

**Q8.**

How many structural isomers with the molecular formula  $C_5H_{10}O$  react with Tollens' reagent?

- A 3
- B 4
- C 5
- D 6

(Total 1 mark)

**Q9.**

The aldehyde  $CH_3CH_2CH_2CH_2CHO$  reacts with KCN followed by dilute acid to form a racemic mixture of the two stereoisomers of  $CH_3CH_2CH_2CH_2CH(OH)CN$

(a) Give the IUPAC name of  $CH_3CH_2CH_2CH_2CH(OH)CN$

\_\_\_\_\_

(1)

(b) Describe how you would distinguish between separate samples of the two stereoisomers of  $CH_3CH_2CH_2CH_2CH(OH)CN$

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(2)

(c) Explain why the reaction produces a racemic mixture.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(3)



- (d) An isomer of  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHO}$  reacts with KCN followed by dilute acid to form a compound that does not show stereoisomerism.

Draw the structure of the compound formed and justify why it does not show stereoisomerism.

Structure

Justification

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(2)  
(Total 8 marks)

### Q10.

Which alcohol could **not** be produced by the reduction of an aldehyde or a ketone?

- A 2,2-dimethylpropan-1-ol
- B 2-methylbutan-2-ol
- C 3-methylbutan-2-ol
- D pentan-3-ol

(Total 1 mark)

**Q11.**

Ethanol can be oxidised by acidified potassium dichromate(VI) to ethanoic acid in a two-step process.



- (a) In order to ensure that the oxidation to ethanoic acid is complete, the reaction is carried out under reflux.

Describe what happens when a reaction mixture is refluxed and why it is necessary, in this case, for complete oxidation to ethanoic acid.

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**(3)**

- (b) Write a half-equation for the overall oxidation of ethanol into ethanoic acid.

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**(1)**



- (c) The boiling points of the organic compounds in a reaction mixture are shown in the following table.

Compound	ethanol	ethanal	ethanoic acid
Boiling point / °C	78	21	118

Use these data to describe how you would obtain a sample of ethanal from a mixture of these three compounds. Include in your answer a description of the apparatus you would use and how you would minimise the loss of ethanal. Your description of the apparatus can be either a description in words or a labelled sketch.

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(5)

- (d) Use your knowledge of structure and bonding to explain why it is possible to separate ethanal in this way.

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(2)



- (e) A student obtained a sample of a liquid using the apparatus in part (c).

Describe how the student could use chemical tests to confirm that the liquid contained ethanal and did **not** contain ethanoic acid.

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(5)

(Total 16 marks)

**Q12.**

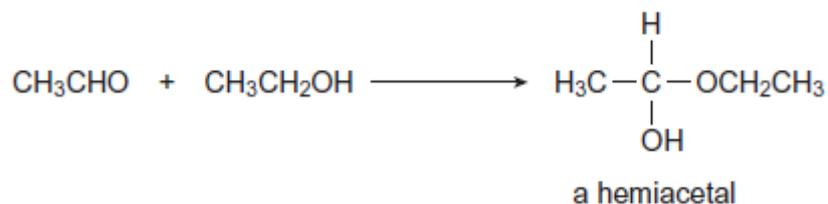
Which alcohol could **not** be produced by the reduction of an aldehyde or a ketone?

- A 2-methylbutan-1-ol
- B 2-methylbutan-2-ol
- C 3-methylbutan-1-ol
- D 3-methylbutan-2-ol

(Total 1 mark)

**Q13.**

Hemiacetals and acetals are compounds formed by the reaction of aldehydes with alcohols, such as the reaction of ethanal with ethanol.



- (a) (i) Use your knowledge of carbonyl mechanisms to suggest the name of the mechanism of this reaction.
- \_\_\_\_\_
- (1)**
- (ii) Outline how an ethanol molecule reacts with an ethanal molecule in the first step of this mechanism. Include two curly arrows to show the movement of electron pairs.

**(2)**

- (b) The reaction produces a racemic mixture of chiral molecules.

- (i) Explain the meaning of the term racemic mixture.

\_\_\_\_\_  
\_\_\_\_\_

**(1)**

- (ii) State the relationship between two chiral molecules with the same structural formula.

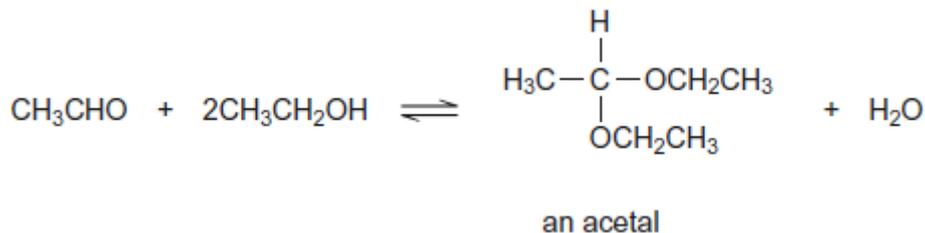
\_\_\_\_\_  
\_\_\_\_\_

**(1)**



- (c) In the presence of an acid catalyst such as dry hydrogen chloride, ethanal reacts with an excess of ethanol to form an acetal.

The overall reaction of ethanal with an excess of ethanol forms an equilibrium mixture as shown. All reactants and products are liquids.



A mixture of 0.75 mol of ethanal and 5.00 mol of ethanol was left to reach equilibrium in the presence of dry hydrogen chloride at a given temperature. The equilibrium mixture contained 0.42 mol of the acetal.

- (i) Calculate the amount, in moles, of ethanal and of ethanol in this equilibrium mixture.

Amount of ethanal \_\_\_\_\_ mol

Amount of ethanol \_\_\_\_\_ mol

Space for working \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

(2)

- (ii) In a different experiment using the same reaction as in part (c), an equilibrium mixture was established at a given temperature. This mixture contained 0.58 mol of ethanal, 3.76 mol of ethanol, 0.37 mol of the acetal and 0.65 mol of water in a total volume of 310 cm<sup>3</sup>.

Write an expression for the equilibrium constant  $K_c$  for this reaction.  
Calculate a value for  $K_c$  at this temperature. Give units with your answer.

$K_c$  \_\_\_\_\_

\_\_\_\_\_

Calculation \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(4)



- (d) Draw the structure of the acetal ( $C_4H_8O_2$ ) formed by the reaction of ethanal with ethane-1,2-diol.

(1)

(Total 12 marks)

**Q14.**

The carbonyl compound  $CH_3CH_2CHO$  reacts very slowly with HCN

- (a) Name and outline a mechanism for the reaction of  $CH_3CH_2CHO$  with HCN

Name of mechanism \_\_\_\_\_

Mechanism

(5)

- (b) The reaction in part (a) produces a pair of enantiomers.

- (i) Draw the structure of each enantiomer to show how they are related to each other.

(2)

- (ii) State and explain how you could distinguish between the two enantiomers.

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(2)



- (c) Give the IUPAC name of the product of the reaction in part (a).

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(1)

- (d) In practice, KCN rather than HCN is added to the carbonyl compound.

Given that  $K_a$  for HCN =  $4.0 \times 10^{-10} \text{ mol dm}^{-3}$ , suggest why the reaction with HCN is very slow.

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(2)

- (e) Acrylic fibres are used as a substitute for wool. Acrylics are copolymers of acrylonitrile with other compounds.

Acrylonitrile is the common name for the following compound.



- (i) Acrylonitrile can be formed from propene.

Write an equation for the reaction of propene with ammonia and oxygen to form acrylonitrile and one other product.

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(1)

- (ii) The term copolymer is used to describe the product obtained when two or more different monomers form a polymer.

Draw the repeating unit of the acrylic copolymer that contains 75% acrylonitrile monomer and 25% chloroethene monomer.

(1)

- (iii) Name the type of polymerisation involved in part (ii)

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(1)

(Total 15 marks)

**Q15.**

Lactic acid,  $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ , is formed in the human body during metabolism and exercise. This acid is also formed by the fermentation of carbohydrates such as sucrose,  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ .

- (a) (i) Give the IUPAC name for lactic acid.

\_\_\_\_\_

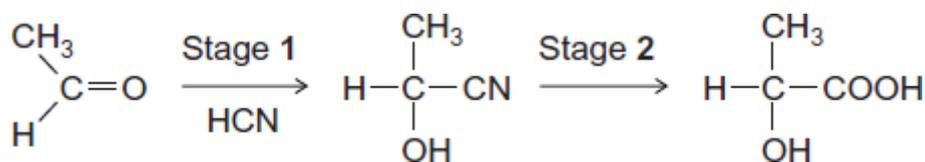
**(1)**

- (ii) Write an equation for the formation of lactic acid from sucrose and water.

\_\_\_\_\_

**(1)**

- (b) A molecule of lactic acid contains an asymmetric carbon atom. The lactic acid in the body occurs as a single enantiomer. A racemic mixture (racemate) of lactic acid can be formed in the following two-stage synthesis.



- (i) Name and outline a mechanism for Stage 1.

Name of mechanism \_\_\_\_\_

Mechanism

**(5)**

- (ii) Give the meaning of the term *racemic mixture (racemate)*.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**(1)**



- (iii) Explain how you could distinguish between a racemic mixture (racemate) of lactic acid and one of the enantiomers of lactic acid.

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(2)

- (c) A mixture of lactic acid and its salt sodium lactate is used as an acidity regulator in some foods. An acidity regulator makes sure that there is little variation in the pH of food.

- (i) Write an equation for the reaction of lactic acid with sodium hydroxide.

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(1)

- (ii) The acid dissociation constant  $K_a$  for lactic acid has the value  $1.38 \times 10^{-4} \text{ mol dm}^{-3}$  at 298 K.

Calculate the pH of an equimolar solution of lactic acid and sodium lactate.

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(2)

- (iii) Suggest an alternative name for the term *acidity regulator*.  
Explain how a mixture of lactic acid and sodium lactate can act as a regulator when natural processes increase the acidity in some foods.

Name \_\_\_\_\_

Explanation \_\_\_\_\_

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(3)



(d)



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The cup shown is made from PLA, poly(lactic acid).  
PLA is the condensation polymer formed from lactic acid.

The polymer is described as 100% biodegradable and 100% compostable.

Compostable material breaks down slowly in contact with the moist air in a garden bin.  
This produces compost that can be used to improve soil.

The manufacturers stress that PLA cups differ from traditional plastic cups that are neither biodegradable nor compostable.

(i) Draw a section of PLA that shows **two** repeating units.

(2)

(ii) Name the type of condensation polymer in PLA.

\_\_\_\_\_

(1)



- (iii) An intermediate in the production of PLA is a cyclic compound ( $C_6H_8O_4$ ) that is formed from two PLA molecules.

Draw the structure of this cyclic compound.

(1)

- (iv) Traditional non-biodegradable plastic cups can be made from poly(phenylethene), commonly known as *polystyrene*.

Draw the repeating unit of poly(phenylethene).

(1)

- (v) The manufacturers of PLA claim that the material will break down to compost in just 12 weeks.

Suggest **one** reason why PLA in landfill may take longer than 12 weeks to break down.

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(1)

(Total 22 marks)



## Mark Scheme

Q8.

B

[1]

Q9.

(a) 2-hydroxyhexanenitrile

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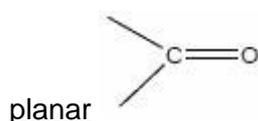
(b) (Plane) polarised light

1

Enantiomers would rotate light in opposite directions  
*not different alone*

1

(c) planar carbonyl group or



*Not planar molecule,  
not planar bond, not planar C=O*

1

Attack from either side

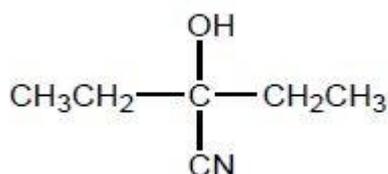
1

With equal probability

**OR** produces equal amounts (of the two isomers/enantiomers)

1

(d)



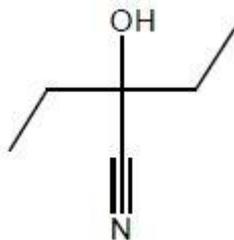
Does not contain a chiral centre

**OR** does not contain C attached to 4 different groups

**OR** contains two identical/ethyl groups

**OR** symmetrical (product)

*Allow C<sub>2</sub>H<sub>5</sub> or skeletal*



M2 dependent on correct M1 (No structure = 0)

If pentan-3-one drawn then allow symmetrical ketone for M2

[8]

Q10.

B

[1]

Q11.

(a) A mixture of liquids is heated to boiling point for a prolonged time

1

Vapour is formed which escapes from the liquid mixture, is changed back into liquid and returned to the liquid mixture

1

Any ethanal and ethanol that initially evaporates can then be oxidised

1

(b)  $\text{CH}_3\text{CH}_2\text{OH} + \text{H}_2\text{O} \longrightarrow \text{CH}_3\text{COOH} + 4\text{H}^+ + 4\text{e}^-$

1

(c) Mixture heated in a suitable flask / container

*A labelled sketch illustrating these points scores the marks*

1

With still head containing a thermometer

1

Water cooled condenser connected to the still head and suitable cooled collecting vessel

1

Collect sample at the boiling point of ethanal

1

Cooled collection vessel necessary to reduce evaporation of ethanal

1

(d) Hydrogen bonding in ethanol and ethanoic acid or no hydrogen bonding in ethanal

1

Intermolecular forces / dipole-dipole are weaker than hydrogen bonding

1

(e) Reagent to confirm the presence of ethanal:



Add Tollens' reagent / ammoniacal silver nitrate / aqueous silver nitrate followed by 1 drop of aqueous sodium hydroxide, then enough aqueous ammonia to dissolve the precipitate formed

**OR**

Add Fehling's solution

1

Warm

*M2 and M3 can only be awarded if M1 is given correctly*

1

Result with Tollen's reagent:

Silver mirror / black precipitate

**OR**

Result with Fehling's solution:

Red precipitate / orange-red precipitate

1

Reagent to confirm the absence of ethanoic acid

Add sodium hydrogencarbonate or sodium carbonate

1

Result; no effervescence observed; hence no acid present

1

*M5 can only be awarded if M4 is given correctly*

**OR**

Reagent; add ethanol and concentrated sulfuric acid and warm

Result; no sweet smell / no oily drops on the surface of the liquid,

hence no acid present

[16]

**Q12.**

B

[1]

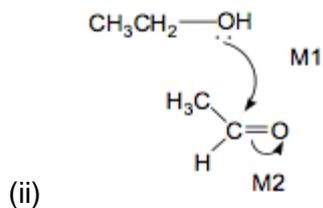
**Q13.**

(a) (i) Nucleophilic addition

*Any extra loses the mark*

*Allow minor spelling errors e.g. nucleophyllic*

1



*M1 for arrow from lone pair on oxygen in ethanol to C of C=O (or to space half way between O and C)*

*M2 for arrow from C=O bond to oxygen in ethanal*

*Do not allow M2 as first step without nucleophilic attack, but can allow M1 for attack on C<sup>+</sup> produced*

*+ rather than δ<sup>+</sup> on C=O loses M2*

*Ignore any further steps*

*Mark independently*

1  
1

(b) (i) Equal mixture of enantiomers/optical isomers OWTTE

1

(ii) (Non-superimposable) mirror images  
*Ignore rotates light in opposite directions*  
*Ignore stereoisomers*

1

(c) (i) Ethanal 0.33

1

Ethanol 4.16

*Allow 4.2 for ethanol*

1

(ii)

$$K_c = \frac{[\text{acetal}][H_2O]}{[CH_3CHO][CH_3CH_2OH]^2} \text{ or with names}$$

$$\frac{(0.37/0.31)(0.65/0.31)}{(0.58/0.31)(3.76/0.31)^2} \text{ OR } \frac{(0.37)(0.65)}{(0.58)(3.76)^2} \times 0.31$$

*Ignore slips in acetal structure or formula C<sub>6</sub>H<sub>14</sub>O<sub>2</sub>*

*If K<sub>c</sub> wrong, allow M4 only for units consequent to their K<sub>c</sub>*

*If volume omitted (gives 2.93 × 10<sup>-2</sup>) may only score M1 and M4*

*If volume used = 310 cm<sup>3</sup> allow M2 then award M3 for 9.08 – 9.23 only and M4 for mol<sup>-1</sup> cm<sup>3</sup> only*

*Treat error in converting 310 cm<sup>3</sup> to dm<sup>3</sup> as AE*

M1  
M2

$$9.1 \times 10^{-3}$$

*Allow range 9.08 × 10<sup>-3</sup> – 9.23 × 10<sup>-3</sup>*

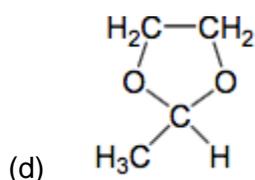
M3

$$\text{mol}^{-1}\text{dm}^3$$

*Not moles<sup>-1</sup>dm<sup>3</sup>*



M4



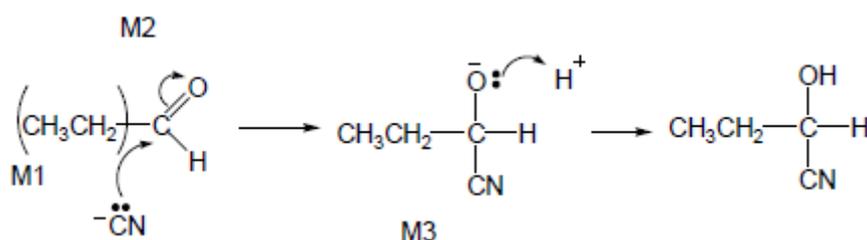
1  
[12]

**Q14.**

(a) Nucleophilic addition

1

M4 for lp, arrow and H+

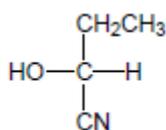


Allow C<sub>2</sub>H<sub>5</sub>- for CH<sub>3</sub>CH<sub>2</sub>-

- M1 and M4 include lone pair and curly arrow.
- Allow: CN<sup>-</sup> but arrow must start at lone pair on C.
- M2 not allowed independent of M1, but allow M1 for correct attack on C<sup>+</sup>.
- + rather than δ+ on C=O loses M2.
- Penalise incorrect partial charges.
- M3 is for correct structure including minus sign but lone pair is part of M4.
- Penalise extra curly arrows in M4.

4

(b) (i) M1



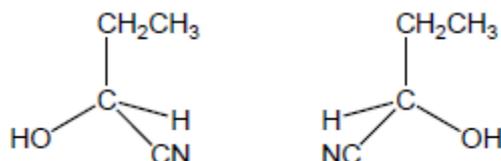
M1 for correct structure of product of part (a).

Allow C<sub>2</sub>H<sub>5</sub>- for CH<sub>3</sub>CH<sub>2</sub>-.

Penalise wrongly bonded, OH or CN or CH<sub>2</sub>CH<sub>3</sub> once only in clip.

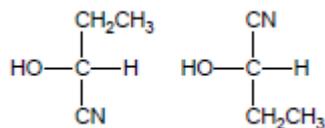
1

M2



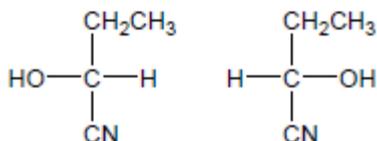


M2 cannot be gained by simply swapping two or more groups with no attempt to show a mirror image., e.g. do not allow M2 for



because these do not show the enantiomers as mirror images.

Students must show an attempt at mirror images, eg allow

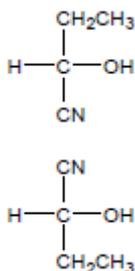


ie vertical groups same and horizontal swapped as if there was a mirror between them

No mirror need be shown

Do not penalize wedge bond when wedge comes into contact with both C & N

However these two could score M2 if placed as below as if with a "mirror" horizontally between them.



1

- (ii) M1 (Plane) polarized light  
M2 only scores following correct M1

1

M2 or Rotated in opposite directions (equally) (only allow if M1 correct or close)

Not just in different directions but allow one rotates light to the left and one to the right.

Not molecules rotate.

1

- (c) 2-hydroxybutane(-1-)nitrile

1

- (d) Weak acid / (acid) only slightly / partially dissociated / ionised  
Ignore rate of dissociation.

1

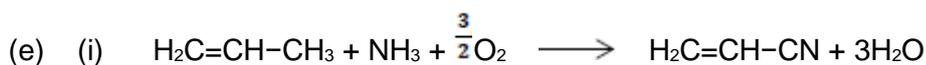
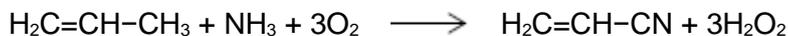
[CN<sup>-</sup>] very low

Allow (very) few cyanide ions.

Mark independently.

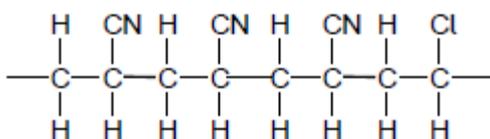


1

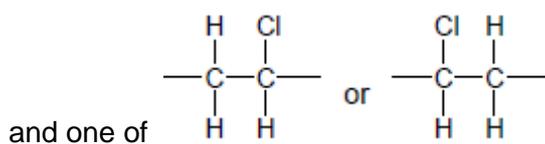
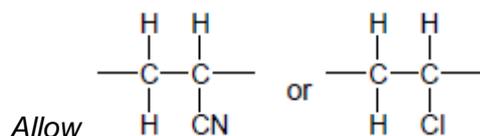
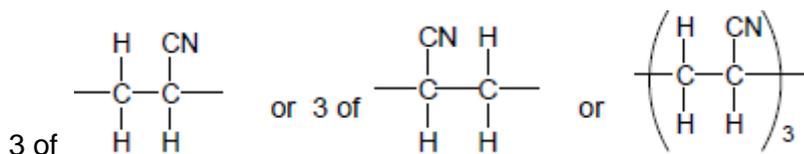
**OR***OR doubled.**Allow C<sub>3</sub>H<sub>6</sub> and CH<sub>2</sub>CHCN or C<sub>3</sub>H<sub>3</sub>N on this occasion only.*

1

(ii)

*Ignore n.**Must show trailing bonds.**Do not penalise C–NC bond here on this occasion.*

Must contain, in any order,

*Allow –CH<sub>2</sub>CH(CN)CH<sub>2</sub>CHCl– etc.*

1

(iii) Addition (polymerization)

*Allow self-addition.**Do not allow additional.*

1

[15]

**Q15.**

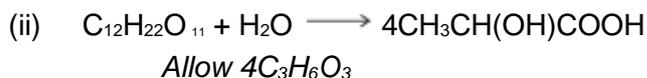
(a) (i) 2-hydroxypropanoic acid

**OR**2-hydroxypropan(-1-)oic acid*Do not penalise different or missing punctuation or extra spaces.**Spelling must be exact and order of letters and numbers as here.*

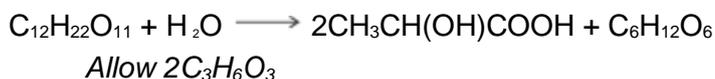


Can ignore -1- before -oic, but penalise any other numbers here.

1



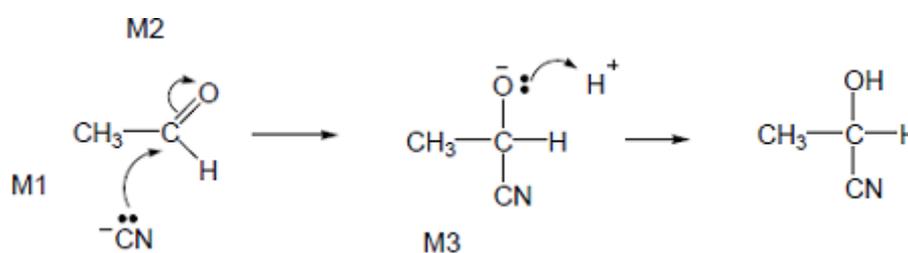
**OR**



1

(b) (i) Nucleophilic addition

M4 for lp, arrow and H+



- M1 lp and minus must be on C
- M1 and M4 include lone pair and curly arrow.
- M2 not allowed independent of M1, but allow following some attempt at attack on carbonyl C
- allow M1 for correct attack on C+
- + rather than  $\delta+$  on C=O loses M2
- M3 is for correct structure including minus sign but lone pair is part of M4
- Allow arrow in M4 to H of H-CN with arrow forming cyanide ion.

5

(ii) Equal mixture of enantiomers / (optical) isomers

1

(iii) (Plane) polarized light

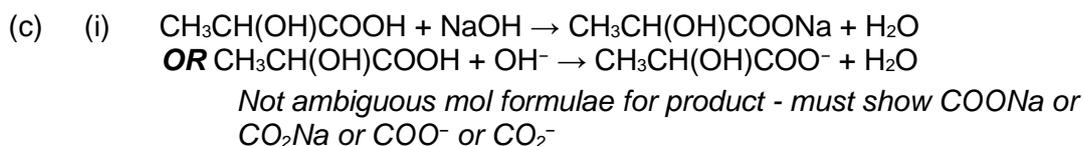
If missing no further mark.

1

(Polarised light) rotated by single enantiomer but unaffected by racemate

Both needed; not allow bend, twist etc.

1



1

(ii)  $[H^+] = K_a$  **OR**  $pH = pK_a$

1



pH = 3.86

*Allow more than 2 decimal places but not fewer.*

1

(iii) M1 buffer

*Ignore acidic but penalise alkaline or basic.*

1

**Any two out of the three marks M2 , M3 & M4**

M2 Large lactate concentration in buffer  
**OR** sodium lactate completely ionised

M3 added acid reacts with / is removed by lactate ion or  $A^-$  or sodium lactate or salt

**OR** equation  $H^+ + A^- \rightarrow HA$

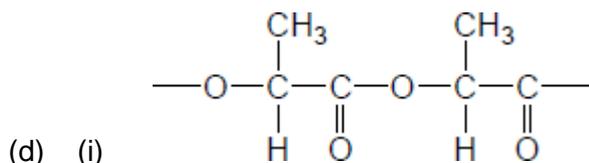
*Ignore reaction of  $H^+$  with  $OH^-$*

*Ignore reference to equilibrium unless it is shown.*

M4 ratio  $[HA] / [A^-]$  stays almost constant

*Ignore  $H^+$  or pH remains constant.*

Max 2



No marks if ester link missing

Correct ester link

allow  $-\text{COO}-$

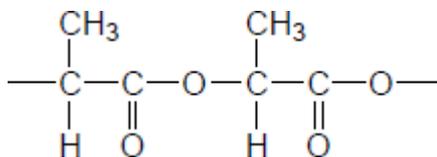
**NB Correct answer scores 2**

*Ignore n here (compare with (d)(iv)).*

*Ignore brackets*

1

**OR**



All rest correct with trailing bonds

*If OH or COOH on either or both ends, lose one, ie dimer scores 1*

*If more than two repeating units, lose 1*

1

(ii) (Poly)ester ie allow ester

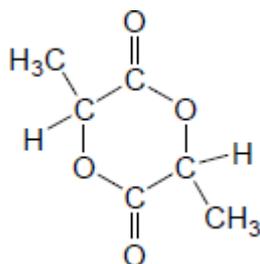
*Not terylene.*

*Ignore spaces and brackets in answer.*

1



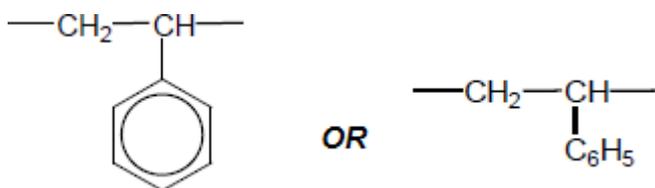
(iii)



Allow any cyclic  $C_6H_8O_4$

1

(iv)



Penalise  $n$  here (compare with (d)(i))

Ignore brackets.

Not allow  $Ph$  for phenyl.

1

- (v) In landfill, no air or UV, to assist decay  
**OR** not enough water or moisture (to hydrolyse polyester)

Allow landfill has / contains:

no or few bacteria / micro-organisms / enzymes compared with  
 compost heap

**OR** less oxygen

**OR** lower temperature.

1

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