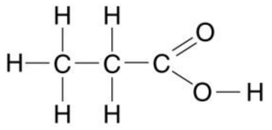
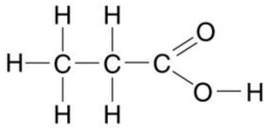
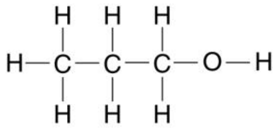
17.2 Carbonyl compounds Answers to Exam practice questions

Pages 192–193

1

Reactant	**Reagent**	**Organic product**	
		Name	**Displayed formula**
CH_3CH_2CHO	Tollens' reagent	Propanoic acid [1]	 [1]
CH_3CH_2CHO	$Cr_2O_7^{2-}/H^+$ [1]	Propanoic acid	 [1]
CH_3CH_2CHO	$LiAlH_4$	Propan-1-ol [1]	 [1]

2 **a)** $C_{10}H_{16}O$ [1]

b) **i)** Carbon–carbon double bond as in an alkene [1]; aldehyde group. [1]

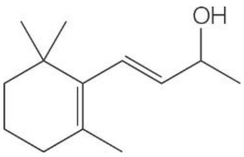
ii) Ketone group. [1]

c) **i)** The blue reagent gives an orange-brown precipitate [1] with citral; but not with β-ionone. [1]

ii) The reagent gives a bright orange precipitate [1]; both with citral and with β-ionone. [1]

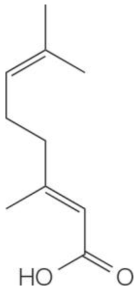
iii) The reagent gives a pale yellow precipitate [1] with β-ionone; but not with citral. [1]

d) **i)**



[1]

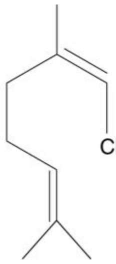
ii)



[1]

e) **i)** Both compounds have *E*/*Z* isomers. [1]

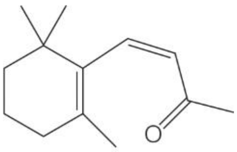
ii) EITHER



[1]

Z-citral [1]

OR



[1]

Z-β-ionone [1]

iii) Neither compound has a chiral centre and so neither has optical isomers. [1]

3 X must have four separate groups around the central carbon atom [1] including an acid group to give carbon dioxide with a carbonate [1]: $CH_3CHOHCOOH$. [1]

Oxidation gives a carbonyl compound Y which is a ketone because it does not react with Fehling's solution [1]: $CH_3COCOOH$. [1]

4 **a)** W: empirical formula CH_2, molecular formula C_4H_8 [1]; could be but-1-ene or but-2-ene [1]; because both give 2-bromobutane when they add HBr.

X: 2-bromobutane [1]; because it hydrolyses to butan-2-ol. [1]

Y: butan-2-ol [1]; a secondary alcohol because it oxidises to a ketone. [1]

Z: butanone [1]; a ketone because it does not react with Benedict's reagent. [1]

b) $CH_3CH{=}CHCH_3(l) + HBr(g) \rightarrow CH_3CH_2CHBrCH_3(l)$ [1]

$CH_3CH_2CHBrCH_3(l) + NaOH(aq) \rightarrow CH_3CH_2CHOHCH_3(l) + NaBr(aq)$ [1]

$CH_3CH_2CHOHCH_3(l) + [O] \rightarrow CH_3CH_2COCH_3(l)$ [1] (oxidation)

c) W: Electrophilic addition [1]

X: Nucleophilic substitution [1]

5 **i)** **a)** Tollens' [1]: pentanal gives a silver mirror [1]; no reaction with pentan-3-one. [1]

b) Acidified $K_2Cr_2O_7$ [1]: no reaction with pentan-3-one [1]; solution turns from orange to green with pentan-3-ol. [1]

c) Iodine and sodium hydroxide [1]: no reaction with pentan-3-ol [1]; yellow precipitate with pentan-2-ol. [1]

ii) **a)** Infrared absorptions: pentanal gives an absorption in infrared in the region 1740–1720 cm^{-1} [1]; pentan-3-one gives an absorption in infrared in the region 1720–1700 cm^{-1}. [1]

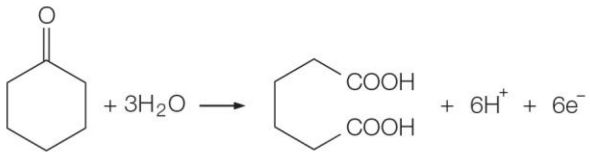
b) Infrared absorptions: pentan-3-one gives an absorption in infrared in the region 1720–1700 cm^{-1} [1]; pentan-3-ol gives an absorption in the region 3750–3200 cm^{-1}. [1]

c) Optical activity: pentan-2-ol has a chiral centre so each enantiomer will show optical activity [1]; pentan-3-ol does not have a chiral centre so does not show any optical activity. [1]

6) **a)** $CH_3CH_2CHO + H_2O \rightarrow CH_3CH_2COOH + 2H^+ + 2e^-$ [1]

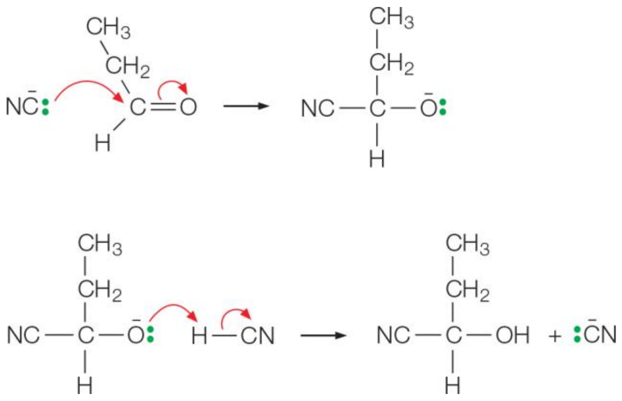
b) $CH_3CH_2CHO + 3OH^- \rightarrow CH_3CH_2COO^- + 2H_2O + 2e^-$ [1]

c)



[1]

7 **a)**



Cyanide ion plus lone pair plus arrow [1]; propanal plus arrow. [1]

Structure of intermediate ion. [1]

Arrow from lone pair on O to H–CN and arrow from H–CN bond to C of CN. [1]

b) If the pH is too high, then [H^+] is low [1] (and [HCN] falls), so the second stage becomes slow. [1]

If the pH is too low, then [CN^-] is low [1] and the first stage becomes slow. [1]

c) A racemic mixture is formed [1] because attach by the nucleophile can occur from above or below the plane of the carbonyl group. [1]

8 **a)** **i)** $C_6H_{12}O_6$ [1]

ii) The formula can be rewritten as $C_6(H_2O)_6$. So glucose contains carbon with hydrogen and oxygen in the same proportions as in water. [1] Hence the name carbo*hydrate*.

b) The large number of –OH groups means that there is extensive hydrogen bonding between glucose molecules. [1]

These intermolecular forces are strong enough for the relatively small molecules to form a solid at room temperature. [1]

Glucose molecules can also form many hydrogen bonds with water molecules [1]. The interaction with water is strong enough for glucose molecules to break away from the solid and dissolve. [1]

c) The functional group in open chain glucose is an aldehyde group. Glucose is an aldose. [1]

d) **i)** Glucose gives an orange precipitate when it reacts with 2,4-dintrophenylhydrazine. [1]

ii) 2,4-Dinitrophenylhydrazine reacts with the aldehyde group in the open chain form. [1]

Only 1% of glucose is in the open chain form in solution. [1]

e) **i)** As an aldehyde, glucose reacts with Tollens' reagent to give a silver mirror. [1]

ii) Glucose is a reducing agent. It reduces silver(I) ions in Tollens' solution to metallic silver. [1] (Glucose similarly reduces copper(II) to copper(I) when it reacts with Fehling's or Benedict's reagent.)

f) The oxygen on carbon number 5 [1] uses its lone pair to act as a nucleophile [1] to attack the δ+ carbon of the carbonyl group on carbon number 1. Nucleophilic addition [1] occurs to produce the six-membered ring structure. [1] A racemic [1] mixture is formed of α and β glucose.

9 Equations to describe the mechanism of addition to C=C and C=O. (2 × [2])

	Propene with bromine	**HCN with propanone**
Similarities	Addition reaction Heterolytic bond breaking Two-step process (*any 2* for [2])	
Differences	Electrophilic reagent Attacks electron-rich π bond Intermediate is a positive ion (*any 2* for [2])	Nucleophilic reagent Attacks δ+ end of polar C=O bond Intermediate is a negative ion (*any 2* for [2])

10 a) $CH_3COCH_2CH_3 + 2[H] \rightarrow CH_3CHOHCH_2CH_3$ [1]

b) i) $LiAlH_4$ effectively contains hydride ions so reacts by nucleophilic addition. [1]

C=O bonds are polar and the nucleophile can attack the δ+ carbon. [1]

C=C bond in alkenes is non-polar so nucleophiles cannot attack

OR The π cloud of electrons in alkenes repels the negative hydride ion. [1]

ii) Hydride ions react with δ+ H atoms [1] in water molecules so $LiAlH_4$ is decomposed by solvents which can donate protons. [1]

c) $LiAlH_4$ is the stronger [1] as it is a better hydride donor.

AlH_4^- ions contain H^- ion co-ordinately bonded to Al (using vacant orbital in level 3). [1]

These hydride ions are less strongly held than the H^- ion co-ordinately bonded to B in BH_4^- ions, which use vacant orbital in level 2. [1]

11 a) A molecule of P adds two molecules of HCN so P has two aldehyde groups. [1]

P is $OHCCH_2CH_2CHO$ [1] rather than $CH_3CH(CHO)_2$. [1]

Q is $HOCH(CN)CH_2CH_2CH(CN)OH$. [1]

Oxidation converts aldehyde groups to acid groups. [1]

R is $HOOCCH_2CH_2COOH$. [1]

1.0 g R is 0.00847 mol of the compound. [1]

In the titration this reacts with 0.0169 mol sodium hydroxide [1];

so 1.0 mol of the acid reacts with 2.0 mol of the alkali. [1]

This confirms that there are two acid groups in R.

b) The ratio of amounts in Z is C : H : O = 5.36 : 7.11 : 1.79 [1], which is 3 : 4 : 1.

The simplest (empirical) formula of Z is C_3H_4O. [1]

The molar mass of Z is 56 and its molecular formula is also C_3H_4O. [1]

0.00179 mol Z [1] reacts with 0.00356 mol hydrogen. [1]

So 1 mol Z reacts with 2 H_2, showing that there are two double bonds in the molecule. [1]

Z reduces Fehling's solution so one of the double bonds is in an aldehyde group. [1]

Z is $CH_2{=}CH{-}CHO$. [1]

12 *Step 1*: Warm 2-bromobutane with aqueous/alcoholic sodium hydroxide [1] to form butan-2-ol. [1]

Step 2: Heat with acidified potassium dichromate(VI) [1] to form butanone. [1]

Step 3: Add iodine and sodium hydroxide [1] to form propanoate ions [1] (and CHI_3).

Step 4: Acidify with dilute hydrochloric acid. [1]