

GCE AS / A LEVEL – CHEMISTRY UNIT 2 QUESTION PACK

1092-01 (Legacy CH2) · New spec Unit 2 Topic 6 · AS unit, first sat 2016, 80 marks, 1h 30min paper

REVISE.wales

CHEMISTRY – UNIT 2 · CARBOXYLIC ACIDS & ESTERS

Topic 2.7 – Carboxylic acids: properties, reactions and ester formation

Properties and reactions of carboxylic acids: acidic behaviour, esterification with alcohols (concentrated H₂SO₄ catalyst), naming esters, hydrogen bonding and physical-property trends in homologous series, and identifying unknown organic acids.

Legacy 2008 specification

Estimated time for entire question pack: ~1 h 36 min*Derived from the legacy CH2 paper's pace of ~1.1 min/mark, padded for long-prose answers (60 marks over 4 questions).**You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC CH2 papers (2008 modular spec, Jan 2010 – Jun 2016) that maps onto the new-spec AS Unit 2 Topic 2.7.

Questions are ordered by source paper date.

INSTRUCTIONS

Use black ink or black ball-point pen. Show all working – quality of written communication will affect marks. A calculator is allowed. You may need the WJEC Periodic Table / Data Booklet.

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Q	Source	Max	Mark
1	Jun 11 Q9	13	
2	Jan 14 Q9	16	

Q	Source	Max	Mark
3	Jun 15 Q13	14	
4	Jun 16 Q10	17	
Total		60	

Carboxylic Acids & Esters – what the new spec asks

WJEC GCE AS / A Level Chemistry (from 2015) · Unit 2: Energy, Rate & Chemistry of Carbon Compounds · Topic 2.7.

Carboxylic acids – structure

- Functional group -COOH = carbonyl + hydroxyl on same C.
- Weak acids: partial dissociation $\text{R-COO}^- + \text{H}^+$.
- H-bonding (often dimers) \Rightarrow high boiling temps relative to molar mass.
- Short-chain acids: water-soluble (ethanoic, propanoic).

Reactions as acids

- With metals: $2\text{RCOOH} + \text{Mg} \rightarrow (\text{RCOO})_2\text{Mg} + \text{H}_2$.
- With carbonates: $\text{RCOOH} + \text{Na}_2\text{CO}_3 \rightarrow \text{RCOONa} + \text{CO}_2 + \text{H}_2\text{O}$.
- With bases: $\text{RCOOH} + \text{NaOH} \rightarrow \text{RCOONa} + \text{H}_2\text{O}$ (salt).

Ester formation & naming

- Acid + alcohol $\xrightarrow{[\text{H}^+]}$ ester + H_2O (reversible).
- Naming: alcohol part first (as -yl) then acid part (as -oate).
- Example: $\text{CH}_3\text{COOH} + \text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{COOC}_2\text{H}_5$ (ethyl ethanoate).
- Esters give characteristic sweet / fruity smells – flavourings, solvents.

Identifying carboxylic acids

- Effervescence with NaHCO_3 / Na_2CO_3 – CO_2 released.
- IR: broad O-H $\sim 2500\text{-}3300\text{ cm}^{-1}$; sharp C=O $\sim 1700\text{ cm}^{-1}$.
- Mass spec M^+ gives M_r ; (M-17) loss of OH; (M-45) loss of COOH.

Carboxylic Acids & Esters in one page

Quick-reference notes – revisit before each question.

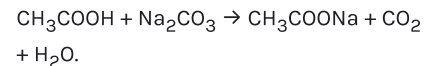
-COOH polarity

Both C=O and O-H polar; H-bonded dimers in liquid state \Rightarrow b.p. \sim alcohols of similar M_r .

Why weak acids

Carboxylate anion partially delocalised over both O's but K_a small (10^{-5} for ethanoic).

Acid + carbonate



Effervescence distinguishes from alcohols/phenols (phenol doesn't react with CO_3^{2-}).

Ester naming

X-COO-Y \Rightarrow name from alcohol-Y (yl) and acid-X (oate). Example: methyl propanoate = $\text{CH}_3\text{CH}_2\text{COOCH}_3$.

Solubility trend

Methanoic, ethanoic, propanoic, butanoic – fully water-soluble. From pentanoic onward solubility drops sharply.

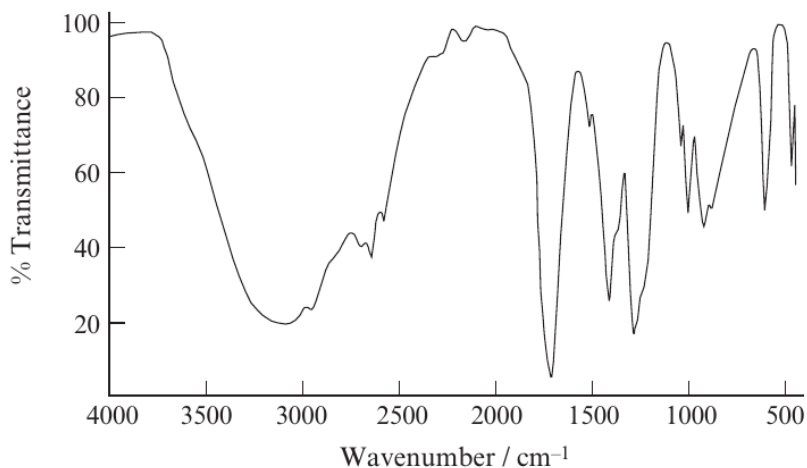
IR signatures

Acid: broad O-H $2500\text{--}3300\text{ cm}^{-1}$, C=O $\sim 1710\text{ cm}^{-1}$.

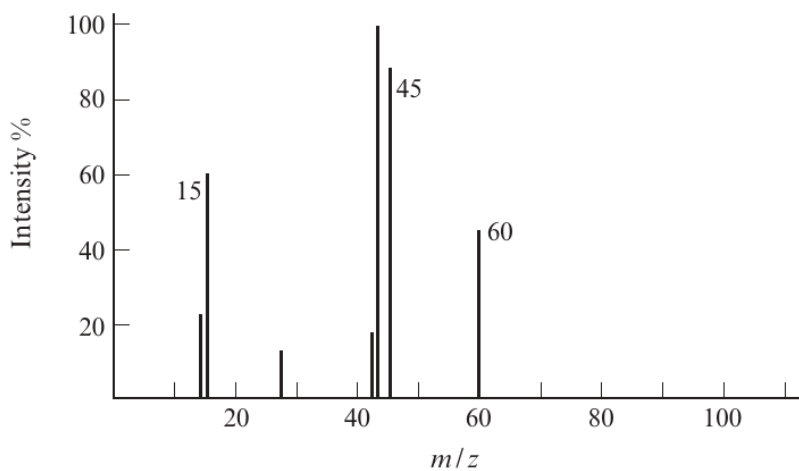
Ester: no broad O-H; C=O $\sim 1735\text{ cm}^{-1}$, C-O $1050\text{--}1300\text{ cm}^{-1}$.

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9. Ethanoic acid, CH_3COOH , commonly known as acetic acid, is an organic acid that gives vinegar its sour taste and pungent smell.
- (a) Ethanoic acid contains C—O, C=O and O—H bonds and has the infrared spectrum shown below. Using the Data Sheet, label the characteristic absorptions for **each** of these **three** bonds on the spectrum. [2]



- (b) The mass spectrum of ethanoic acid is shown below.



Explain how this shows that the formula for ethanoic acid is CH_3COOH . [2]

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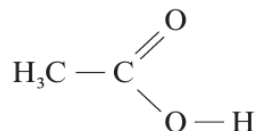
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(c) The crystal structure of ethanoic acid shows that the molecules are found in pairs with hydrogen bonds between each pair.

(i) Complete the diagram to show how **two** molecules of CH₃COOH can join together through hydrogen bonding. [1]



(ii) Describe what is meant by *hydrogen bonding*. [3]
QWC [1]

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(d) Ethanoic acid can be formed from the oxidation of ethanol by potassium dichromate(VI).

(i) State the conditions required for this reaction to take place. [1]

(ii) State what you would observe during the reaction. [1]

.....

(e) The boiling temperature of ethanol is 78 °C. Giving a reason in **both** cases, state how you would expect the boiling temperatures of the following compounds to differ from that of ethanol. [2]

Propane

.....

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Butan-1-ol

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Total [13]
Turn over.

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9. (a) The table below shows some physical properties of six carboxylic acids.

Acid	Formula	Boiling temperature / °C	Solubility in water
ethanoic	CH ₃ COOH	118	solubility decreasing ↓
propanoic	CH ₃ CH ₂ COOH	141	
butanoic	CH ₃ (CH ₂) ₂ COOH		
pentanoic	CH ₃ (CH ₂) ₃ COOH		
hexanoic	CH ₃ (CH ₂) ₄ COOH	205	
heptanoic	CH ₃ (CH ₂) ₅ COOH	223	

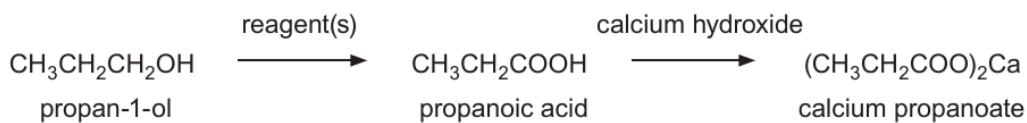
- (i) Suggest the boiling temperature of butanoic acid. [1]

- (ii) Describe the trend in boiling temperature as the number of carbon atoms in the acids increases and suggest a reason for this effect. [3]

- (iii) Explain why the acids become less soluble in water as the sizes of the molecules increase. [2]

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- (b) Calcium propanoate, $(\text{CH}_3\text{CH}_2\text{COO})_2\text{Ca}$, is added to bread to prevent mould formation. It can be made from propan-1-ol by the following reactions.



- (i) State the name of the reagent(s) used in the first stage. [1]

- (ii) Propanoic acid, in its liquid state, exists as a dimer, where two molecules of the acid bond together using hydrogen bonding.

Draw the structural formula of this dimer and show the hydrogen bonding between the two molecules. [1]

- (iii) In an experiment to make calcium propanoate, 50.0 cm^3 of a solution of propanoic acid of concentration 1.00 mol dm^{-3} was completely neutralised by calcium hydroxide.

- I Calculate the number of moles of propanoic acid used. [1]

..... mol

- II State the number of moles of calcium hydroxide needed to just react with all the propanoic acid. [1]

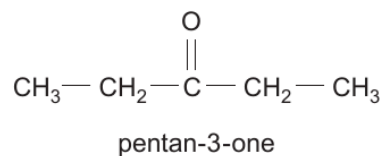
..... mol

- III Calculate the maximum mass of calcium propanoate ($M_r = 186$) which could be formed. [1]

..... g

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- (iv) Calcium propanoate produces pentan-3-one when it is strongly heated.



Write the displayed formula of **two** structural isomers of pentan-3-one. [2]

- (c) A dicarboxylic acid, $\text{HOOC}-(\text{CH}_2)_n-\text{COOH}$, contains 49.3% of carbon and 43.8% of oxygen by mass. In both parts (i) and (ii) **show your working**.

- (i) Use these figures to find the ratio of carbon atoms to oxygen atoms in the acid. [2]

Ratio C : O

- (ii) Use this ratio to find the value of n in the formula of the acid.
You are reminded that 1 molecule of the acid contains four oxygen atoms. [1]

$n =$

Total [16]

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13. (a) An acid **F** was known to be one of the following.



A sample of 1.20 g of acid **F** was burned in excess oxygen. 1.79 g of carbon dioxide was formed.

(i) Calculate the mass of carbon present in the sample of acid **F**. [1]

Mass of carbon = g

(ii) The mass of hydrogen in the sample is 0.061 g. Assuming that the rest of the sample is oxygen, calculate the mass of oxygen in the sample. [1]

Mass of oxygen = g

(iii) Use your answers to parts (i) and (ii) to find the empirical formula of acid **F**. [2]

Empirical formula

(iv) State the identity of acid **F**. Show clearly how you reached this conclusion. [1]

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- (v) Describe a chemical test that would distinguish between Acid 1 and Acid 2. You should include the expected results. [1]

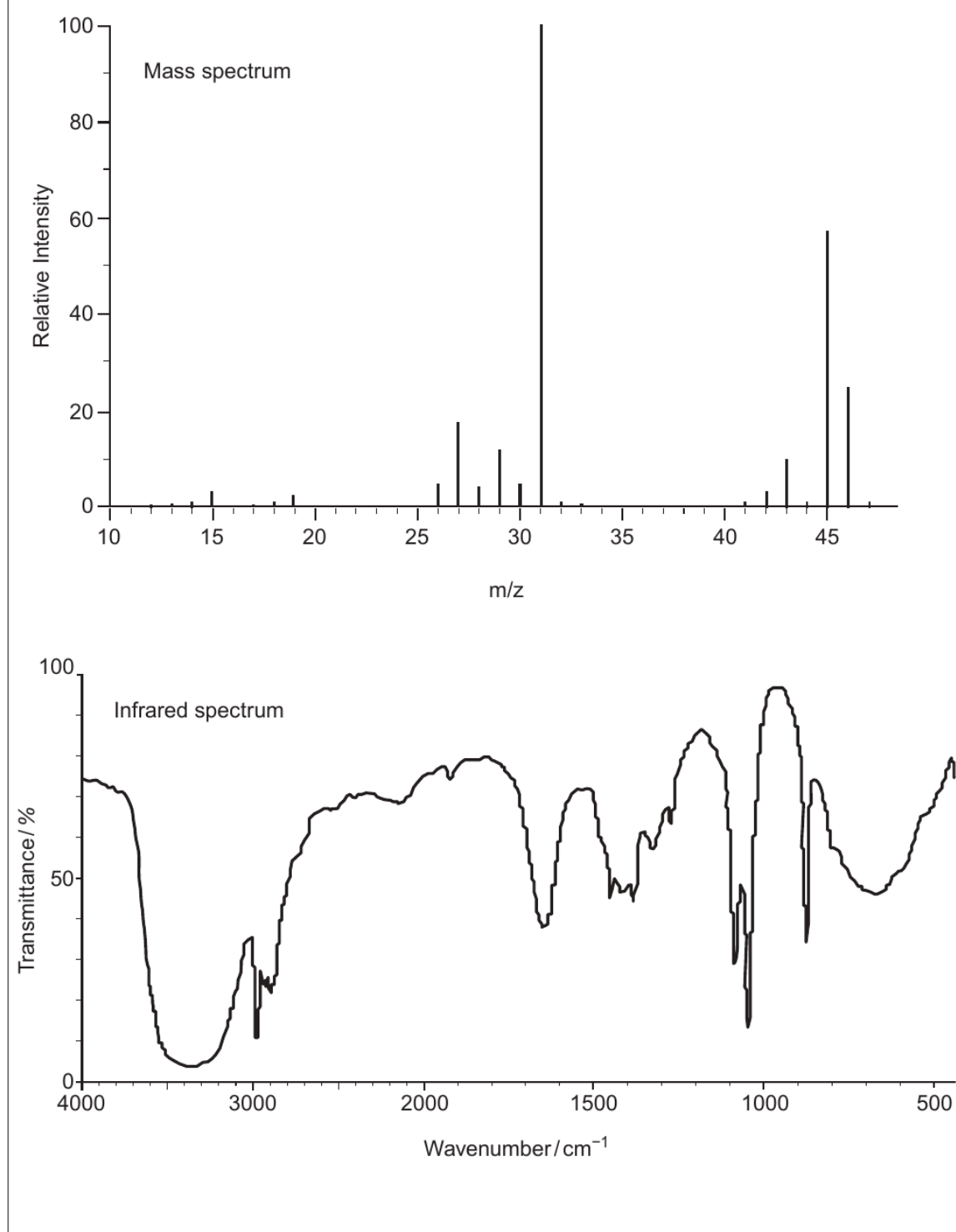
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- (vi) Draw the structural formula of the alcohol that can be oxidised to form Acid 2. [1]



(b) Spectra give much information about the structure of organic compounds.

The mass spectrum and infrared spectrum of ethanol, C_2H_5OH , are shown.



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(i) What can be deduced by the presence of the peak at m/z 46 in the mass spectrum? [1]

.....
(ii) What can be deduced by the presence of the peak at m/z 15 in the mass spectrum? [1]

.....
(iii) What can be deduced by the presence of an absorption peak at 3100 to 3500 cm^{-1} in the infrared spectrum? [1]

.....
(c) Ethene can be converted into ethanol and ethanol can be converted into ethene. For each conversion, state the reagent(s) used and the conditions needed. [4]

ethene to ethanol

.....

ethanol to ethene

.....

Total [14]

Total Section B [70]

END OF PAPER









GCE AS/A level

1092/01-A



S15-1092-01A

**CHEMISTRY – DATA SHEET
FOR USE WITH CH2**

P.M. TUESDAY, 2 June 2015

Infrared Spectroscopy characteristic absorption values

Bond	Wavenumber / cm⁻¹
C—Br	500 to 600
C—Cl	650 to 800
C—O	1000 to 1300
C=C	1620 to 1670
C=O	1650 to 1750
C≡N	2100 to 2250
C—H	2800 to 3100
O—H	2500 to 3550
N—H	3300 to 3500

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10. Fatty acids are carboxylic acids that contain a range of saturated or unsaturated hydrocarbon chains attached to a carboxylic acid group, $-\text{COOH}$.

(a) Two fatty acids are propanoic acid and hexanoic acid.

(i) State and explain which of these fatty acids will have the higher boiling temperature. [2]

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(ii) State and explain which of these fatty acids will be more soluble in water. [3]

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(b) Pentenoic acid, $\text{C}_5\text{H}_9\text{COOH}$, has some isomers that can show *E-Z* isomerism and others that cannot.

(i) Pent-2-enoic acid, $\text{CH}_3\text{CH}_2\text{CHCHCOOH}$, can form *E-Z* isomers. Give the **skeletal** formulae for the *E*- and *Z*-isomers of this molecule. [2]

E-isomer

Z-isomer

- (ii) Give the structure of an isomer of pentenoic acid that cannot show *E-Z* isomerism and explain why it cannot. [2]

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- (c) Arachidonic acid is an unsaturated fatty acid containing more than one double bond.

Bromine water is used to confirm that the fatty acid is unsaturated, with sufficient bromine used to react with **all** the double bonds.

- (i) Give the colour change expected in this chemical test. [1]

.....

- (ii) The product of the reaction of arachidonic acid with excess bromine contains 25.44% carbon, 3.39% oxygen and 67.75% bromine by mass with the remainder being hydrogen.

- I. Calculate the empirical formula of this compound. [3]

Empirical formula

- II. State the number of $C=C$ double bonds present in a molecule of arachidonic acid. Explain how you reached your conclusion. [1]

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- (iii) HBr reacts with alkenes in a similar way to bromine.
Draw the mechanism for the reaction of HBr with propene to give the major product.
[3]

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Total [17]

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END OF QUESTION PACK

4 questions · 60 marks · ~1 h 36 min

Source: WJEC CH2 (2008 modular spec, Jan 2010 – Jun 2016)

Curated for WJEC Chemistry 2015 spec AS Unit 2 – Topic 6 (2.7)

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