**Week 30**

# A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

## Contents 目录

# 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

A-Level Chemistry

1. **–COOH (carboxyl)**

   Carboxylic acids contain the –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 –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.

A-LEVEL CHEMISTRY • EXERCISE SHEET

# 18.1 Carboxylic acids

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

**KEY WORDS** esterification 酯化 • neutralisation 中和 • reflux 回流 • carboxylic acid 羧酸 • 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.

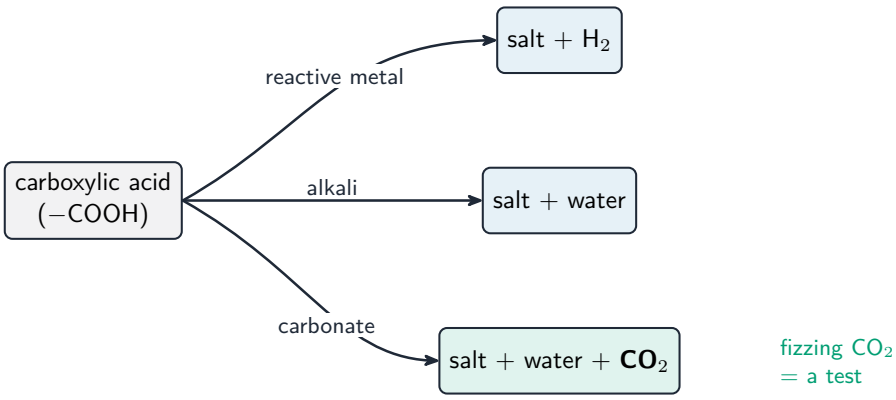
**You must be able to:**

- 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 –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 → salt + $H_2$; with an alkali → salt + water; with a carbonate → salt + water + $CO_2$ (the fizz is a test)*

$$CH_3COOH + HOC_2H_5 \rightleftharpoons CH_3CO\,O\,C_2H_5 + H_2O$$

the –OH (acid) and –H (alcohol) leave as water; the C–O–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. $H_2SO_4$) → ester; **reduction** by $LiAlH_4$ → 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 $K_2Cr_2O_7$
- **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** $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$.

**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) $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$; neutralisation.
(b) acidified $K_2Cr_2O_7$ (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 $CH_3CH_2CHO$ + $NaBH_4(aq)$

2 $CH_3CH_2CH_2OH$ + $Na(s)$

3 $CH_3CH_2CN$ + $NaOH(aq)$

**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 + $Na_2CO_3$ | $CH_3CO_2Na$ + $H_2O$ + $CO_2$ |
| 2 | ethanoic acid + Mg | $(CH_3CO_2)_2Mg$ + $H_2O$ |
| 3 | ethanoic acid + $CH_3OH$ | $CH_3CO_2CH_3$ + $H_2O$ |

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 $K_2Cr_2O_7$ until there is no further reaction.

What is the final product of this reaction?

**A** HOOCCHO

**B** $HOCH_2COOH$

**C** HOOCCOOH

**D** $HOOCCH_2COOH$

**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 | $(CH_2COOH)_2$ | Na |
| X | $CH_3CH(OH)CH_2COOH$ | $Na_2CO_3$ |
| Y | $CH_3CH(OH)CH_2COOH$ | NaOH |
| Z | $CH(OH)(COOH)CH_2COOH$ | 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 |

A-LEVEL CHEMISTRY • EXERCISE SHEET

# 18.2 Esters

Name: _____ Class: _____ Date: _____ **Total: 11 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

$$CH_3COOH + HOC_2H_5 \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

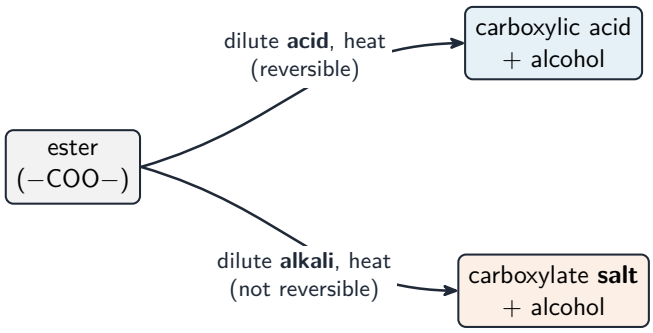
the –OH (acid) and –H (alcohol) leave as water; the C–O–C ester link forms

(concentrated $H_2SO_4$ catalyst; reversible)

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

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

### 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]

## 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) $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$.
(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.

**35** Which compound is a product of the hydrolysis of $CH_3CO_2CH_2C_2H_5$ using aqueous sodium hydroxide?

**A** $CH_3CO_2^-Na^+$

**B** $CH_3CO_2H$

**C** $C_2H_5CH_2O^-Na^+$

**D** $C_2H_5CH_2CO_2^-Na^+$



**36** The structural formula of compound P is $CH_3CH_2COOCH_2CH_3$.

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



**3** Half-fill the 250 $cm^3$ 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**

| *test* | *observations* | |
|---|---|---|
| | **FA 4** | **FA 5** |
| **Test 1**<br>Add aqueous<br>sodium hydroxide. | | |
| **Test 2**<br>Add aqueous ammonia. | | |
| **Test 3**<br>Add aqueous<br>sodium carbonate. | | |
| **Test 4**<br>Add aqueous barium chloride<br>or aqueous barium nitrate. | | |
| **Test 5**<br>Add acidified aqueous<br>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**

| *ions present* | **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**

| *test* | *observations* | |
|---|---|---|
| | **FA 6** | **FA 7** |
| **Test 1**<br>Add a few drops of acidified aqueous potassium manganate(VII), then | | |
| place the test-tube in the hot water bath. | | |
| **Test 2**<br>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**<br>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.<br>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<br>insoluble in excess | green ppt. turning brown on contact with air<br>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<br>insoluble in excess | off-white ppt. rapidly turning brown on contact with air<br>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;<br>decolourises acidified aqueous $KMnO_4$ |
| sulfate, $SO_4^{2-}$(aq) | gives white ppt. with $Ba^{2+}$(aq) (insoluble in excess dilute strong acids);<br>gives white ppt. with high [$Ca^{2+}$(aq)] |
| sulfite, $SO_3^{2-}$(aq) | gives white ppt. with B q) (soluble in excess dilute strong acids);<br>decolourises acidified aqueous $KMnO_4$ |
| thiosulfate, $S_2O_3^{2-}$(aq) | gives off-white/pale yellow ppt. slowly with $H^+$ |

## 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 |