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ANSWER BOOK

Carboxylic acids, esters and biodiesel

Carbonyls and carboxylic acids · Unit C20

AQA 3.3.9.1 · OCR A 6.1.3, 6.2.2, 6.2.4

20 questions · 62 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 CAE-Q5

B1 ethanoic acid is a weak acid, only slightly dissociated into ions, whereas hydrochloric acid is fully dissociated. **B1** the concentration of H^+ ions in the ethanoic acid solution is therefore lower, so its pH is higher. [2]

A2 CAE-Q7

B1 the C–O bond of the alcohol is not broken, so the alcohol's oxygen becomes the ester's single-bonded oxygen. **B1** the water is formed from the OH of the acid and the H of the alcohol. [2]

A3 CAE-Q14

B1 glycerol has three OH groups and hydrogen bonds strongly, so it does not mix with the much less polar methyl esters. **B1** it is denser, so it forms a separate lower layer that can be run off. [2]

A4 CAE-Q21

B1 the carbon of methanoic acid carries a hydrogen atom, as an aldehyde's carbonyl carbon does. **B1** so methanoic acid can be oxidised further, to carbon dioxide and water, reducing the silver(I) to silver; ethanoic acid cannot be oxidised by a mild oxidising agent. [2]

SECTION B · Standard, 3 to 5 marks

B1 CAE-Q1

B1 add solid sodium carbonate or sodium hydrogencarbonate to each liquid. **B1** ethanoic acid effervesces, giving a gas that turns limewater milky; ethanol gives no change. **B1** $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$; allow the hydrogencarbonate equation. **B1** the salt is sodium ethanoate. [4]

B2 CAE-Q15

B1 both are carried out by heating under reflux, and both give methanol. **B1** acid hydrolysis gives ethanoic acid, while alkaline hydrolysis gives sodium ethanoate. **B1** acid hydrolysis is reversible and incomplete, while alkaline hydrolysis goes to completion. **B1** in acid, H_2SO_4 is a catalyst, while in alkali the hydroxide is used up in the reaction. [4]

B3 CAE-Q16

B1 distil the mixture and collect the crude ester. **B1** shake the distillate with sodium carbonate solution in a separating funnel to remove acid, releasing the pressure of carbon dioxide. **B1** run off the aqueous layer and dry the ester with anhydrous calcium chloride. **B1** redistil, collecting the fraction boiling close to 77 °C. [4]

B4 CAE-Q3

B1 $CH_3CH_2COOCH_2CH_3$ is ethyl propanoate. **B1** $HCOOCH_3$ is methyl methanoate. **B1** $CH_3CH_2CH_2COOCH_3$ is methyl butanoate; reject butyl methanoate. [3]

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B5 CAE-Q4 **B1** propan-1-ol, with concentrated sulfuric acid as the catalyst. **B1** warm, or heat under reflux. **B1** $CH_3COOH + CH_3CH_2CH_2OH \rightleftharpoons CH_3COOCH_2CH_2CH_3 + H_2O$. [3]

B6 CAE-Q6 **B1** acid hydrolysis is the reverse of esterification and reaches the same equilibrium, so some ester remains. **B1** in alkali the carboxylic acid formed is at once neutralised to a carboxylate ion. **B1** the carboxylate ion does not react with the alcohol, so the reverse reaction cannot occur. [3]

B7 CAE-Q8 **B1** the plasticiser molecules fit between the polymer chains. **B1** they push the chains further apart, weakening the intermolecular forces between them. **B1** the chains can then slide past each other, so the polymer bends instead of being rigid. [3]

B8 CAE-Q10 **M1** amount of triglyceride = 403 ÷ 806.0 = 0.500 mol. **M1** each triglyceride gives three methyl esters, so 3 × 0.500 = 1.50 mol of methyl hexadecanoate. **A1** mass = 1.50 × 270.0 = 405 g, to 3 significant figures. [3]

B9 CAE-Q11 **B1** the fat is heated with concentrated aqueous sodium hydroxide. **B1** the three ester links of the triglyceride are hydrolysed. **B1** the products are glycerol, propane-1,2,3-triol, and the sodium salts of the fatty acids, which are the soap. [3]

B10 CAE-Q12 **B1** perfumes or food flavourings, because small esters are volatile with sweet, fruity smells. **B1** solvents such as nail-varnish remover or glue, because they dissolve organic compounds and evaporate easily. **B1** plasticisers in PVC, because their molecules fit between the polymer chains and let them slide; a use with no property is not credited. [3]

B11 CAE-Q13 **B1** use an excess of one reactant, usually the cheaper one. **B1** distil the ester off as it forms, or remove water, for example with the concentrated sulfuric acid. **B1** removing a product or adding a reactant moves the position of equilibrium to the right, by Le Chatelier's principle. [3]

B12 CAE-Q18 **B1** the ethanoate ion's negative charge is delocalised over both oxygen atoms. **B1** the ethoxide ion's charge is on one oxygen, and the ethyl group pushes electron density towards it. **B1** so the ethanoate ion is more stable and ethanoic acid dissociates further, releasing more H^+. [3]

B13 CAE-Q19 **B1** trichloroethanoic acid, then chloroethanoic acid, then ethanoic acid. **B1** chlorine is more electronegative than carbon and draws electron density away from the COO^- group, spreading its charge and stabilising the anion. **B1** each extra chlorine adds to the effect, so the more chlorines, the further the acid dissociates. [3]

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B14 CAE-Q20 **B1** dilute hydrochloric acid (or another dilute strong acid). **B1** the mixture is heated under reflux. **B1** $CH_3CH_2CN + 2H_2O + HCl \rightarrow CH_3CH_2COOH + NH_4Cl$. [3]

B15 CAE-Q22 **M1** a saturated ester with no ring has the general formula $C_nH_{2n}O_2$, so Mr = 14n + 32.0 = 102.0 and n = 5: the ester is $C_5H_{10}O_2$. **M1** hydrolysis gives ethanol, so the alcohol part is the ethyl group, OCH_2CH_3, which accounts for two of the five carbons; the acid part therefore has three carbons and is propanoic acid, CH_3CH_2COOH. **A1** the ester of propanoic acid and ethanol is ethyl propanoate, $CH_3CH_2COOCH_2CH_3$, whose Mr is 5 × 12.0 + 10 × 1.0 + 2 × 16.0 = 102.0, as required. [3]

SECTION C · Long, 6 marks or more

C1 CAE-Q17 **Indicative content** [6]

B1 the carbon dioxide released on burning was taken in by the rapeseed plants during photosynthesis, which supports the claim of carbon neutrality. **B1** fossil fuels are burned in farming, making fertiliser, transport and processing, so extra carbon dioxide is released overall. **B1** the methanol used in transesterification is usually made from natural gas, a fossil fuel, so the claim is not fully supported. **B1** the oil is a renewable resource, where crude oil is finite, and biodiesel contains almost no sulfur, so little sulfur dioxide forms. **B1** land used to grow oil crops is land not growing food, which can raise food prices or lead to forest clearance. **B1** a justified conclusion: biodiesel releases less fossil carbon than diesel but is not carbon-neutral, so it reduces rather than removes the impact.

Levels

Level 3 (5–6 marks) the basis of the carbon-neutral claim is explained through photosynthesis, the fossil-fuel inputs including the methanol are identified, the renewability and low sulfur of biodiesel and the land-use cost are all weighed, and a justified conclusion is drawn that it reduces rather than removes the impact.

Level 2 (3–4 marks) the claim is explained and at least one fossil-fuel input named, with one more advantage or drawback; the conclusion is absent or does not follow from the points made.

Level 1 (1–2 marks) biodiesel is accepted as carbon-neutral because it comes from plants, with no fossil-fuel input such as the methanol or the fertiliser considered.

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