

Organic 2 – Alcohols, Carboxylic acids and Esters

Mark Scheme



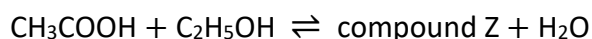
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1. Alcohols, a family of compounds containing an -OH group, react with weak organic acids known as carboxylic acids to produce esters, which are often responsible for the sweet and fruity aromas in foods and perfumes. Circle the letter of the correct answer for each of the following questions.

- a. What type of compound is shown below.

D – is the only correct answer.	1 mark
	Total: 1 mark

- b. The equation shows the reaction between an alcohol and a carboxylic acid.



What is the name of the ester, compound Z?

B – is the only correct answer.	1 mark
	Total: 1 mark

- c. The table shows four molecular structures.

Which row **correctly** identifies the homologous series for the structure shown?

B – is the only correct answer.	1 mark
	Total: 1 mark

- d. Which statements about the ester ethyl ethanoate are correct?

D – is the only correct answer.	1 mark
	Total: 1 mark

- e. The figures below show different organic compounds. Which structure shows butanoic acid?

B – is the only correct answer.	1 mark
	Total: 1 mark

- f. The figure below shows the structure of an ester.

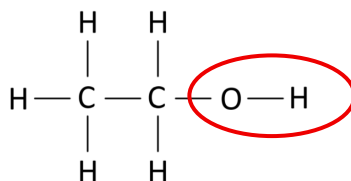
What are the names of the carboxylic acid and the alcohol that react together to form this ester?

C – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 6 marks)

2. Ethanol, propanol, and butanol are alcohols with different chain lengths.

Look at the displayed formula of ethanol.



- a. Draw a **ring** around the functional group of ethanol.

A ring to be clearly visible around the OH group. As shown above.	1 mark
	Total: 1 mark

- b. Ethanol can be produced by the hydration of ethene.

- i. State the conditions required for this reaction to occur industrially.

Any two from:	
• High temperature. • High pressure. • Catalyst / Phosphoric acid. • Steam.	
	Total: 2 marks

- ii. Explain why ethene is described as unsaturated.

It contains a (carbon-carbon) double bond / C=C.	1 mark
	Total: 1 mark

- c. Alcohols have the general formula $\text{C}_n\text{H}_{2n+2}\text{O}$.

- i. A molecule of propanol contains 3 carbon atoms. State the molecular formula of propanol.

$\text{C}_3\text{H}_7\text{OH}$	1 mark
	Total: 1 mark

- ii. Draw the displayed formula of **butanol**, showing all the atoms and bonds.

$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{O}-\text{H} \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array} $	
Award 1 mark for four carbon atoms linked in a chain.	
Award 1 mark for rest of the diagram correct.	
Award 1 mark for all covalent bonds shown correctly.	
Award 1 mark for the bond from the carbon must attach to the oxygen.	
	Total: 2 marks

(Total for Question 2 is 7 marks)

3. Ethanol is an important alcohol with many industrial uses.

It is manufactured by reacting ethene with steam in a process called hydration.

- a. Write a **balanced** chemical equation for the hydration of ethene to produce ethanol.

$C_2H_4 + H_2O \rightarrow C_2H_5OH$	2 marks
Award one mark for the correct formulae.	
Award one mark for the correct balancing.	
	Total: 2 marks

- b. State the conditions used for this industrial process.

Any two from:	
- Temperature of 300 °C - Pressure of 60 – 70 atmospheres - Phosphoric acid catalyst	
	Total: 2 marks

- c. A chemical plant uses 112 kg of ethene (C_2H_4) to produce ethanol (C_2H_5OH).
Calculate the maximum theoretical mass of ethanol that can be produced from 112 kg of ethene.
Relative atomic masses (A_r): H = 1, C = 12, O = 16.

Step 1: Calculate Mr of ethene and ethanol. Ethene $C_2H_4 = 28$ Ethanol (C_2H_5OH) = 46	1 mark
Step 2: Calculate moles. $112,000 \div 28 = 4000 \text{ mol}$	1 mark
Step 3: Calculate theoretical mass. $4000 \times 46 = 184,000 \text{ (g)}$	1 mark
Step 4: Conversion of grams to kilograms. $184,000 \div 1000 = 184 \text{ kg}$	1 mark
	Total: 4 marks

- d. In the reaction, the actual mass of pure ethanol produced was 174.8 kg.

- i. Calculate the percentage yield of ethanol.
(Use your answer from part (c) in this calculation.)

$(174.8 \div 184) \times 100$	1 mark
= 95 %	1 mark
	Total: 2 marks

ii. Suggest **two** reasons why the actual yield is less than the theoretical maximum.

Any two from:	
• The reaction is reversible (so does not go to completion) • Some product is lost when separated / collected. • Side reactions occur (producing other products).	
	Total: 2 marks

e. Evaluate the two methods for the industrial production of ethanol.

Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple statements are made comparing the processes (for example "hydration is faster" or "fermentation uses plants"). No valid conclusion is made.
Level 2	3 - 4	Attempts to evaluate both methods, citing relevant points from the table (for example rate, purity, or raw materials). The link to "large-scale" may be weaker. A conclusion is offered but may not be fully justified
Level 3	5 - 6	A detailed and coherent evaluation is provided. Advantages and disadvantages of both methods are considered, linked to the specific context of "large-scale manufacturing". A logical conclusion is drawn based on the evidence.

Indicative content:	
Hydration advantages: • Continuous process allows for efficient, large-scale automation. • Fast rate of reaction produces ethanol quickly. • Product is pure (no need for fractional distillation, saving energy/money). • 100% atom economy means less waste. Hydration disadvantages: • Uses finite resources (crude oil). • High temperature and pressure require expensive equipment and high energy costs. Fermentation advantages: • Uses renewable resources (sugar cane / plants). • Low temperature requires less energy for heating. Fermentation disadvantages: • Batch process is labour intensive and inefficient for very large scale. • Slow rate of reaction. • Product is impure (requires distillation). • Low atom economy (waste CO₂ produced). Conclusion: Hydration is better for large-scale UK manufacturing because it is a continuous, fast process that produces pure ethanol efficiently, whereas fermentation is slow, labour-intensive (batch), and produces impure ethanol.	
	Total: 6 marks

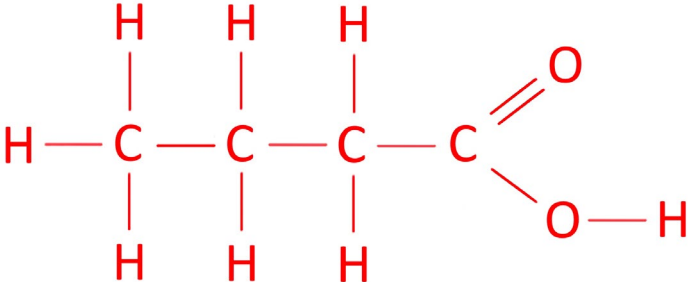
(Total for Question 3 is 18 marks)

4. Ethanoic acid can be made by the oxidation of ethanol.
It is a member of the carboxylic acid homologous series.

a. State the functional group of a carboxylic acid.

-COOH.	1 mark
Allow carboxyl group and allow the displayed formula.	
	Total: 1 mark

b. Draw the displayed formula of the carboxylic acid containing four carbon atoms.
Show all of the atoms and all of the bonds.

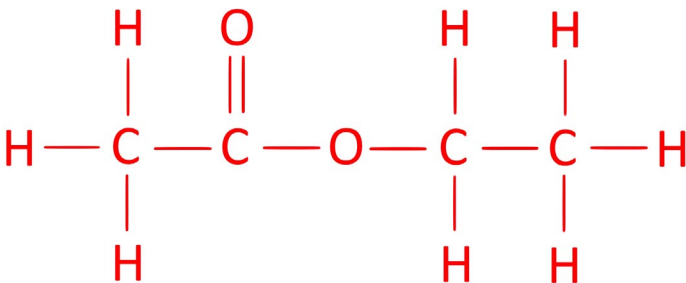
	
Allow any correct versions of the above diagram.	
Award 1 mark for the correct atoms.	1 mark
Award 1 mark for the correct bonds.	1 mark
	Total: 2 marks

c. Carboxylic acids react with alcohols in the presence of an acid catalyst to produce esters and water.
Ethanoic acid reacts with ethanol.

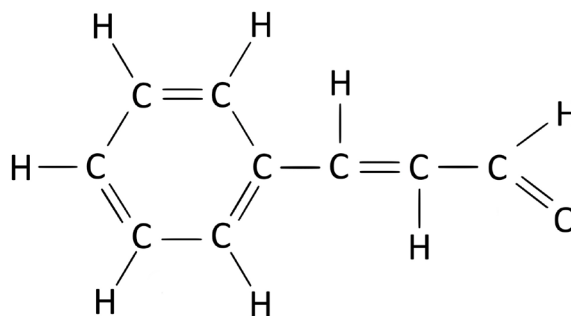
i. Name the ester produced in this reaction.

Ethyl ethanoate.	1 mark
	Total: 1 mark

ii. Draw the displayed formula of the ester formed when ethanoic acid reacts with ethanol.

	
Allow any correct versions of the above diagram.	
Award 1 mark for correct ethyl and methyl groups attached to the correct sides.	1 mark
Award 1 mark for the correct ester link.	1 mark
	Total: 2 marks

Toothpaste contains cinnamal. Cinnamal is the organic compound that gives cinnamon its characteristic warm, spicy, and slightly sweet aroma and flavour. It is widely used as a flavouring agent in a vast range of products. The structure of cinnamal is shown.



Cinnamal can be oxidised to form a carboxylic acid.

- d. Draw the displayed formula of the **carboxylic acid functional group**. Show all atoms and all bonds.

	1 mark
Allow any correct versions of the above diagram.	
1 mark for C=O double bond	1 mark
mark for O-H bond attached to the same carbon.	1 mark
	Total: 2 marks

- e. A student adds sodium carbonate powder to a solution of ethanoic acid. A chemical reaction occurs.

- i. Describe **one** thing the student would observe.

Fizzing / bubbling / effervescence.	1 mark
Allow: gas produced.	
	Total: 1 mark

- ii. State the **three** products formed in this reaction.

Award 1 mark for each of the following products.	
Sodium ethanoate.	1 mark
Water.	1 mark
Carbon dioxide.	1 mark
	Total: 3 marks

(Total for Question 4 is 12 marks)

5. Methanoic acid is the first member of the homologous series of carboxylic acids.

a. Give **three** characteristics of a homologous series.

Any three from the following:	
• Same general formula. • Same functional group. • Similar chemical properties / reactions. • Gradation in physical properties (e.g. boiling points). • Each successive member differs by a $-\text{CH}_2$ unit.	
	Total: 3 marks

b. Methanoic acid is the simplest carboxylic acid. It is often used in household products to remove limescale.

Methanoic acid (HCOOH) is the first member of the carboxylic acid homologous series.

i. The fourth member of this series is butanoic acid. State its molecular formula.

$\text{C}_4\text{H}_8\text{O}_2$	1 mark
Allow any correct version of the formula for butanoic acid.	
	Total: 1 mark

ii. Determine the empirical formula of butanoic acid.

$\text{C}_2\text{H}_4\text{O}$	1 mark
Allow any correct version of the empirical formula for butanoic acid.	
	Total: 1 mark

c. A kettle is coated with 5.0 g of limescale, which is calcium carbonate (CaCO_3). Methanoic acid is added to remove it.

i. Write a balanced chemical equation for the reaction between methanoic acid and calcium carbonate.

Accept either of the following equations: $2\text{CH}_2\text{O}_2 + \text{CaCO}_3 \rightarrow \text{C}_2\text{H}_2\text{O}_4\text{Ca} + \text{H}_2\text{O} + \text{CO}_2$ $2\text{HCOOH} + \text{CaCO}_3 \rightarrow (\text{HCOO})_2\text{Ca} + \text{H}_2\text{O} + \text{CO}_2$	
Award 1 mark for the correct formulae of reactants and products.	1 mark
Award 1 mark for correct balancing.	1 mark
	Total: 2 marks

- ii. Calculate the minimum mass of methanoic acid required to completely remove 5.0 g of calcium carbonate from the kettle.

Step 1: Calculate Mr of calcium carbonate and methanoic acid.	
$\text{CaCO}_3 = 100$ $\text{HCOOH} = 46$	1 mark
Step 2: Calculate mass of CaCO_3.	
Moles of $\text{CaCO}_3 = 5.0 \div 100 = 0.05$	
Mol ratio is 1 : 2	
Moles of methanoic acid = $0.05 \times 2 = 0.10$	
Mass of methanoic acid = $0.1 \times 46 = 4.6 \text{ (g)}$	1 mark
	Total: 2 marks

- d. Carboxylic acids react with metals.

- i. Name the two products formed when zinc reacts with methanoic acid.

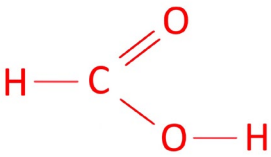
Zinc methanoate.	1 mark
Hydrogen	1 mark
	Total: 2 marks

- ii. Aluminium is more reactive than zinc.

Suggest why methanoic acid can be used **safely** in an aluminium kettle without the kettle dissolving.

Methanoic acid is a weak acid / only partially ionised or partially dissociates.	1 mark
Allow low concentration of H^+ ions.	
	Total: 1 mark

- iii. Draw the structural formula of methanoic acid, showing all the bonds.

	
Award 1 mark for the $\text{C}=\text{O}$ bond.	1 mark
Award 1 mark O-H bond attached to C and H attached to C.	1 mark
	Total: 2 marks

- e. An ester is produced by warming propanol with methanoic acid in the presence of an acid catalyst.

- i. Name the ester formed in this reaction.

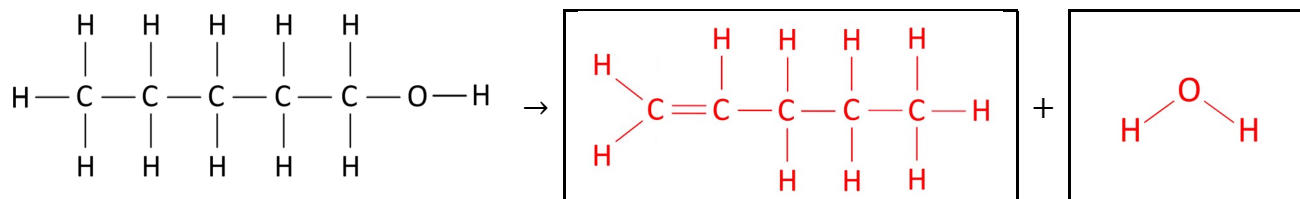
Propyl methanoate.	1 mark
	Total: 1 mark

- ii. Complete the word equation for this reversible reaction.

Propyl methanoate	1 mark
Water	1 mark
	Total: 2 marks

(Total for Question 5 is 17 marks)

6. Alcohols can be dehydrated to produce useful products.
- a. Complete the balanced equation for the dehydration of pentan-1-ol by drawing the **structures** of the two products in the boxes provided.



Award 1 mark for the correct structure of pentene.	1 mark
Award 1 mark for the correct structure of water.	1 mark
	Total: 2 marks

- b. Name the **two** products formed from the dehydration of pentan-1-ol.

Pentene	1 mark
Water	1 mark
	Total: 2 marks

- c. In an experiment, a student dehydrates 13.2 g of pentan-1-ol.

- i. Calculate the maximum theoretical mass of pentene (C_5H_{10}) that can be produced.
(Relative atomic masses: H = 1, C = 12, O = 16)

Step 1: Calculate the Mr of pentan-1-ol and pentene. Mr of pentan-1-ol (C_5H_{12}) = 88 Mr of pentene (C_5H_{10}) = 70	1 mark
Step 2: Calculate moles of pentan-1-ol $13.2 \div 88 = 0.15 \text{ (mol)}$ Marking note the molar ratio is 1:1 therefore the moles of pentene is also 0.15 mol.	1 mark
Step 3: Calculate the mass of pentene: $0.15 \times 70 = 10.5 \text{ (g)}$	1 mark
	Total: 3 marks

- ii. The student collected 8.4 g of pure pentene.
Calculate the percentage yield for this experiment.

$(8.4 \div 10.5) \times 100$	1 mark
$= 80 \text{ (\%)}$	1 mark
	Total: 2 marks

(Total for Question 6 is 9 marks)