EXAM PAPERS PRACTICE

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Detailed mark scheme

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Level: CIE A & AS Level Chemistry (9701)
Subject: Chemistry
Topic: A & AS Chemistry
Type: Mark Scheme

Chemistry CIE A & AS Level
To be used for all exam preparation for 2025+

CHEMISTRY A & AS

Key skills

Mark Scheme

Answer 1.

a) The completed table is:

Carboxylic Acid	Alcohol	Ester
ethanoic acid	methanol; [1 mark]	methyl ethanoate
propanoic acid; [1 mark]	ethanol	ethyl propanoate
butanoic acid	propan-1-ol	propyl butanoate; [1 mark]

[Total: 3 marks]

- **Remember:** When naming an ester, the alcohol provides the first part of the name, and the carboxylic acid the second part of the name.

b) The conditions needed to form an ester by reacting an alcohol and carboxylic acid together are:

- Conc sulfuric acid catalyst; [1 mark]
- Heat under reflux; [1 mark]

[2 marks]

- This is also called esterification
- You need to learn the conditions for this reaction

c) The conditions needed for this reaction are:

- Dilute acid / dilute sulfuric acid / dilute hydrochloric acid
  OR
  Dilute alkali / sodium hydroxide; [1 mark]
- Heat **AND** reflux; [1 mark]

[Total: 2 marks]

- Either the acid or alkali can be used but the reaction with dilute acid is reversible whereas the reaction with you can deduce one is for the reagents and another for the conditions

d) Esters are used in the manufacture of foods because:

- They have nice flavours/ fruity smells; [1 mark]

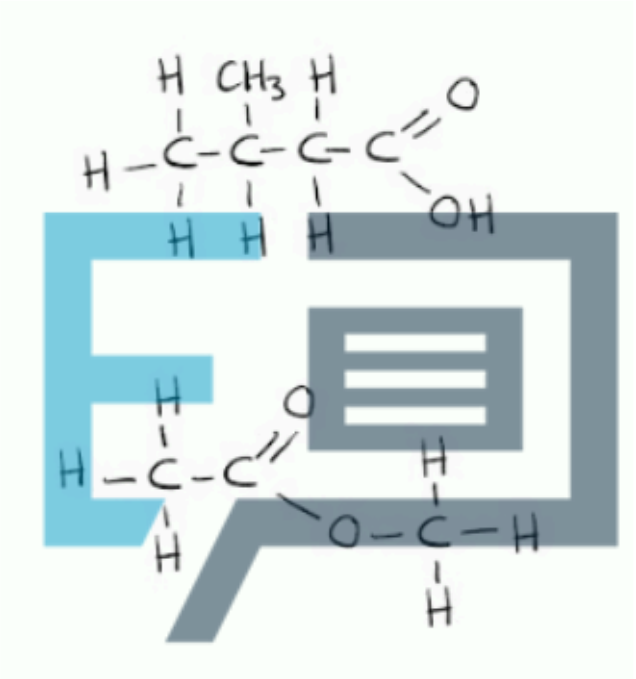
[Total: 1 mark]

- There are many other uses of esters including:
  - Perfumes
  - Glue
  - Nail Varnish
  - Solvents
  - Soaps

Answer 2.

a) The structures are:

The structures of 3–methylbutanoic acid and methyl ethanoate are:



- Correct displayed formula of 3–methylbutanoic acid; [1 mark]
- Correct displayed formula of methyl ethanoate; [1 mark]

[Total: 2 marks]

- **Remember:** When drawing carboxylic acids, the C of the COOH group is counted as the first carbon, so the methyl group goes on the H second from the left
- When drawing esters, such as methyl ethanoate,
  - The first part of the displayed formula indicates the ethanoate
  - The second part of the displayed formula indicates the methyl

b) The colour change that would occur during this reaction is:

- Orange to green; [1 mark]

[Total: 1 mark]

- The oxidising agent, $K_2Cr_2O_7$ gets reduced causing the solutions to change colour
  - The orange dichromate ions ($Cr_2O_7^{2-}$) are reduced to green Cr^{3+} ions

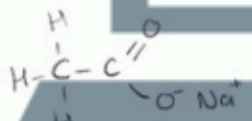
c) The products formed are:

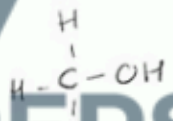
- Methanol
  AND
  Ethanoic acid; [1 mark]

[Total: 1 mark]

- When an ester is hydrolysed using dilute acid, the original carboxylic acid and alcohol is formed
- **Remember:** For an ester, the first part of the name comes from the alcohol, and the second part from the carboxylic acid

d) i) The salt and alcohol formed during alkaline hydrolysis are:





- Correct displayed formula for sodium ethanoate; [1 mark]
- Correct displayed formula for methanol; [1 mark]

ii) The salt is converted into the carboxylic acid by

- Adding dilute acid / dilute HCl / dilute H_2SO_4; [1 mark]

iii) One other difference between acid and alkaline hydrolysis is:

- An equilibrium is established in acidic hydrolysis
  OR
  Acid hydrolysis is a reversible reaction; [1 mark]

[Total: 4 marks]

- During acid hydrolysis, an equilibrium is established so there is always some ester present in addition to the carboxylic acid and alcohol

$$\text{methyl ethanoate} + \text{water} \rightleftharpoons \text{ethanoic acid} + \text{methanol}$$

- Alkaline hydrolysis is an irreversible reaction, producing the salt of the carboxylic acid and an alcohol

$$\text{methyl ethanoate} + \text{sodium hydroxide} \rightarrow \text{sodium ethanoate} + \text{methanol}$$

- The salt is then acidified to produce the carboxylic acid
- Alkaline hydrolysis is much quicker than acidic hydrolysis and is the basis of soap making

Answer 3.

i) The isomers are:

- A = 3,3–hydroxymethylbutanoic acid **OR** 3–hydroxy–3–methylbutanoic acid;
  AND
  B = 2,3–hydroxymethylbutanoic acid **OR** 2–hydroxy–3–methylbutanoic acid; [1 mark]

ii) A reagent to distinguish between the isomers and the type of reaction is:

- Acidified / H^+ / H_2SO_4
  AND
  (potassium) dichromate / $K_2Cr_2O_7$ / $Cr_2O_7^{2-}$
  OR
  Acidified / H^+ / H_2SO_4
  AND
  (potassium) manganate(VII) / $KMnO_4$ / MnO_4^- ; [1 mark]
- The reaction is oxidation; [1 mark]

iii) The observations in each case are:

Example 1 (with potassium dichromate)

- Isomer A has no change / no reaction; [1 mark]
- Isomer B changes the colour from orange to green; [1 mark]

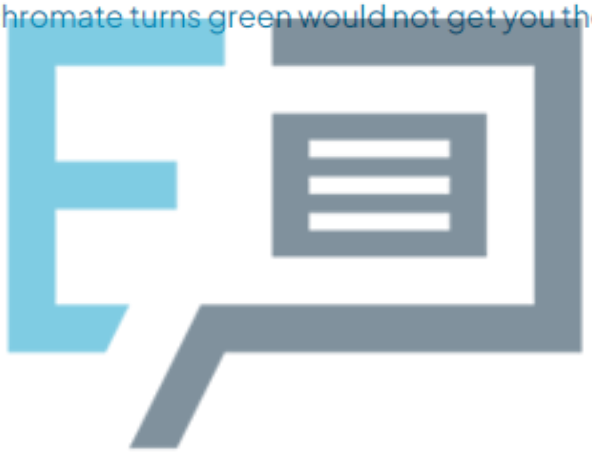
OR

Example 2 (with potassium manganate(VII))

- Isomer A has no change / no reaction; [1 mark]
- Isomer B changes the colour from purple to colourless; [1 mark]

[Total: 5 marks]

- Where there are two functional groups present naming priority is generally given to the functional group with the larger mass
  - In this case, the carboxylic acid takes priority over the hydroxyl group
  - Carbon groups are put together in the carbon 'skeleton' so the methyl group comes in front of the butanoic acid, not the hydroxyl group
- You need to know the test for an alcohol and the result, although the test will not work on all classes of alcohol as this question shows
- You must also state when there is no reaction, not just the positive result of a test
- Before and after colours are essential.
  - E.g., stating that dichromate turns green would not get you the mark



b)

ii) The overall redox reaction is:

- $CH_3CH(CH_3)CH(OH)COOH \rightarrow CH_3CH(CH_3)COCOOH + 2H^+ + 2e^-$; [1 mark]

ii) The overall redox reaction is:

$3CH_3CH(CH_3)CH(OH)COOH\,(aq) + Cr_2O_7^{2-}\,(aq) + 8H^+\,(aq) \rightarrow 3CH_3CH(CH_3)COCOOH\,(aq) + 2Cr^{3+}\,(aq) + 7H_2O\,(l)$

- The correct reactants and products are shown; [1 mark]
- Balancing the equation; [1 mark]

[Total: 3 marks]

- Compound B is a secondary alcohol so it can only be oxidized to a ketone
- This involves the loss of two hydrogens
  - This is not hydrogen gas, but hydrogen ions, which must be balanced by the addition of two electrons on the right-hand side of the half equation
- Always check that half-equations have balanced charges on either side
- To balance the half-equations, deduce the lowest common factor that balances the number of electrons
- The B to C half-equation has two electrons, so it must be multiplied by three so that both half-equations now have six electrons

$3CH_3CH(CH_3)CH(OH)COOH \rightarrow 3CH_3CH(CH_3)COCOOH + 6H^+ + 6e^-$

- When you combine them together there are H^+ ions on each side which you can cancel down

$3CH_3CH(CH_3)CH(OH)COOH\,(aq) + Cr_2O_7^{2-}\,(aq) + \mathbf{14H^+}\,(aq) \rightarrow 3CH_3CH(CH_3)COCOOH\,(aq) + \mathbf{6H^+} + 2Cr^{3+}\,(aq) + 7H_2O\,(l)$

- State symbols can be ignored in the equation

c) The reaction conditions can be changed in the oxidation of ethanol by:

- To produce ethanal: the reaction is carried out as a simple distillation, so the product is removed as soon as it is formed; [1 mark]
- To produce ethanoic acid: the reaction is heated under reflux;
  OR
  An excess of the oxidising agent is used; [1 mark]

[Total: 2 marks]

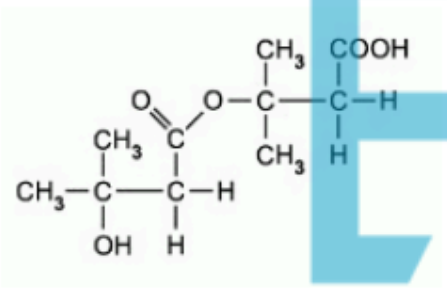
- The reason you want to distil off aldehydes as soon as they are formed is so that you don't allow them to further oxidise to a carboxylic acid
- Aldehydes do not have the hydrogen bonds that are present in alcohols and carboxylic acids, so they have lower boiling points and vaporise more easily
- The reactions are equilibrium reactions, so removing the aldehyde product encourages the equilibrium to shift to the right in favour of producing more aldehyde, and so it increases the yield of the reaction

d)

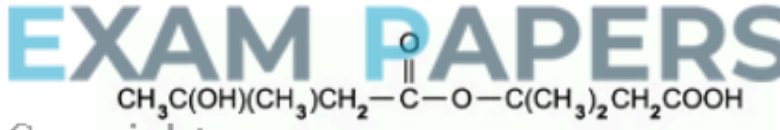
i) The type of reaction taking place and the reaction conditions are:

- Esterification / condensation; [1 mark]
- Warm / heat with concentrated sulfuric acid / H_2SO_4; [1 mark

ii) The structure of the product is:



OR



- Either correct drawing showing the ester group; [1 mark]

[Total: 3 mark]

- A dimer is any molecule made from two repeating units
  - Dimers are quite commonly found in sugars e.g., disaccharides like sucrose which is made from two glucose molecules joined together
- The role of the sulfuric acid is a catalyst for the reaction
- Water is also a product of the reaction, but don't get confused
  - The reaction is not a condensation reaction even though water is produced
  - Condensation refers to the joining together of two molecules to make one

Answer 4.

a) The molecular formula of **B** is:

- $C_4H_8O_2$; [1 mark]

[Total: 1 mark]

- The M_r of the empirical formula is (2 x 12) + 4 + 16 = 44
- 87.5 / 44 = 1.99
- You therefore multiply the empirical formula by 2

b) The structural formulae for the isomers are:

- **W** = $HCO_2CH(CH_3)_2$; [1 mark]
- **X** = $HCO_2CH_2CH_2CH_3$; [1 mark]
- **Y** = $CH_3CO_2CH_2CH_3$
  OR
  $CH_3CO_2C_2H_5$; [1 mark]
- **Z** = $CH_3CH_2CO_2CH_3$
  OR
  $C_2H_5CO_2CH_3$; [1 mark]

[Total: 4 marks]

- It doesn't matter which structural formulae you have given for each letter, each correct structure is worth one mark
- Start by drawing the ester functional group, -COO- and then trying different lengths of carbon chain on either side until you have four combinations

c)

i) The reaction with 2,4–dinitrophenylhydrazine reagent shows the presence of:

- C=O group / carbonyl group; [1 mark]

ii) The result of the test with Tollens' reagent shows:

- There is no -CHO / aldehyde group
  OR
  There is a ketone present; [1 mark]

iii) The structural formula of the alcohol **C is:**

- $(CH_3)_2CHOH$; [1 mark]

iv) The esters, **W**, **X**, **Y,** or **Z** has the same structure as that of the ester **B**

- Ester W / $HCO_2CH(CH_3)_2$; [1 mark]

[Total: 4 marks]

- Ester **B** has **four** carbon atoms in total from a combination of the carboxylic acid and alcohol
- The alcohol used to form Ester **B** has been oxidised to a ketone (shown by the lack of a positive result with Tollen's reagent)
- Ketones have an alkyl group bonded to either side of the C=O bond
- The ketone formed must be propanone as one less carbon atom and it would be an aldehyde, and one more carbon atom and there would not be enough once it has formed an alcohol to form Ester **B**
- A secondary alcohol forms a ketone when it is oxidised so the alcohol must be propan-2-ol, $(CH_3)_2CHOH$
- When looking at the structure of an ester
  - The chain attached to the oxygen atom (on the right hand side) in the -COO- is from the alcohol
  - The chain attached to the carbon atom (on the left hand side) in the -COO- is from the carboxylic acid
- Look at the structures drawn in part b)
  - You can narrow Ester **B** down to **W** and **X** as they both have three carbon atoms on the right hand side of the -COO- group
  - Propan-1-ol would form Ester **X**
  - Propan-2-ol, $(CH_3)_2CHOH$ would form Ester **W**
- Your answer to part (iv) must match your drawing as you may not have drawn $HCO_2CH(CH_3)_2$ as Ester **W**

d) Which, if any of your esters, **W**, **X**, **Y,** or **Z** is chiral:

- None
  AND
  Because there are no chiral centres present in any of the four esters; [1 mark]

[Total: 1 mark]

- A chiral centre is one in which a carbon atom is bonded to four different atoms / groups of atoms

Answer 5.

a)

i) The reagents and conditions needed for the hydrolysis of this ester are:

- Dilute Acid / sulfuric acid
  OR
  Dilute alkali / sodium hydroxide; [1 mark]
- Heat / reflux / warm; [1 mark]

ii) The equation for the hydrolysis of this ester

- $CH_3(CH_2)_2CO_2CH_3 + H_2O \rightarrow CH_3(CH_2)_2CO_2H + CH_3OH$; [1 mark]

iii) One major commercial use of esters is:

Any **one** from:

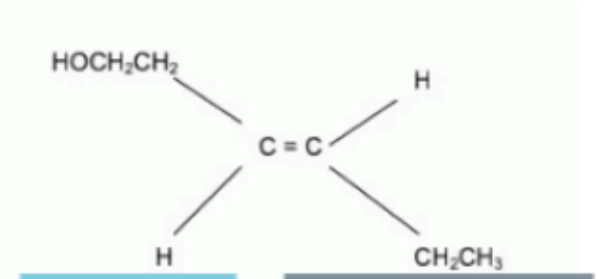
- Solvents; [1 mark]
- Plastics; [1 mark]
- Textiles; [1 mark]

[Total: 4 marks]

- **Remember:** When an ester is hydrolysed, it reforms the carboxylic acid and alcohol it was made from
  - The left hand side of the structural formula is formed from the carboxylic acid: $CH_3(CH_2)_2CO_2H$
    - There are four carbon atoms so butanoic acid was used
  - The right hand side of the structural formula is from the alcohol: $CH_3(CH_2)_2CO_2CH_3$
    - There is one carbon atom so methanol was used

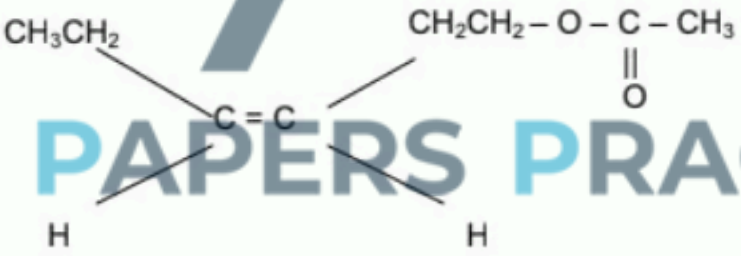
b)

i) The other stereoisomer of leaf alcohol is:



- Correct structure; [1 mark]

ii) The structure for the ester formed when leaf alcohol reacts with ethanoic acid is:



- Ester link; [1 mark]
- Rest of molecule; [1 mark]

[Total: 3 marks]

- To draw the other stereoisomer, just swap the position of the CH_2CH_3 group so that it is on the opposite side of the carbon carbon double bond
  - Cis isomers have their functional groups on the same side of the double bond
  - Trans isomers have their functional groups on opposite sides of the double bond
- Drawing the ester formed might look a bit tricky initially- but all you need to do is replace the -OH group on leaf ethanol with an ester linkage and add CH_3 onto the other side

c)

i) The relative molecular mass, M_r, for leaf alcohol is:

- 100; [1 mark]

ii) The structure of the product and type of reaction is:

- $CH_2 = CH - CH = CH - CH_2CH_3$; [1 mark]
- Dehydration / elimination; [1 mark]

[Total: 3 marks]

- It would be easy to miscalculate the M_r for alcohol so count the number of atoms of each element first:
  - $(12 \times 6) + 16 + (1 \times 12) = 100$
- The command word suggest means you need to apply your understanding to a new context
  - You should recognise that water has an M_r of 18 and deduce that this has been lost from the alcohol
  - Water is lost from an alcohol to form an alkene
  - The double bond will form between the carbon atoms to which the OH group was attached

d) A simple chemical test to distinguish between leaf alcohol and your product in part **(c)(ii)** is:

Any pair from:

Alternative 1:

- Add PCl_5; [1 mark]
- Misty fumes; [1 mark]

Alternative 2:

- Add H^+ / $Cr_2O_7^{2-}$; [1 mark]
- Turns from orange to green; [1 mark]

Alternative 3:

- Add concentrated sulfur acid and a carboxylic acid; [1 mark]
- Ester smell; [1 mark]

Alternative 4:

- Add sodium; [1 mark]
- Bubbles / effervescence; [1 mark]

[Total: 2 marks]

- **Careful:** The test you describe must be for an alcohol
- You cannot use bromine water as this tests for an unsaturated compound (the presence of a double bond)
- Both leaf alcohol, and the alkene formed from dehydration have double bonds

Answer 6.

a) To obtain $CH_3CH_2COOCH_2CH(CH_3)_2$ the reaction needs to involve:

- Propanoic acid; [1 mark]
- 2–methylpropan–1–ol; [1 mark]
- Heat; [1 mark]
- Concentrated H_2SO_4; [1 mark]

The equation is:

$$CH_3CH_2COOH + (CH_3)_2CHCH_2OH \rightarrow CH_3CH_2COOCH_2CH(CH_3)_2 + H_2O$$

- Correct reactants;[1 mark]
- Correct products; [1 mark]

[Total: 6 marks]

- You should be able to write equations for the formation of any named ester you are given
- A good place to start is to draw the displayed formula of the ester so that you can deduce which alcohol and carboxylic acid (or derivative) it is formed from

b) Compare the **two** types of hydrolysis that take place:

Similarities

- Ester **S** is heated under reflux; [1 mark]
- Both types of reaction produce the alcohol / 2-methylpropan-1-ol ; [1 mark]

Differences

Any **two** from:

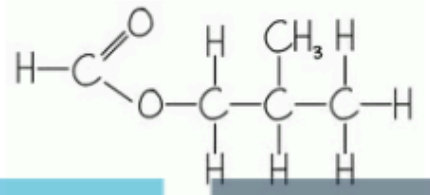
- Acid hydrolysis uses dilute acid / dilute H_2SO_4 whereas alkaline hydrolysis uses dilute alkali / dilute; [1 mark]
- Acid hydrolysis produces the carboxylic acid (and the alcohol) whereas alkaline hydrolysis produces a sodium salt of the carboxylic acid / sodium propanoate; [1 mark]
- Acid hydrolysis is a reversible reaction whereas alkali hydrolysis is irreversible; [1 mark]
- Acid hydrolysis results in an equilibrium being established; [1 mark]

[Total: 4 marks]

- A comparison question means include similarities and differences
- When discussing the differences you must include the relevant information for each type of hydrolysis
- You will not be penalised for not identifying the names of the alcohol, carboxylic acid or sodium salt of the carboxylic acid as this is tested in part **(a)**
- This question is testing your knowledge of ester hydrolysis

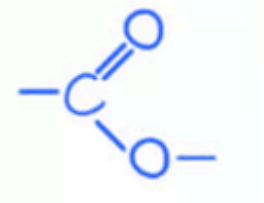
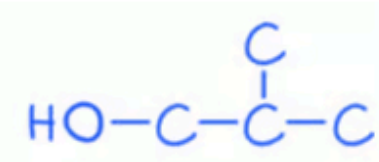
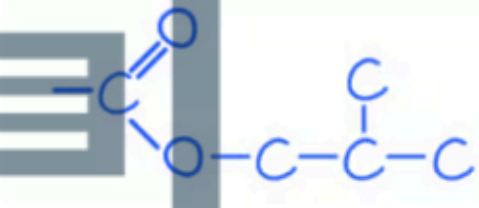
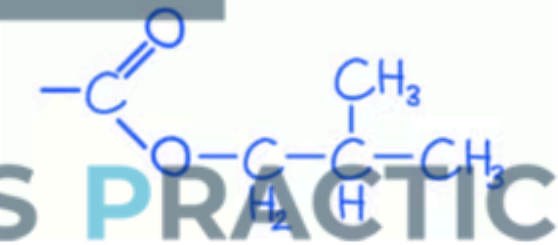
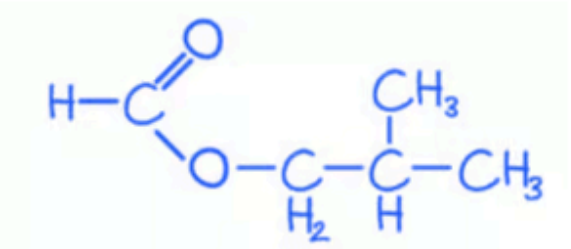
c) The acid and alcohol used to prepare ester A are:

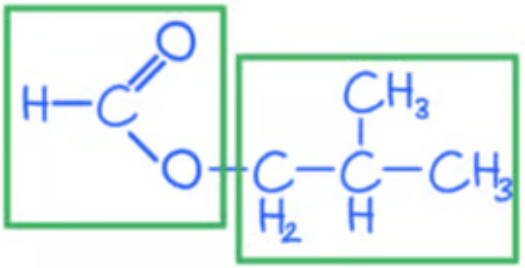
- Methanoic acid / formic acid; [1 mark]
- 2–methylpropan-1–ol; [1 mark]
- Ester A is 2–methylpropyl methanoate; [1 mark]



- Correct structure of ester A as shown; [1 mark]

[Total: 4 marks]

Starting from the $C_5H_{10}O_2$ formula Draw the ester linkage / bond (4 C and 10 H left)	
Branched primary alcohol- therefore, it must use all four carbons or it could not have a branched group	
Join the pieces together (10 H left)	
Add the hydrogens to the alcohol portion (1 H left)	
 Add the hydrogen to the acid portion	

Highlight the acid and alcohol portions	
Name the acid and alcohol	Methanoic acid / 2-methylpropan-1-ol
Name the ester	2-methylpropyl methanoate