A-LEVEL CHEMISTRY • EXERCISE SHEET

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

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

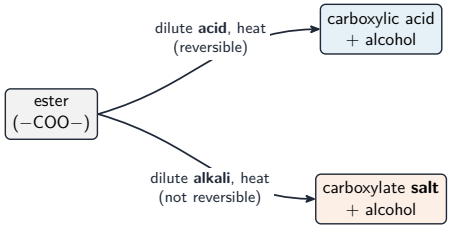
the –OH (acid) and –H (alcohol) leave as water; the C–O–C ester link forms

(concentrated H_2SO_4 catalyst; reversible)

*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]

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

3.5 (a) $CH_3COOH + CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$; 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) $CH_3COOCH_2CH_3 + NaOH \rightarrow CH_3COO^-Na^+ + CH_3CH_2OH$; 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.