Solutions

Each answer shows the steps, then the **result**.

2.1

- ethanoic acid

2.2

- addition–elimination (nucleophilic)

2.3

- Ethyl propanoate

2.4

- A vigorous reaction; steamy white fumes of hydrogen chloride are produced

2.5

- Chloride is a much better leaving group than the hydroxyl of an acid; and the carbonyl carbon is more $\delta+$ because both the oxygen and the chlorine withdraw electrons, so it is attacked more readily

3.1 B

- Acyl chloride + ammonia
- amide (ethanamide) + HCl

3.2 B

- Acyl chloride $\gg$ alkyl chloride $\gg$ aryl chloride

3.3

- the nucleophile (the alcohol's O lone pair) adds to the slightly positive carbonyl carbon, forming a tetrahedral intermediate; the C=O double bond reforms; the C–Cl bond breaks and HCl is eliminated, giving the ester

3.4

- the carbonyl carbon of an acyl chloride is strongly $\delta+$ and easily attacked by a nucleophile; in an aryl chloride the C–Cl bond is strengthened by overlap with the ring and the ring repels nucleophiles, so it resists hydrolysis

3.5

(a)

- Ethanoic acid; methyl ethanoate; ethanamide; phenyl ethanoate

(b)

- Curly arrow from the nitrogen's lone pair to the $\delta+$ carbonyl carbon; arrow from the C = O π bond onto the oxygen, giving the tetrahedral intermediate with a negative

oxygen; arrow from the oxygen re-forming the double bond, with a second arrow expelling the chloride ion; loss of a proton to give ethanamide, and HCl

(c)

- Nucleophilic addition–elimination

(d)

- The reaction with an acyl chloride is fast and goes essentially to completion; esterification of a carboxylic acid is slow, needs an acid catalyst and reaches an equilibrium, so the yield is limited; the acyl chloride route therefore gives a higher yield in less time

(e)

- Phenol is a weak nucleophile because its oxygen lone pair is delocalised into the ring; the acyl chloride is reactive enough to be attacked even by a weak nucleophile, whereas the far less reactive carboxylic acid is not