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)

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(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)

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(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)

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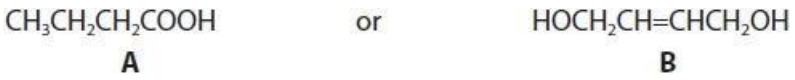
(Total for question = 7 marks)

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**.



A **B**

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

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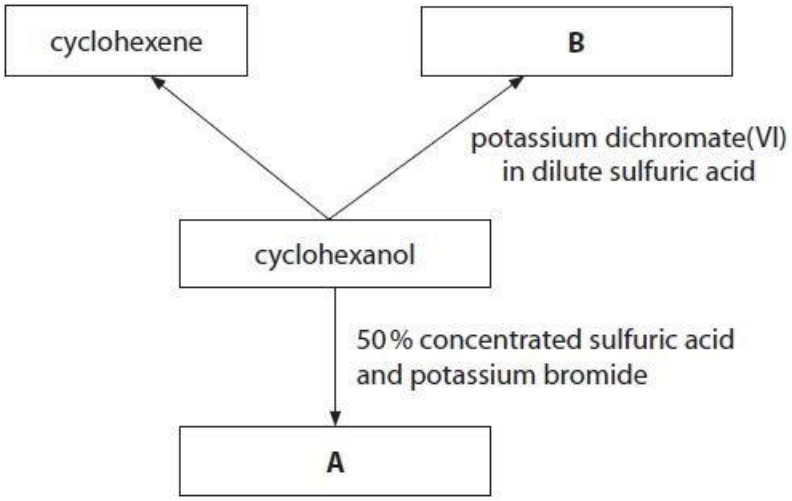
(Total for question = 2 marks)

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.

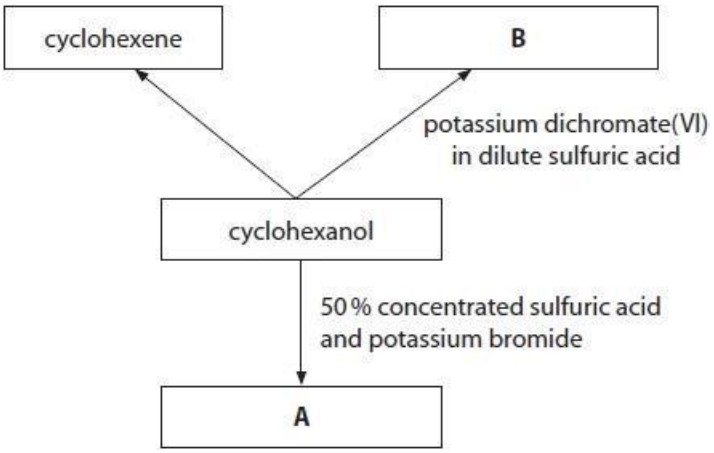
Devise a procedure to obtain a pure, dry sample of cyclohexene from the distillate.
Include a reason for each step.
[Boiling temperature of cyclohexene = 83 °C
Density of cyclohexene = 0.811 g cm^{-3}]

(6)

(Total for question = 11 marks)

Q7.

This question is about some reactions of cyclohexanol.

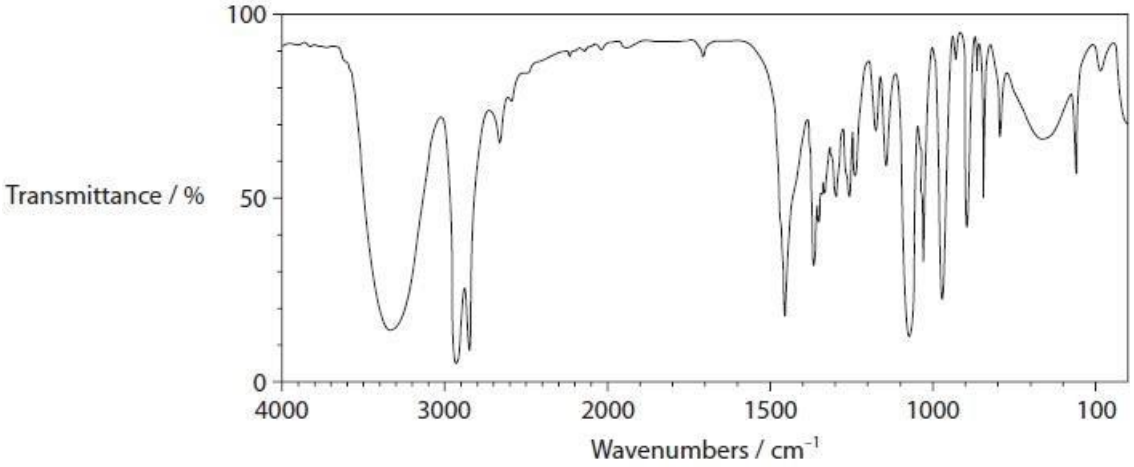


(i) Give the name **and** displayed formula of compound **B**.

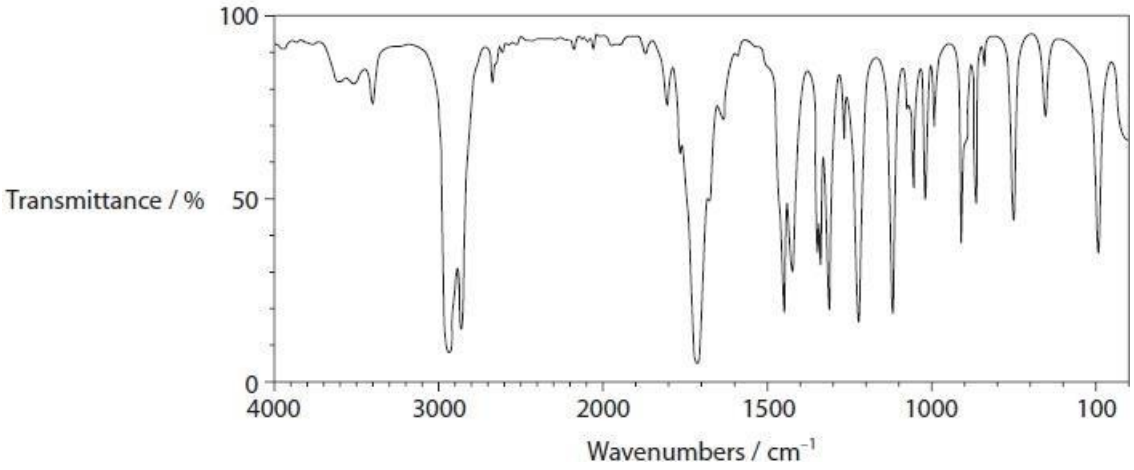
(2)

(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.

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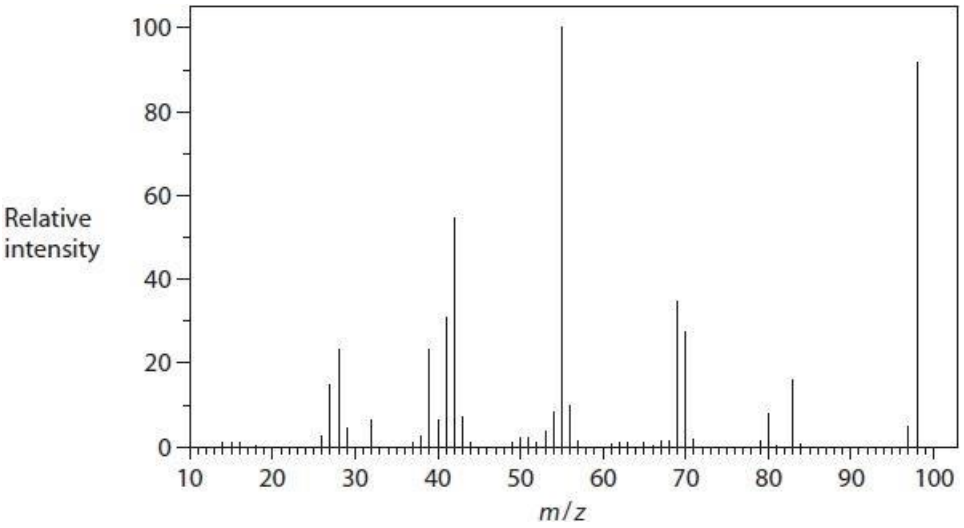
(iii) The mass spectrum of compound **B** is shown.



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

(1)

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(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.

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(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)

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

(1)

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

Include the name of a suitable drying agent.

(2)

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(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)

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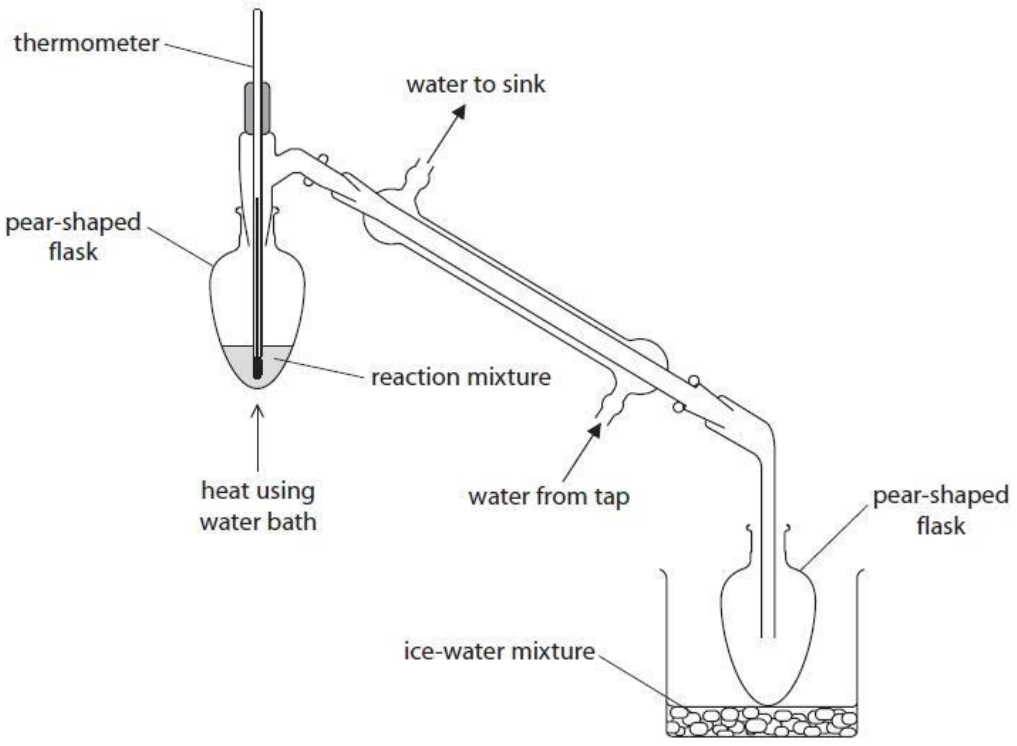
* (ii) A diagram of the distillation apparatus is shown.



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.

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(Total for question = 7 marks)

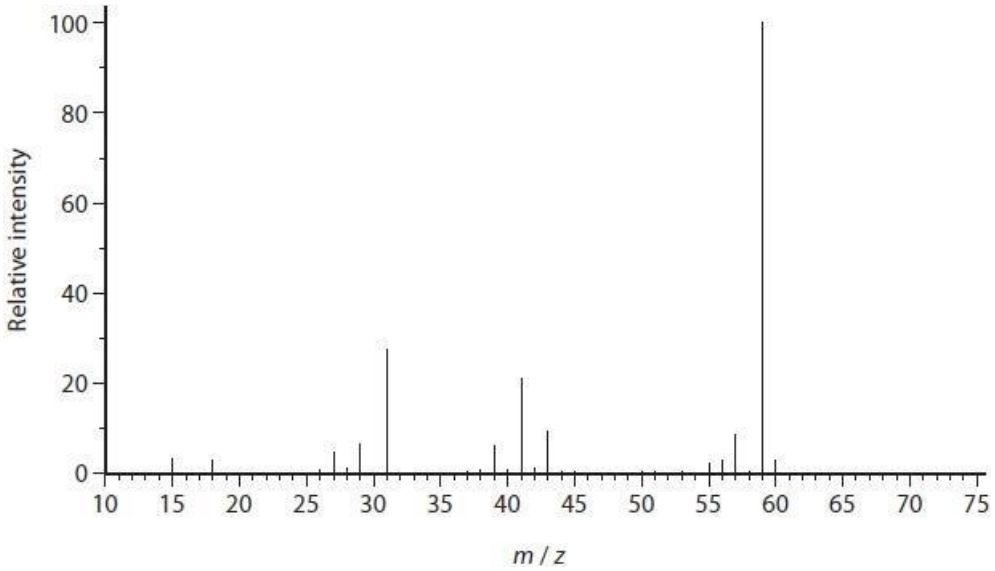
Q12.

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)

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(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)

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(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)

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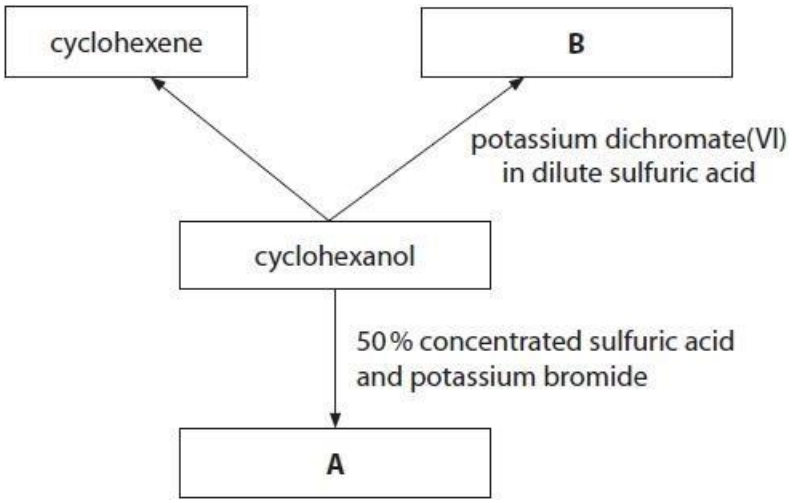
(Total for question = 10 marks)

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)

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(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)

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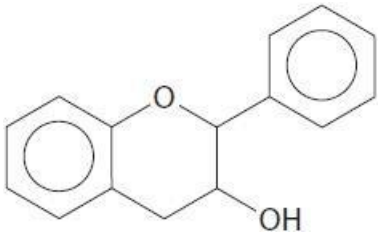
(Total for question = 9 marks)

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.

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(Total for question = 6 marks)

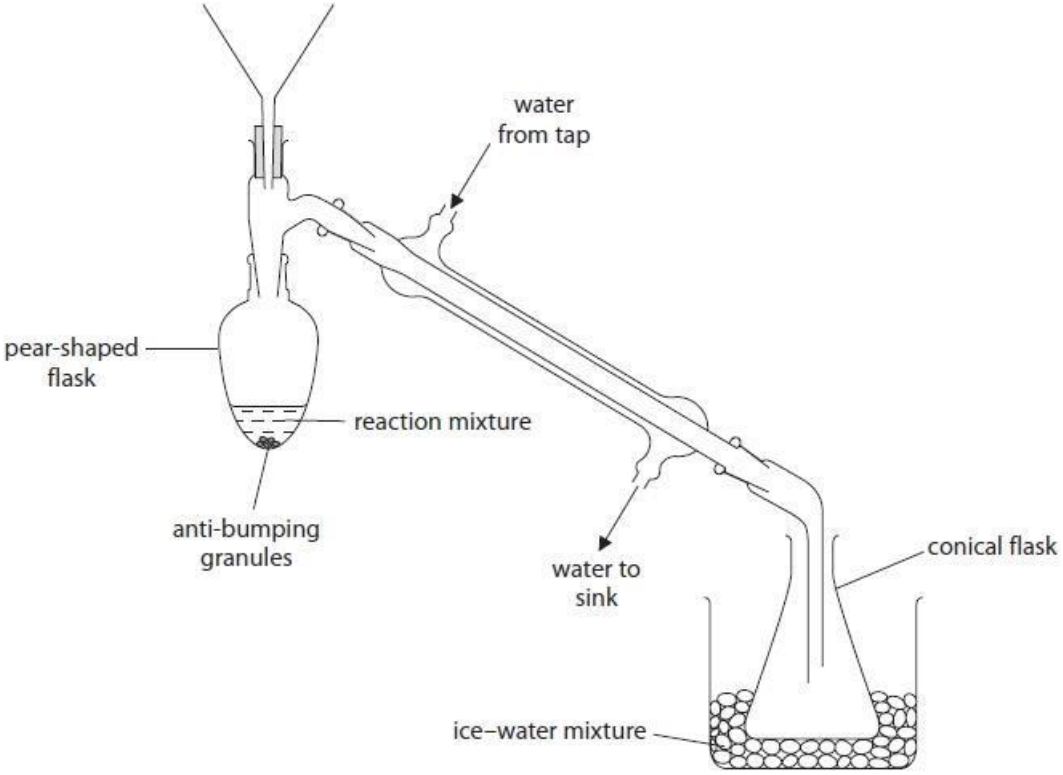
Q16.

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)

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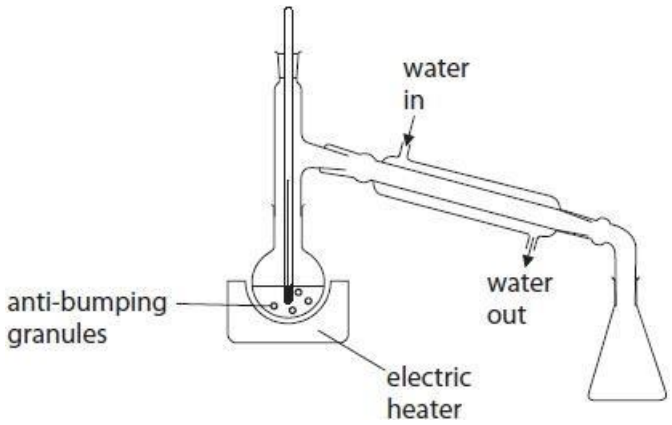
(c) Which **one** of these anhydrous compounds may be used as a drying agent in **Step 6**?

(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)

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

(1)

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(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

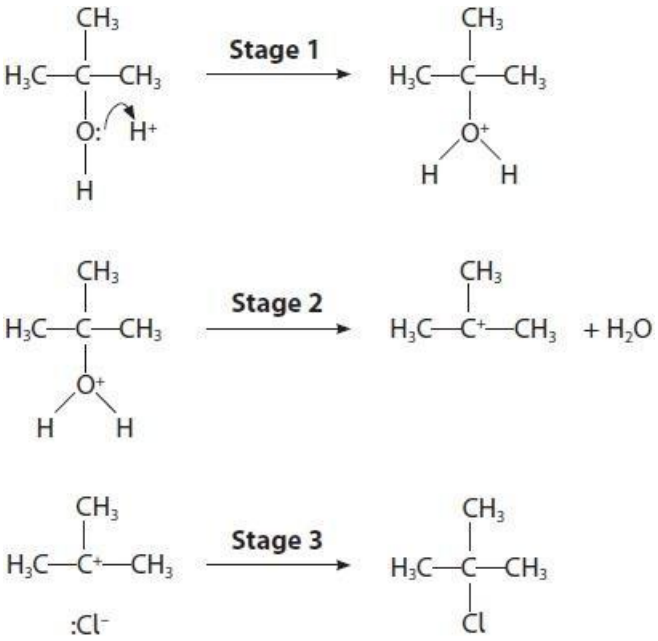
$$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$$

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.

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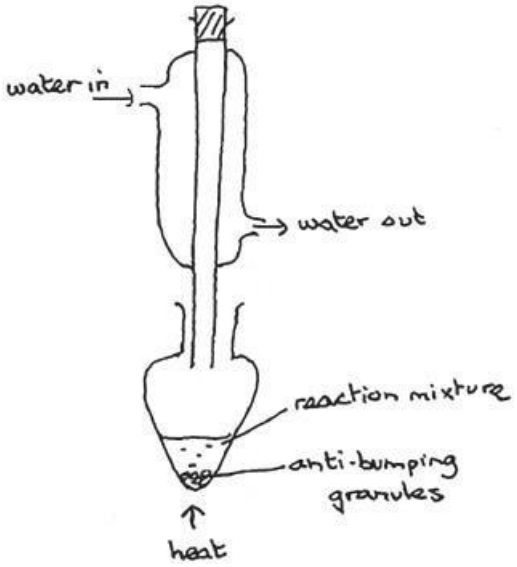
(ii) A student drew a diagram of the apparatus used for heating under reflux in Step **4**.
There are three errors in the apparatus shown in the diagram.
Assume the apparatus is suitably clamped.



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

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(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.

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(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)

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(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)

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

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(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)

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(Total for question = 1 mark)

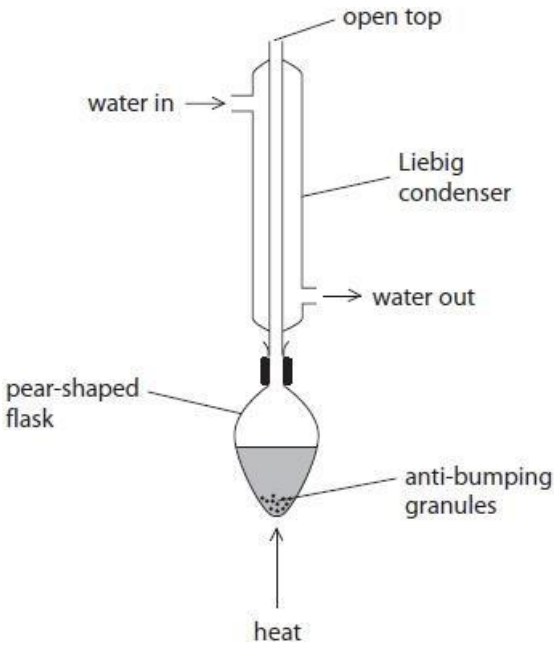
Q20.

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)

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(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)

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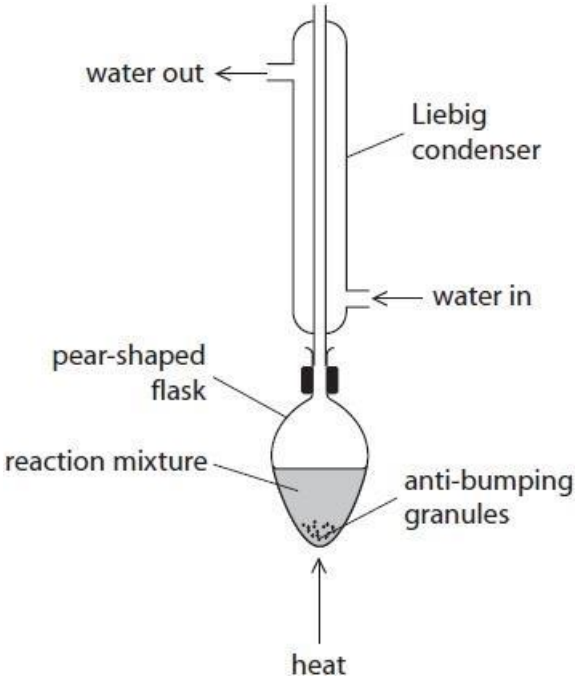
(Total for question = 3 marks)

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)

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(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)

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(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.

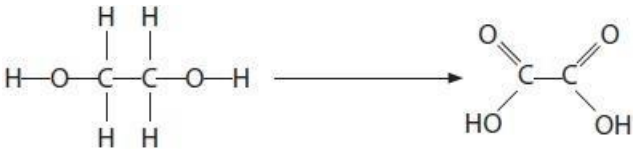
(3)

(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

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Condition

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(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)

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(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)

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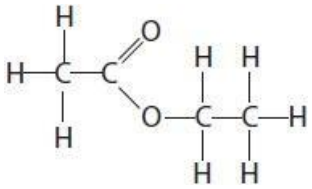
(Total for question = 14 marks)

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)

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(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)

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(Total for question = 1 mark)

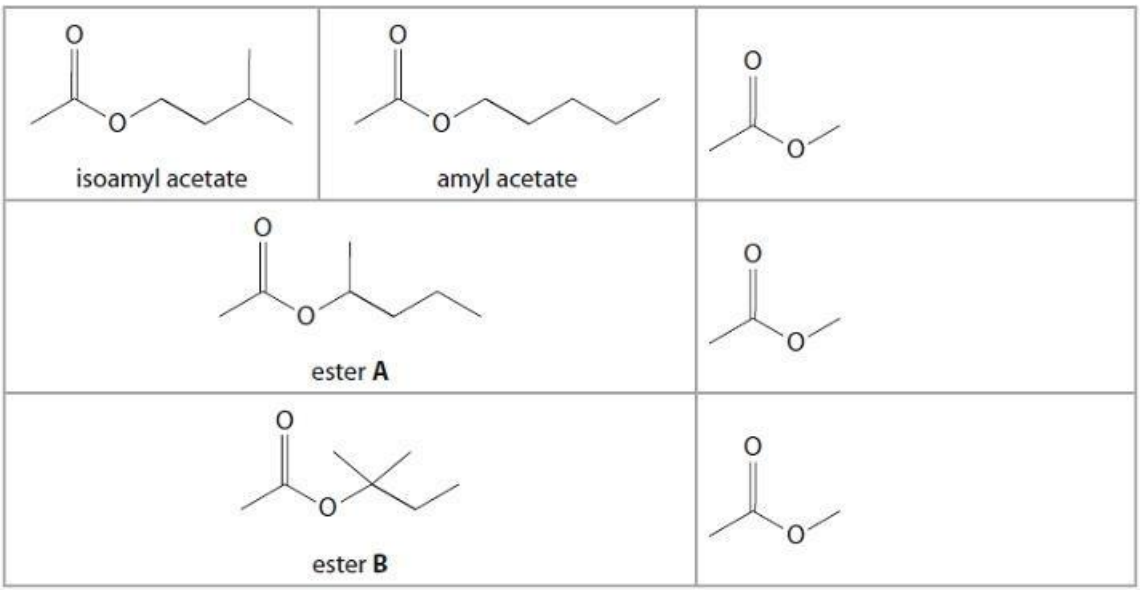
Q26.

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)