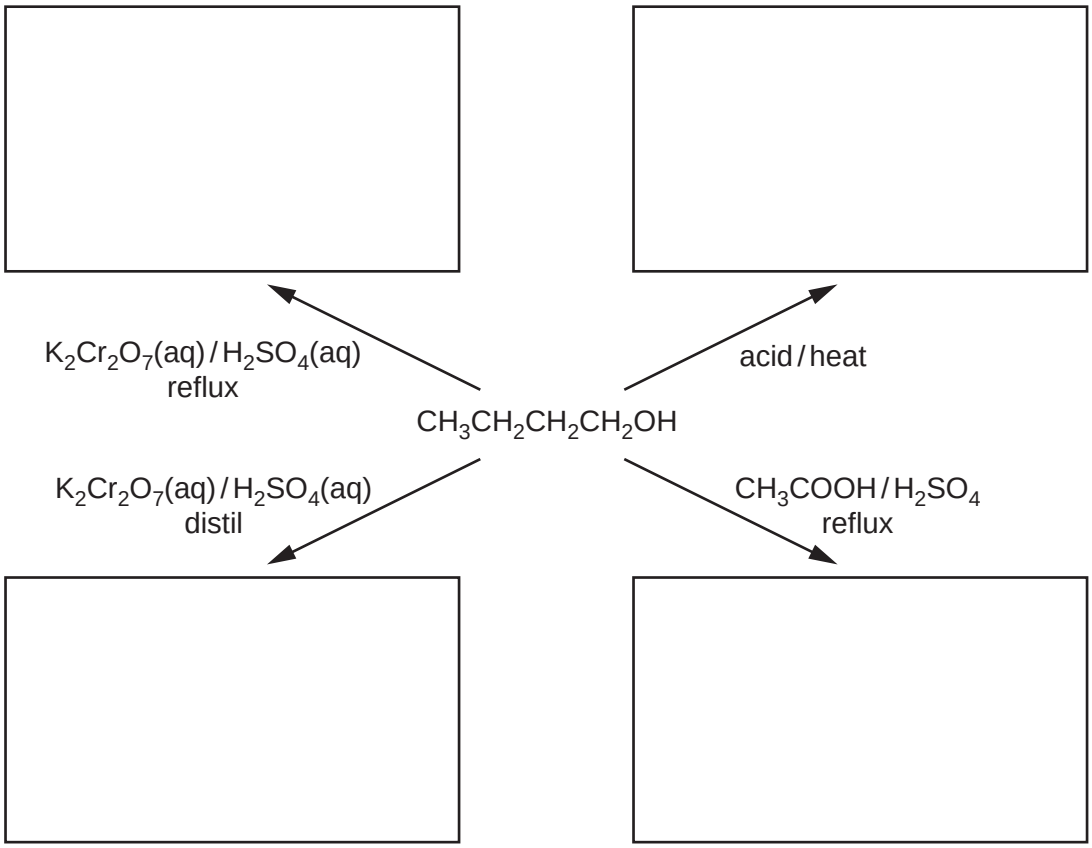
1 Alcohols are used in the industrial production of many organic compounds.

(a) Complete the flowchart below to show the organic product formed in each of the reactions of butan-1-ol.



[4]

(b) Butan-1-ol can be prepared by the alkaline hydrolysis of 1-iodobutane.

$$CH_3CH_2CH_2CH_2I + OH^- \longrightarrow CH_3CH_2CH_2CH_2OH + I^-$$

The reaction mixture is gently heated for 20 minutes.

(i) The curly arrow model is used in reaction mechanisms to show the movement of electron pairs.

Use the curly arrow model to outline the mechanism for the alkaline hydrolysis of 1-iodobutane.

In your answer, include the name of the mechanism, the type of bond fission and relevant dipoles.

name of mechanism .....

type of bond fission ..... **[5]**

(ii) A student decides to prepare butan-1-ol by the alkaline hydrolysis of 1-chlorobutane.

Suggest, with reasons, any change in the conditions from those used in the alkaline hydrolysis of 1-iodobutane.

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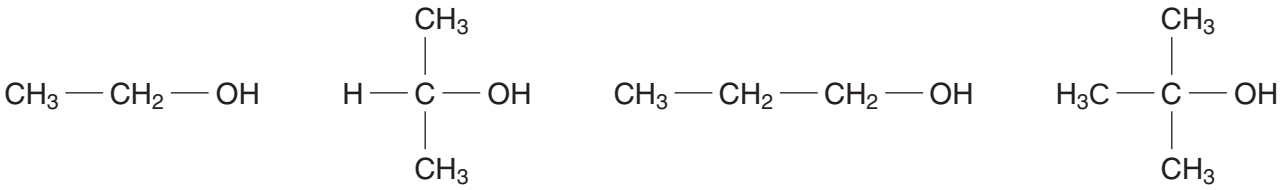
..... **[2]**

[Total: 11]

2 Alcohols **A**, **B**, **C** and **D** are shown below.



A **B** **C** **D**

(a) Compound **A** is ethanol, a very useful alcohol.

Identify the two main methods used in the industrial production of ethanol.
Write an equation for each method.

method 1 .....

.....

equation .....

method 2 .....

.....

equation ..... **[4]**

(b) A student heated each alcohol, **A**–**D**, with acidified potassium dichromate(VI) as the oxidising agent. With alcohols **A**, **B** and **C**, the colour turned from orange to green.

(i) Identify the organic product and write a balanced equation for the reaction of alcohol **B** with acidified potassium dichromate(VI).

Use [O] to represent the oxidising agent, acidified potassium dichromate(VI).

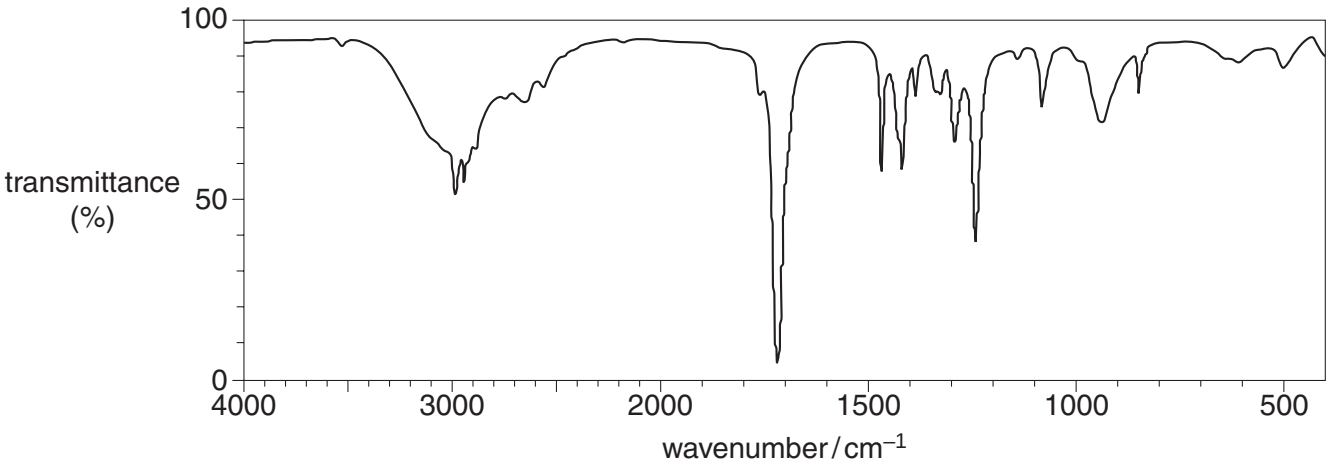
organic product:

balanced equation:

[2]

(ii) The organic product obtained from **C** was analysed by infrared (IR) spectroscopy.

The IR spectrum of the product is shown below.



Use your *Data Sheet* to identify the organic product. Explain your reasoning.

organic product:

reasoning .....

.....

..... **[3]**

(c) The student heated alcohol **D** with ethanoic acid in the presence of an acid catalyst. An organic product **E** was formed with a fruity smell.

(i) Name alcohol **D**.

..... **[1]**

(ii) Name the functional group in the organic product **E**.

..... **[1]**

(iii) Draw the structure of the organic product **E**.

[2]

[Total: 13]

3 Butyl ethanoate is an ester used as a flavouring.
This ester can be synthesised from butan-1-ol by two different processes.

Process 1 is a one-step process that involves a reversible reaction.

$$CH_3CH_2CH_2CH_2OH + CH_3COOH \rightleftharpoons CH_3COOCH_2CH_2CH_2CH_3 + H_2O$$

The percentage yield for **process 1** is 67.1%.
The atom economy for **process 1** is 86.6%.

Process 2 is a two-step process.

$$CH_3COOH + SOCl_2 \rightarrow CH_3COCl + SO_2 + HCl$$

$$CH_3CH_2CH_2CH_2OH + CH_3COCl \rightarrow CH_3COOCH_2CH_2CH_2CH_3 + HCl$$

The overall percentage yield for **process 2** is 93.3%.
The overall atom economy for **process 2** is 45.8%.

(a) Draw the skeletal formula for the ester butyl ethanoate.

[1]

(b) Show that the atom economy for **process 1** is 86.6%.

[2]

(c) A research chemist investigates **process 1**.
She finds that 6.25 g of butan-1-ol forms 6.57 g of butyl ethanoate.

(i) Suggest the conditions needed for this reaction.

.....

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..... **[2]**

(ii) Show that the percentage yield of **process 1** is 67.1%.

[2]

(d) Explain why **process 2** has a high percentage yield but a low atom economy.

.....

.....

.....

.....

..... **[2]**

(e) Suggest **two** reasons why butyl ethanoate is manufactured by **process 1** rather than by **process 2**.

.....

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.....

..... **[2]**

[Total: 11]