InkChemistry

ANSWER BOOK

Acylation: acyl chlorides and acid anhydrides

Carbonyls and carboxylic acids · Unit C20

AQA 3.3.9.2 · OCR A 6.1.3

18 questions · 59 marks

NAVY EDITION

Every question in this book has a code beside its number.
Type inklearning.co.uk/q/ followed by the code to open that question online.
© 2026 Ink Learning Ltd. All rights reserved.
inklearning.co.uk/chemistry/

SECTION A · Short, 1 to 2 marks

A1 AA-Q8

B1 one mole of ammonia acts as the nucleophile and forms the amide, releasing HCl. **B1** ammonia is a base, so a second mole reacts with the HCl to form ammonium chloride. [2]

A2 AA-Q9

B1 the leaving group from an anhydride is a carboxylate ion, a poorer leaving group than the chloride ion. **B1** the carbonyl carbon of the anhydride is less δ+ than that of the acyl chloride, so it attracts nucleophiles less strongly. [2]

A3 AA-Q16

B1 the OH group to be acylated is a phenol group, which reacts only very slowly with a carboxylic acid. **B1** the anhydride is a more reactive acylating agent, and the reaction is not a slow equilibrium, so the yield is much higher. [2]

A4 AA-Q18

B1 the by-products of $SOCl_2$, sulfur dioxide and hydrogen chloride, are both gases that leave the flask. **B1** so the acyl chloride needs little separating, whereas with PCl_5 it must be distilled away from liquid $POCl_3$. [2]

SECTION B · Standard, 3 to 5 marks

B1 AA-Q6

B1 curly arrow from a lone pair on the oxygen of ethanol to the carbonyl carbon. **B1** curly arrow from the C=O double bond to the oxygen atom. **B1** intermediate drawn with O^- and with a positive charge on the oxygen of the ethanol group. **B1** three arrows: from O^- back to reform C=O, from the C–Cl bond to Cl, and from the O–H bond to O^+. **B1** the mechanism is nucleophilic addition–elimination. [5]

B2 AA-Q1

B1 CH_3CH_2COCl is propanoyl chloride. **B1** $(CH_3CO)_2O$ is ethanoic anhydride. **B1** methanol gives methyl ethanoate, CH_3COOCH_3. **B1** ethylamine gives N-ethylethanamide, $CH_3CONHCH_2CH_3$; the N is required. [4]

B3 AA-Q2

B1 $CH_3COCl + H_2O \rightarrow CH_3COOH + HCl$. **B1** steamy white fumes of hydrogen chloride, and a vigorous reaction; 'gas given off' alone is not credited. **B1** $CH_3COCl + 2NH_3 \rightarrow CH_3CONH_2 + NH_4Cl$. **B1** the organic product is ethanamide. [4]

B4 AA-Q5

B1 curly arrow from the lone pair on the nitrogen of CH_3NH_2 to the carbonyl carbon. **B1** curly arrow from the C=O double bond to the oxygen atom. **B1** intermediate drawn with O^- and with a positive charge on the nitrogen of the $CH_3NH_2^+$ group. **B1** three arrows: from O^- back to reform C=O, from the C–Cl bond to Cl, and from an N–H bond to N^+. [4]

© 2026 Ink Learning Ltd. All rights reserved.

B5 AA-Q20 [4]

B1 $CH_3CONH_2 + H_2O + HCl \rightarrow CH_3COOH + NH_4Cl$; allow H^+ in place of HCl with NH_4^+ as the product. **B1** the organic product with acid is ethanoic acid, the nitrogen leaving as ammonium ions. **B1** $CH_3CONH_2 + NaOH \rightarrow CH_3COONa + NH_3$; allow OH^- with CH_3COO^- as the product. **B1** the organic product with alkali is sodium ethanoate, and ammonia gas is given off, turning damp red litmus blue.

B6 AA-Q7 [3]

B1 the carbonyl carbon of the acyl chloride is bonded to two electronegative atoms, O and Cl. **B1** so it carries a larger δ+ charge and attracts the nucleophile more strongly. **B1** the chloride ion is a good leaving group, much better than the hydroxide ion an acid would lose.

B7 AA-Q10 [3]

M1 total Mr of reactants = 78.5 + 46.0 = 124.5. **M1** atom economy = 88.0 ÷ 124.5 × 100. **A1** atom economy = 70.7%, to 3 significant figures.

B8 AA-Q13 [3]

B1 both give the same organic product, ethyl ethanoate, by nucleophilic addition–elimination. **B1** ethanoyl chloride reacts quickly at room temperature, while the anhydride reacts more slowly and needs warming. **B1** the by-product is HCl with ethanoyl chloride and ethanoic acid with the anhydride.

B9 AA-Q14 [3]

B1 ethanoyl chloride gives a white precipitate of silver chloride at once. **B1** 1-chlorobutane gives a white precipitate only slowly, after warming. **B1** the acyl chloride is hydrolysed rapidly, releasing Cl^- ions, because its carbonyl carbon is strongly δ+ and is attacked by water, while the C–Cl bond of 1-chlorobutane is broken far more slowly.

B10 AA-Q15 [3]

B1 the organic product is propanamide, $CH_3CH_2CONH_2$. **B1** ammonium propanoate, $CH_3CH_2COONH_4$, from propanoic acid and the second ammonia molecule. **B1** $(CH_3CH_2CO)_2O + 2NH_3 \rightarrow CH_3CH_2CONH_2 + CH_3CH_2COONH_4$; allow 1 : 1 with propanoic acid as the by-product.

B11 AA-Q17 [3]

B1 a pure sample melts sharply at the data-book value, 135 °C. **B1** an impure sample melts below that value and over a range of several degrees. **B1** iron(III) chloride solution gives a purple colour with the free phenol group of 2-hydroxybenzoic acid, and none with pure aspirin.

B12 AA-Q19 [3]

B1 the carbonyl carbon of ethanoyl chloride is bonded to both O and Cl, so it is strongly δ+ and water adds to it readily. **B1** the C–Cl carbon of 1-chlorobutane is bonded to only one electronegative atom, so it is less δ+, and its C–Cl bond is broken only slowly by substitution. **B1** in chlorobenzene a chlorine lone pair overlaps with the ring's π electrons, strengthening the C–Cl bond, and the electron-rich ring repels nucleophiles.

© 2026 Ink Learning Ltd. All rights reserved.

B13 AA-Q21

B1 $C_6H_5OH + C_6H_5COCl \rightarrow C_6H_5COOC_6H_5 + HCl$. **B1** the organic product is phenyl benzoate. **B1** the alkali turns phenol into the phenoxide ion, a far better nucleophile, because phenol's own lone pair is partly delocalised into the ring. [3]

SECTION C · Long, 6 marks or more

C1 AA-Q12

Indicative content [6]

B1 the acyl chloride route has the higher atom economy, because its by-product, HCl, is lighter than ethanoic acid, which on its own favours it. **B1** ethanoic anhydride is cheaper to make in bulk, which matters more than atom economy at industrial scale. **B1** the anhydride is less corrosive and reacts less violently, so the reaction is easier to control in a large vessel. **B1** it is hydrolysed only slowly by water vapour in the air, so it is safer to store and handle than ethanoyl chloride. **B1** its by-product, ethanoic acid, is far less hazardous than hydrogen chloride gas and can be recovered and sold or reused. **B1** a justified conclusion: cost, safety and a useful by-product outweigh the lower atom economy, so the anhydride is the better choice.

Levels

Level 3 (5–6 marks) the higher atom economy of the acyl chloride route is acknowledged and outweighed by all the factors on the other side, cost, controllability, ease of storage and the safer, saleable by-product, with a justified conclusion in favour of the anhydride; the answer compares the two reagents throughout rather than describing one.

Level 2 (3–4 marks) two or three reasons for the anhydride are right and a conclusion is drawn; atom economy is left out, or the by-products are not set side by side.

Level 1 (1–2 marks) the anhydride is called safer or cheaper with no reason, or is preferred for a higher atom economy, which in fact belongs to the acyl chloride route.

© 2026 Ink Learning Ltd. All rights reserved.

THIS BOOK ONLINE



Scan the code, or type the address, to open the questions in this book online:

inklearning.co.uk/chemistry/practise/questions/acylation/

© 2026 Ink Learning Ltd. All rights reserved.