

Week 27

A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

Topic 18 quiz	2
Exercise sheet 18.1	5
Past-paper questions 18.1	9
Exercise sheet 18.2	11
Past-paper questions 18.2	16

18. Carboxylic acids and derivatives

Starter Quiz · 课前小测

A-Level Chemistry

Name: _____ Score: _____

1. The functional group of a carboxylic acid is:

- ☐ -COOH (carboxyl)
- ☐ -OH
- ☐ C=O alone
- ☐ -COO-

2. An ester is made by reacting:

- ☐ an alcohol with a carboxylic acid (condensation, losing water)
- ☐ an alkene with hydrogen
- ☐ a halogenoalkane with NaOH
- ☐ two alkanes

3. A carboxylic acid is made by oxidising a primary alcohol or aldehyde, using:

- ☐ acidified dichromate with reflux
- ☐ distillation to stop early
- ☐ no heating
- ☐ a tertiary alcohol

4. Esters are often recognised by their:

- ☐ sweet or fruity smell
- ☐ sharp acidic smell
- ☐ lack of any smell
- ☐ blue colour

5. A carboxylic acid added to a carbonate gives a salt, water and:

- ☐ carbon dioxide (the fizzing is a test)
- ☐ hydrogen
- ☐ oxygen
- ☐ ammonia

6. Carboxylic acids are weak acids that react with carbonates to give carbon dioxide.

- ☐ True ☐ False

7. An ester is made by reacting a carboxylic acid with an _____.

8. Hydrolysing an ester with dilute acid gives:

- ☐ the carboxylic acid and the alcohol (reversible)
- ☐ the carboxylate salt and the alcohol
- ☐ an alkene
- ☐ a nitrile

9. A carboxylic acid reacting with an alcohol (conc. H_2SO_4 catalyst) makes:

- ☐ an ester
- ☐ an alkene
- ☐ a nitrile
- ☐ an amine

10. Hydrolysing an ester with dilute alkali gives:

- ☐ the carboxylate salt and the alcohol (not reversible)
- ☐ the carboxylic acid and alcohol
- ☐ an ester again
- ☐ an alkene

18. Carboxylic acids and derivatives

Answers · 答案

A-Level Chemistry

1. $-\text{COOH}$ (carboxyl)

Carboxylic acids contain the $-\text{COOH}$ group and behave as weak acids.

2. an alcohol with a carboxylic acid (condensation, losing water)

Esterification is a reversible condensation of an alcohol and a carboxylic acid, releasing water.

3. acidified dichromate with reflux

Reflux ensures full oxidation all the way to the carboxylic acid (distillation would stop at the aldehyde).

4. sweet or fruity smell

Many esters have pleasant, fruity smells.

5. carbon dioxide (the fizzing is a test)

Like other acids, it releases CO_2 from a carbonate — the fizz is a useful test.

6. True

A test for the $-\text{COOH}$ group.

7. alcohol

Esterification, usually with an acid catalyst.

8. the carboxylic acid and the alcohol (reversible)

Acid hydrolysis is the reverse of esterification, giving back the carboxylic acid and alcohol.

9. an ester

Esterification joins the acid and alcohol into an ester (losing water).

10. the carboxylate salt and the alcohol (not reversible)

Alkali hydrolysis gives the salt of the carboxylic acid (plus the alcohol) and is not reversible.

18.1 Carboxylic acids

Name: _____ Class: _____ Date: _____

Total: 11 marks

KEY WORDS esterification 酯化 • neutralisation 中和 • reflux 回流 • nitrile 腈 • alcohol 醇

Objective

Build the skills to answer exam questions on **carboxylic acids** 羧酸 — making them, and their reactions as **acids** and to change the functional group.

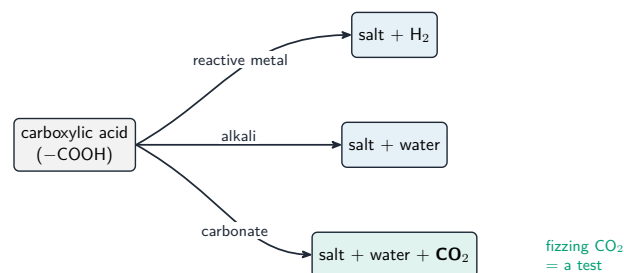
You must be able to:

- recall how carboxylic acids are made (oxidation, hydrolysis of nitriles/esters)
- describe the reactions with metals, alkalis and carbonates
- describe esterification and reduction by LiAlH_4

1 Worked examples

■ Making and reacting carboxylic acids

A **carboxylic acid** has the $-\text{COOH}$ group (a weak acid). Made by: oxidising a primary alcohol/aldehyde (reflux); hydrolysing a nitrile or ester then acidifying.



Acid reactions: with a metal $\rightarrow$ salt + H_2 ; with an alkali $\rightarrow$ salt + water; with a carbonate $\rightarrow$ salt + water + CO_2 (the fizz is a test)



the $-\text{OH}$ (acid) and $-\text{H}$ (alcohol) leave as **water**; the $\text{C}-\text{O}-\text{C}$ ester link forms
(concentrated H_2SO_4 catalyst; reversible)

Carboxylic acids form esters with alcohols

Two reactions change the functional group: **esterification** with an alcohol (conc. H_2SO_4) $\rightarrow$ ester; **reduction** by LiAlH_4 $\rightarrow$ primary alcohol.

2 Practice

2.1 Write the equation for ethanoic acid reacting with sodium carbonate. [1]

2.2 State a chemical test, with result, that shows a compound is a carboxylic acid. [2]

3 Exam-style questions

3.1 Which reagent reduces a carboxylic acid to a primary alcohol? [1]

- A NaBH_4
- B LiAlH_4
- C acidified $\text{K}_2\text{Cr}_2\text{O}_7$
- D concentrated H_2SO_4

3.2 Ethanoic acid reacts with magnesium to give: [1]

- A an ester and water
- B a salt and hydrogen
- C a salt, water and CO_2
- D no reaction

3.3 (a) Write the equation for the reaction of ethanoic acid with sodium hydroxide and name the type of reaction. [2]

(b) State the reagents and conditions to make ethanoic acid from ethanol. [2]

3.4 Explain why carboxylic acids fizz with a carbonate but alcohols do not. [2]

Solutions

2.1 $2\text{CH}_3\text{COOH} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{CH}_3\text{COONa} + \text{H}_2\text{O} + \text{CO}_2$.

2.2 add a carbonate (e.g. sodium carbonate); effervescence / fizzing of CO_2 is seen.

3.1 B. LiAlH_4 reduces a carboxylic acid to a primary alcohol.

3.2 B. A reactive metal gives a salt and hydrogen.

3.3 (a) $\text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}$; neutralisation.

(b) acidified $\text{K}_2\text{Cr}_2\text{O}_7$ (or KMnO_4); heat under reflux.

3.4 carboxylic acids are acidic — they release H^+ which reacts with the carbonate to give CO_2 ; alcohols are not acidic enough to react with a carbonate.

34 Three mixtures are heated under reflux.

Which mixtures will produce sodium propanoate as one product?

- 1 $\text{CH}_3\text{CH}_2\text{CHO} + \text{NaBH}_4(\text{aq})$
- 2 $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{Na}(\text{s})$
- 3 $\text{CH}_3\text{CH}_2\text{CN} + \text{NaOH}(\text{aq})$

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 3 only

37 The table shows the reagents and products of three reactions.

	reagents	products
1	ethanoic acid + Na_2CO_3	$\text{CH}_3\text{CO}_2\text{Na} + \text{H}_2\text{O} + \text{CO}_2$
2	ethanoic acid + Mg	$(\text{CH}_3\text{CO}_2)_2\text{Mg} + \text{H}_2\text{O}$
3	ethanoic acid + CH_3OH	$\text{CH}_3\text{CO}_2\text{CH}_3 + \text{H}_2\text{O}$

Which rows are correct?

A 1, 2 and 3 **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

33 HOCH_2CHO is heated under reflux with an excess of acidified $\text{K}_2\text{Cr}_2\text{O}_7$ until there is no further reaction.

What is the final product of this reaction?

- A** HOOCCHO
B HOCH_2COOH
C HOCCOOH
D $\text{HOOCCH}_2\text{COOH}$

36 Which organic starting material could be used in a single reaction to produce propanoic acid?

- A** ethanenitrile
B propan-2-ol
C propanal
D propyl ethanoate

37 In four separate reactions, W, X, Y and Z, 1 mol of an organic compound reacts with an excess of a reagent.

	organic compound	reagent
W	$(\text{CH}_2\text{COOH})_2$	Na
X	$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{COOH}$	Na_2CO_3
Y	$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{COOH}$	NaOH
Z	$\text{CH}(\text{OH})(\text{COOH})\text{CH}_2\text{COOH}$	Na

The volume of any gas produced is collected and measured. All gas volumes are measured at the same temperature and pressure.

What is the order of the reactions from greatest total volume of gas collected to least total volume of gas collected?

	greatest volume	→			least volume
A	W	Y	Z	X	
B	W	Z	Y	X	
C	Z	W	X	Y	
D	Z	X	W	Y	

18.2 Esters

Name: _____ Class: _____ Date: _____

Total: 23 marks

KEY WORDS hydrolysis 水解 • condensation 缩合 • esters 酯 • esterification 酯化 • alcohol 醇

Objective

Build the skills to answer exam questions on **esters** 酯 — their formation by **esterification** 酯化 and their **hydrolysis** 水解.

You must be able to:

- recall how esters are made (condensation of an alcohol and a carboxylic acid)
- describe the hydrolysis of esters by dilute acid and by dilute alkali

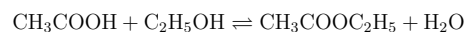
1 Worked examples

■ Making esters

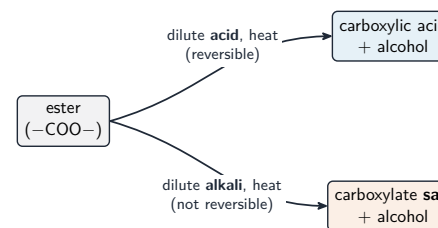


the $-\text{OH}$ (acid) and $-\text{H}$ (alcohol) leave as **water**; the $\text{C}-\text{O}-\text{C}$ ester link forms
(concentrated H_2SO_4 catalyst; reversible)

*Esterification is a reversible **condensation**: alcohol + carboxylic acid (conc. H_2SO_4 catalyst) $\rightarrow$ ester + water*



■ Hydrolysis of esters



Dilute acid (reversible): carboxylic acid + alcohol. Dilute alkali (not reversible): the carboxylate salt + alcohol

2 Practice

2.1 State the reagents and catalyst needed to make an ester from an alcohol and a carboxylic acid. [2]

2.2 Name the small molecule lost when an ester is formed. [1]

3 Exam-style questions

3.1 The type of reaction by which an ester is formed from an alcohol and a carboxylic acid is: [1]

- A addition
 - B condensation
 - C elimination
 - D free-radical substitution
- _____

3.2 Hydrolysis of an ester with dilute **alkali** gives an alcohol and: [1]

- A the carboxylic acid
 - B the salt of the carboxylic acid (carboxylate)
 - C carbon dioxide
 - D an aldehyde
- _____

3.3 (a) Write the equation for the formation of ethyl ethanoate from ethanol and ethanoic acid. [2]

(b) State the products of the hydrolysis of ethyl ethanoate by dilute sulfuric acid. [2]

3.4 Explain why hydrolysis with dilute alkali is **not** reversible, but hydrolysis with dilute acid is. [2]

3.5 Ethyl ethanoate is made by refluxing ethanoic acid with ethanol and a few drops of concentrated sulfuric acid.

(a) Write the equation for the esterification, and state the role of the sulfuric acid. [3]

(b) The reaction reaches equilibrium with a yield of about 65%. State **two** changes that would increase the yield of ester, and justify each. [4]

(c) The ester is then refluxed with aqueous sodium hydroxide. Write the equation for this hydrolysis and name the organic products. [3]

(d) Explain why alkaline hydrolysis goes to completion whereas acid hydrolysis does not. [2]

Solutions

2.1 an alcohol and a carboxylic acid; concentrated sulfuric acid catalyst.

2.2 water.

3.1 B. Esterification is a condensation reaction.

3.2 B. Alkaline hydrolysis gives the carboxylate salt (plus the alcohol).

3.3 (a) $\text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \rightleftharpoons \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}$.

(b) ethanoic acid and ethanol.

3.4 with alkali the carboxylic acid is converted to its carboxylate salt, which does not react back, so the reaction goes to completion; with acid the products are the acid and alcohol, which can re-esterify, so it is reversible.

3.5 (a) $\text{CH}_3\text{COOH} + \text{CH}_3\text{CH}_2\text{OH} \rightleftharpoons \text{CH}_3\text{COOCH}_2\text{CH}_3 + \text{H}_2\text{O}$; the sulfuric acid is a **catalyst** — it protonates the carbonyl and speeds both directions equally, and it also removes water, which shifts the position of equilibrium.

(b) Use an excess of one reactant — by Le Chatelier the system shifts right to oppose the increase; remove the water (or distil off the ester) as it forms, so the system again shifts right to replace it.

(c) $\text{CH}_3\text{COOCH}_2\text{CH}_3 + \text{NaOH} \rightarrow \text{CH}_3\text{COO}^-\text{Na}^+ + \text{CH}_3\text{CH}_2\text{OH}$; the products are **sodium ethanoate** and **ethanol**.

(d) The alkali converts the carboxylic acid to its **anion**, which is not attacked by the alcohol; the reverse reaction is therefore impossible and the hydrolysis goes to completion, whereas acid hydrolysis leaves both products free to re-esterify.

Name:

A-Level Chemistry: **w25 11**

35 Which compound is a product of the hydrolysis of $\text{CH}_3\text{CO}_2\text{CH}_2\text{C}_2\text{H}_5$ using aqueous sodium hydroxide?

A $\text{CH}_3\text{CO}_2^-\text{Na}^+$

B $\text{CH}_3\text{CO}_2\text{H}$

C $\text{C}_2\text{H}_5\text{CH}_2\text{O}^-\text{Na}^+$

D $\text{C}_2\text{H}_5\text{CH}_2\text{CO}_2^-\text{Na}^+$

A-Level Chemistry: **w25 14**

36 The structural formula of compound P is $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3$.

P can be formed by reacting together two organic compounds in the presence of a suitable catalyst.

Which pair of compounds could react together to produce P?

A ethanoic acid and propanoic acid

B ethanoic acid and propan-1-ol

C ethanol and propanoic acid

D ethanol and propan-1-ol

A-Level Chemistry: **w25 33**

3 Half-fill the 250cm^3 beaker with water and place it on a tripod and gauze. Heat the water until boiling then switch off your Bunsen burner. This will be your hot water bath for use in **(b)(i)**. Start **(a)(i)** while the water is heating.

(a) **FA 4** is an aqueous solution containing three ions. One ion is **not** listed in the Qualitative analysis notes. **FA 5** is an aqueous solution containing two ions. The cation in **FA 5** is listed in the Qualitative analysis notes. The anions in both **FA 4** and **FA 5** contain sulfur.

(i) Carry out the following tests using a 1 cm depth of either **FA 4** or **FA 5** in a test-tube. Record your observations in Table 3.1.

Table 3.1

<i>test</i>	<i>observations</i>	
	FA 4	FA 5
Test 1 Add aqueous sodium hydroxide.		
Test 2 Add aqueous ammonia.		
Test 3 Add aqueous sodium carbonate.		
Test 4 Add aqueous barium chloride or aqueous barium nitrate.		
Test 5 Add acidified aqueous potassium manganate(VII).		

[5]

- (ii) From your observations in (a)(i), deduce the identities of the ions present in **FA 4** and **FA 5**. Give the formula of each ion in Table 3.2. If you are unable to identify an ion write 'unknown'.

Table 3.2

<i>ions present</i>	FA 4	FA 5
cations		
anions		

[3]

- (b) (i) Both **FA 6** and **FA 7** are one of propan-1-ol, propan-2-ol, methanoic acid or ethanoic acid. You will carry out tests to investigate the identities of **FA 6** and **FA 7**. For each test use a 1 cm depth of **FA 6** or **FA 7** in a test-tube. Record your observations in Table 3.3.

Table 3.3

<i>test</i>	<i>observations</i>	
	FA 6	FA 7
Test 1 Add a few drops of acidified aqueous potassium manganate(VII), then place the test-tube in the hot water bath.		
Test 2 Add a 2 cm depth of aqueous iodine followed by drops of aqueous sodium hydroxide until the colour just disappears. If no reaction is visible, place the test-tube in the hot water bath.		
Test 3 Add aqueous sodium carbonate.		

[3]

- (ii) From your observations in (b)(i) deduce the identities of **FA 6** and **FA 7**. Give reasons for your answers.

FA 6 is

reasons

.....

FA 7 is

reasons

.....

[2]

- (c) A student carrying out a similar set of tests identifies two unknown compounds to be ethanol and propanoic acid.

Write an equation for the reaction between these two compounds.

..... [1]

[Total: 14]

Qualitative analysis notes

1 Reactions of cations

cation	reaction with	
	NaOH(aq)	NH ₃ (aq)
aluminium, Al ³⁺ (aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH ₄ ⁺ (aq)	no ppt. ammonia produced on warming	–
barium, Ba ²⁺ (aq)	faint white ppt. is observed unless [Ba ²⁺ (aq)] is very low	no ppt.
calcium, Ca ²⁺ (aq)	white ppt. unless [Ca ²⁺ (aq)] is very low	no ppt.
chromium(III), Cr ³⁺ (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu ²⁺ (aq)	pale blue ppt. insoluble in excess	pale blue ppt. soluble in excess giving dark blue solution
iron(II), Fe ²⁺ (aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe ³⁺ (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg ²⁺ (aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn ²⁺ (aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn ²⁺ (aq)	white ppt. soluble in excess	white ppt. soluble in excess

2 Reactions of anions

anion	reaction
carbonate, CO ₃ ²⁻	CO ₂ liberated by dilute acids
chloride, Cl ⁻ (aq)	gives white ppt. with Ag ⁺ (aq) (soluble in NH ₃ (aq))
bromide, Br ⁻ (aq)	gives cream/off-white ppt. with Ag ⁺ (aq) (partially soluble in NH ₃ (aq))
iodide, I ⁻ (aq)	gives pale yellow ppt. with Ag ⁺ (aq) (insoluble in NH ₃ (aq))
nitrate, NO ₃ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil
nitrite, NO ₂ ⁻ (aq)	NH ₃ liberated on heating with OH ⁻ (aq) and Al foil; decolourises acidified aqueous KMnO ₄
sulfate, SO ₄ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (insoluble in excess dilute strong acids); gives white ppt. with high [Ca ²⁺ (aq)]
sulfite, SO ₃ ²⁻ (aq)	gives white ppt. with Ba ²⁺ (aq) (soluble in excess dilute strong acids); decolourises acidified aqueous KMnO ₄
thiosulfate, S ₂ O ₃ ²⁻ (aq)	gives off-white/pale yellow ppt. slowly with H ⁺

Name:

A-Level Chemistry: w25 33

3 Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater
hydrogen, H_2	'pops' with a lighted splint
oxygen, O_2	relights a glowing splint