Questions

Q1.

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 ☒.

This question is about alcohols and their reactions.

(i) Some alcohols react with concentrated phosphoric acid to form alkenes.

What is the type of this reaction?

(1)

☐ **A** addition

☐ **B** elimination

☐ **C** oxidation

☐ **D** substitution

(ii) When butan-2-ol reacts with concentrated phosphoric acid, two stereoisomers are formed.

Explain what is meant by the term stereoisomers.

(2)

.....

.....

.....

(iii) Draw the structures and give the names of the two stereoisomers.

(2)

Stereoisomer 1	Stereoisomer 2
Name:	Name:

(iv) Name this type of stereoisomerism.

(1)

.....

(Total for question = 6 marks)

Q2.

This question is about alcohols and their reactions.

(i) $CH_3CH_2CH_2CH_2OH$ reacts with the oxidising agent potassium dichromate(VI) in dilute sulfuric acid.

Two organic products can be formed, depending on the conditions.
Write a balanced equation for the formation of **one** of these products, giving its name and the condition required to achieve this product in high yield.
Use **[O]** in the equation to represent each oxygen atom from the oxidising agent.

(3)

Equation

Name
.....

Condition
.....

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 ☒.

(ii) The colour of the solution at the end of the reaction in (i) will be

(1)

☐ **A** brown

☐ **B** green

☐ **C** orange

☐ **D** yellow

(Total for question = 4 marks)

Q3.

Some alcohols can be oxidised by acidified sodium dichromate(VI), $Na_2Cr_2O_7$.

Balance the ionic half-equation for the reduction of the dichromate(VI) ion.

Give the colours of all of the species involved, or state colourless if appropriate.

(2)

$$Cr_2O_7^{2-} + \ldots\ldots H^+ + \ldots\ldots e^- \rightarrow \ldots\ldots Cr^{3+} + \ldots\ldots H_2O$$

Colour ....

(Total for question = 2 marks)

Q4.

This question is about the chemistry of propane-1,3-diol and propanedioic acid.

In an experiment, 15.2 g of propane-1,3-diol was oxidised to propanedioic acid, which is a solid **dibasic** acid. This acid may be represented as H_2X.

250 cm^3 of a solution was prepared from all of the acid in a volumetric flask.

10.0 cm^3 portions of this solution were then titrated with 0.400 mol dm^{-3} sodium hydroxide solution. The mean titre was 18.45 cm^3.

$$H_2X + 2NaOH \rightarrow Na_2X + 2H_2O$$

[Relative formula masses: propane-1,3-diol = 76.0; propanedioic acid = 104.0]

(i) Calculate the moles of propanedioic acid in 10.0 cm^3 of the acid solution.

(2)

(ii) Calculate the mass of propanedioic acid in the 250 cm^3 solution.

(2)

(iii) Calculate the percentage yield for the oxidation of propane-1,3-diol to propanedioic acid.

(2)

(iv) Give **one** reason why the yield calculated in (iii) is less than 100%.

(1)

.....

.....

.....

(Total for question = 7 marks)

Q5.

Analysis shows that a compound has the molecular formula $C_4H_8O_2$.

A student suggests that the compound could be either **A** or **B**.

$CH_3CH_2CH_2COOH$ **A** or $HOCH_2CH{=}CHCH_2OH$ **B**

Deduce a **chemical** test which would give a positive result for **B** but **not** for **A**.
Include the reagent and observation.

(2)

.....

.....

.....

.....

.....

.....

.....

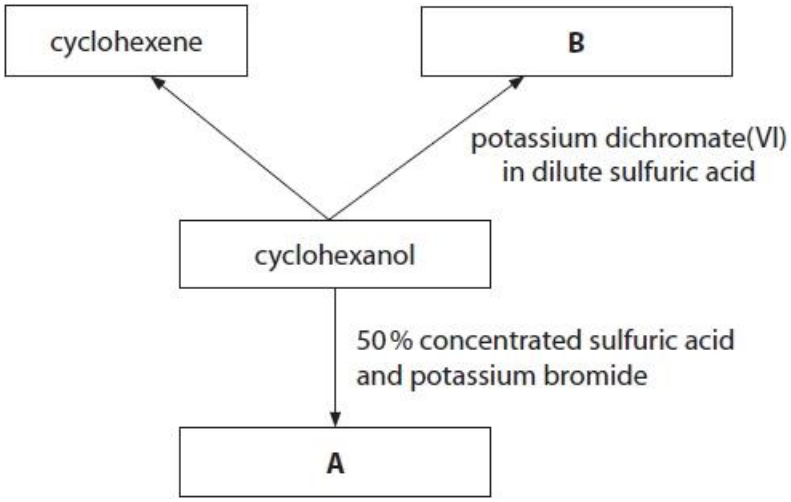
.....

(Total for question = 2 marks)

Q6.

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 ☒ .

This question is about some reactions of cyclohexanol.



(i) Cyclohexanol can be converted to cyclohexene.
What is the classification for this reaction?

(1)

- ☒ **A** addition
- ☒ **B** elimination
- ☒ **C** oxidation
- ☒ **D** substitution

(ii) In an experiment, 10.0 cm^3 of cyclohexanol was converted to cyclohexene with a 63.0 % yield.

Compound	Molar mass / $g\,mol^{-1}$	Density / $g\,cm^{-3}$
cyclohexanol	100	0.962
cyclohexene	82.0	0.811

Calculate the volume of cyclohexene produced.

(4)

*(iii) Cyclohexene can be prepared by reacting cyclohexanol with phosphoric(V) acid.
The mixture is warmed in a water bath for 15 minutes before distilling off a mixture of cyclohexene and water.

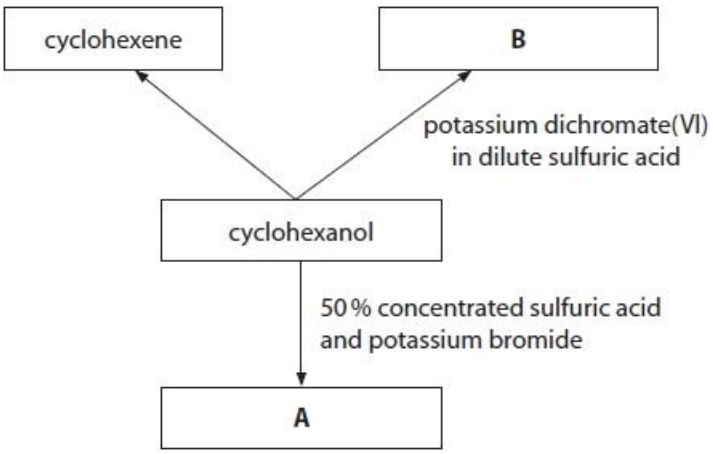
Devise a procedure to obtain a pure, dry sample of cyclohexene from the distillate.
Include a reason for each step.
[Boiling temperature of cyclohexene = 83 °C
Density of cyclohexene = 0.811 g cm^{-3}]

(6)

(Total for question = 11 marks)

Q7.

This question is about some reactions of cyclohexanol.

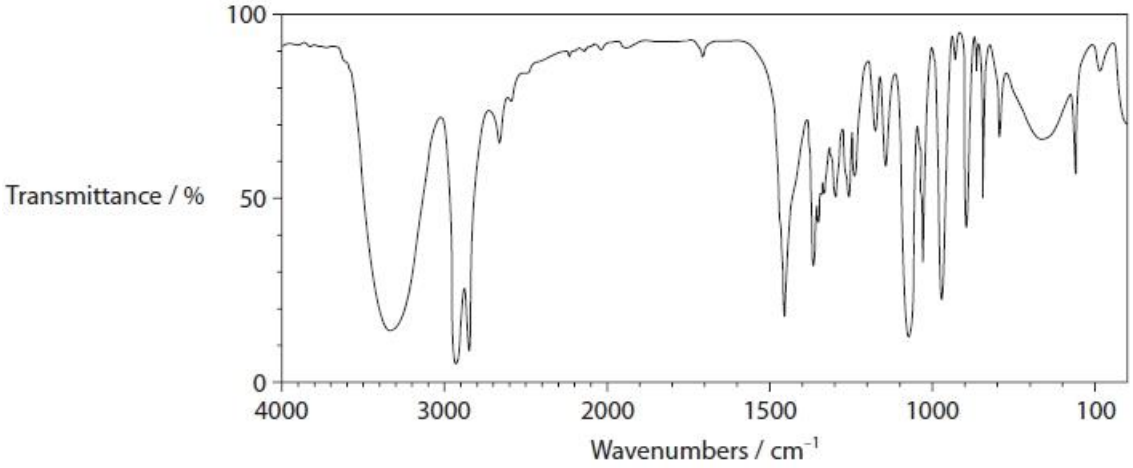


(i) Give the name **and** displayed formula of compound **B**.

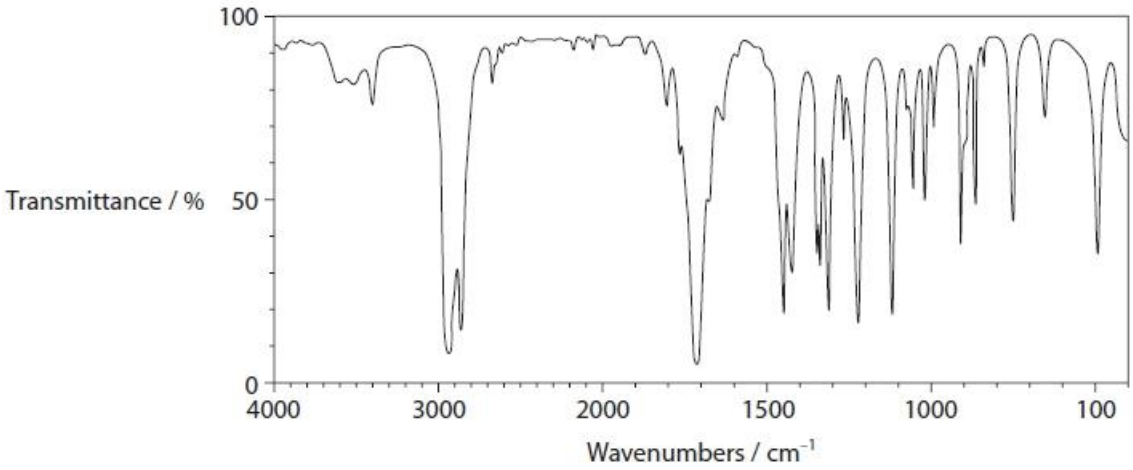
(2)

(ii) The infrared (IR) spectra of cyclohexanol and compound **B** are shown.

IR Spectrum of cyclohexanol



IR Spectrum of compound **B**



Identify the bonds, using **both** IR spectra, that help to confirm the reaction of cyclohexanol to produce compound **B**.
Your answer must include the wavenumber ranges of any relevant bonds.

(2)

.....

.....

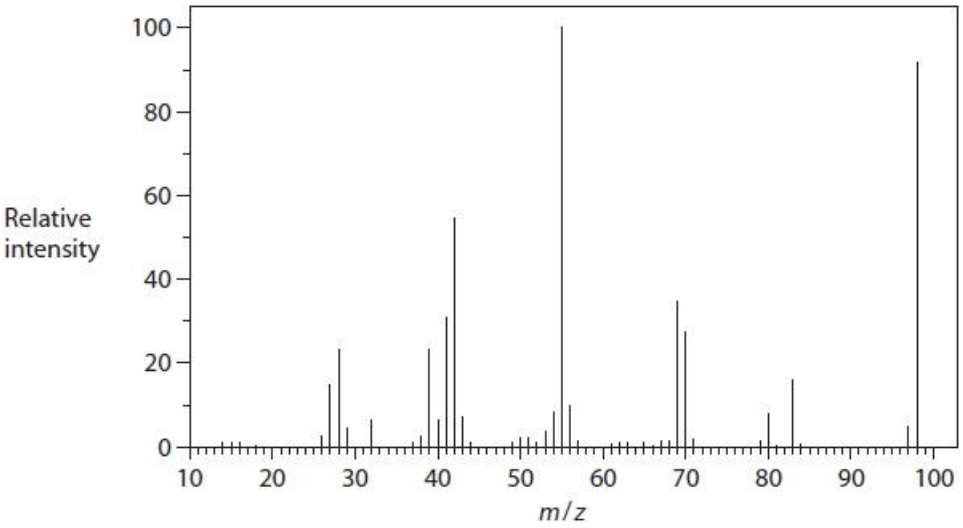
.....

.....

.....

.....

(iii) The mass spectrum of compound **B** is shown.



Deduce the relative molecular mass of compound **B** using the mass spectrum. Justify your answer.

(1)

.....

.....

.....

.....

(iv) In the mass spectrum of cyclohexanol, there is a peak at *m*/*z* = 83.

Give the formula of a fragment that could be responsible for this peak.

(2)

(Total for question = 7 marks)

Q8.

Some alcohols can be oxidised by acidified sodium dichromate(VI), $Na_2Cr_2O_7$.

Reflux apparatus can be used to carry out the oxidation of alcohols.

Using the apparatus for distillation instead of reflux is not an efficient way to produce ethanoic acid from ethanol. Explain why.

(2)

.....

.....

.....

.....

.....

.....

(Total for question = 2 marks)

Q9.

The preparation of 2-chloro-2-methylpropane, $(CH_3)_3CCl$, involves the reaction of concentrated hydrochloric acid with 2-methylpropan-2-ol, $(CH_3)_3COH$, a tertiary alcohol.

$$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$$

In an experiment, 12.0 g of 2-methylpropan-2-ol was shaken with excess concentrated hydrochloric acid in a separating funnel.

After about 15 minutes, the product formed as a separate layer.

Data:

Substance	Boiling temperature /°C	Density /g cm^{-3}
2-methylpropan-2-ol	82	0.79
2-chloro-2-methylpropane	51	0.84
water	100	1.00

Draw a diagram of the separating funnel after 15 minutes, labelling the layer containing 2-chloro-2-methylpropane.

(2)

(Total for question = 2 marks)

Q10.

The preparation of 2-chloro-2-methylpropane, $(CH_3)_3CCl$, involves the reaction of concentrated hydrochloric acid with 2-methylpropan-2-ol, $(CH_3)_3COH$, a tertiary alcohol.

$$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$$

In an experiment, 12.0 g of 2-methylpropan-2-ol was shaken with excess concentrated hydrochloric acid in a separating funnel.

After about 15 minutes, the product formed as a separate layer.

Data:

Substance	Boiling temperature /°C	Density /g cm^{-3}
2-methylpropan-2-ol	82	0.79
2-chloro-2-methylpropane	51	0.84
water	100	1.00

After separation, the organic layer was shaken with sodium hydrogencarbonate solution. Fizzing was observed.

(i) Identify, by name or formula, the gas that was given off.

(1)

.....

(ii) Give the **formula** of the ion that reacted with the hydrogencarbonate ion to form the gas.

(1)

.....

(iii) Describe how to dry the organic layer to prepare it for distillation.

Include the name of a suitable drying agent.

(2)

.....

.....

.....

.....

(Total for question = 4 marks)

Q11.

The preparation of 2-chloro-2-methylpropane, $(CH_3)_3CCl$, involves the reaction of concentrated hydrochloric acid with 2-methylpropan-2-ol, $(CH_3)_3COH$, a tertiary alcohol.

$$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$$

In an experiment, 12.0 g of 2-methylpropan-2-ol was shaken with excess concentrated hydrochloric acid in a separating funnel.

After about 15 minutes, the product formed as a separate layer.

Data:

Substance	Boiling temperature /°C	Density /g cm^{-3}
2-methylpropan-2-ol	82	0.79
2-chloro-2-methylpropane	51	0.84
water	100	1.00

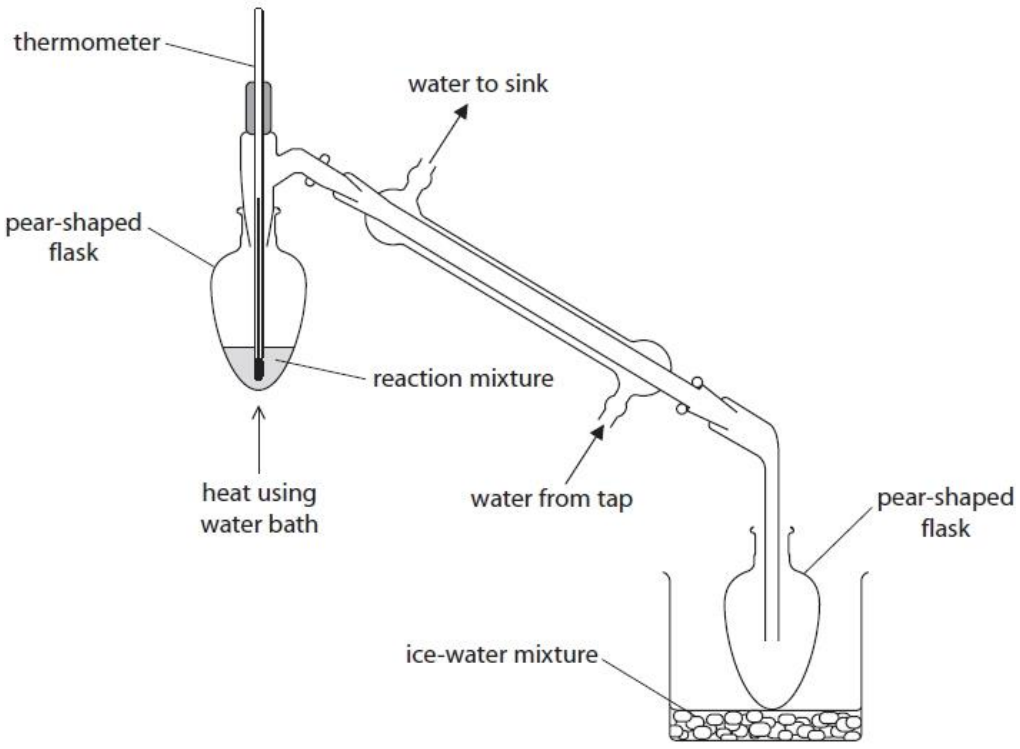
The dried 2-chloro-2-methylpropane was transferred to the distillation apparatus.

(i) State the appropriate temperature range over which to collect the product.

(1)

.....

* (ii) A diagram of the distillation apparatus is shown.



Discuss the improvements that should be made to the set-up of the apparatus. Include the likely effect of the errors identified on the yield or purity of the product.
Assume the apparatus is suitably clamped.

(6)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(Total for question = 7 marks)

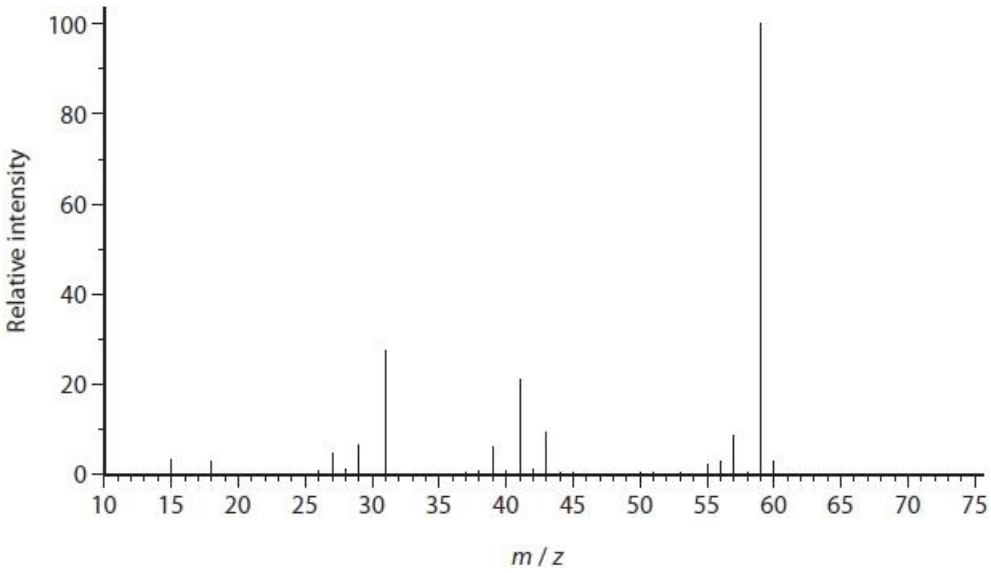
Q12.

This question is about 2-methylpropan-2-ol.

(a) Draw the fully **displayed** formula of 2-methylpropan-2-ol.

(1)

(b) The mass spectrum of 2-methylpropan-2-ol is shown.



(i) The relative molecular mass of 2-methylpropan-2-ol is 74.
Give a possible reason why there is no molecular ion peak in the mass spectrum of 2-methylpropan-2-ol.

(1)

.....

.....

.....

.....

(ii) Write the formula for a species that could be responsible for the peak at $m / z = 59$.

(1)

(c) The equation for the complete combustion of 2-methylpropan-2-ol is

$$C_4H_{10}O(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

(i) Using the bond enthalpies shown in the table, calculate a value for the enthalpy change, in kJ mol^{-1}, for the complete combustion of 2-methylpropan-2-ol.

(4)

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C—H	413
C—O	358
O—H	464
O═O	498
C═O	805

(ii) 2-methylpropan-2-ol burns in air with a smoky flame.
Explain how burning with a smoky flame affects the value of the experimentally determined enthalpy change of combustion.

(2)

.....

.....

.....

.....

(iii) A Data Book value for the enthalpy change of combustion of 2-methylpropan-2-ol is −2643.8 kJ mol^{-1}.
Give the main reason for the difference between this value and your answer to part (c)(i).

(1)

.....

.....

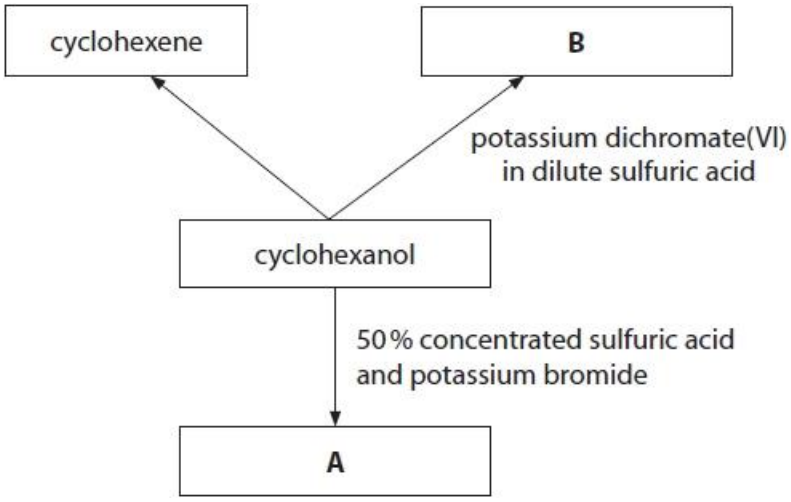
.....

.....

(Total for question = 10 marks)

Q13.

This question is about some reactions of cyclohexanol.



Write the **skeletal** formula of compound **A**.

(1)

(Total for question = 1 mark)

Q14.

This question is about the identification of an alcohol, **X**.

(a) Alcohol **X** has the following percentage composition by mass:

carbon, C = 68.2%
hydrogen, H = 13.6%
oxygen, O = 18.2%

The molecular ion peak in the mass spectrum for alcohol **X** occurs at *m*/*z* = 88.
Use all of these data to show that the molecular formula for alcohol **X** is $C_5H_{12}O$. Include your working.

(2)

(b) (i) When alcohol **X** is oxidised, a carboxylic acid is formed.

State what information this gives about alcohol **X**.

(1)

.....

(ii) Draw the **displayed** formulae of the four possible structural isomers that could be alcohol **X**.

(3)

Alcohol 1	Alcohol 2
Alcohol 3	**Alcohol 4**

(iii) The mass spectrum of alcohol **X** has a major peak at *m*/*z* = 45.
Draw the structure of the species that could give this peak.

(1)

(iv) Alcohol **X** has a branched chain.
Identify alcohol **X**, explaining your reasoning.

(2)

.....

.....

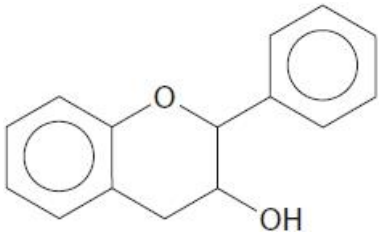
.....

.....

(Total for question = 9 marks)

Q15.

The compound flavan-3-ol is found in tea, fruit and wine.



*A sample of flavan-3-ol extracted from wine contained some ethanol. The sample was left in a flask, open to the air for several days. The contents were then analysed to identify any new compounds formed. Several new compounds were found to be present, including some with a distinctive fruity smell.

Identify **four** new organic compounds that could form under these conditions by considering the chemistry of alcohols. Justify your answers. Include the structure of two compounds formed from flavan-3-ol, one of which has a fruity smell.

(6)

.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
.....

(Total for question = 6 marks)

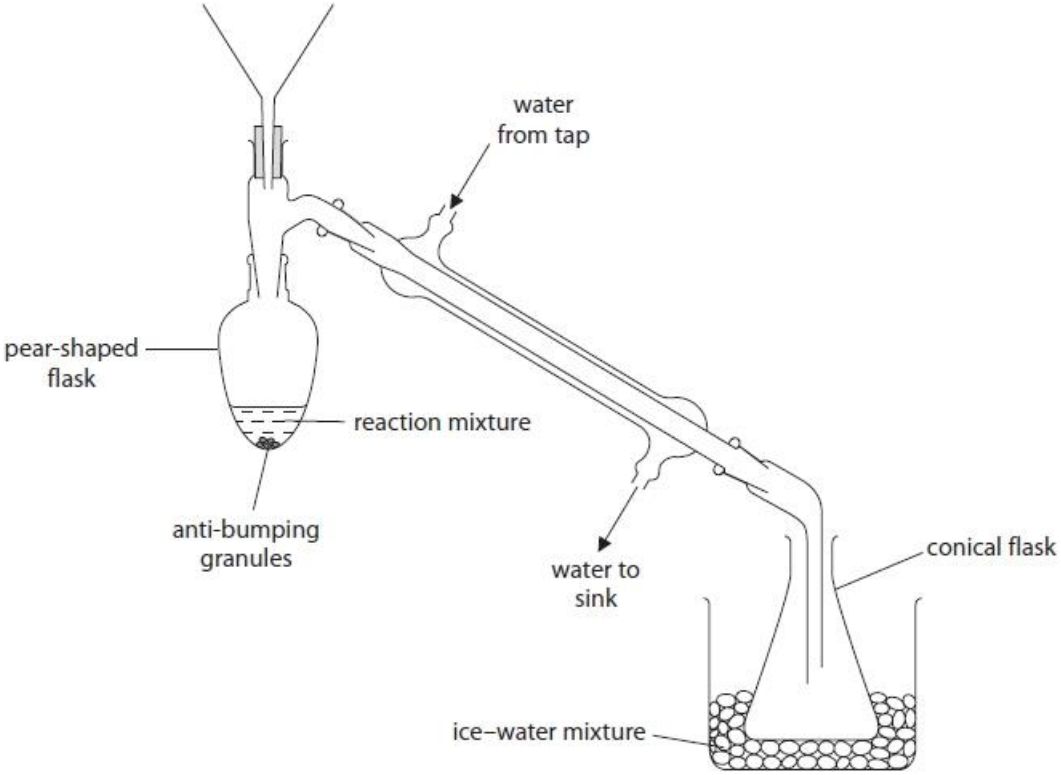
Q16.

This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.



The sample of purified 3-methylbutan-2-one is found to have a mass of 2.15 g.
This mass of 3-methylbutan-2-one represents a yield of 62.5% by mass.

(i) Write an equation, using **molecular** formulae, for the oxidation of 3-methylbutan-2-ol to 3-methylbutan-2-one.

Use [O] to represent the oxidising agent.

(2)

(ii) Calculate the mass of 3-methylbutan-2-ol that the student uses at the start of the preparation.

(2)

(Total for question = 4 marks)

Q17.

The following procedure may be used to prepare 2-chloro-2-methylpropane.

Step 1 Place 15 cm^3 of 2-methylpropan-2-ol in a separating funnel and slowly add 30 cm^3 of concentrated hydrochloric acid (an excess), while swirling the funnel.

Step 2 When all the hydrochloric acid has been added, leave the mixture to stand for 20 minutes, shaking it gently at intervals.

Step 3 Once the organic and aqueous layers have completely separated, discard the aqueous layer.

Step 4 Add saturated sodium hydrogencarbonate solution, a little at a time, to the organic layer. After each addition, invert the separating funnel and open the tap.

Step 5 Discard the aqueous layer.

Step 6 Transfer the organic layer to a small flask, add a solid drying agent and swirl the flask.

Step 7 Decant the liquid into a clean flask and distil it to collect pure 2-chloro-2-methylpropane.

Some data on the organic reactant and product are given in the table.

Data	2-methylpropan-2-ol	2-chloro-2-methylpropane
molar mass / g mol^{-1}	74.0	92.5
boiling temperature / °C	82	51
density / g cm^{-3}	0.79	0.84

(a) Draw a diagram of a separating funnel, labelling the aqueous layer and the layer of 2-chloro-2-methylpropane that would be observed at the end of **Step 2**.

(2)

(b) Give the reason why sodium hydrogencarbonate solution is added to the organic layer in **Step 4** and why it is important to open the tap after adding this solution.

(2)

.....

.....

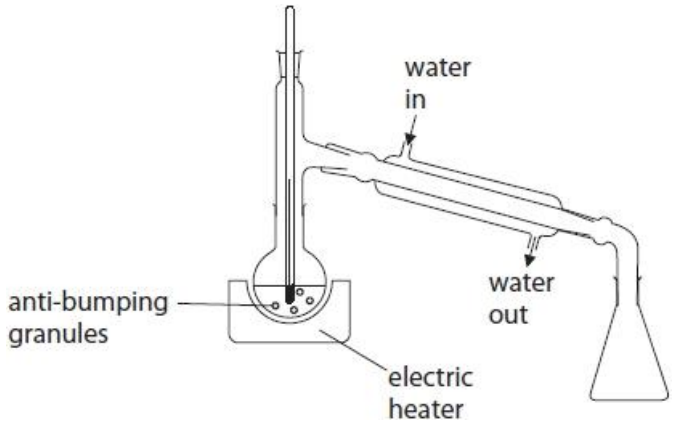
.....

(c) Which **one** of these anhydrous compounds may be used as a drying agent in **Step 6**?

(1)

- ☒ **A** sodium chloride
- ☒ **B** sodium hydroxide
- ☒ **C** sodium nitrate
- ☒ **D** sodium sulfate

(d) A student set up this apparatus for distillation in **Step 7** as shown.



(i) Describe **three** ways in which this apparatus must be modified for safe and efficient use. Assume the apparatus is suitably clamped.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(ii) Give a suitable temperature range over which to collect the final product during the distillation.

(1)

.....

(e) In the preparation, 15cm^3 of 2-methylpropan-2-ol produced 6.9 cm^3 of 2-chloro-2-methylpropane.

The equation for the reaction is

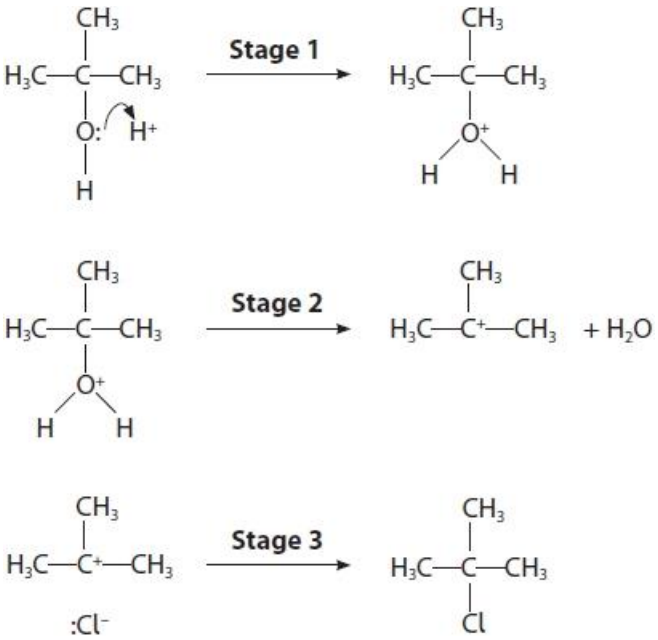
$$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$$

Calculate the percentage yield of 2-chloro-2-methylpropane, using data from the table.

Data	2-methylpropan-2-ol	2-chloro-2-methylpropane
molar mass / g mol^{-1}	74.0	92.5
boiling temperature / °C	82	51
density / g cm^{-3}	0.79	0.84

(3)

(f) The mechanism for the reaction is in three stages.



Add curly arrows to the reactants in **Stages 2** and **3** to complete the mechanism.

(2)

(Total for question = 14 marks)

Q18.

1-bromobutane can be prepared from butan-1-ol and hydrogen bromide.

$$CH_3CH_2CH_2CH_2OH + HBr \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$$

Hydrogen bromide can be made from sodium bromide and 50% concentrated sulfuric acid.

(a) The steps for the preparation of impure 1-bromobutane are summarised.

Step **1** Dissolve the sodium bromide in distilled water in a pear-shaped flask and then add 20.0 cm^3 of butan-1-ol.
Step **2** Surround the flask with an ice bath to **cool the mixture**, before adding concentrated sulfuric acid drop by drop.
Step **3** Remove the flask from the ice bath and add a few **anti-bumping granules** to the reaction mixture.
Step **4** Set up the apparatus for **heating under reflux**. Heat the mixture in the flask for 30 minutes and then allow the apparatus to cool.
Step **5** Rearrange the apparatus for distillation and heat the mixture until no more 1-bromobutane distils over.

(i) Parts of the method are given in **bold** type in Steps **2**, **3** and **4**.
Give a reason why each of these parts is necessary.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

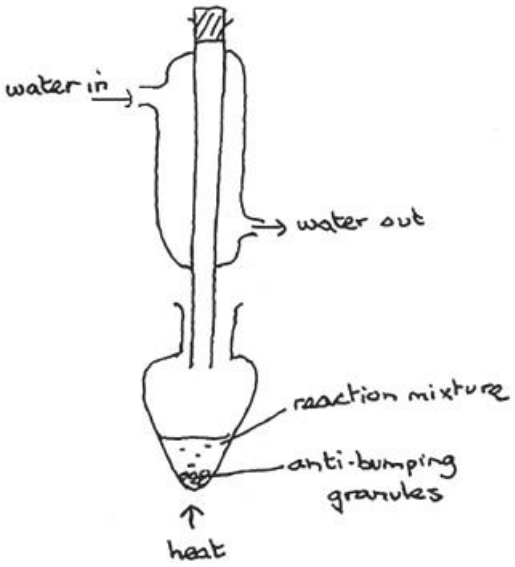
.....

.....

.....

.....

(ii) A student drew a diagram of the apparatus used for heating under reflux in Step **4**.
There are three errors in the apparatus shown in the diagram.
Assume the apparatus is suitably clamped.



Identify the three errors, including the effect of each error.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(iii) The student corrected the errors.
While the mixture was heating under reflux, the student noticed a small amount of a brown vapour was formed.
Explain why the brown vapour forms.

(2)

.....

.....

.....

.....

(b) The distillate collected in Step **5** is a mixture consisting of two layers.

There is an aqueous layer and a layer containing impure 1-bromobutane.

Data

Densities:	
water	$1.00\,g\,cm^{-3}$
butan-1-ol	$0.81\,g\,cm^{-3}$
1-bromobutane	$1.27\,g\,cm^{-3}$

Boiling temperature of 1-bromobutane = 102 °C

The steps for the purification of the 1-bromobutane are summarised.
Step **6** Transfer the mixture from Step **5** to a separating funnel and remove the aqueous layer.
Step **7** Wash the impure 1-bromobutane with concentrated hydrochloric acid in the separating funnel.
Remove the aqueous layer.
Step **8** Add aqueous sodium hydrogencarbonate to the impure 1-bromobutane in the separating funnel.
Step **9** Shake the mixture in the separating funnel and, from time to time, invert the funnel and open the tap.
Step **10** Collect the 1-bromobutane layer from Step **9** in a small conical flask.
Add anhydrous sodium sulfate and swirl the flask until the liquid becomes clear.
Step **11** Decant the 1-bromobutane into a clean pear-shaped flask and redistil it.
Measure the volume of 1-bromobutane produced.

(i) State the position of the aqueous layer in the separating funnel at the start of Step **6**.
Justify your answer.

(1)

.....

.....

(ii) Concentrated hydrochloric acid is used to remove any unreacted butan-1-ol in the mixture in Step **7**.
Give the reasons for carrying out Steps **8**, **9** and **10**.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(iii) Give a suitable temperature **range** over which to collect the pure 1-bromobutane in the redistillation in Step **11**.

(1)

.....

(iv) The volume of 1-bromobutane collected was 12.0 cm^3.
Calculate the number of molecules of 1-bromobutane produced in this experiment.
Give your answer to an appropriate number of significant figures.

(2)

(Total for question = 15 marks)

Q19.

The preparation of 2-chloro-2-methylpropane, $(CH_3)_3CCl$, involves the reaction of concentrated hydrochloric acid with 2-methylpropan-2-ol, $(CH_3)_3COH$, a tertiary alcohol.

$$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$$

Primary alcohols react very slowly with concentrated hydrochloric acid.
State a different reagent for the chlorination of primary alcohols.

(1)

.....

(Total for question = 1 mark)

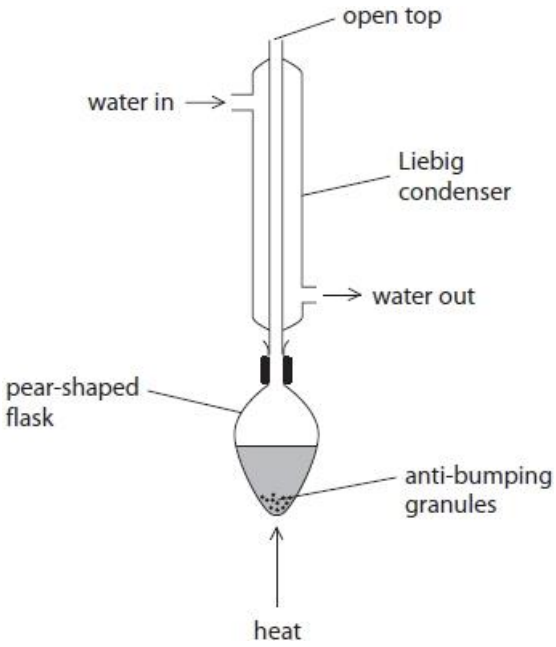
Q20.

Some alcohols can be oxidised by acidified sodium dichromate(VI), $Na_2Cr_2O_7$.

Reflux apparatus can be used to carry out the oxidation of alcohols.

(i) This Liebig condenser has been set up incorrectly. Add shading to the diagram to show the water in the condenser, illustrating the effect of the incorrect water flow.

(1)



(ii) State how the granules prevent bumping.

(1)

.....

.....

.....

.....

(Total for question = 2 marks)

Q21.

This question is about esters with the molecular formula $C_6H_{12}O_2$.

Another ester, **A**, with molecular formula $C_6H_{12}O_2$, was hydrolysed.
It produced ethanoic acid, and an alcohol, **B**, with molecular formula $C_4H_{10}O$.

Alcohol **B** undergoes an elimination reaction to produce a mixture of
but-1-ene and but-2-ene.

Deduce the structures of **B** and **A**. Justify your structure of **B**.

(3)

.....

.....

.....

.....

.....

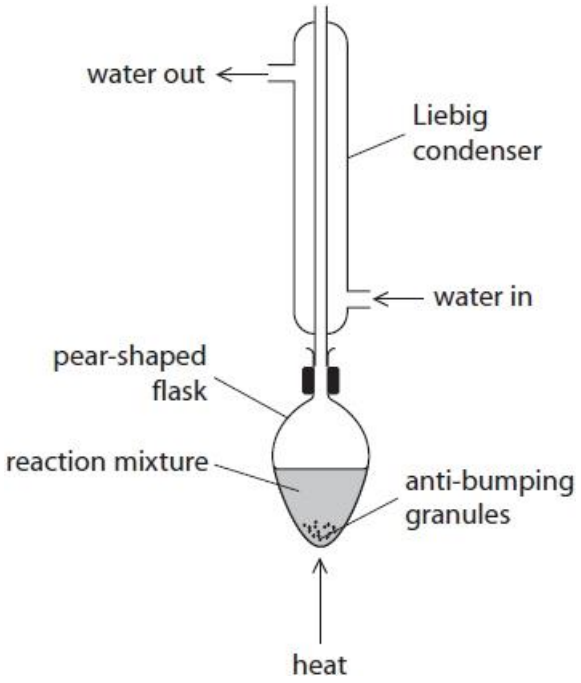
.....

(Total for question = 3 marks)

Q22.

Propanal can be produced from the oxidation of propan-1-ol.

(i) A student assembled the apparatus shown for this oxidation.



Explain why the use of this apparatus would give a very low yield of propanal.

(2)

.....

.....

.....

.....

(ii) The oxidising agent is acidified $Na_2Cr_2O_7$.

State the oxidation number of chromium in $Na_2Cr_2O_7$.

(1)

.....

(iii) Complete the ionic half-equation for the oxidation of propan-1-ol.

(1)

$$CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO + ...H^+ + ...e^-$$

(iv) State how the use of anti-bumping granules gives smoother boiling.

(1)

.....

.....

(v) Another student used the correct apparatus for this oxidation. 1.50 g of propan-1-ol produced 0.609 g of propanal.

Calculate the percentage yield of propanal by mass.

(3)

(Total for question = 8 marks)

Q23.

Ethanedioic acid has two carboxylic acid groups.

(a) Ethanedioic acid, $H_2C_2O_4$, can be prepared from ethane-1,2-diol.

Give the reagents and condition required for this reaction.

(2)

Reagents

.....

Condition

.....

(b) The formula for ethanedioic acid crystals is $H_2C_2O_4.nH_2O$.

To determine the number of moles of water of crystallisation, n, in 1 mol of ethanedioic acid crystals, a student carried out the following procedure.

- Prepare 250.0cm^3 of a solution containing a known mass of about 1g of ethanedioic acid crystals.
- Titrate 25.0cm^3 portions of the ethanedioic acid solution with 0.103 mol dm^{-3} sodium hydroxide solution, using phenolphthalein as indicator.

The student obtained these results:
mass of ethanedioic acid crystals = 1.09g
mean titre = 16.20cm^3
The equation for the reaction is

$$H_2C_2O_4 + 2NaOH \rightarrow Na_2C_2O_4 + 2H_2O$$

(i) Describe how the student should prepare the 250.0 cm^3 of ethanedioic acid solution.

(4)

.....

.....

.....

.....

.....

.....

.....

(ii) Give the colour change at the end-point in this titration.

(1)

From ..... to .....

(iii) Calculate a value of n in the formula $H_2C_2O_4.nH_2O$ from these data.

(5)

(iv) The student thought that the ethanedioic acid crystals used may have been slightly damp.

Explain the effect of using damp crystals on the titre and on the value of n.

(2)

.....

.....

.....

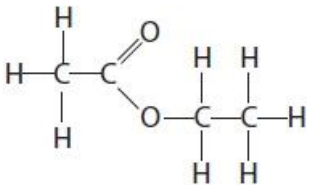
.....

.....

(Total for question = 14 marks)

Q24.

Ethyl ethanoate is an ester.



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 = 3 marks)

Q25.

Esters have many uses due to their characteristic aromas and often have common names. For example, isoamyl acetate is referred to as banana oil and amyl acetate has a scent similar to apples.

Deduce the **name** of the alcohol that forms isoamyl acetate.

(1)

.....

(Total for question = 1 mark)

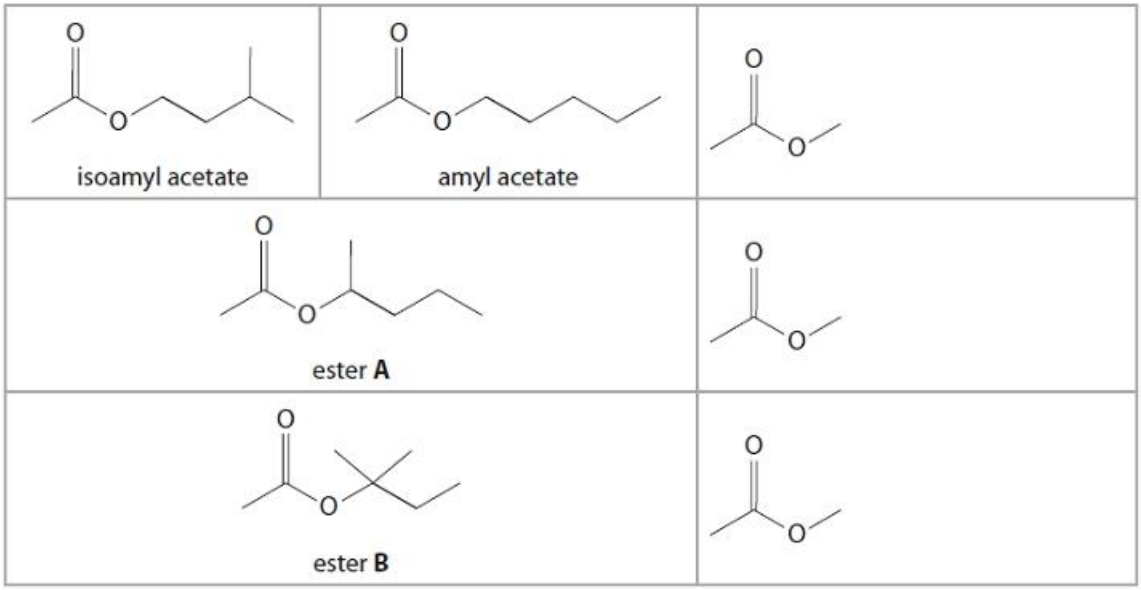
Q26.

Esters have many uses due to their characteristic aromas and often have common names. For example, isoamyl acetate is referred to as banana oil and amyl acetate has a scent similar to apples.

The carboxylic acid used to make isoamyl acetate and amyl acetate can also be used to make six further ester isomers. The structures of two of these esters, **A** and **B**, are shown.

(i) Complete the **skeletal** formulae of **three** of the remaining esters. Names are **not** required.

(3)



(ii) Write an equation to show the formation of ester **A** from an acyl chloride and an alcohol.

(2)

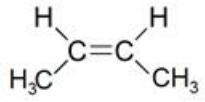
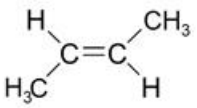
(Total for question = 5 marks)

Mark Scheme

Q1.

Question Number	Answer	Mark
(i)	The only correct answer is **B** (elimination) ***A*** *is not correct because this is a typical reaction of alkenes, not a reaction to form alkenes* ***C*** *is not correct because alcohols are typically oxidised to aldehydes, ketones or carboxylic acids* ***D*** *is not correct because substitution removes just the –OH not an –H as well*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • compounds with the same structural formula **(1)** • where the atoms have a different arrangement in space **(1)**	Allow the bonds/groups have different spatial arrangements or orientation or configuration or 3D arrangement Allow have a different displayed formula Do not award where the molecules have a different arrangement in space Do not award a discussion of optical isomerism Do not award just 'cis/trans isomerism / *E/Z* isomerism'	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• any two of structures and/or names correct **(1)** • both structures and names correct. **(1)**	 *Z*/cis-but-2-ene  *E*/trans-but-2-ene Can be in either order. If the isomerism described in (b)(ii) is the position of the double bond allow but-1-ene and either *Z*/cis- or *E*/trans-but-2-ene here. Allow skeletal/displayed formulae	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iv)	• geometric (isomerism)	Accept *cis-trans* / *E-Z*	**(1)**

Q2.

Question Number	Answer	Additional Guidance	Mark
(i)	EITHER • correct equation **(1)** • butanal **(1)** • distil (off immediately) / distillation **(1)** OR • correct equation **(1)** • butanoic acid **(1)** • heat under reflux **(1)**	The condition mark is dependent on one of the other two marks being scored Allow 2 marks for correct use of propan-1-ol $CH_3CH_2CH_2CH_2OH + [O] \rightarrow CH_3CH_2CH_2CHO + H_2O$ $CH_3CH_2CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2CH_2COOH + H_2O$ Allow just 'reflux' Award other correct formulae for butan-1-ol, butanal and butanoic acid, e.g. $C_3H_7CH_2OH$, C_3H_7CHO and C_3H_7COOH Do not award molecular formulae for butanal and butanoic acid	**(3)**

Question Number	Answer	Mark
(ii)	The only correct answer is **B** (green) ***A*** *is not correct because brown is not a colour which is associated with this reaction* ***C*** *is not correct because this is the colour of potassium dichromate(*VI*) before the reaction* ***D*** *is not correct because this is the colour of potassium chromate*(VI)	**(1)**

Q3.

Question Number	Acceptable Answer	Additional guidance	Mark
	• Balanced equation **(1)** • Appropriate colours **(1)**	Example of equation: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ Allow multiples Orange colourless green colourless Allow 'No colour' for colourless Do not award 'blue' for 'green' Do not award 'clear' for colourless Do not award if any spaces left blank Ignore any colour given for electrons Ignore any shades of colour	**(2)**

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	moles of NaOH $18.45 \times 0.400/1000 = 7.38 \times 10^{-3}/0.00738$ **(1)** moles of propanedioic acid $7.38 \times 10^{-3}/2 = 3.69 \times 10^{-3}/0.00369$ **(1)**	TE: moles of NaOH/2	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	moles of propanedioic acid in 250 cm^3 **(1)** mass of propanedioic acid in 250 cm^3 **(1)**	example of calculation moles of propanedioic acid 25 x answer to (c)(i) = 25 x 3.69 x 10^{-3} = 0.09225 0.09225 x 104 = 9.6/9.59/9.594 (g) Allow calculation in either order e.g. calculate mass propanedioic acid in 10.0 cm^3 first then x 25 Allow TE from c(i) eg 0.00738 gives 19.188 (g)	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	theoretical yield **(1)** % yield **(1)**	example of calculation theoretical yield 15.2 x104/76 = 20.8 g % yield answer to c(ii) x 100/20.8 9.594 x 100/20.8 = 46/46.1/46.12/46.13/46.125 (%) use of 9.6 gives 46.15385 allow any number of sig figs except one Correct answer with or without working scores 2 marks TE on incorrect theoretical yield and answer to c(ii) Both marks will be lost for use of 15.2 as theoretical yield (gives 63.1%)	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iv)	an answer that makes reference to one of the following points: • transfer losses • incomplete reaction/oxidation/ formation of aldehyde • side reaction(s)	 Ignore spillage/impure reactants/incompetence/references to uncertainties Ignore other products formed/loss by evaporation Penalise additional incorrect reasons ie +1 -1 = zero	**(1)**

Q5.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td></td><td>A description that makes reference to two of the following points:

• reagent (1)

• corresponding observation (1)</td><td>Examples of reagents and observations

<table>
<tr><th>Reagent</th><th>Observation</th></tr>
<tr><td>bromine water
Allow bromine (in an organic solvent)</td><td>orange / yellow / brown solution goes colourless
Allow bromine water is decolourised</td></tr>
<tr><td>carboxylic acid and (concentrated) H_2SO_4 / HCl / H^+</td><td>characteristic smell (of an ester)</td></tr>
<tr><td>acidified potassium manganate(VII) / permanganate</td><td>purple to colourless / decolourised</td></tr>
<tr><td>alkaline potassium manganate(VII)</td><td>purple to green</td></tr>
<tr><td>(neutral) potassium manganate(VII)</td><td>purple to brown ppt</td></tr>
<tr><td>acidified (potassium) dichromate((VI)) (ions)</td><td>orange to green</td></tr>
</table>

Allow names or formulae for reagents but if both are given, both must be correct

Ignore conditions e.g. heat

Do not award PCl_5 / Na

If more than one test is given, penalise any incorrect tests</td><td>(2)</td></tr>
</table>

Q6.

Question Number	Answer	Mark
(i)	**The only correct answer is B** (elimination) **A** *is not correct because the reaction involves only one reacting molecule (cyclohexanol)* **C** *is not correct because there is no change in the oxidation numbers of any of the elements involved* **D** *is not correct because nothing has been substituted.*	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of mass and mol of cyclohexanol **(1)** • calculation of mol of cyclohexene **(1)** • calculation of mass of cyclohexene **(1)** • calculation of volume of cyclohexene **(1)**	<u>Example of calculation</u> Mass cyclohexanol = 10.0 × 0.962 = 9.62 (g) and Mol of cyclohexanol = 9.62 ÷ 100 = 0.0962 (mol) Mol of cyclohexene = 0.63 × 0.0962 = 0.060606 (mol) Mass of cyclohexene = 0.060606 × 82.0 = 4.9697 (g) Volume of cyclohexene = 4.9697 ÷ 0.811 = 6.1279 = 6 / 6.1 / 6.13 (cm^3) / 6.1 x 10^{-3} dm^3 Ignore SF in final answer Allow TE at each stage Correct answer with no working scores 4	(4)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>* (iii)</td><td>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.
<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 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></td><td>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).

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).
Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.</td><td>(6)</td></tr>
<tr><td></td><td>Indicative content:

• IP1 separate cyclohexene from water using separating funnel

• IP2 remove the lower aqueous layer because it has a higher density

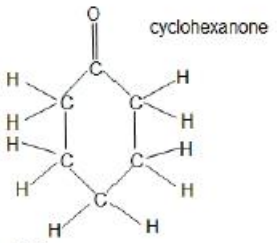
• IP3 suitable drying agent

• IP4 separate the cyclohexene from the drying agent</td><td>Mark independently

Suitable specified drying agents: (anhydrous) $CaCl_2$, Na_2SO_4, $CaSO_4$, $MgSO_4$</td><td></td></tr>
<tr><td></td><td>• IP5 redistil product

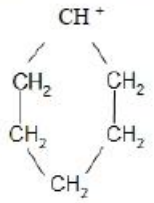
• IP6 collect the distillate boiling over between 80 and 86 °C to collect the pure cyclohexene</td><td>By filtering or decanting</td><td></td></tr>
</table>

Q7.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • name (1) • displayed formula (1)	Example of displayed formula  Allow CH_2 groups Allow skeletal formula Do not award molecular formula	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • O-H bond (stretching) 3750 – 3200 cm^{-1} in cyclohexanol is not present in cyclohexanone /disappears (when cyclohexanol reacts). (1) • C=O bond (stretching) 1720 – 1700 cm^{-1} appears in cyclohexanone (1)	Allow a range within the specified range Allow 1725 – 1700 cm^{-1} Do not allow 1740 – 1720 cm^{-1} (aldehyde)	(2)

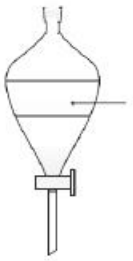
Question Number	Answer	Additional Guidance	Mark
(iii)	• highest $m/z = M_r = 98$	Check, answer may be shown on mass spectrum Do not accept just '98' with no supporting evidence Allow peak furthest to the right / molecular ion peak is 98	(1)

Question Number	Answer	Additional Guidance	Mark
(iv)	• fragment (1) • charge (1)	Examples of fragment structure  $C_6H_{11}^+$ Allow charge anywhere on fragment, including outside brackets around the fragment Allow straight chain fragment provided it has the correct number of C and H atoms	(2)

Q8.

Question Number	Acceptable Answer	Additional guidance	Mark
	An explanation that makes reference to the following • ethanol would be oxidised to ethanal **(1)** • because ethanal has a low boiling temperature **or** ethanal will distil before ethanoic acid can be formed **(1)**	Allow aldehyde for ethanal Allow ethanal will be formed Allow ethanal is (more) volatile Accept reverse argument in terms of reflux condensing ethanal for oxidation to ethanoic acid	**(2)**

Q9.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • a separating funnel (with or without a stopper or bung) **(1)** • a two layer system with the top layer labelled as the organic layer / 2-chloro-2- methylpropane **(1)**	Allow any shape separating funnel with a tap at the bottom (no label required) with a bung, stopper or appropriate joint / gap at the top. Allow anything labelled as a tap Do not award a sealed apparatus if stopper / bung is unclear  2-chloro-2methylpropane Do not award a three layer system	**(2)**

Q10.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following point: • carbon dioxide / CO_2	Ignore references to limewater turning cloudy	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following point: • H^+ / H_3O^+	Ignore 'hydrogen ion' Ignore numbers before e.g. $2H^+$	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: • mixed with an appropriate named drying agent, e.g. (anhydrous) calcium chloride / $CaCl_2$ / (anhydrous) magnesium sulfate / $MgSO_4$ / (anhydrous) sodium sulfate / Na_2SO_4 / silica gel **(1)** • leave until the solution becomes clear / left until added drying agent remains powdered / left until added drying agent does not clump together **(1)** **or** decant the liquid / filter the solid (to separate from the drying agent	M2 is dependent on a drying agent being added in M1 Do not award sodium hydroxide, potassium hydroxide, anhydrous copper sulfate, anhydrous cobalt chloride, calcium sulfate, calcium carbonate, potassium sulfate	**(2)**

Q11.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following point: • 50-52 (°C)	Allow 48-54 (°C) Allow a range within these limits to include 51 (°C) Do not award just 51 (°C)	**(1)**

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>* (ii)</td>
<td>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>
</td>
<td>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, which 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).</td>
<td>(6)</td>
</tr>
</table>

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>* (ii) contd</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
<table><tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr><tr><td>Answer shows a coherent and 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></td><td>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.

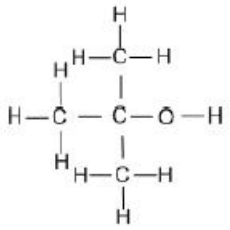
Reasoning marks may be reduced for extra incorrect chemistry

Ignore stated errors which are not present

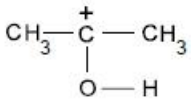
Allow to prevent uneven boiling / ensure smooth boiling
Ignore prevents bumping
Do not award so reaction does not explode / shatter glassware / damage apparatus</td><td>(6)</td></tr>
</table>

	Indicative content: • IP1 add anti-bumping granules • IP2 to prevent the formation of large bubbles / rapid heating / transfer of reaction mixture to collecting vessel (leading to impure product) • IP3 the thermometer should be opposite the entrance of the condenser • IP4 collecting over the wrong temperature range (therefore impure or the wrong product) • IP5 add more ice-water mixture • IP6 ensure you collect as much product as possible	Allow thermometer should be measuring the vapour temperature not the liquid temperature Allow collecting impure product but must be linked to wrong position of thermometer Do not award just the temperature is inaccurate without mention of vapour Allow collection flask should be further in the ice-water mixture Allow to ensure greater / quicker condensation	

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)		display all three methyl groups allow –OH do not award C-H-O	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	An answer that makes reference to one of the following: molecular ion/molecule fragments/is unstable		(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)		allow + charge on any part of the ion/outside the structure but + must be shown allow displayed/structural/skeletal/ molecular formulae or any combination of these.	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)(i)	• calculation for bonds broken in the alcohol (*) **(1)** • calculation for bonds broken in oxygen **and** total energy for bonds broken(**) **(1)** • calculation for bonds made(***) **(1)** • calculation of $\Delta_c H$ (2-methylpropan-2-ol) with sign **(1)**	Example of calculation 3(C-C) + 9(C-H) + (C-O) + (O-H) =(3x347) + (9x413) + 358 + 464 = (+)5580 (kJ mol^{-1}) 6(O=O) = (6 x 498) = (+)2988 (kJ mol^{-1}) total = + 5580 + 2988 = (+)8568 (kJ mol^{-1}) TE from ans * M1 + 2988 = 8(C=O) + 10(O-H) = (8x805) + (10x464) = -11080 (kJ mol^{-1}) = +8568 – 11080 = -2512 (kJ mol^{-1}) allow TE for answer(**) + answer(***) units not required but if given they must be correct correct final answer with no working scores 4 marks	(4)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • incomplete combustion **(1)** • $\Delta_c H$ (2-methylpropan-2-ol) will be less negative /less exothermic than data book value **(1)**	mark independently do not award just lower/smaller/decreases/ more positive allow reduce the magnitude (of the value)	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: $\Delta_c H$ figures are at 298 K /data book bond energies refer to gaseous state and water and/or 2-methylpropan-2-ol are/is (both) liquid(s) (at 298 K)	allow just liquid involved do not award data book bond energies are mean (values)/not specific to 2-methylpropan-2-ol	**(1)**

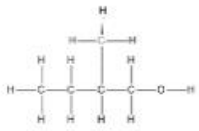
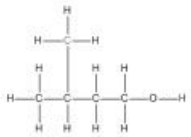
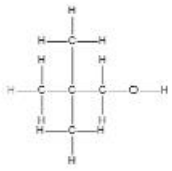
Q13.

Question Number	Answer	Additional Guidance	Mark
	• skeletal formula	Example of skeletal formula  Bond from ring to Br must be shown but the length is not important.	(1)

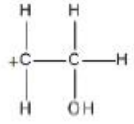
Q14.

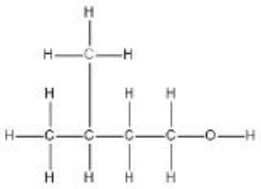
Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• calculation of empirical formula **(1)** • uses molecular ion to prove molecular formula **(1)** **or** • calculation of percentage of each element in compound all 3 correct scores **(2)** any 2 correct scores **(1)** **or** • calculation of the number of atoms of each element directly all 3 correct scores **(2)** any 2 correct scores **(1)**	Example of calculation C : H : O $\frac{68.2}{12}$ $\frac{13.6}{1}$ $\frac{18.2}{16}$ = 5.68 13.6 1.14 = 5 12 1 Use of 88 to show molecular formula is $C_5H_{12}O$ e.g. M_r is (5x12) + (12x1) + 16 = 88 or states that M_r of empirical formula is 88 **or** % C = $\frac{5 \times 12 \times 100}{88}$ = 68.2 % H = $\frac{12 \times 1 \times 100}{88}$ = 13.6 % O = $\frac{1 \times 16 \times 100}{88}$ = 18.2 **or** C atoms = $\frac{68.2 \times 88}{100 \times 12}$ = 5 H atoms = $\frac{13.6 \times 88}{100 \times 1}$ = 12 O atoms = $\frac{18.2 \times 88}{100 \times 16}$ = 1	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• (**X** is a) primary/ 1° (alcohol)		**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	   	Allow alcohols in any order Allow CH_3 / OH Allow slip of 1 H missing from 1 alcohol / 1 C-C bond missing Ignore names, even if incorrect Penalise O-H-C- / -C-H-O at end of molecule once only If no other mark is given, allow (2) for 4 correct skeletal / structural formulae or any combination of these or (1) for 3 correct Allow (2) for displayed formulae of pentan-2-ol, pentan-3-ol and 3-methylbutan-2-ol if secondary alcohol in (b)(i), or (1) for any two of those	(3)

	• 4 correct **(3)** • 3 correct **(2)** • 2 correct **(1)**	If no other mark awarded and if (b)(i) is blank or incorrect, allow (2) for any 4 different alcohols with formula $C_5H_{12}O$, (1) for 3 alcohols	

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	• 	Allow structural formula or any combination of displayed and structural formula Allow + anywhere on structure or outside of a formula in a bracket Do not allow $C_2H_5O^+/C_2H_4OH^+$ Do not allow missing charge Allow CH_3C^+HOH if secondary alcohol identified in (b)(i)	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iv)	•  **(1)**	Allow any type of identification, including name 3-methylbutan-1-ol Ignore incorrect name with correct structure	(2)
	• because this is the **only** alcohol with a branched chain <u>and</u> forms $CH_2OHCH_2^+$ / $C_2H_4OH^+$ / peak at 45 / fragment identified in (b)(iii) **(1)**	Conditional on correct identification Ignore missing charge on fragment Allow reasons why the others are not correct e.g. not pentan-1-ol as it is not branched <u>and</u> not 2-methylbutan-1-ol or 2,2-dimethylpropan-1-ol as they do not form $CH_2OHCH_2^+$ If secondary alcohol identified in (b)(i): Allow 3-methylbutan-2-ol (1) as it is the only alcohol with a branched chain that forms CH_3C^+HOH (1)	

Q15.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>
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>
</td><td>
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 and overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

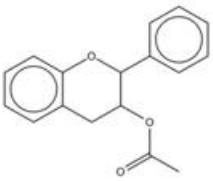
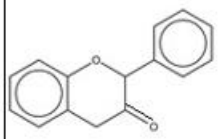
Typically

Number of IPs
Reasoning mark

6 or 5 scores 2

4 or 3 scores 1

2 or 1 or 0 scores 0
</td><td>(6)</td></tr>
</table>

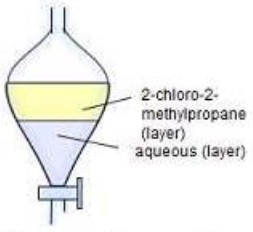
	Indicative content • **IP1** any mention of **oxidation** of ethanol **or oxidation** of flavan-3-ol (by oxygen in the air) • **IP2** for formation of **either** ethanoic acid **or** ethanal (from ethanol) • **IP3** for formation of ethyl ethanoate (from the reaction between ethanol and ethanoic acid) • **IP4** for structure / name of flavan-3-one • **IP5** for (-OH group on) flavan-3-ol forms an ester with ethanoic acid • **IP6** correct structure of the ester formed between flavan-3-ol and ethanoic acid  **This is the structure of the ester formed between flavan-3-ol and ethanoic acid**	Allow names or formulae **but** if both are given **both** must be correct  **Comment** For correct structure of the ester formed between flavan-3-ol and ethanoic acid award both **IP5** and **IP6** Do not award IP4 if the product is described as an aldehyde	

Q16.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	$C_5H_{12}O + [O] \rightarrow C_5H_{10}O + H_2O$ • left-hand side of equation correct **(1)** • right-hand side of equation correct **(1)**	**Molecular** formulae must be used throughout Allow [O] above the arrow Do not award for $C_5H_{11}OH$ as the alcohol Ignore state symbols if incorrect or conditions mentioned	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• calculation of moles of both of $C_5H_{10}O$ and $C_5H_{12}O$ **(1)** • calculation of mass of $C_5H_{12}O$ **(1)** OR • calculation of theoretical mass of $C_5H_{10}O$ **and** moles of $C_5H_{10}O$ **(1)** • calculation of mass of $C_5H_{12}O$ **(1)**	Example of calculation Moles $C_5H_{10}O = \frac{2.15}{86.0} = 0.025(0)$ (mol) **and** moles $C_5H_{12}O = \frac{0.025(0)}{62.5} \times 100 = 0.04(00)$ (So) mass of $C_5H_{12}O = 0.04(00) \times 88 = 3.52$ g Theoretical mass $C_5H_{10}O = \frac{2.15}{62.5} \times 100 = 3.44$ g **and** moles $C_5H_{10}O = \frac{3.44}{86.0} = 0.04(00) =$ mol $C_5H_{12}O$ (So) mass of $C_5H_{12}O = 0.04(00) \times 88 = 3.52$ g Correct answer with no working scores (2) Allow TE from MP1 Award 1 mark for 3.36 g, 1.375 g or 2.2 g	**(2)**

Q17.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• diagram of separating funnel **(1)** • aqueous and organic layers labelled as shown **(1)**	Mark independently Allow any shape separating funnel with tap at the bottom (does not need to be labelled), with a narrowing top or vertical sides but do not allow a burette Allow stopper/bung in separating funnel  Allow two layers shown and just one labelled correctly Allow organic layer/ product for top layer / hydrochloric acid for aqueous layer Do not allow 'reactant' for top layer	**(2)**

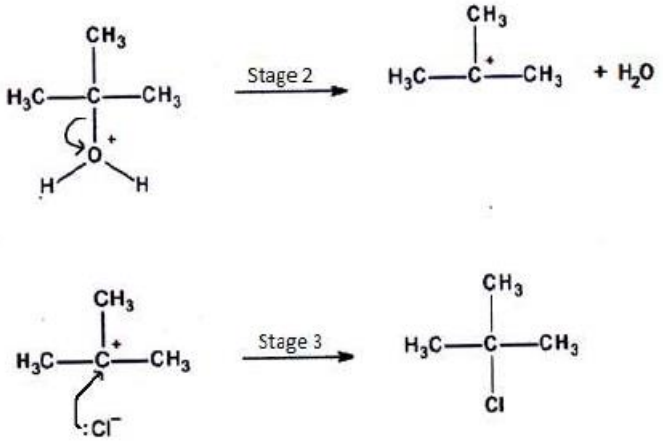
Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	• to react with/ neutralise any (unreacted/ excess hydrochloric) acid **(1)** • to release the carbon dioxide produced **or** to relieve the build-up of pressure **(1)**	Mark independently Allow to remove the (hydrochloric) acid Allow to neutralise the organic layer/ solution Allow to release gases Ignore just 'pressure builds up' Do not allow incorrect gases e.g. hydrogen	**(2)**

Question Number	Answer	Mark
(c)	**D** (sodium sulfate)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	A description that makes reference to the following points: • the (bulb of the) thermometer should be opposite the opening to the condenser **(1)** • the water in and out of the condenser should be reversed **(1)** • put a vent after the condenser **or** leave a gap between the condenser and the receiver **or** conical flask must be open **(1)**	Allow these changes if shown on the diagram Allow thermometer should be higher up / above the liquid / should measure the temperature of the vapour / out of the mixture/liquid Allow water should enter the bottom (of the condenser) Ignore just 'vent' / the apparatus should not be completely sealed Ignore references to using a fume cupboard	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	• 50-52°C	Allow any range between 49 and 53°C, provided it includes 51°C Do not allow just 51°C	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	• calculation of moles of alcohol used **(1)** • calculation of theoretical volume of 2-chloro-2-methylpropane made **or** calculation of actual moles of 2-chloro-2-methylpropane **or** calculation of actual mass of 2-chloro-2-methylpropane **(1)** • calculation of percentage yield **(1)**	Example of calculation mass of alcohol used = 15.0 x 0.79 = 11.85 (g) moles of alcohol used = 11.85/74.0 = 0.16014 theoretical mass of chloro compound = 0.16014 x 92.5 = 14.8125 (g) theoretical volume = 14.8125/0.84 = 17.634 (cm^3) **or** actual moles of chloro compound = 6.9 x 0.84 / 92.5 = 0.062659 **or** actual mass of chloro compound = 0.062659 x 92.5 = 5.796 (g) % yield = (6.9/17.634) x 100 = 39.1% **or** = (0.062659/0.16014) x 100 = 39.1% **or** = (5.796/14.8125) x 100 = 39.1% TE on M1 and M2 Ignore SF except 1 SF	**(3)**
		Correct answer without working scores 3	

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	• curly arrow from C–O bond to O **(1)** • curly arrow from lone pair on Cl^- to C^+ **(1)**	 Do not allow single-headed arrows Do not allow additional, incorrect arrows	**(2)**

Q18.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: • cool the mixture because the reaction (with concentrated sulfuric acid / H_2SO_4) is (very) exothermic / releases (a lot of) heat **(1)**	Ignore reaction is violent / to prevent splashing / to slow down the reaction / to stop reactants evaporating Do not award to quench the reaction / reference to explosion	(3)
	• anti-bumping granules are added to prevent violent / sudden / localised boiling **or** to prevent superheating / large bubbles forming **or** to promote smooth / even / controlled boiling **or** to promote the formation of small bubbles **or** to provide nucleation centres / (rough) surface for bubble formation **(1)**	Ignore to stop bumping / spitting / explosion / liquid splashing out / vigorous reaction / loss of reactants / to distribute heat more evenly / any reference to rate / to promote smooth heating	
	• heating under reflux is used to prevent the loss of any volatile substances / volatile reactants / volatile products / organic compound / named organic compound **or** to make sure the vapour / gas condenses **or** to prevent vapour escaping **(1)**	Allow so that the reaction goes to completion Ignore just 'to prevent gas escaping' / just 'to prevent loss of reactants / products' / just 'reactants / products are volatile' / 'because 1-bromobutane / butan-1-ol is flammable' / to increase yield / reference to safety Do not award for reference to oxidation or reduction	

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: • there is a gap between the condenser and the flask / seal the joint between the flask and condenser **and** so vapour / gas / reactants / products will escape **(1)** • the water is flowing the wrong way through the condenser / the water should go in at the bottom (and out at the top) **and** so it doesn't fill with water / is only part filled /there is an airlock **(1)** • there is a stopper on the condenser / there should not be a stopper on the condenser **and** so there will be a build-up of pressure (if the gap between condenser and flask is closed) **(1)**	Allow answers shown on annotated diagram e.g. gap circled Ignore any additional errors Ignore additional suggested modifications even if incorrect Do not award just 'the apparatus is not sealed' unless it is clear it means between the condenser and flask Allow so this will lower the yield of product / 1-bromobutane Ignore condenser is fitted the wrong way up Allow so there will be inefficient condensation / cooling Allow so the stopper will blow off / there will be an explosion / it will be dangerous	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	An explanation that makes reference to the following points: • (brown vapour / it) is bromine / Br_2 **(1)** • bromide ions / Br^- / HBr oxidised (by concentrated sulfuric acid) **(1)**	Stand alone mark Do not award just 'Br' Do not award any other brown gas in addition to bromine Allow bromide ions / Br^- / HBr reduce sulfuric acid / act as a reducing agent Ignore sodium bromide / NaBr is oxidised Ignore just 'redox reaction' Do not award bromine is oxidised Do not award oxidation by anything other than sulfuric acid	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	An answer that makes reference to the following: • aqueous layer is on the top **and** because water / it has a lower density than 1-bromobutane	Allow 'it' for aqueous layer Allow because 1-bromobutane has a higher density than water Ignore reference to butanol unless in a third layer Do not award water is 'lighter' Do not award reference to three layers	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	An answer that makes reference to the following points: Step **8** • (aqueous sodium hydrogencarbonate / $NaHCO_3$) reacts with / neutralises / removes the (hydrochloric) acid / H^+ (ions) in the mixture **(1)** Step **9** • (the tap is opened) to release the carbon dioxide / gas (formed) **or** to allow the carbon dioxide / gas to escape **or** to prevent the build-up of pressure **(1)** Step **10** • (anhydrous sodium sulfate is added) to remove / absorb water **(1)**	 Do not award reacts with incorrect acid e.g. H_2SO_4 / HBr / ethanoic acid Ignore removes water Do not award an incorrect gas e.g. hydrogen Allow (anhydrous) sodium sulfate is a drying agent / added to dry the product Do not award dehydration / reacts with water	(3)

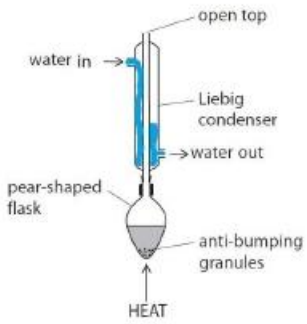
Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	• starting temperature 99 or 100 or 101 (°C) **and** final temperature 103 or 104 or 105 (°C)	Do not award just one value / 102 (°C) Do not award 102 (°C) with another temperature	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iv)	• calculation of mol of 1- bromobutane **(1)** • calculation of number of molecules **and** answer to 2/3 SF **(1)**	Example of calculation mol of 1-bromobutane = $\frac{12.0 \times 1.27}{136.9}$ = 0.11132 (mol) Do not award 0.1 number of molecules = $0.11132 \times 6.02 \times 10^{23}$ = 6.7×10^{22} / 6.70×10^{22} TE on a calculated mol 1-bromobutane using M_r Correct answer to 2 or 3 SF with no working scores (2)	**(2)**

Q19.

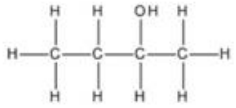
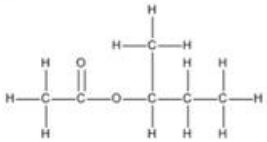
Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following point: • PCl_5 / phosphorus(V) chloride / phosphorus pentachloride	Allow thionyl chloride / $SOCl_2$ Allow phosphorus(III) chloride / PCl_3 / phosphorus trichloride Ignore phosphorus chloride If name and formula are given both must be correct	**(1)**

Q20.

Question Number	Acceptable Answer	Additional guidance	Mark
(i)	A diagram with any shading that is not 100%	An example of a suitable diagram:  Allow shaded area to show 'air pockets'	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
(ii)	An answer that makes reference to the following prevention of uncontrolled boiling by: • distributing the heat more evenly **or** • providing a surface for bubbles to form/allow smaller bubbles to form/provides nucleation sites for bubbles	 Do not award provide surface area for reaction Ignore reference to mixing the reagents/provide smooth boiling	(1)

Q21.

Question Number	Acceptable Answers	Additional Guidance	Mark
	Identifications • structure of alcohol **B** **(1)** • structure of ester **A** **(1)** **Justification** • butan-2-ol / $CH_3CH_2CHOHCH_3$ is the **only** alcohol (with formula $C_4H_{10}O$) that (undergoes elimination and) produces (but-1-ene and) but-2-ene **(1)**	Allow any combination of structural, displayed or skeletal formulae / correct species in unbalanced equations Allow structures not labelled **A** and **B** Penalise missing H once only Examples of identification **(B)**  Ignore connectivity of the OH group unless horizontal **(A)**  Ignore incorrect name for **A** TE on incorrect alcohol Allow butan-2-ol can form a double bond either side of the C with OH / between the 1st and 2nd carbon atoms and the 2nd and 3rd carbon atoms – this can be shown on diagram / equation Allow OH must be on the 2nd carbon atom / secondary alcohol to form but-1-ene and but-2-ene Allow butan-1-ol gives but-1-ene **and** 2- methylpropan-1-ol / 2-methylpropan-2-ol gives (2-)methylpropene Allow the other alcohols (with formula $C_4H_{10}O$) do not give but-2-ene	**(3)**

Q22.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to • propanal is condensed back (to the pear-shaped flask) **(1)** • so propanal is (further) oxidised (to propanoic acid) or propanal is more readily oxidised than propan-1-ol **(1)**	Allow aldehyde for propanal Allow 'apparatus is reflux' Allow propanal is not being removed /distilled off (from the oxidising agent) Ignore just 'reacts further' Do not award reference to propanal being completely oxidised	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• (+)VI	Allow (+) six / (+)6 / six (+) / 6(+)	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• balanced equation	Example of equation $CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO + 2H^+ + 2e^-$	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iv)	• provides a surface for bubbles to form / enables smaller bubbles to form / provides nucleation sites for bubbles or to prevent large bubbles forming	Allow distribution of heat more evenly / to prevent superheating Ignore mixing / to stop bumping / spitting / explosion / liquid splashing out / vigorous reaction / loss of reactants Do not award reference to large gas molecules	**(1)**

Question Number	Answer	Additional Guidance	Mark
(v)	• (**M1**) evaluation of number of moles of propan-1-ol **(1)** Method one using masses for percentage calculation • (**M2**) evaluation of maximum mass of propanal **(1)** • (**M3**) percentage yield **(1)** or Method two using moles for percentage calculation • (**M2**) evaluation of actual moles of propanal **(1)** • (**M3**) percentage yield **(1)**	<u>Example of calculation</u> n(propan-1-ol) = (1.50 ÷ 60) = 0.025 (mol) n(propan-1-ol) = n(propanal) max m(propanal) = (0.025 x 58) = 1.45 (g) %Yield = ((0.609 ÷ 1.45) x 100) = 42 % n(propanal) = (0.609 ÷ 58) = 0.0105 (mol) %Yield =((0.0105 ÷ 0.025) x 100) = 42 % Allow TE at each stage Ignore SF except 1SF Penalise incorrect M_r values once only Correct answer without working scores (3)	**(3)**

Q23.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• potassium dichromate((VI))/$K_2Cr_2O_7$ and sulfuric acid/H_2SO_4 **or** sodium dichromate((VI))/$Na_2Cr_2O_7$ and (dilute) sulfuric acid/H_2SO_4 **(1)**	Allow $Cr_2O_7^{2-}$ and H^+ / acidified (potassium / sodium) dichromate((VI)) If name and formula given, both must be correct Ignore concentration of acid Do not allow hydrochloric acid / HCl / nitric acid / HNO_3	**(2)**
	• heat/reflux **(1)**	Conditional on correct reagents or near miss, provided dichromate or (per)manganate((VII)) is mentioned Allow a specified temperature in the range 60 – 150°C Ignore distillation / warm Allow answers written on either dotted line	

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	A description that makes reference to the following points: • **Flask** - use of a volumetric / graduated flask **(1)**	Ignore heat Do not allow just 'flask' / conical flask	**(4)**
	• **Weighing** - weigh the ethanedioic acid (in a weighed container and record the exact mass) **(1)**	Ignore just 'put 1 /1.0 /1.09 g solid in beaker'	
	• **Dissolve, transfer and washings** – allow these in any order depending on the method used **(1)**	Distilled / deionised water must be mentioned once in M3 or M4 Allow pure water	
	• **Mark and mix** - make up to the mark / 250 cm^3 and then mix **(1)**	Allow any indication of mixing eg swirl / invert the flask	

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• (From) colourless (to) pink	Allow (to) red Do not allow purple / pink/purple Do not allow clear	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	• calculation of moles of NaOH **(1)** • calculation of moles of $H_2C_2O_4$ in 25 cm^3 **(1)** • calculation of moles of $H_2C_2O_4$ in 250 cm^3 **(1)** • calculation of M_r of crystals **(1)** • calculation of value of n **(1)**	Correct answer of 2.2582/2.258/2.26/2.3 without working scores 5 Final answer of 2, with working, resulting from a number between 2.2 and 2.3, scores 5 If no other mark is scored, an answer of just 2 scores 1 <u>Example of calculation</u> moles NaOH = 16.2 x 0.103/1000 = 1.6686×10^{-3} moles $H_2C_2O_4$ in 25 cm^3 = $1.6686 \times 10^{-3}/2 = 8.343 \times 10^{-4}$ TE on mole NaOH moles $H_2C_2O_4$ in 250 cm^3 = $8.343 \times 10^{-4} \times 10 = 8.343 \times 10^{-3}$ TE on moles $H_2C_2O_4$ in 25 cm^3 M_r of crystals = $1.09/8.343 \times 10^{-3}$ = 130.648 /130.65 / 130.6 TE on moles $H_2C_2O_4$ in 250 cm^3 For first 4 marking points ignore SF except 1 SF 130.65 = (2 + (2x12) + (4x16)) + 18n n = 2.2582/ 2.258/2.26/2.3/2 TE on M_r of crystals, provided n is positive	(5)

	Alternative method for M4 and M5 • calculation of moles of H_2O **(1)** • calculation of value of n **(1)**	mass $H_2C_2O_4$ = $8.343 \times 10^{-3} \times 90$ = 0.75087 (g) mass H_2O = 1.09 – 0.75087 = 0.3391 (g) moles H_2O = 0.3391/18 = 0.01884 mole ratio $H_2C_2O_4$: H_2O = 1 : $0.01884/8.343 \times 10^{-3}$ = 1 : 2.2582/ 2.258/2.26/2.3/2	

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iv)	An explanation that makes reference to the following points: • (damp crystals will have more water so) lower mass / moles / concentration of $H_2C_2O_4$ **(1)** • so titre will be lower and the value of n will be higher **(1)**		(2)

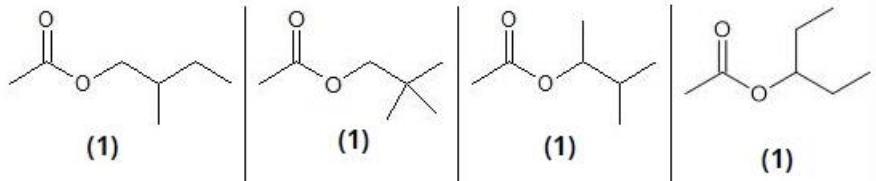
Q24.

Question Number	Answer	Additional Guidance	Mark
	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)

Q25.

Question Number	Answer	Additional Guidance	Mark
	• 3-methylbutan-1-ol	Allow 'methly' for methyl Allow name with missing hyphens Allow 3-methylbutane-1-ol Allow 3-methylbut-1-anol Allow 1-hydroxy-3-methylbutane Do not allow 3-methylbut-1-ol Ignore formulae even if incorrect	(1)

Q26.

Question Number	Answer	Additional Guidance	Mark
(i)	Any three of the following four structures  (1) (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	(3)

Question Number	Answer	Additional Guidance	Mark
(ii)	An equation that has • ethanoyl chloride **(1)** • alcohol **and** ester+ HCl product **(1)**	Example of equation  Allow structural, displayed formulae in any combination Ignore connectivity to OH except horizontal Ignore state symbols even if incorrect If molecular formulae used then allow (1) for correct equation Allow (1) for a correct equation to form ester A from ethanoic acid e.g. $CH_3COOH + CH_3CH(OH)CH_2CH_2CH_3 \rightleftharpoons CH_3COOCH(CH_3)CH_2CH_2CH_3 + H_2O$	(2)