equation for the reaction taking place.

(2)

Reagent

.....

Equation

(iv) For Reaction **4**, the reagent used is potassium hydroxide (KOH).

Give the conditions required for this reaction, stating the role of the hydroxide ions in this reaction.

(2)

Conditions

.....

Role of hydroxide ions

.....

(e) Many cyclists carry a small cylinder of carbon dioxide to inflate their inner tube if it is punctured. The carbon dioxide is stored under pressure.



(Source: © Douglas Sacha/Getty Images)

A gas cylinder contains 16.0 g of carbon dioxide (CO_2).
The cylinder has a volume of 20 cm^3 .

Calculate the pressure in the cylinder at 25 °C. Include units in your answer.
Assume that all the CO_2 in the cylinder is a gas.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(5)

(Total for question = 20 marks)

Q6.

Iodine can be extracted from seaweed. The seaweed is heated strongly to burn off the organic matter. The resultant ash is boiled in water to dissolve the iodide ions, and the mixture is filtered.

(a) Acidified hydrogen peroxide (H_2O_2) is added to the filtrate.

A redox reaction takes place with iodine and water as the only products.

(i) Write half-equations for the oxidation and reduction reactions that take place.

State symbols are not required.

(2)

(ii) Use your answers to (a)(i) to write the overall equation for this redox reaction.

State symbols are not required.

(1)

(b) The iodine is separated from the aqueous solution using solvent extraction.

The aqueous solution is mixed with cyclohexane in a separating funnel, forming two layers.

The mixture is then shaken gently and left until the layers separate.

Most of the iodine dissolves in the cyclohexane layer.

(i) State the colour of each layer **after** separation.

(2)

Aqueous layer
.....

Cyclohexane layer
.....

(ii) Explain why iodine is very soluble in cyclohexane but only slightly soluble in water.

(2)

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(c) The cyclohexane layer is then removed from the separating funnel and dried.

Identify, by name or formula, a suitable drying agent.

(1)

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(Total for question = 8 marks)

Q7.

A chloroalkane is heated with dilute aqueous sodium hydroxide and the pure organic product is obtained.

When the organic product is warmed with acidified potassium dichromate(VI) solution, there is no change in colour.

The chloroalkane could be

(1)

☒ **A** 1-chlorobutane

☒ **B** 2-chloro-2-methylpropane

☒ **C** 1-chloro-2-methylpropane

☒ **D** 2-chlorobutane

(Total for question = 1 mark)

Q8.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Organic reactions can be classified in different ways.

(a) How should the reaction shown be classified?

(1)



☒ **A** addition

☒ **B** oxidation

☒ **C** polymerisation

☒ **D** substitution

(b) How should the reaction shown be classified?

(1)



☒ **A** addition

☒ **B** oxidation

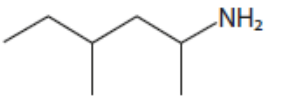
☒ **C** reduction

☒ **D** substitution

(Total for question = 2 marks)

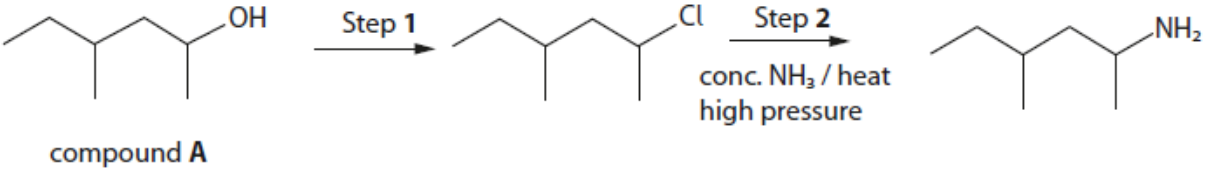
Q9.

The compound DMAA was originally synthesised as a decongestant.



DMAA

A suggested synthetic route for DMAA is shown.



compound **A**

(a) (i) Give the systematic name of compound **A**.

(1)

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(ii) Identify, by name or formula, a suitable reagent for Step **1**.

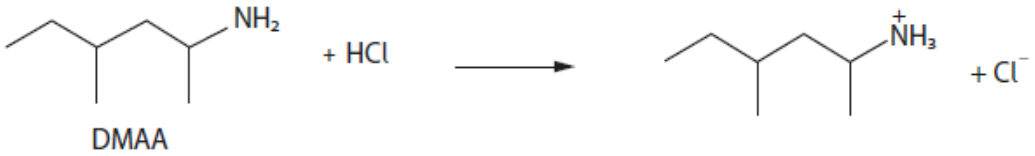
(1)

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(iii) Give the mechanism for the reaction in Step **2**.
Include curly arrows, and any relevant dipoles and lone pairs.

(4)

(b) DMAA is only slightly soluble in water but dissolves readily in hydrochloric acid to form an aqueous solution.



DMAA

(i) Explain the type of bonding that occurs between the nitrogen atom and the hydrogen ion, when the positive ion forms.

(3)

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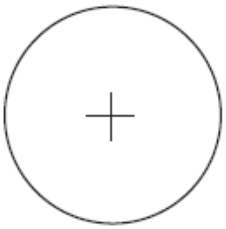
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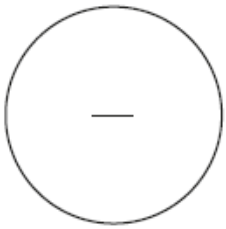
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(ii) Complete the diagrams to show how the ions formed in the reaction between DMAA and hydrochloric acid interact with water molecules.

(3)





(Total for question = 12 marks)

Q10.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which reagent would convert an alcohol into an alkene?

☒ **A** acidified potassium dichromate(VI)

☒ **B** anhydrous calcium sulfate

☒ **C** concentrated phosphoric acid

☒ **D** ethanolic potassium hydroxide

(Total for question = 1 mark)

Q11.

The halogenoalkane 1-chlorobutane reacts under suitable conditions with potassium hydroxide to form the alcohol butan-1-ol.

(a) (i) Name a suitable solvent for the potassium hydroxide in this reaction.

(1)

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(ii) State the type and mechanism of this reaction.

(1)

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(iii) Draw the mechanism for this reaction.

Use curly arrows, and show relevant dipoles and lone pairs.

(3)

(b) A student carried out the reaction.

After separation and purification, the mass of butan-1-ol formed was 12.1 g.

The yield of the reaction was 64.0 %.

Calculate the volume of 1-chlorobutane used in the reaction.

Give your answer to an appropriate number of significant figures.

[Density of 1-chlorobutane = 0.886 g cm^{-3}]

(4)

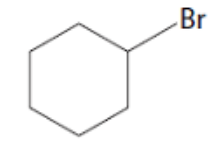
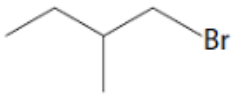
(Total for question = 9 marks)

Q12.

This question is about some halogenoalkanes.

(a) Give the classification of each halogenoalkane shown in the table as primary, secondary or tertiary.

(1)

Halogenoalkane	Classification
	
	

(b) Samples of 1-iodobutane and 2-chloro-2-methylpropane were hydrolysed using aqueous silver nitrate in ethanol.

Explain whether or not it is possible to predict the relative rate of hydrolysis of these two compounds.

(3)

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(c) Butylamine is formed when 1-bromobutane reacts with excess concentrated alcoholic ammonia.

$$CH_3CH_2CH_2CH_2Br + 2NH_3 \rightarrow CH_3CH_2CH_2CH_2NH_2 + NH_4Br$$

(i) Give a reason why this reaction should be carried out by heating the reactants in a sealed tube rather than heating under reflux.

(1)

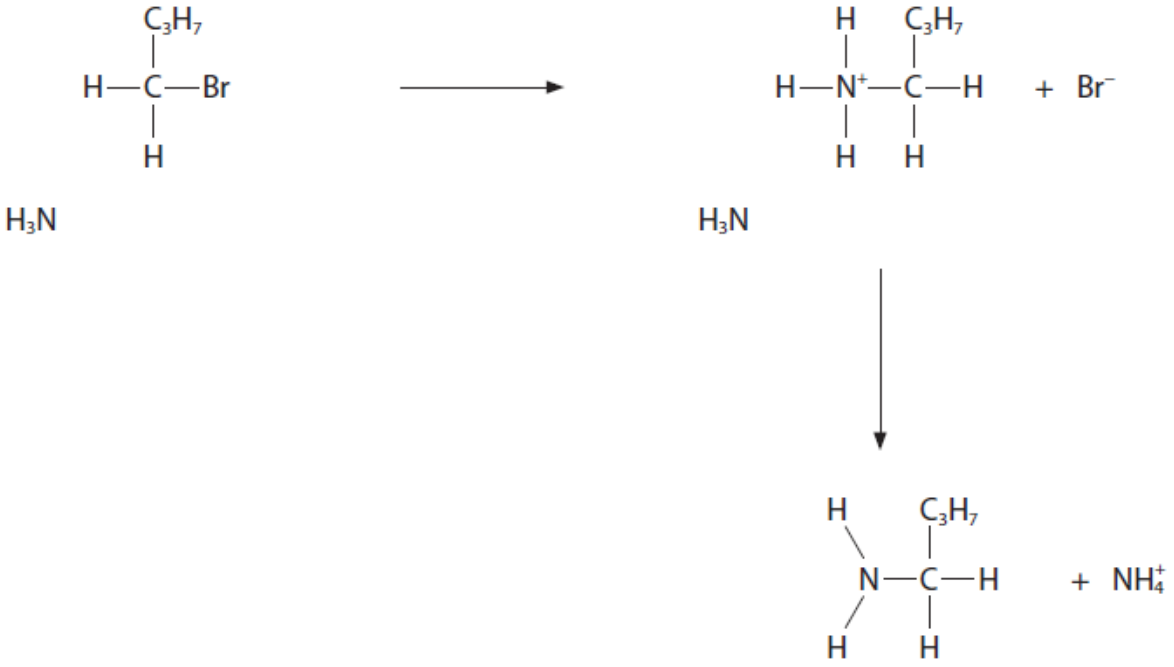
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(ii) Complete the mechanism for this reaction by adding curly arrows, and any relevant lone pairs and dipoles.

(4)



(d) Bromoethane is prepared by reacting ethanol with potassium bromide and concentrated sulfuric acid.

$$C_2H_5OH + KBr + H_2SO_4 \rightarrow C_2H_5Br + KHSO_4 + H_2O$$

Calculate the maximum mass of bromoethane that could be prepared from 4.65 g of ethanol, 14.90 g of potassium bromide and a solution containing 16.35 g of H_2SO_4.

[Ar values: H = 1.0 C = 12.0 O = 16.0 S = 32.1 K = 39.1 Br = 79.9]

(3)

*(e) The reaction between 2-bromopropane and potassium hydroxide takes place under two different conditions:

- in aqueous solution
- in ethanolic solution.

Compare and contrast these two reactions.

Include equations for the reactions.
Detailed mechanisms of these reactions are **not** required.

(6)

(Total for question = 18 marks)

Q13.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Separate samples of some halogenoalkanes were dissolved in ethanol and a few drops of silver nitrate solution added. The faster the reaction of the halogenoalkane, the quicker a precipitate forms.

(a) Which of these halogenoalkanes reacts the **fastest**?

(1)

☐ **A** CH_3CHICH_3

☐ **B** $CH_3CHBrCH_3$

☐ **C** $CH_3CHClCH_3$

☐ **D** CH_3CHFCH_3

(b) Which of these halogenoalkanes reacts the **fastest**?

(1)

☐ **A** $CH_3CHBrCH(CH_3)CH_3$

☐ **B** $CH_3CH_2CBr(CH_3)CH_3$

☒ **C** $CH_3CH(CH_2Br)CH_2CH_3$

☒ **D** $CH_3CH_2CH_2CH_2CH_2Br$

(Total for question = 2 marks)

Q14.

Which compound is hydrolysed most rapidly?

(1)

☒ **A** 1-chloropropane

☒ **B** 1-chlorobutane

☒ **C** 2-chloro-2-methylpropane

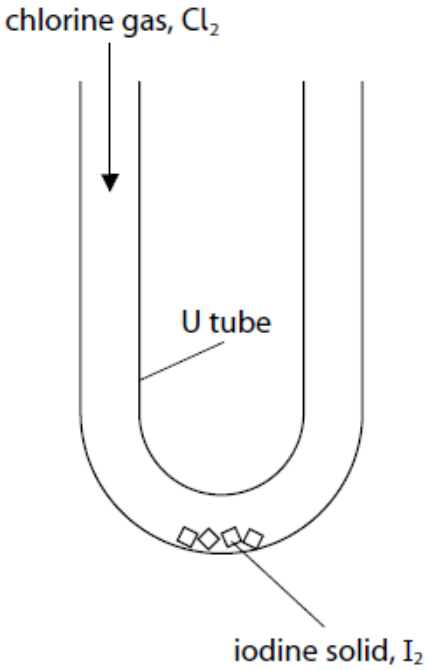
☒ **D** 2-chlorobutane

(Total for question = 1 mark)

Q15.

Iodine monochloride, ICl, is a covalent compound produced by the reaction of iodine with chlorine. Iodine monochloride is a dark brown liquid at room temperature.

The equipment shown can be used to pass chlorine over solid iodine to produce iodine monochloride.



When excess chlorine is passed through the U tube, the iodine monochloride reacts to produce iodine trichloride in an equilibrium reaction.

(a) Write a chemical equation for the reaction of iodine with chlorine to produce iodine monochloride. Include state symbols.

(2)

(b) The iodine monochloride molecule has a permanent dipole. Complete the following table using the electronegativity data from your Data Booklet and hence show the dipole on the diagram of the iodine monochloride molecule.

(1)

Element	Electronegativity
Cl	
I	

I — Cl

(c) Iodine monochloride reacts with propene to form two isomeric products. This is an addition reaction that is similar to the reaction of propene with hydrogen halides.

(i) Draw the skeletal formulae of both isomers.

(2)

(ii) Explain which of these isomers is the major product.

(3)

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(d) The equation for the reaction between iodine monochloride and chlorine is:

$$\underset{\text{brown liquid}}{ICl(l)} + Cl_2(g) \rightleftharpoons \underset{\text{yellow solid}}{ICl_3(s)}$$

(i) State and justify **one** precaution that must be taken when preparing iodine trichloride.

(2)

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(ii) Give the oxidation number of iodine in both iodine-containing compounds in the equilibrium.

(1)

I in ICl

.....

I in ICl_3

.....

(iii) Iodine trichloride can also be made by reacting potassium chlorate(V) with iodine in hydrochloric acid. The equation for the reaction is

$$KClO_3 + I_2 + 6HCl \rightarrow KCl + 2ICl_3 + 3H_2O$$

By considering oxidation numbers for chlorine, explain whether or not this reaction is a disproportionation.

(2)

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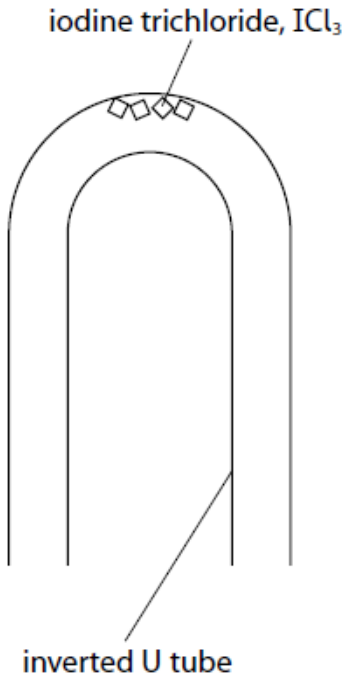
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(e) Chlorine gas has a molar volume of 24 000 cm^3 mol^{-1} under the conditions used in this reaction.

(i) Show that the density of chlorine gas is approximately 3 g dm^{-3}.

(2)

(ii) Air has an average density of 1.25 g dm^{-3}. If the U-tube used in part (d) is inverted, as shown in the diagram, the solid yellow iodine trichloride produced in the equilibrium reaction turns to a brown liquid.



Explain this observation.

(3)

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(f) A mass of 0.64 g of iodine reacted with fluorine to form 1.31 g of a fluoride of iodine.

Calculate the empirical formula of this compound of iodine and fluorine.

(2)

(Total for question = 20 marks)

Q16.

1-bromobutane reacts with alkali:

CH_3-CH_2-CH_2-$CH_2Br + OH^- \rightarrow CH_3$-$CH_2$-$CH_2$-$CH_2OH + Br^-$

The mechanism and type of reaction is:

(1)

☒ **A** electrophilic addition

☒ **B** electrophilic substitution

☒ **C** nucleophilic addition

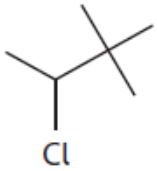
☒ **D** nucleophilic substitution

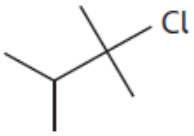
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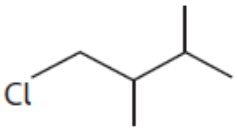
Q17.

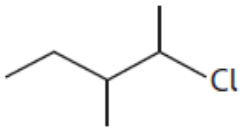
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which structure represents a primary halogenoalkane?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q18.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Butanenitrile can be formed by reacting 1-bromopropane with potassium cyanide.

Which is the correct mechanism and type of reaction that occurs?

☒ **A** electrophilic addition

☒ **B** nucleophilic addition

☒ **C** electrophilic substitution

☒ **D** nucleophilic substitution

(Total for question = 1 mark)

Q19.

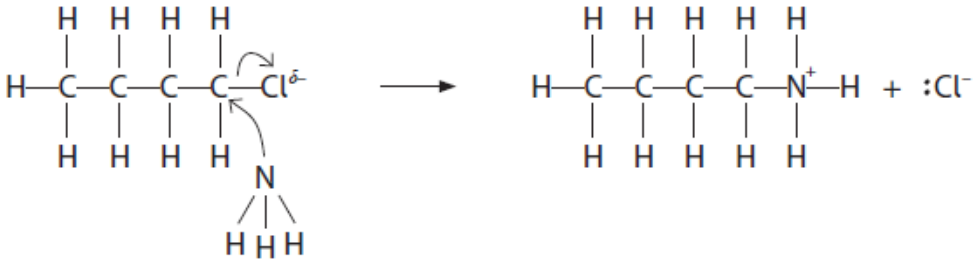
Ammonia reacts with 1-chlorobutane.

(a) State the type and mechanism of this reaction.

(2)

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(b) A student drew the first step of the mechanism for the reaction.



(i) Identify **two** omissions in the student's mechanism.

(2)

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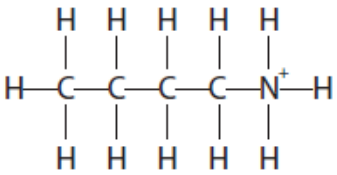
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(ii) To obtain butylamine, sodium hydroxide solution is added.

Complete the next step of the mechanism to form butylamine, showing curly arrows, relevant lone pairs and the reaction products.

(3)



(c) The reactions of ammonia and of hydroxide ions with halogenoalkanes are similar.

Compare the rate of reaction of ammonia with 1-chlorobutane and with 2-bromo-2-methylpropane.

Justify your answer.

(3)

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(Total for question = 10 marks)

Q20.

This question is about halogenoalkanes.

(a) The rates of hydrolysis of 1-chloropropane, 1-bromopropane and 1-iodopropane in reactions with aqueous silver nitrate solution were compared.

(i) State what would be measured in the experiment to compare the rates of hydrolysis.

(1)

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(ii) State which of these halogenoalkanes would hydrolyse the fastest.
Justify your answer.

(2)

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(b) The equation for the hydrolysis of 1-chloropropane by aqueous hydroxide ions is shown.

$$CH_3CH_2CH_2Cl + OH^- \rightarrow CH_3CH_2CH_2OH + Cl^-$$

Give the mechanism for this hydrolysis.
Include curly arrows, and relevant dipoles and lone pairs.

(2)

(c) The boiling temperatures of some halogenoalkanes are shown.

Halogenoalkane	Boiling temperature / °C
1-chloropropane	47
1-bromopropane	71
1-iodopropane	103

Explain the trend in boiling temperature of these halogenoalkanes by comparing the intermolecular forces involved.

Detailed explanations of the forces involved are not required.

(4)

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(d) In another experiment, 2-bromobutane is heated with ethanolic potassium hydroxide and an elimination reaction occurs.

Draw the **skeletal** formulae of the three possible organic products, giving their names.

(3)

Skeletal formula	Name

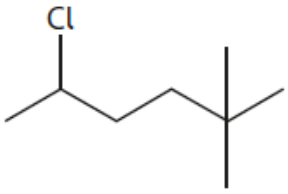
(Total for question = 12 marks)

Q21.

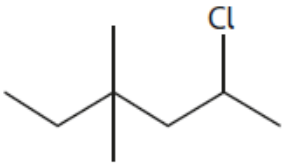
Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

What is the skeletal formula of 2-chloro-4,4-dimethylhexane?

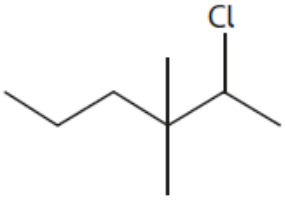
☒ **A**



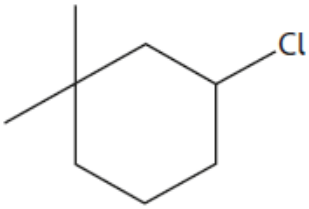
☒ **B**



☒ **C**



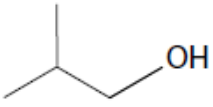
☒ **D**



(Total for question = 1 mark)

Q22.

2-methylpropan-1-ol has the skeletal formula:



(a) 2-methylpropan-1-ol can be converted to 1-bromo-2-methylpropane.

Give the reagents and conditions used for this reaction.

(2)

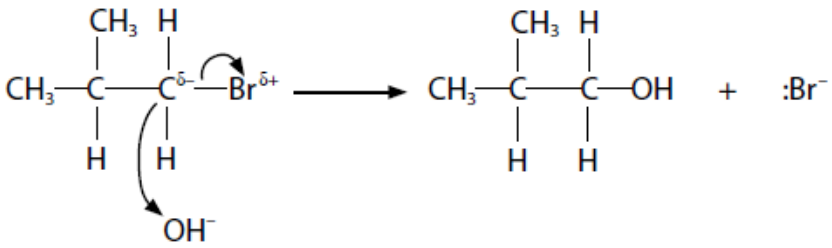
Reagents

.....

Conditions

.....

(b) 1-bromo-2-methylpropane can be converted back to 2-methylpropan-1-ol by heating with aqueous alkali. A student suggested the following mechanism for the reaction.



Identify and correct the three mistakes in the mechanism shown.

(3)

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(c) 1-bromo-2-methylpropane can be converted to 2-methylpropene.

Give the reagents and conditions used for this reaction.

(2)

Reagents

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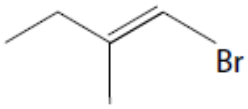
Conditions

.....

(Total for question = 7 marks)

Q23.

Give the systematic name for the following molecule.



(1)

☒ **A** *E*-1-bromo-2-methylbut-2-ene

☒ **B** *E*-2-methyl-1-bromobut-1-ene

☒ **C** *E*-1-bromo-3-methylpent-2-ene

☒ **D** *E*-1-bromo-2-methylbut-1-ene

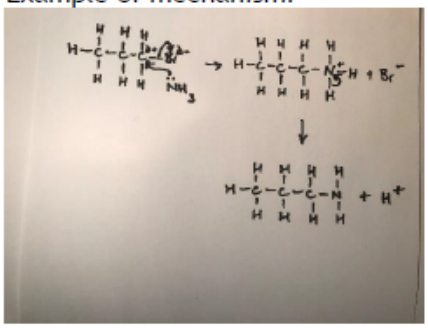
(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Answer					Additional Guidance	Mark
(a)	Reaction	Reagent	Solvent	Type of reaction		IGNORE nucleophilic in first three reactions but penalise electrophilic/free radical once only ALLOW alcoholic for reactions 2 and 4 Do not award: cyanide/CN^-/HCN Do not award OH^- 8 correct scores 4 marks 6/7 correct scores 3 marks 4/5 correct scores 2 marks 2/3 correct scores 1 mark	(4)
	1	(potassium Hydroxide)	Water/ aqueous	substitution	(1)		
	2	(ammonia)	Ethanol/ C_2H_5OH	substitution	(1)		
	3	sodium/ potassium cyanide NaCN/KCN	(ethanol)	substitution	(1)		
	4	potassium/ sodium hydroxide KOH/NaOH	Ethanol/ C_2H_5OH	(elimination)	(1)		

Question Number	Answer	Additional Guidance	Mark
(b)	butanenitrile **(1)**	ALLOW butane nitrile Butan(e)(1) nitrile Butanitrile Do not award 1-nitrile butane	**(1)**

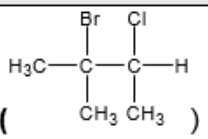
Question Number	Answer	Additional Guidance	Mark
(c)	• Curly arrow to show attack on C-Br carbon by lone pair of electrons on the N of ammonia and dipole C-Br **(1)** • Curly arrow to show loss of Br^- **(1)** • Curly arrow to show loss of H^+ from intermediate **(1)**	Example of mechanism:  Leaving groups must be shown for M2 and M3 but penalise only once Could show another molecule of ammonia or bromide ion acting as a base to remove H^+	**(3)**

Question Number	Answer	Additional Guidance	Mark
(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. 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 The following table shows how the marks should be awarded for structure and lines of reasoning.	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)**

	<table><tr><th></th><th>Number of marks awarded for structure and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated thoughout.</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>	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).	

	Indicative points: • (mechanism is nucleophilic) substitution • (Precipitation/precipitate of) silver halide forms • the time taken for the precipitate to form/rate of reaction depends on the carbon - halogen bond strength • Strength/bond enthalpy of the C-Halogen bond decreases going down group 7/any correct comparison of at least two Hal-C bond strengths (because the **atomic** radius increases) • The reactivity/rate of reaction of the bromoalkanes increases 1° < 2° < 3°/ • 1-bromobutane is 1°/2-bromobutane is 2° /2-bromo-2-methyl butane is 3°	Ignore hydrolysis as given in the question Can be shown in an equation Incorrect colours of ppts loses 1RP Ignore length of bond in IP3 and IP4 Incorrect reason for decrease loses 1 RP. Ignore references to electronegativity. Consideration of intermolecular forces loses 1 RP IP5 could be scored by correct comparison of the reactivity/rate of reaction of any 2 bromoalkanes ALLOW the production of the appropriate carbocation	

Q2.

Q	Answer	Mark
	 **The only correct answer is A (** **)** ***B*** *is incorrect because the bromine and chlorine are on the wrong carbon atoms* ***C*** *is incorrect because there is an additional methyl group* ***D*** *is incorrect because the chlorine and the bromine are on the same carbon atom*	**1**

Q3.

Question Number	Answer	Mark
	The only correct answer is C (arrow 3) ***A*** *is not correct because the arrow 1 is correctly used* ***B*** *is not correct because the arrow 2 is correctly used* ***D*** *is not correct because the arrow 4 is correctly used*	**1**

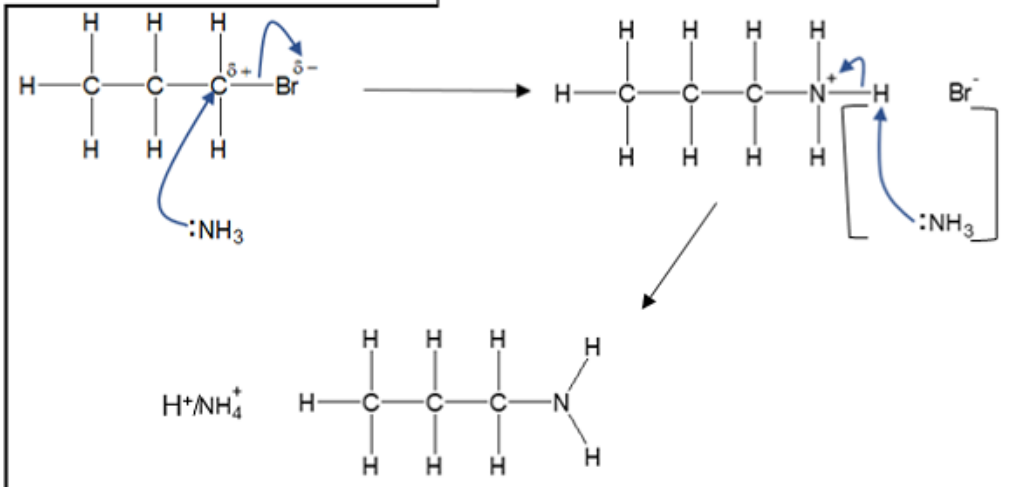
Q4.

Q	Answer	Additional Guidance	Mark
(a)	• identification of suitable reagent(s)	50% / concentrated **and** sulfuric acid / H_2SO_4 **and** potassium bromide / KBr Allow Other named bromides Phosphorus **and** bromine Phosphorus(V) bromide / PBr_5 Phosphorus(III) bromide / PBr_3 Thionyl bromide / $SOBr_2$ If the name and the formula are given, then both must be correct Do not award dilute sulfuric acid	**1**

Q	Answer	Additional Guidance	Mark
(b)(i)	• conditions	Ethanolic / alcoholic (solution) Allow ethanol / alcohol Ignore heat / solid / reflux Do not award aqueous solution	**1**

Q	Answer	Additional Guidance	Mark
(b)(ii)	• C_4H_7N	Allow elements in any order Ignore C_3H_7CN	**1**

Q	Answer	Additional Guidance	Mark
(b)(iii)	• nucleophilic **(1)** • substitution **(1)**	Allow nucleophile for nucleophilic Mark independently List principle applies (further incorrect answers will each lose a mark) Allow phonetic spelling	**2**

Q	Answer	Additional Guidance	Mark
(b)(iv)	• dipole and arrow from C–Br bond to $Br^{\delta-}$ or just beyond **(1)** • arrow from ammonia to $C^{\delta+}$ **and** 1 or 2 correct curly arrows on intermediate (each from bond or lone pair to atom) **(1)** **(1)**  • intermediate with charge **(1)** • ammonium / H^+ **and** bromide ion **OR** HBr **OR** NH_4Br	Accept bromide and H^+/ammonium ions shown anywhere on answer (i.e. they don't have to be with intermediate and final product respectively) Allow 3rd arrow for M2 to be from bromide lone pair to the hydrogen atom Negative charge on ammonia should be penalised once only Accept correct SN2 mechanism for 4 marks	4
		Total for Question = 9 marks)	

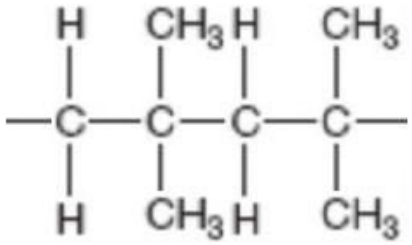
Q5.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	$TiO_2 + 2Cl_2 + 2C \rightarrow TiCl_4 + 2CO$	Ignore state symbols even if incorrect Allow multiples	1

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Question Number	Answer	Additional Guidance	Mark
(a)(ii)	• Ti is reduced **and** from +4 to 0 **(1)** • Mg is oxidised **and** from 0 to +2 **(1)**	Four correct oxidation numbers with no or incorrect mention of reduced or oxidised scores (1) Ti is reduced as it gains electrons and Mg is oxidised as it loses electrons with no or incorrect oxidation numbers scores (1)	**2**

Question Number	Answer	Additional Guidance	Mark
(b)	• hydrolysis **(1)** • titanium((IV)) oxide/TiO_2 **(1)**	Do not award hydration Ignore hydrogen chloride/HCl Allow titanium((IV))hydroxide/$Ti(OH)_4$	**2**

Question Number	Answer	Additional Guidance	Mark
(c)	 • correct repeating unit **(1)** • two repeating units and extension **(1)** Note M2 depends on M1 or near miss eg missing a H	Allow adjacent pairs of methyl groups Ignore square brackets and subscript n/2 Ignore connectivity of CH_3	**2**

Question Number	Answer	Additional Guidance	Mark
(d)(i)	An answer that makes reference to the following points: • reagent: potassium hydroxide / KOH (1) • conditions: aqueous/water (1) M2 dependent on M1or near miss e.g. OH^- will not score M1 but will allow access to M2.	Allow sodium hydroxide / NaOH Ignore any reference to concentration or heat Allow dilute	2

Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to the following points: • reagent: (concentrated) phosphoric((V)) acid / H_3PO_4 (1) • reaction type: elimination/dehydration (1) Independent marks	Allow (concentrated) sulfuric acid Ignore heat Do not award H_3PO_3 Allow passing vapour over porous pot / alumina or any surface catalyst **and** heat	2

Question Number	Answer	Additional Guidance	Mark
(d)(iii)	An answer that makes reference to the following points: • reagent: phosphorus(V) chloride/ phosphorus pentachloride/PCl_5 (1) • equation: $C_4H_9OH + PCl_5 \rightarrow C_4H_9Cl + HCl + POCl_3$ (1)	Allow thionyl chloride / $SOCl_2$ Allow phosphorus (III) chloride / phosphorus trichloride / PCl_3 Allow $C_4H_9OH + SOCl_2 \rightarrow C_4H_9Cl + HCl + SO_2$ $3C_4H_9OH + PCl_3 \rightarrow 3C_4H_9Cl + H_3PO_3$ Allow skeletal, structural, displayed or molecular formulae	2

Question Number	Answer	Additional Guidance	Mark
(d)(iv)	An answer that makes reference to the following points: • conditions: alcoholic (1) • role of the hydroxide ions: base (1) Note answers may be given on either line	Allow ethanol/ethanolic Ignore heat and concentration Allow proton acceptor/reacts with H^+	2

Question Number	Answer	Additional Guidance	Mark
(e)	An answer that makes reference to the following points: • moles of carbon dioxide (1) • conversion of cm^3 to m^3 (1) • conversion of °C to K (1) • rearrangement of the ideal gas equation (1) • calculation of pressure and correct units given (1)	Examples of calculation 16 ÷ 44 = 0.36364 (mol)/ 4÷11(mol) 20 ÷ 1000000 = 2×10^{-5} / 0.00002 (m^3) 273 + 25 = 298 (K) $p = \frac{nRT}{V}$ $\frac{0.3636 \times 8.31 \times 298}{2 \times 10^{-5}}$ = 45025000 Pa / 45025 kPa 4.5×10^7 Pa / 45MPa Ignore SF except 1 Allow TE for answers to M1, M2 and M3 But no TE on wrong rearrangement of gas equation Correct answer, including units with or without working scores (5)	5

Q6.

Question Number	Answer	Additional guidance	Mark
(a)(i)	• $2I^- \rightarrow I_2 + 2e^{(-)}$ **(1)** • $2H^+ + 2e^- + H_2O_2 \rightarrow 2H_2O$ **(1)**	Allow $2I^- - 2e^{(-)} \rightarrow I_2$ Ignore state symbols, even if incorrect Allow multiples Allow equations in either order	**(2)**

Question Number	Answer	Additional guidance	Mark
(a)(ii)	$2I^- + 2H^+ + H_2O_2 \rightarrow I_2 + 2H_2O$ OR $2HI + H_2O_2 \rightarrow I_2 + 2H_2O$	Ignore state symbols, even if incorrect Allow multiples No TE from (a)(i) Do not award uncancelled electrons	**(1)**

Question Number	Answer	Additional guidance	Mark
(b)(i)	An answer that makes reference to the following points: (pale) yellow aqueous layer **(1)** Pink cyclohexane layer **(1)**	 Do not award just 'brown' / colourless / orange allow light brown / pale brown / yellowbrown / straw Allow purple / violet Do not award red / grey	**(2)**

Question Number	Answer	Additional guidance	Mark
(b)(ii)	An explanation that makes reference to the following points: Cyclohexane and iodine form London forces (between molecules) **(1)** Hydrogen bonds between water molecules are stronger than London forces (between iodine and water molecules so less soluble in aqueous layer) **(1)**	Allow 'van der Waals' / dispersion forces / instantaneous dipole – induced dipole forces Allow 'Hydrogen bonds in water are strong' Allow one mark for answers that compare type of attraction without any reference to magnitude or answers based solely on polarity e.g. Just 'iodine forms London forces with cyclohexane but cannot form hydrogen bonds with water' scores 1 mark 'iodine and cyclohexane are non-polar, but water is polar' scores 1 e.g. 'Intermolecular forces formed by iodine and water are weaker than intermolecular forces in water' scores 1	**(2)**

Question Number	Answer	Additional guidance	Mark
(c)	(Anhydrous) sodium sulfate / Na_2SO_4 / magnesium sulfate / $MgSO_4$ / calcium chloride / $CaCl_2$ / calcium sulfate / $CaSO_4$ / calcium oxide / CaO	Allow silica gel Do not award concentrated sulfuric acid / phosphoric acid Do not award $CuSO_4$ / $CaCO_3$	**(1)**

Q7.

Question Number	Answer	Mark
	The only correct answer is B (2-chloro-2-methylpropane) *A is incorrect because a primary alcohol would be formed which would be oxidised* *C is incorrect because a primary alcohol would be formed which would be oxidised* *D is incorrect because a secondary alcohol would be formed which would be oxidised*	**(1)**

Q8.

Question Number	Answer	Mark
(a)	**The only correct answer is A** (addition) *B is not correct because it is not an oxidation reaction* *C is not correct because it is not a polymerisation reaction* *D is not correct because it is not a substitution reaction*	**(1)**

Question Number	Answer	Mark
(b)	**The only correct answer is B** (oxidation) *A is not correct because it is not an addition reaction* *C is not correct because it is not a reduction reaction* *D is not correct because it is not a substitution reaction*	**(1)**

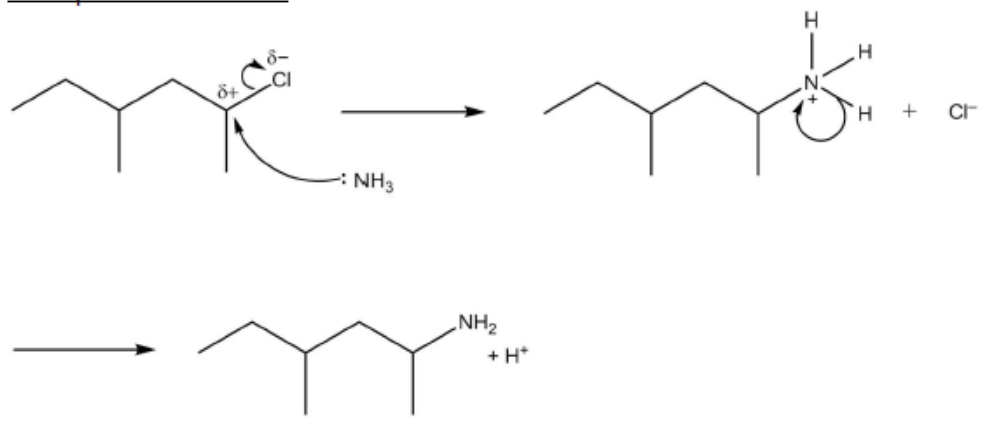
Q9.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	• 4-methylhexan-2-ol	Allow 4-methyl-2-hexanol Allow 4-methylhexane-2-ol Ignore incorrect punctuation Do not award 4-methylhex-2-ol	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	• PCl_5 / phosphorus(V) chloride / phosphorus pentachloride	Allow **concentrated** hydrochloric acid / conc.HCl or thionyl chloride / $SOCl_2$ Allow PCl_3 / phosphorus(III) chloride / phosphorus trichloride Allow conc.H_2SO_4 and KCl If name and the formula are given, both must be correct Ignore just HCl / hydrochloric acid	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	A mechanism that includes the following points • arrow from lone pair on nitrogen atom in ammonia to carbon atom **(1)** • dipole shown and arrow from C–Cl bond to Cl or just beyond **(1)** • formula of intermediate including the + charge on the N atom **and** Cl^- **(1)** • arrow from N-H bond of the intermediate to N(+ and formulae of products) **(1)**	See example mechanism below M1 and M2 can be awarded if shown in 2 steps, via a carbocation Ignore any bases Ignore missing H^+ Ignore errors in hydrocarbon chain	4

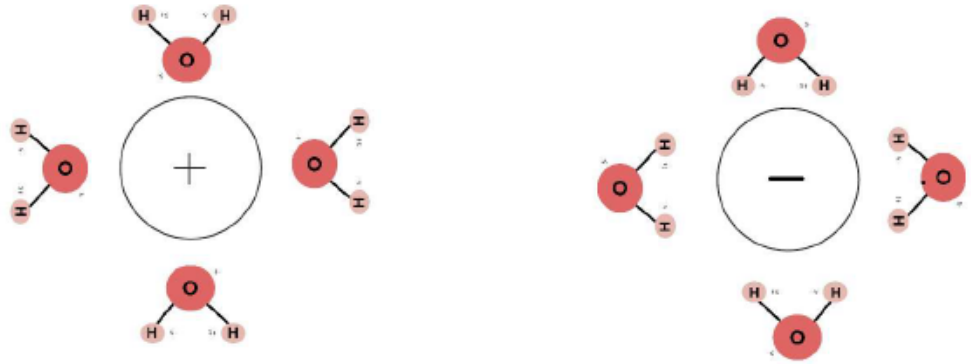
Example of mechanism



Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	An explanation that makes reference to the following points: • (the bond formed is a) dative (covalent) / coordinate bond **(1)** • As the (lone) pair of electrons on the nitrogen (atom) **(1)** • (form the bond) as hydrogen (ion) has an empty orbital / no electrons **(1)**	Allow 'two electrons from the nitrogen' Ignore 'lone pair on the ammonia' Allow can be donated to / shared with the hydrogen (ion) Do not award hydrogen atom	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	A diagram that includes the following points: • dipole on at least one of the water molecules **(1)** • DMAA ion is attracted to slightly negative oxygen atoms (in water) **(1)** • chloride ion is attracted to slightly positive hydrogen atoms (in water) **(1)**	must be at least 2 water molecules surrounding an ion Ignore lone pairs on oxygen Allow orientation showing only 1 H attracted to ion Allow slight positive charge shown on only 1 H atom Correct diagram but with missing dipoles loses M1 but can score M2 and M3 Ignore attempts to show 'force' or 'bond' e.g. with dashes / arrows Ignore any additions to the circles	**3**

Example of diagram for Qbii



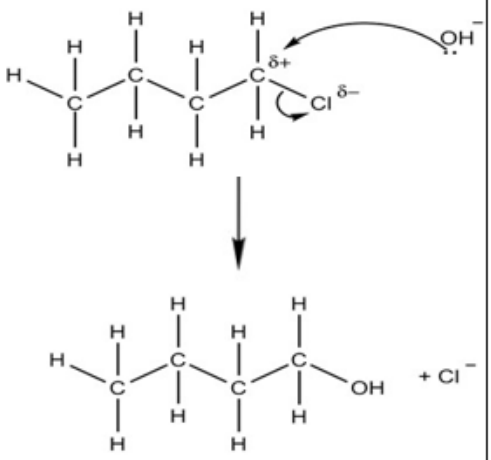
Q10.

Question Number	Answer	Mark
	The only correct answer is C (concentrated phosphoric acid) ***A*** *is incorrect because this would oxidise the alcohol* ***B*** *is incorrect because this is a drying agent* ***D*** *is incorrect because this produces an alkene from a halogenoalkane*	**(1)**

Q11.

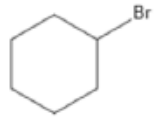
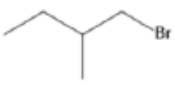
Question Number	Answer	Additional guidance	Mark
(a)(i)	• water / H_2O / aqueous	Do not award **just** ethanol / alcohol But allow 'water and ethanol'	**(1)**

Question Number	Answer	Additional guidance	Mark
(a)(ii)	• correct mechanism name and type	Nucleophilic substitution Allow nucleophile for nucleophilic Ignore S_N2 or S_N1 Ignore hydrolysis	(1)

Question Number	Answer	Additional guidance	Mark
(a)(iii)	A mechanism that shows: • dipole on C-Cl bond and arrow from bond to Cl or just beyond **(1)** • arrow from lone pair on OH^- ion to carbon **(1)** • both products **(1)** 	Ignore S_N2 transition state Do not award M2 if covalent bond in KOH Allow KCl as a product if KOH or K^+ is shown on LHS Allow skeletal formulae / $C_3H_7CH_2Cl$ Penalise use of half arrows once only in M1 and M2	(3)

Question Number	Answer	Additional guidance	Mark
(b)	• moles of alcohol formed **(1)** • moles of 1-chlorobutane required **(1)** • mass of 1-chlorobutane required **(1)** • volume of 1-chlorobutane required, to 2 or 3SF **(1)**	<u>Example of calculation</u> 12.1 / 74.0 = 0.16351 (mol) (0.16351/64) x 100 = 0.25549 (mol) 0.25549 x 92.5 = 23.633 (g) 23.633 / 0.886 = 26.674 = 26.7 / 27 (cm^3) Correct answer with no working scores 4 marks Allow TE at each step Ignore rounding in steps 1-3 Ignore SF except 1 SF in steps 1- 3 Units, if given, must be correct in M4	**(4)**

Q12.

Question Number	Answer	Additional Guidance	Mark
(a)	• both classifications correct	Example of table: Halogenoalkane | Classification  | secondary  | primary Allow 2° for secondary Allow 1° for primary Ignore halogenoalkane	(1)

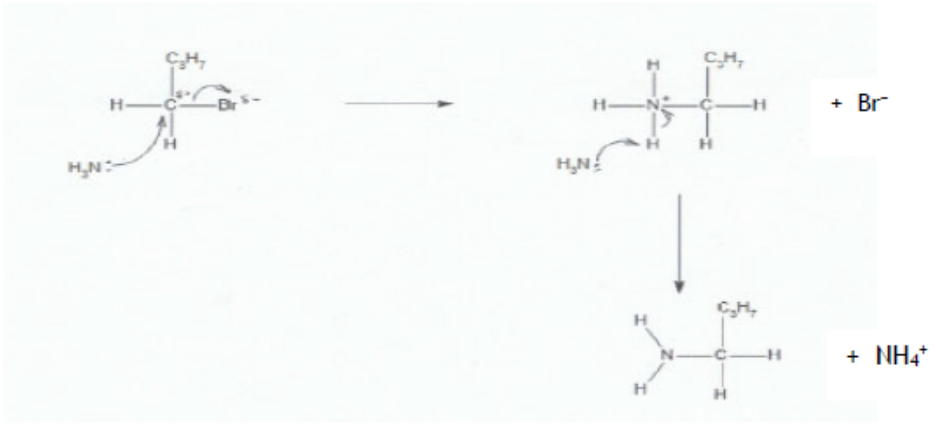
Question Number	Answer	Additional Guidance	Mark
(b)	An explanation that makes reference to the following points: • 2-chloro-2- methylpropane should react faster than 1-iodobutane because it is tertiary (1) • 1-iodobutane should react faster than 2-chloro-2-methylpropane because the C–I bond enthalpy is lower enthalpy is lower than C–Cl (1) • it is not possible to predict the relative effects of these two opposing factors / structure and bond enthalpies (1)	Stand alone mark Allow tertiary / branched chain / more branched halogenoalkanes have a higher rate of hydrolysis than primary halogenoalkanes Do not award secondary for 2-chlor-2-methylpropane Do not award tertiary carbocation Stand alone mark Allow just 'the C–I bond is weaker / has a lower bond enthalpy than C–Cl' Ignore just 'bonds in 1-iodobutane are weaker' Do not award H–I / H–Cl bonds Conditional on two opposing factors If M1 and M2 scored, allow 'so it is not possible to predict the relative rate of hydrolysis'	(3)

Question Number	Answer	Additional Guidance	Mark
(c)(i)	• **ammonia** (gas) would escape (from the condenser when heated under reflux) **or** to prevent **ammonia** (gas) escaping (from the condenser when heated under reflux)	Ignore just 'ammonia will evaporate' Ignore concentrated alcoholic Ignore references to safety Ignore just 'gas / reactant escapes' Do not award any other substance escaping	(1)

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Question Number	Answer	Additional Guidance	Mark
(c)(ii)	• lone pair on N of NH_3 **and** curly arrow from lone pair on N to, or towards C **(1)** • dipole on C-Br **and** curly arrow from C-Br bond to, or just beyond, Br **(1)** • lone pair on N of NH_3 **and** curly arrow from lone pair on N to, or towards H **(1)** • curly arrow from N-H bond to, or towards N **(1)**	Penalise missing lone pair on N once only Penalise negative charge on NH_3 once only Penalise half-arrow heads once only Do not award any charge / dipole on H Ignore any changes to final products	**(4)**

Example of mechanism:



Question Number	Answer	Additional Guidance	Mark
(d)	• calculation of amounts of KBr and H_2SO_4 (1)	Example of calculation: amount KBr = $\frac{14.90}{119}$ = 0.12521 (mol) amount H_2SO_4 = $\frac{16.35}{98.1}$ = 0.16667 (mol) Allow use of 98 for M_r of H_2SO_4 giving 0.16684 (mol)	(3)
	• calculation of amount of C_2H_5OH **and** statement or implication that this is the limiting quantity (1)	amount C_2H_5OH = $\frac{4.65}{46}$ = 0.10109 / 0.10 / 0.1 (mol) **and** any indication that the limiting reagent is C_2H_5OH e.g. by use of mol of ethanol in M3	
	• calculation of maximum mass of C_2H_5Br formed (1)	(maximum amount C_2H_5Br formed = 0.10109 (mol) maximum mass C_2H_5Br formed = 0.10109 x 108.9 = 11.008 / 11.01 / 11.0 / 11 (g) Allow use of 109 for M_r of C_2H_5Br giving 11.018 (g) Ignore SF except 1 SF, but allow 0.1 for mol C_2H_5OH	

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)*	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. 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 The following table shows how the marks should be awarded for structure and lines of reasoning.	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)

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	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	Penalise use of incorrect halogenoalkane once only
• **IP1 –Similarity** Both reactions involve hydroxide ions / OH^-	Allow OH^- shown with both reactions anywhere in the answer e.g. in the equations Allow both reactions need heat (under reflux)
• **IP2 – Type of reaction** Reaction with aqueous solution is substitution **and** reaction with ethanolic solution is elimination	Ignore displacement for substitution Ignore dehydration for elimination Do not award dehydrogenation for elimination
• **IP3 – Type of reagent** (OH^- is a) nucleophile in aqueous solution **and** a base in ethanolic solution	If IP2 and IP3 not awarded, allow 1 IP for just 'nucleophilic substitution' or 'elimination by a base'
• **IP4 – Products** In aqueous solution propan-2-ol / an alcohol forms **and** in ethanolic solution propene / an alkene forms	This can be scored from the equations
• **IP5 – Equation in aqueous solution** $CH_3CHBrCH_3 + OH^- \rightarrow CH_3CHOHCH_3 + Br^-$	In IP5 and IP6, allow displayed formulae / any combination of displayed and structural formulae / skeletal formula Allow KOH / KBr / $K^+ + OH^-$ / $K^+ + Br^-$ The equations must be balanced Ignore state symbols even if incorrect Ignore mechanisms even if incorrect
• **IP6 – Equation in ethanolic solution** $CH_3CHBrCH_3 + OH^- \rightarrow CH_3CH{=}CH_2 + H_2O + Br^-$	

Q13.

Q	Answer	Mark
(a)	**The only correct answer is A** (CH_3CHICH_3) ***B*** *is incorrect because the rate of reaction increases as the carbon-halogen bond strength decreases* ***C*** *is incorrect because the rate of reaction increases as the carbon-halogen bond strength decreases* ***D*** *is incorrect because the rate of reaction increases as the carbon-halogen bond strength decreases*	1

Q	Answer	Mark
(b)	**The only correct answer is B** ($CH_3CH_2CBr(CH_3)CH_3$) ***A*** *is incorrect because secondary halogenoalkanes take longer to hydrolyse than tertiary* ***C*** *is incorrect because primary halogenoalkanes take longer to hydrolyse than tertiary* ***D*** *is incorrect because primary halogenoalkanes take longer to hydrolyse than tertiary*	1

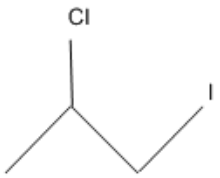
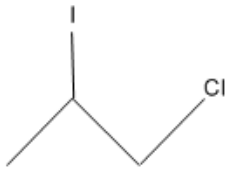
Q14.

Question number	Answer	Mark
	C 2-chloro-2-methylpropane	1

Q15.

Question number	Answer	Additional guidance	Mark
(a)	• balanced equation (1) • all states correct (1)	$I_2(s) + Cl_2(g) \rightarrow 2ICl(l)$ Accept multiples	2

Question number	Answer	Additional guidance	Mark
(b)	• correct electronegativity values and correct dipole diagram	Cl = 3.0 **and** I = 2.5 δ+ I — Cl δ- Do not award full charges	1

Question number	Answer	Additional guidance	Mark
(c)(i)	• 1 mark each correct formula	  Allow 1 mark for 2 correct non-skeletal formulae	2

Question number	Answer		Additional guidance	Mark
(c)(ii)	An explantion that makes reference to the following points:			3
	• identification of correct isomer	(1)	2-chloro-1-iodopropane	
	• iodine is δ+ and is attacked by the π electrons	(1)		
	• more stable secondary carbocation formed.	(1)		

Question number	Answer		Additional guidance	Mark
(d)(i)	An answer that makes reference to the following points:			2
	• carry out in fume cupboard	(1)	Allow fume hood or similar description	
	• chlorine is toxic.	(1)	Do not allow 'harmful'	

Question number	Answer	Additional guidance	Mark
(d)(ii)	• I in ICl = +1 I in ICl_3 = +3	Both needed for the mark	1

Question number	Answer		Additional guidance	Mark
(d)(iii)	• +5 **and** -1 to -1 (and -1)	(1)		2
	• not disproportionation because the chlorine has not undergone both oxidation and reduction	(1)		

Question number	Answer		Additional guidance	Mark
(e)(i)	• correct method	(1)	$Cl_2 = 2 \times 35.5 = 71$ $71 \div 24000$	2
	• answer with units	(1)	$= 0.0029583$ g cm^{-3} $= 3$ g dm^{-3}	

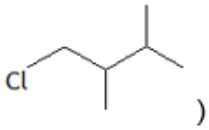
Question number	Answer	Additional guidance	Mark
(e)(ii)	An explanation that makes reference to the following points: • chlorine (gas) is more dense than air (1) • chlorine (gas) removed (from the equilibrium) (1) • position of equilibrium moves to the LHS (more brown liquid/ICl). (1)		3

Question number	Answer	Additional guidance	Mark
(f)	• calculation of mols of iodine and fluorine (1) • calculation of whole number ratio and formula (1)	Mols of iodine = $0.64 \div 126.9 = 5.04 \times 10^{-3}$ Mols of fluorine = $(1.31-0.64) \div 19 = 3.53 \times 10^{-2}$ Ratio 1:7 therefore formula IF_7	2

Q16.

Question number	Answer	Mark
	D nucleophilic substitution	1

Q17.

Q	Answer	Mark
	The only correct answer is C ( **)** ***A** is incorrect because this is a secondary haloalkane* ***B** is incorrect because this is a tertiary haloalkane* ***D** is incorrect because this is a secondary haloalkane*	1

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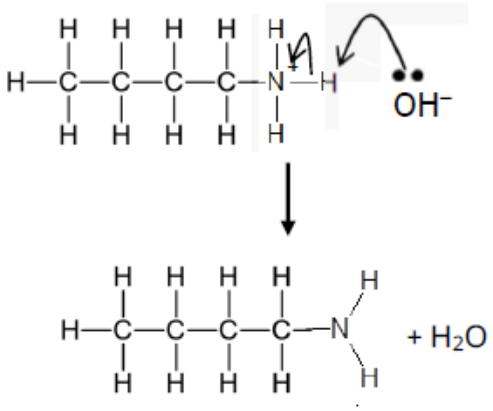
Q18.

Question Number	Answer	Mark
	The only correct answer is D (nucleophilic substitution) *A is not correct because the CN^- ion is a nucleophile and the reaction is a substitution* *B is not correct because the reaction is a substitution* *C is not correct because the CN^- ion is a nucleophile*	1

Q19.

Question Number	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following point: • nucleophilic **(1)** • substitution **(1)**		**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	An answer that makes reference to the following points: • lone pair on the **nitrogen** / N **(1)** • delta +/δ+/partial positive (charge) on the **carbon** (attached to the chlorine) **(1)**	The answers may be shown on the diagram Ignore "pairs" if only one lone pair shown on diagram Ignore "lone pair on the ammonia/NH_3" Do not award ammonium Ignore "positive dipole" alone Ignore any references to missing dipoles on ammonia molecule NOTE: The specific carbon does not need to be referenced but if annotated on diagram must be correct Use the list principle for extra comments	**(2)**

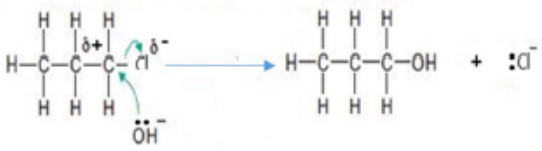
Question Number	Answer	Additional Guidance	Mark
(b)(ii)	A correctly drawn mechanism showing: • curly arrow from the lone pair on the oxygen going to the hydrogen **(1)** • curly arrow from the same N-H bond to N atom or + **(1)** • correct products **(1)**	An example of a mechanism:  Assume arrows drawn are curly Ignore spectator ions Penalise the use of ammonia once only i.e. M3 can be awarded for the correct products of reaction with further ammonia Covalent bonding in sodium hydroxide loses M1 Missing negative charge on OH^- loses M1 Allow structural formulae for M3	**(3)**

Question Number	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points: • the rate of reaction will be slower for 1-chlorobutane **(1)** • C–Cl has a higher bond enthalpy (than C–Br) **(1)** • 1-chlorobutane is a primary halogenoalkane (rather than a tertiary halogenoalkane) **(1)**	Allow reverse answers Allow less / decreased Allow reference to bond strength Allow C–Cl requires more energy to break Allow 1-chlorobutane is 1° / 2-bromo-2-methylpropane is 3° Allow reference to methyl stabilisation of (partial) positive charge(s) on carbon atom(s) Allow reference to stability of carbocations Do not award alcohol Do not award secondary / 2° M2 is dependent on M1 M3 is independent	**(3)**

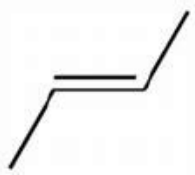
Q20.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• time taken for the (first appearance of the)precipitate (of silver halide) to form	Allow ppt / ppte for precipitate / cloudy/ silver halide Allow how fast / how quickly / rate for time	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: • 1-iodopropane (1) • **C–I** bond weakest/lowest bond enthalpy (1)	Allow any correct formula Do not award for simply saying the iodine /1-iodopropane bond is weakest M2 depends on M1 Ignore reference to bond length Ignore any references to reactivity, electronegativity/size	(2)

Question Number	Answer	Additional Guidance	Mark
(b)	A mechanism that shows: • dipole on C-Cl bond and curly arrow from bond to Cl or just beyond (1) • curly arrow from lone pair on OH^- ion to δ+ carbon (1) 	Ignore S_N2 transition state Do not award curly arrow from negative charge on OH Do not award M2 if a metal hydroxide e.g. KOH has a covalent bond Ignore products Penalise use of half arrows once only in M1 and M2 If S_N1 mechanism M1 as above and then M2 awarded for curly arrow from lone pair on OH^- ion to C+ of carbocation	(2)

Question Number	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points: • London forces (and (permanent) dipole-(permanent) dipole forces) (1) • iodine atoms are more polarisable (than chlorine or bromine)/ 1-iodopropane has more electrons (than 1-chloropropane and 1-bromopropane) (1) • (resulting in) stronger / more London Forces (so more energy required to overcome these forces) (1) • (despite) 1-iodopropane having the weakest (permanent) dipole / (permanent) dipole forces	Accept dispersion forces / instantaneous dipole-(induced) dipole Allow van der Waals' Allow iodine has more electrons than chlorine/ bromine Ignore it is a larger molecule / larger molar mass Do not award iodine has stronger/more London forces. Allow van der Waals / dispersion forces Ignore just stronger intermolecular forces Do not award M3 if any indication that covalent bonds are being broken. Allow 1-chloropropane has the strongest (permanent) dipole / (permanent) dipole forces Ignore abbreviations such as id-id and pd-pd	(4)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(d)</td><td>
<table>
<tr><th>Skeletal formula</th><th>Name</th></tr>
<tr><td></td><td>Z-but-2-ene</td></tr>
<tr><td></td><td>E -but-2-ene</td></tr>
<tr><td></td><td>but-1-ene</td></tr>
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</td><td>Allow any order

Allow cis

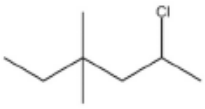
Allow trans
If only one but-2-ene isomer is given the E/Z does not have to be identified

Penalise displayed formulae only once

All 6 correct scores (3)
4-5 correct scores (2)
2-3 correct scores (1)

No TE of names of incorrect formulae</td><td>(3)</td></tr>
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Q21.

<table>
<tr><th>Question Number</th><th>Correct Answer</th><th>Mark</th></tr>
<tr><td></td><td>The only correct answer is B

A is incorrect as it is 2-chloro-5,5-dimethylhexane
C is incorrect as it is 2-chloro-3,3-dimethylhexane
D is incorrect as it is 1-chloro-3,3-dimethylcyclohexane</td><td>1</td></tr>
</table>

Q22.

Question number	Answer		Additional guidance	Mark
(a)	• KBr/potassium bromide **and** (50%) sulfuric acid	(1)	Both needed for M1 Ignore acid concentration Allow HBr (dry) PBr_3/Phosphorus(III) bromide PBr_5/Phosphorus(V) bromide	2
	• (heat under) reflux	(1)	Do not allow just heat M2 conditional on correct or near correct M1	

Question number	Answer		Additional guidance	Mark
(b)	• C-Br dipole reversed	(1)	Allow in any order	3
	• OH^- to C arrow reversed	(1)		
	• lone pair missing (from OH^-)	(1)		

Question number	Answer		Additional guidance	Mark
(c)	• KOH/potassium hydroxide	(1)	Allow NaOH/sodium hydroxide Ignore OH^- / alkali	2
	• ethanol(ic)/alcohol(ic) **and** heat (under reflux)	(1)	M2 dependent on M1	

Q23.

Question number	Answer	Mark
	D *E*-1-bromo-2-methylbut-1-ene	1