Carboxylic acids

4.7.2.4 · Organic chemistry · revision notes

Carboxylic acids: the –COOH functional group, the first four acids, their reactions with carbonates, in water and with alcohols to make esters, and (Higher tier) why they are weak acids. GCSE Chemistry only. Expect naming, observations, word equations, ester questions and explaining pH values.

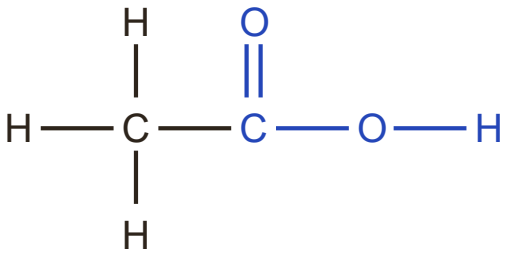
Key facts

- Functional group of carboxylic acids: –COOH
- Methanoic HCOOH, ethanoic CH_3COOH, propanoic C_2H_5COOH, butanoic C_3H_7COOH
- Carboxylic acid + carbonate → salt + water + carbon dioxide (fizzing)
- Salts end in -oate, e.g. sodium ethanoate
- Carboxylic acid + alcohol → ester + water (acid catalyst)
- Ethanoic acid + ethanol → ethyl ethanoate + water
- Ester group: –COO–
- Grade 7+ only Weak acid: only partially ionises in water
- Grade 7+ only $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

Notes

The carboxylic acids

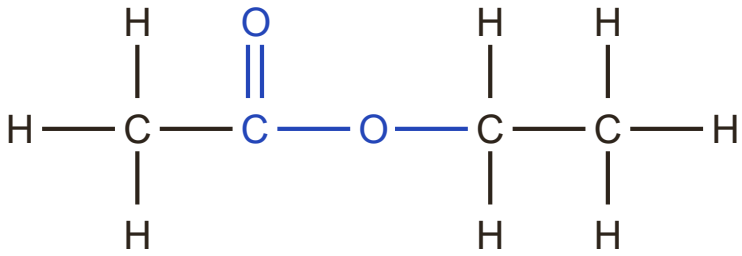
- Carboxylic acids contain the **–COOH** functional group.
- The first four: **methanoic acid** HCOOH, **ethanoic acid** CH_3COOH, **propanoic acid** CH_3CH_2COOH and **butanoic acid** $CH_3CH_2CH_2COOH$.
- The carbon atom in –COOH counts in the name: ethanoic acid has two carbon atoms in total.
- Ethanoic acid:



- Vinegar is a dilute solution of ethanoic acid.

Reactions

- **With carbonates**: fizzing, as **carbon dioxide** is given off (it turns limewater milky). A salt and water also form: ethanoic acid + sodium carbonate → sodium ethanoate + water + carbon dioxide.
- The salts end in **-oate**: methanoate, ethanoate, propanoate, butanoate.
- **In water**: they dissolve to form acidic solutions (pH below 7), but they are **weak acids**.
- **With alcohols**: with an acid catalyst (e.g. concentrated sulfuric acid), they react to form an **ester** and water: ethanoic acid + ethanol → ethyl ethanoate + water.
- Esters contain the –COO– group. Ethyl ethanoate is the only ester you need to name.

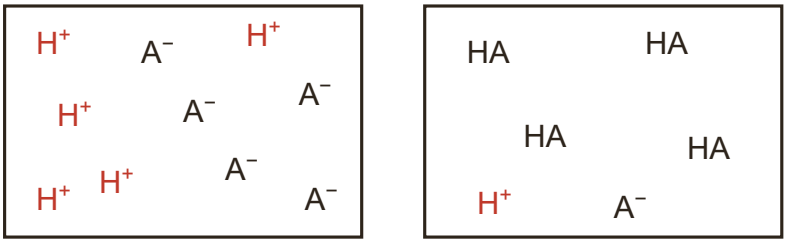


Ethyl ethanoate, $CH_3COOCH_2CH_3$. The ester group –COO– is in blue.

- You do not need balanced equations for these reactions: word equations are enough.

Why they are weak acids Grade 7+ only

- Carboxylic acids only **partially ionise** in water: most molecules stay whole, and only some release H^+ ions.
- $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$: the ⇌ sign shows the ionisation is reversible, so only some molecules are ionised at any time.



strong acid: fully ionised

weak acid: only partly ionised

Same concentration of acid, HA. The weak acid has far fewer H^+ ions (red), so its pH is higher.

- So the concentration of H^+ ions is lower than in a strong acid (such as hydrochloric acid) of the same concentration, and the pH is higher.
- Weak is about how much the acid ionises; dilute is about concentration. A concentrated solution of ethanoic acid is still a weak acid.

How to answer each type of question

Reaction with a carbonate: observations and products

2 to 3 marks | Grade 5

1. Name the salt: metal name + acid stem + '-oate', e.g. potassium propanoate.
2. The other products are water and carbon dioxide.
3. Observation: fizzing or bubbles; the gas turns limewater milky.

Example. Propanoic acid is added to calcium carbonate.
(a) Give **one** observation.
(b) Complete the word equation.
propanoic acid + calcium carbonate → _____ + water + _____

Model answer.

(a) Fizzing / bubbles / the solid disappears (1)
(b) Calcium propanoate (1); carbon dioxide (1)

Esters: the reactants, products and catalyst

1 to 4 marks | Grade 5

1. Carboxylic acid + alcohol → ester + water, with an acid catalyst.
2. Ethanol and ethanoic acid make ethyl ethanoate.
3. Name the catalyst: an acid, e.g. concentrated sulfuric acid.

Example. Ethyl ethanoate is used as a solvent in some nail varnish removers.
(a) Name the alcohol and the carboxylic acid used to make ethyl ethanoate.
(b) Name the other product of the reaction and the type of catalyst used.

Model answer.

(a) Ethanol (1) and ethanoic acid (1)
(b) Water (1); an acid catalyst, e.g. sulfuric acid (1)

Explain why a carboxylic acid has a higher pH than a strong acid

2 to 3 marks | Grade 7

1. Say that the carboxylic acid is a weak acid.
2. Say that it only partially ionises in water (the strong acid ionises completely).
3. Say that the concentration of H^+ ions is lower, so the pH is higher.

Example. A 0.5 mol/dm^3 solution of hydrochloric acid has a pH of 0.3. A 0.5 mol/dm^3 solution of propanoic acid has a pH of 2.6.
Explain the difference in pH.

Model answer. Propanoic acid is a weak acid (1). It only partially ionises in water, whereas hydrochloric acid ionises completely (1). So the concentration of H^+ ions in the propanoic acid is lower, which gives a higher pH (1).

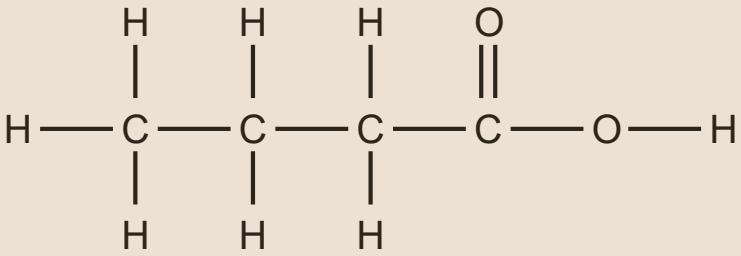
Draw or identify a carboxylic acid

1 to 2 marks | **Grade 5**

1. Find the –COOH group: a carbon atom with a C=O bond and an O–H.
2. Count all the carbon atoms, including the one in –COOH, to name it.
3. Draw every bond; the C=O must be shown as a double bond.

Example. Draw the displayed formula of butanoic acid, $CH_3CH_2CH_2COOH$.

Model answer.



Four carbon atoms in a chain, with seven H atoms on the first three carbons (1). The –COOH group drawn with a C=O and a C–O–H (1).

Don’t lose marks

- Forgetting to count the carbon in –COOH: CH_3COOH is ethanoic acid (2 carbon atoms), not methanoic acid.
- Saying carbonates give hydrogen. Carbonates give carbon dioxide; hydrogen comes from reactions with metals.
- Naming the salt wrongly, e.g. 'sodium ethanol' or 'sodium ethanoic'. It is sodium ethanoate.
- Confusing weak with dilute. Weak means partially ionised; dilute means a low concentration.
- Leaving out the acid catalyst or the water when describing how an ester is made.

More tips

Memory tricks

- Acid + carbonate: fizzing means carbon dioxide. Test it with limewater.
- Ester names: the alcohol part comes first and ends in '-yl'; the acid part comes second and ends in '-oate'. Ethanol + ethanoic acid → ethyl ethanoate.
- '-oic acid' is the carboxylic acid; '-oate' is its salt or ester.
- Weak versus strong: a weak acid partly splits into ions; a strong acid splits completely. It has nothing to do with how much water is added.

Exam technique

- Balanced equations are not needed for carboxylic acid reactions; give clear word equations with correct names.
- For 'explain the pH' questions, make three links: weak acid, partially ionises, lower H^+ concentration, so higher pH.
- For carbonate reactions, give an observation (fizzing, solid disappears) as well as the name of the gas.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Name the functional group of carboxylic acids

The –COOH group.

Grade 4

Name the first four carboxylic acids

Methanoic, ethanoic, propanoic and butanoic acid; ethanoic acid is CH_3COOH.

Grade 5

Describe the reaction with carbonates

Fizzing as carbon dioxide is given off; a salt and water also form, e.g. sodium ethanoate.

Grade 5

Describe how an ester is made

Carboxylic acid + alcohol, with an acid catalyst, gives an ester and water: ethanoic acid + ethanol → ethyl ethanoate + water.

Grade 5

Draw the displayed formula of a carboxylic acid

Show the –COOH group with a C=O bond and a C–O–H.

Grade 7

Explain why carboxylic acids are weak acids

They only partially ionise in water, so the H^+ concentration is lower and the pH higher than a strong acid of the same concentration.

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