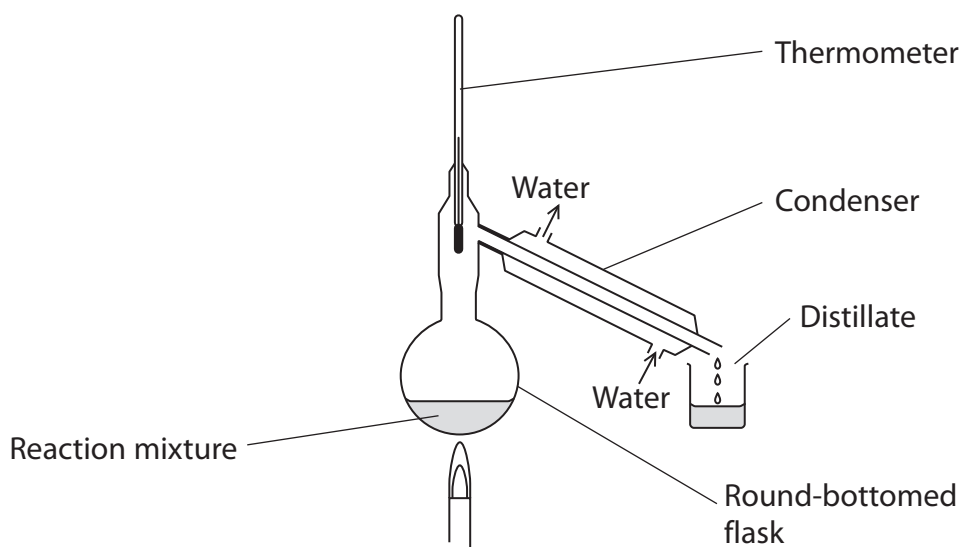


1 Ethane-1,2-diol,  $\text{CH}_2\text{OHCH}_2\text{OH}$ , is commonly used in antifreeze for cars to lower the freezing temperature of the water in the car radiator. It reacts in a similar way to ethanol but both of the alcohol groups can react.

(a) Write an equation for the **complete** reaction between sodium and ethane-1,2-diol. State symbols are **not** required.

(2)

(b) Ethane-1,2-diol is very quickly oxidized to ethanedioic acid,  $(\text{COOH})_2$ , even under the conditions shown below.



However, ethanol requires stronger oxidizing conditions to be converted into ethanoic acid.

Explain how you would change the above apparatus to achieve this oxidation of ethanol.

(2)

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(c) Draw the **skeletal** formula of ethanedioic acid.

(1)

(d) Explain why phosphorus(V) chloride,  $\text{PCl}_5$ , would not be a suitable reagent to be used to distinguish between ethane-1,2-diol and ethanedioic acid.

(1)

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- (e) (i) Depending on the reaction conditions, ethanol can be oxidized to either an aldehyde or to carboxylic acid. Infrared spectroscopy is a suitable technique for determining whether the oxidation product obtained is an aldehyde or a carboxylic acid.

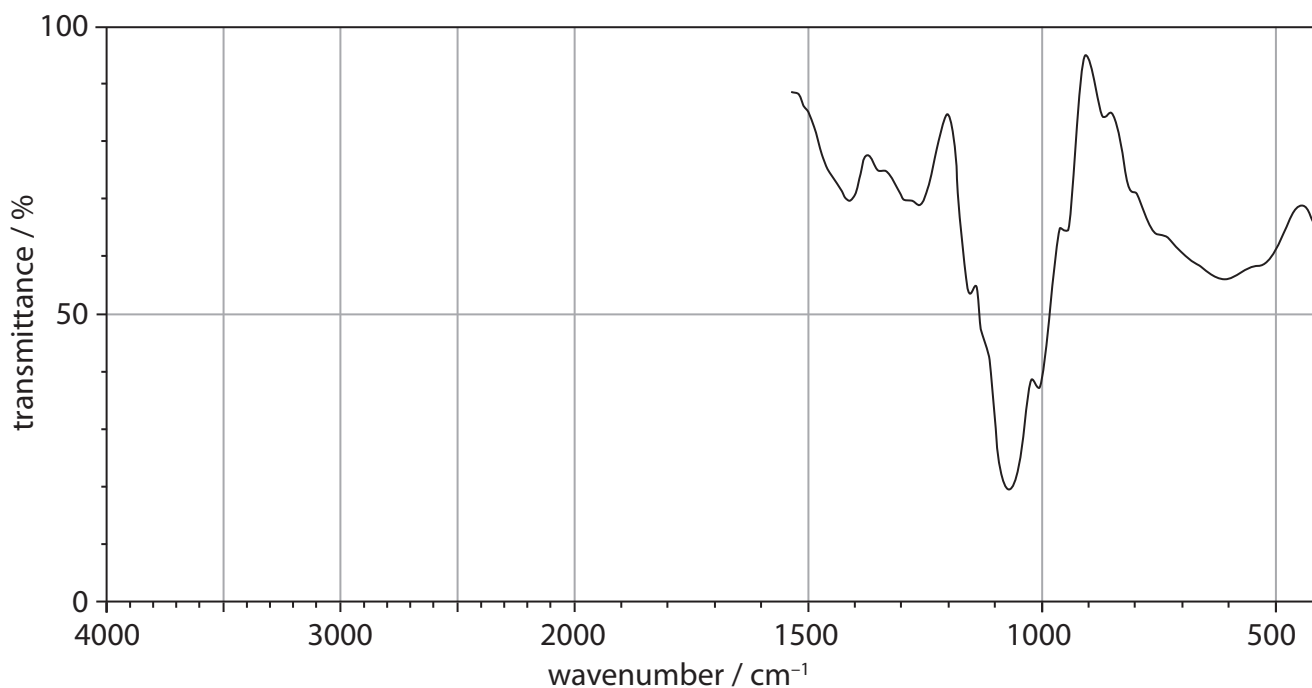
Draw, on the spectrum below, any peak(s) that you would expect to see between 4000 and 1500  $\text{cm}^{-1}$  if the product was an aldehyde and **not** a carboxylic acid.

(2)

### DATA

The IR absorption ranges associated with some organic functional groups are given below:

O—H stretching in alcohols (variable, broad) at	3750 – 3200 $\text{cm}^{-1}$
O—H stretching in carboxylic acids (weak) at	3300 – 2500 $\text{cm}^{-1}$
C=O stretching in aldehydes (strong) at	1740 – 1720 $\text{cm}^{-1}$
C=O stretching in ketones (strong) at	1700 – 1680 $\text{cm}^{-1}$
C=O stretching in carboxylic acids, alkyl (strong) at	1725 – $\text{cm}^{-1}$
C—H stretching in aldehydes (weak) at	2900 – 2820 $\text{cm}^{-1}$
and (weak) at	2775 – 2700 $\text{cm}^{-1}$



- (ii) The infrared spectrum of the distillate from the reaction in (e)(i) included a peak at 3750–3200  $\text{cm}^{-1}$ .

What substance is likely to have caused this?

(1)

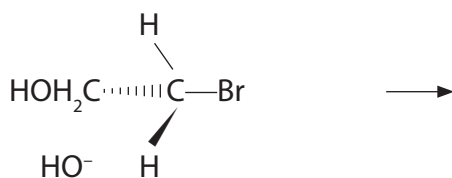
(iii) Mass spectrometry can be used to identify the products of the oxidation of ethanol. Suggest the formula of a fragment that would show when **ethanoic acid** is produced and would not be present in either ethanol or ethanal.

(1)

(f) Treatment of 2-bromoethanol,  $\text{CH}_2\text{BrCH}_2\text{OH}$ , with aqueous sodium hydroxide would be one way to produce ethane-1,2-diol.

(i) Complete a possible mechanism for this reaction in the space below.

(3)



(ii) Classify the mechanism and type of reaction in (f)(i):

(2)

Mechanism.....

Type.....

(g) Aqueous silver nitrate can be used to test for the presence of bromide ions. Write an ionic equation for the reaction. Include **state symbols** in your answer.

(2)

Ionic Equation

\*(h) It can be difficult to distinguish between the colours of the silver halides. The use of solutions of ammonia can be very helpful.

A silver halide dissolved in concentrated ammonia to form a colourless solution.

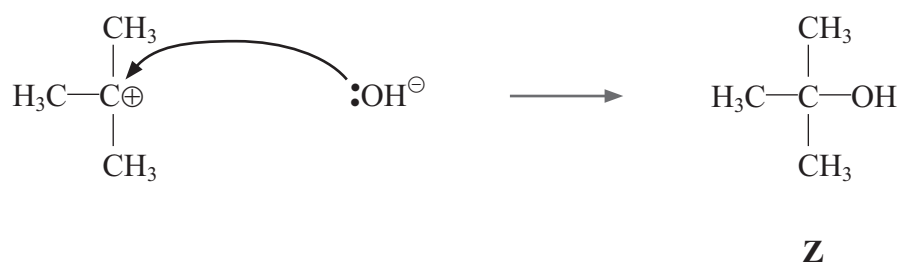
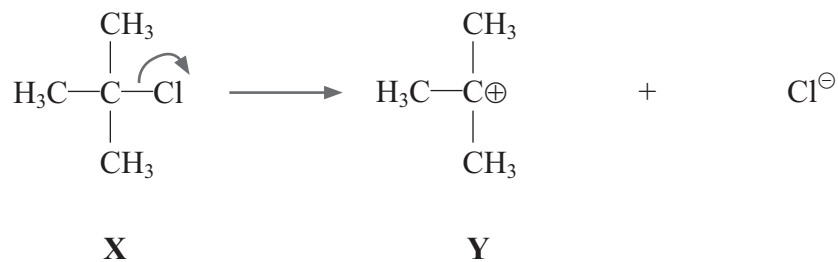
Explain why this result does not prove conclusively that the silver halide was silver bromide and give a further test to confirm that the silver halide is silver bromide.

(2)

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.....  
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**(Total for Question = 19 marks)**

2 The steps below show the reaction mechanism for the reaction of a halogenoalkane with sodium hydroxide in aqueous solution to form an alcohol.



(a) (i) Name **X** and **Z**.

(2)

**X** .....

**Z** .....

(ii) Draw the **skeletal** formula of **X**.

(1)

(iii) What type of alcohol is **Z**?

(1)

.....

(b) (i) Name the mechanism and type of reaction shown above.

(2)

.....  
(ii) Explain what the curly arrows shown in the mechanism represent.

(1)

.....  
\* (iii) Suggest the shape of the intermediate Y. Explain your answer.

(3)

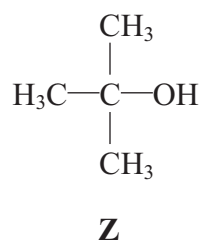
.....  
(iv) If the reaction is carried out in alcoholic (ethanolic) rather than aqueous solution, a different type of reaction occurs and a different product is formed. Name the type of reaction that occurs in alcoholic (ethanolic) solution and identify the product by name or formula.

(2)

Type of reaction.....

Product

- (c) The alcohol **Z** (shown below) resists oxidation. However, **Z** has three structural isomers which are readily oxidized. On complete oxidation, one isomer forms a ketone and the other two isomers form carboxylic acids.



- (i) Draw the structural formula of the isomer of **Z** that forms a ketone.

(1)

- (ii) Draw the structural formulae of the isomers of **Z** that form carboxylic acids.

(2)

(Total for Question 15 marks)

3 This question is about methanol,  $\text{CH}_3\text{OH}$ , and ethanol,  $\text{CH}_3\text{CH}_2\text{OH}$ .

(a) (i) Draw a dot and cross diagram for **methanol**, showing outer electrons only.

(1)

(ii) Give the approximate values for the HCH and COH bond angles in methanol. Justify your answers.

(4)

HCH angle .....

Justification .....

.....

.....

COH angle .....

Justification .....

.....

.....

(iii) Using displayed formulae, draw a diagram to show a hydrogen bond between two methanol molecules. On your diagram, show the bond angle around the hydrogen atom of the hydrogen bond and give its value.

(2)



(b) Methanol reacts with sodium.

(i) State what you would observe in this reaction.

(2)

.....  
.....  
(ii) Write the equation for this reaction. State symbols are **not** required.

(1)

(c) **Ethanol** can be used to make ethanal.

(i) Identify, by name or formula, the two chemicals you would use to make ethanal from ethanol in the laboratory.

(2)

(ii) Draw a diagram of the apparatus you would use to prepare ethanal from ethanol in the laboratory and collect the product.

(2)

(iii) Both ethanal and propane have a molar mass of  $44 \text{ g mol}^{-1}$ , but their boiling temperatures are different.

Suggest which substance has the higher boiling temperature. Justify your answer by comparing the intermolecular forces in each compound.

(2)

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**(Total for Question 16 marks)**

4 Butan-1-ol and three other alcohols, **X**, **Y** and **Z**, are isomers.

(a) (i) Give TWO observations you would make when any one of the alcohols reacts with sodium.

(2)

(ii) Give the molecular formula of the organic product of the reaction.

(1)

(b) Isomer **X** does **not** react with a mixture of potassium dichromate(VI) and sulfuric acid.

Draw the displayed formula of **X** and name it.

(2)

Name

(c) When isomer **Y** is heated under reflux with a mixture of potassium dichromate(VI) and sulfuric acid, it forms 2-methylpropanoic acid.

Deduce the structural formula of the alcohol **Y**.

(1)

- (d) (i) Isomer **Z** reacts with a mixture of potassium dichromate(VI) and sulfuric acid to form a compound **Q**, which does **not** react with Fehling's or Benedict's solution.

Deduce the structural formula of the alcohol **Z**.

(1)

- (ii) What would be the principal difference between the infrared spectrum of **Q** and the infrared spectrum of 2-methylpropanoic acid?

You are **not** expected to quote absorption values.

(1)

- (e) One of the isomers, **X**, **Y** or **Z** can be converted to 2-chlorobutane.

What reagent would you use to carry out this conversion?

(1)

- (f) (i) 2-chlorobutane reacts with silver nitrate in a mixture of ethanol and water as a solvent. What would you see when the reaction occurred?

(1)

- \*(ii) Both ethanol and water contain hydrogen bonds. By considering the hydrogen bonding on these two solvents, suggest why 2-chlorobutane is more soluble in ethanol than in water.

(2)

**(Total for Question = 12 marks)**