17.3 Carboxylic acids and their derivatives

Answers to Exam practice questions

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1 Butane is non-polar. The only intermolecular forces are weak London forces. It has the lowest boiling temperature: 273 K. [1]

Methyl methanoate has a polar C=O bond and so there are attractions between permanent dipoles as well as London forces. It boils at a higher temperature than butane: 305 K. [1]

Hydrogen bonding is the strongest type of intermolecular force. Hydrogen bonding is possible between the molecules of propan-1-ol and between the molecules of ethanoic acid. [1]

There is greater scope for hydrogen bonding in ethanoic acid with the –OH group and O atom in the carboxylic acid group. Hence both compounds boil at a higher temperature than propanal, but ethanoic acid boils at a higher temperature (391 K) than propan-1-ol (371 K). [1]

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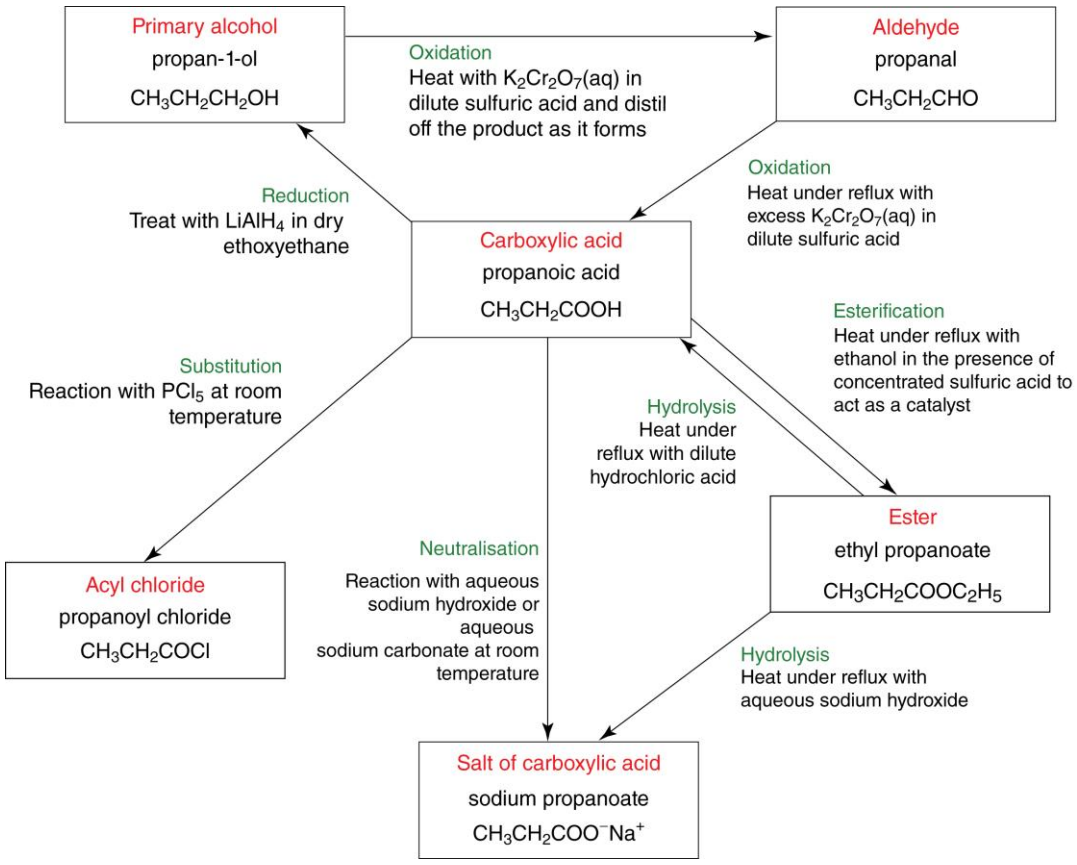


a) 1 mark for each complete box. [6]

b) 1 mark for each correctly labelled arrow. [8]

3 **a)** $CH_3CHBrCHBrCH_2CH_2COOCH_3$ [1]

b) $CH_3CH_2CH_2CH_2CH_2COOCH_3$ [1]

c) $CH_3CH{=}CHCH_2CH_2COONa$ and CH_3OH [1]

4 a) Possible answers:

Reaction with magnesium [1]; colourless flammable gas given off as metal disappears [1]; reaction much faster with hydrochloric acid. [1]

OR

Reaction with sodium carbonate solution [1]; colourless gas given off which turns limewater milky [1]; effervescence much more vigorous with hydrochloric acid. [1]

b) Acid solutions react in a similar way because they contain $H^+(aq)$ ions. [1]

$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$ [1]

$CO_3^{2-}(s) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$ [1]

HCl(aq) is a strong acid and so is fully ionised [1]; ethanoic acid is a weak acid and so is only slightly ionised. [1]

The reactions with HCl(aq) are much faster because of the higher concentration of hydrogen ions. [1]

5 a) Propanoyl chloride, CH_3CH_2COCl [1]

b) Butan-1-ol, $CH_3CH_2CH_2CH_2OH$ [1]

c) Pentan-1-ol, $CH_3CH_2CH_2CH_2CH_2OH$ [1]; and sodium ethanoate CH_3COONa [1]

d) Calcium ethanoate, $(CH_3COO)_2Ca$ [1]

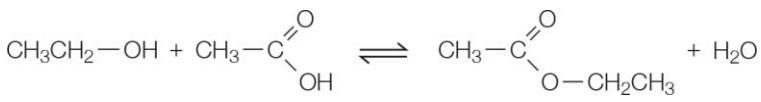
e) Methylethyl ethanoate, $CH_3COOCH(CH_3)_2$ [1]

6 a) $C_{13}H_{18}O_2$ [1]

b) The carboxylic acid group can form hydrogen bonds with water. [1] The hydrocarbon part of the molecule is non-polar and cannot easily break into the hydrogen-bonded structure of water. [1] The large hydrocarbon part of the molecule, including a benzene ring, means that ibuprofen is only likely to be very sparingly soluble in water. [1]

c) i) The same as the structure shown in the question but with the carboxylic acid group turned into a sodium salt: $–COO^-Na^+$. [1]

ii) The same as the structure shown in the question but with the carboxylic acid group turned into an ethyl ester: $–COOC_2H_5$. [1]

7 a) 

Left-hand side structures and reversible arrows [1]; right-hand structures. [1]

b) Sulfuric acid acts as a catalyst in the esterification reaction. [1]

c) The compounds involved, especially ethanol, are volatile [1] and flammable so naked flames must be kept well away from them. [1]

d) Ethyl ethanoate [1]

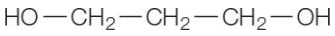
e) Ethanoic acid has a pungent smell. [1]

It dissolves in water and so does not mask the smell of the ester, which floats on the top. [1]

8 a) A condensation reaction is one in which molecules join together by splitting off a small molecule, such as water, from two functional groups, such as a carboxylic acid group and an alcohol group [1]; condensation polymers are produced by a series of condensation reactions between the functional groups of the monomers, where each monomer has at least two of the reactive functional groups. [1]

b) 

[1]



[1]

Benzene-1,4-dicarboxylic acid is a carboxylic acid. [1]

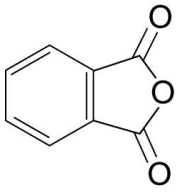
Propane-1,3-diol is an alcohol. [1]

c) Polyesters are used to make fibres and fabrics for clothing and other uses. [1]

Polyesters can be melted and spun into fibres which are strong. The fibres in polyester fabrics do not stretch or shrink. [1]

9 This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained line of reasoning. Assess the quality of the answer taking into account both the key points made (*up to 4 marks*) and the logic and coherence of the discussion (*up to 2 marks*).

Points to make in the answer:

- One mol of acid reacts with 2 mol NaOH therefore each acid contains a benzene ring and two carboxylic acid groups.
- Z has two H and one O less than the formula of its parent acid. Therefore it is an anhydride.
- The anhydride forms from heating the compound with two carboxylic acid groups that are attached to neighbouring carbon atoms in the benzene ring, therefore acid Y is benzene-1,2-dicarboxylic acid (phthalic acid).
- Z is 

- X forms a linear polymer, therefore it has the carboxylic acid groups on opposite sides of the benzene ring, so X is benzene-1,4-dicarboxylic acid (terephthalic acid).
- W is benzene-1,3-dicarboxylic acid.

10 A – an acid liberates CO_2 with a carbonate [1], so CH_3COOH. [1]

B – an aldehyde gives a red ppt with Fehling's [1], so $HOCH_2CHO$. [1]

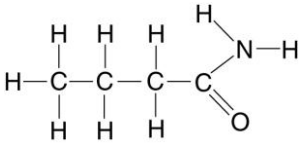
C – an ester is hydrolysed by NaOH(aq) [1], so $HCOOCH_3$. [1]

11 a) *Step 1*: Heat under reflux with dilute hydrochloric acid. [1]

Step 2: React with PCl_5 at room temperature. [1]

b) $CH_3CH_2CH_2COCl$ [1]; butanoyl chloride. [1]

c) Butanamide [1]



[1]

12 a) Amount of $H_2O = 2 \times 0.27 = 0.54$ mol [1]

Amount of A = 0.50 – 0.27 = 0.23 mol [1]

Amount of $CH_3CH_2OH = 0.80 - (2 \times 0.27) = 0.26$ mol [1]

b) $K_c = \dfrac{[B][H_2O]^2}{[A][C_2H_5OH]^2}$ [1]

$= \dfrac{[0.27/V][0.54/V]^2}{[0.23/V][0.26/V]^2}$ [1]

= 5.1 (no units) [1]

It is not necessary to know the volume, *V*, because *V* cancels in the expression for K_c. [1]

c) Exothermic reaction [1]

So, by Le Chatelier's principle, the reaction moves to the LHS to oppose an increase in temperature [1]; so K_c decreases. [1]

d) Diethyl ethanedioate [1]

Any one from:

- flammable so keep away from flames
- corrosive, so wear protective gloves/eye protection
- use in well-ventilated area. [1]

13 a) The four isomeric esters are

1 $HCOOCH_2CH_2CH_3$ [1]

2 $HCOOCH(CH_3)_2$ [1]

3 $CH_3COOCH_2CH_3$ [1]

4 $CH_3CH_2COOCH_3$ [1]

b) This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained line of reasoning. Assess the quality of the answer taking into account both the key points made (*up to 4 marks*) and the logic and coherence of the discussion (*up to 2 marks*).

Points to make in the answer:

- On hydrolysis, the esters form volatile alcohols and carboxylate salts.
- Esters 2 and 3 form propan-2-ol and ethanol respectively, which both form CHI_3 precipitates with I_2/NaOH; but esters 1 and 4 form propan-1-ol and methanol, which do not give a yellow precipitate.
- Therefore esters 2 and 3 are W and X (but not necessarily in that order).
- Acidification of the remaining solution in the flask forms carboxylic acids.
- Esters 1 and 2 form methanoic acid, which can be oxidised by $KMnO_4$ and decolourise it because HCOOH contains the aldehyde group; but ester 3 forms ethanoic acid and ester 4 forms propanoic acid, neither of which have any effect on $KMnO_4$.
- Therefore esters 1 and 2 are W and Z (but not necessarily in that order).
- Therefore: W = ester 2 X = ester 3 Y = ester 4 Z = ester 1