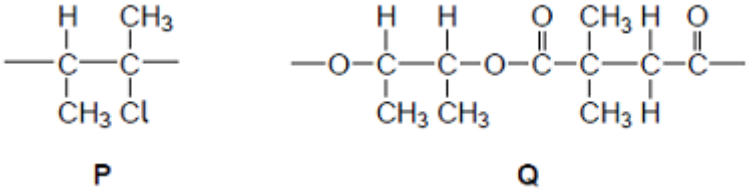
Q12.

Repeating units of two polymers, **P** and **Q**, are shown in the figure below.



P **Q**

(a) Draw the structure of the monomer used to form polymer **P**.
Name the type of polymerisation involved.

Monomer

Type of polymerisation

_____

(2)

(b) Draw the structures of **two** compounds that react together to form polymer **Q**.

Structure of compound 1

Structure of compound 2

(2)

(c) Suggest an environmental advantage of polymer **Q** over polymer **P**.
Justify your answer.

Advantage _____

Justification _____

_____

_____

_____

_____

(3)

(Total 7 marks)

Q13.

Which compound can polymerise by reaction with itself?

A $NH_2CH_2CH_2NH_2$ ⬭

B $CH_3CH_2CONH_2$ ⬭

C $HOOCCH_2COOH$ ⬭

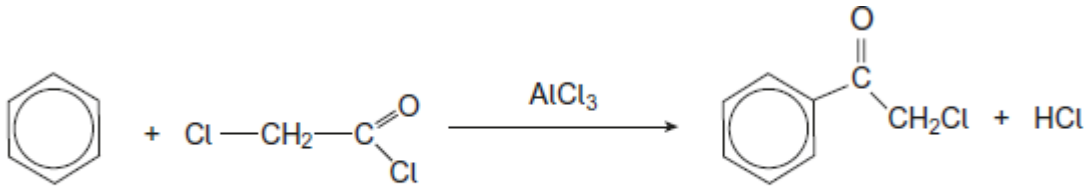
D NH_2CH_2COCl ⬭

(Total 1 mark)

Q14.

Compound **X** ($ClCH_2COCl$) is used as a reagent in organic synthesis.

(a) One important reaction of **X** is in the preparation of compound **P** as shown.



X **P**

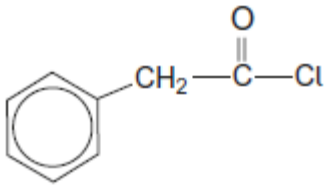
(i) Draw the structure of the electrophile formed by the reaction of **X** with $AlCl_3$.

(1)

(ii) Outline the mechanism for the reaction of the electrophile from part **(a)(i)** with benzene in the preparation of **P**.

(3)

(b) Compound **Q** is an alternative product that could be formed when **X** reacts with benzene.



Q

Describe how you could distinguish between **P** and **Q** by a test-tube reaction.
Give the reagent used and the observation with each compound.

Reagent _____

Observation with **P** _____

Observation with **Q** _____

(3)

(c) **X** is also used to make the compound $HOCH_2COOH$. This compound is polymerised to form the polymer known as PGA. PGA is used in surgical sutures (stitches).

(i) Draw the repeating unit of PGA.

(1)

(ii) Production of PGA occurs via a cyclic compound. Two $HOCH_2COOH$ molecules react together to form the cyclic compound and two molecules of water.

Draw the structure of this cyclic compound.

(1)

(d) Poly(propene) is also used in surgical sutures.

(i) Draw the repeating unit of poly(propene).

(1)

(ii) Suggest an advantage of surgical sutures made from PGA rather than from poly(propene).
Explain your answer.

_____

_____

_____

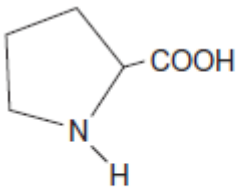
_____

(2)

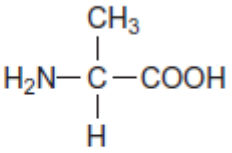
(Total 12 marks)

Q15.

(a) The structures and common names of two amino acids are shown.



proline



alanine

(i) Draw the structure of the zwitterion of proline.

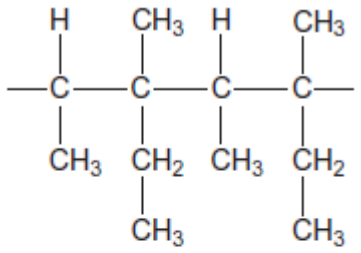
(1)

(ii) Draw the structure of the tripeptide formed when a proline molecule bonds to two alanine molecules, one on each side.

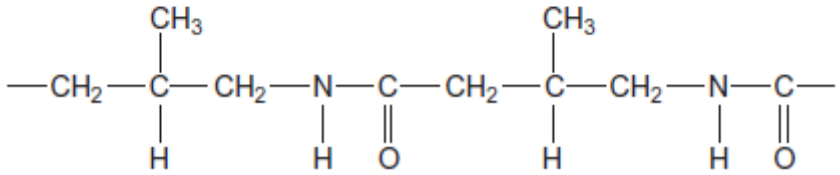
(2)

(b) Sections of two polymers, **L** and **M**, are shown.

L



M



(i) Give the IUPAC name of a monomer that forms polymer **L**.

_____

(1)

(ii) Give the IUPAC name of the monomer that forms polymer **M**.

_____

(1)

(iii) Draw the section of a polymer made from a dicarboxylic acid and a diamine that is isomeric with the section of polymer **M** shown.

(1)

(vi) Explain why polymer **L** is non-biodegradable.

_____

_____

_____

(1)

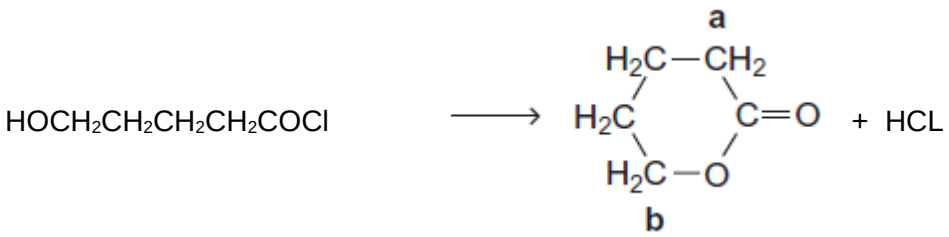
(Total 7 marks)

Q16.

This question is about some isomers of $C_5H_8O_2$

(a) Compound **H** is a cyclic ester that can be prepared as shown.

On the structure of **H**, two of the carbon atoms are labelled.



H

(i) Name and outline a mechanism for this reaction.

Use **Table C** on the Data Sheet to give the ^{13}C n.m.r. δ value for the carbon atom labelled **a** and the δ value for the carbon atom labelled **b**.

(7)

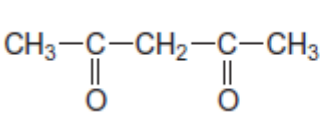
(ii) $HOCH_2CH_2CH_2CH_2COCl$ can also react to form a polyester in a mechanism similar to that in part (i).

Draw the repeating unit of the polyester and name the type of polymerisation involved.

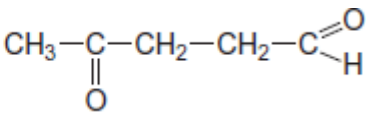
(2)

(b) State how you could distinguish between compounds **J** and **K** by a simple test-tube reaction.

State how you could distinguish between **J** and **K** by giving the number of peaks in the ^1H n.m.r. spectrum of each compound.



J



K

(5)

(c) Draw the structure of each of the following isomers of $C_5H_8O_2$
Label each structure you draw with the correct letter **L**, **M**, **N**, **P** or **Q**.

L is methyl 2-methylpropenoate.

M is an ester that shows E-Z stereoisomerism.

N is a carboxylic acid with a branched carbon chain and does **not** show stereoisomerism.

P is an optically active carboxylic acid.

Q is a cyclic compound that contains a ketone group and has only two peaks in its ^1H n.m.r. spectrum.

(5)

(Total 19 marks)

Q17.

Lactic acid, $CH_3CH(OH)COOH$, is formed in the human body during metabolism and exercise. This acid is also formed by the fermentation of carbohydrates such as sucrose, $C_{12}H_{22}O_{11}$.

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

_____

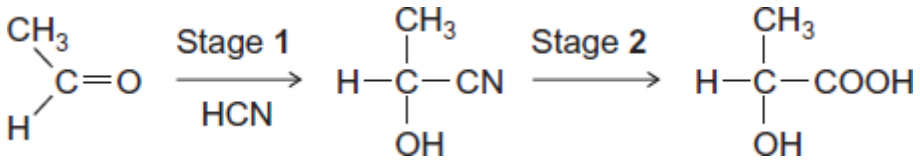
(1)

(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.

_____

_____

_____

_____

(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.

_____

(1)

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

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

_____

_____

_____

_____

(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 _____

_____

_____

_____

(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.

_____

_____

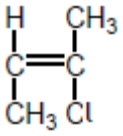
(1)

(Total 22 marks)

Mark Scheme

Q12.

(a)

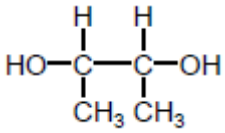


1

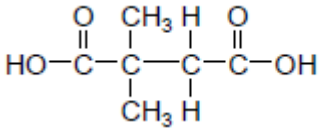
Addition

1

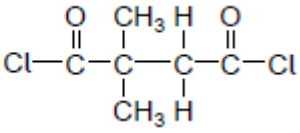
(b)



1



OR



1

(c) **Q** is biodegradable

1

Polar C=O group or δ+ C in **Q** (but not in **P**)

1

Therefore, can be attacked by nucleophiles (leading to breakdown)

1

[7]

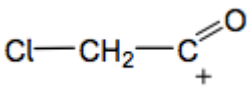
Q13.

D

[1]

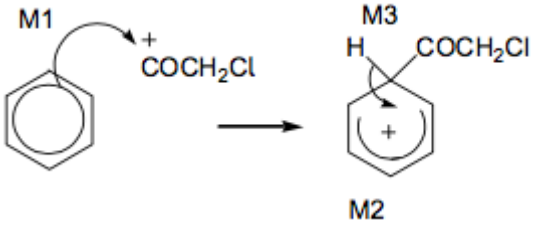
Q14.

(a) (i)



Allow $[ClCH_2CO]^+$

1



(ii)

M1 for arrow from inside hexagon to C or + on C on correct electrophile

M2 for structure of intermediate

- *Horseshoe centred on C1;*
- *+ in intermediate not too close to C1 (allow on or "below" a line from C2 to C6)*

M3 for Arrow from bond to H into ring

- *Allow M3 arrow independent of M2 structure*
- *+ on H in intermediate loses M2 not M3*
- *Ignore Cl- removing H^+*

1
1
1

(b) Reagent

Water

(Aqueous) silver nitrate

NaOH followed by acidified silver nitrate

(Water +) named indicator

Named alcohol

Na_2CO_3 or $NaHCO_3$

Ammonia

1

P

No reaction

No reaction (or slow formation of ppt)

No reaction (or slow formation of ppt)

No colour change

NVC

NVC

No reaction

Do NOT award

No observation

1

Q

Steamy /misty/ white fumes

White precipitate (immediately formed)

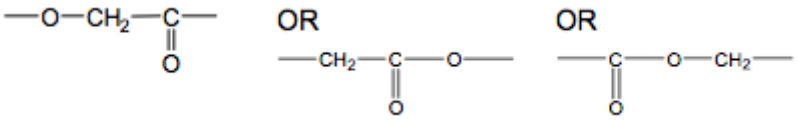
White precipitate (immediately formed)

Indicator turns to correct acid colour

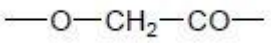
Fruity or sweet smell or misty fumes
Fizzing or effervescence (not just gas produced)
White smoke

1

(c) (i)

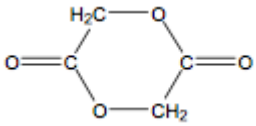


One unit only
Must have trailing bonds
Ignore n and brackets

allow 

1

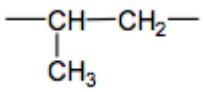
(i)



Allow CO for C=O

1

(d) (i)



One unit only
Must have trailing bonds
Ignore n and brackets

1

(ii) PGA sutures react/dissolve/break down/are biodegradable/ are hydrolysed / attacked by water or nucleophiles /no need to remove

OR Polypropene not biodegradeable/ not hydrolysed / not attacked by water/nucleophiles

1

(Ester links have) <u>polar bonds</u>

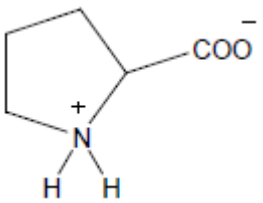
polypropene contains <u>non-polar bonds</u>
ignore intermolecular forces

1

[12]

Q15.

(a) (i)



Allow CO_2^- and NH_2^+

1

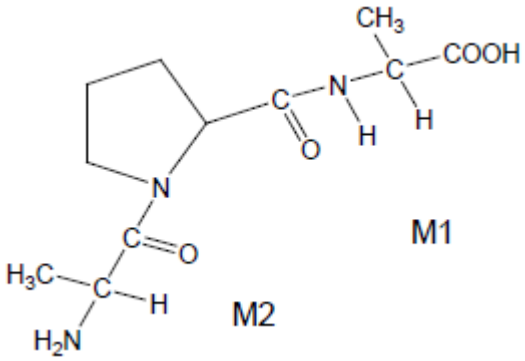
(ii) NOTE − **Two** marks for this clip

M1 for alanine section bonded through N

M2 for alanine section bonded through C

But penalise error in proline ring

1



Allow MAX 1 for correct tripeptide in polymer structure

1

(b) (i) 3-methylpent-2-ene

Ignore E-Z, commas, spaces or missing hyphens

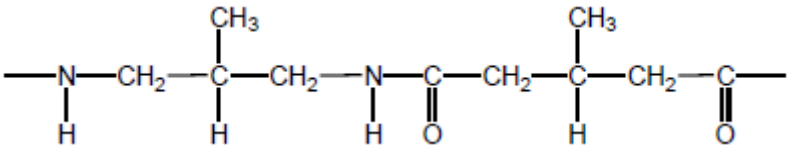
1

(ii) 4-amino-3-methylbutanoic acid

Ignore commas, spaces or missing hyphens

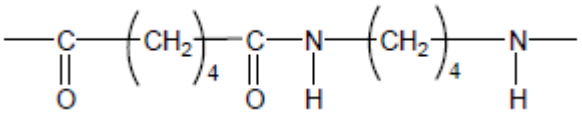
1

(iii)



or any polyamide section containing

8 carbons plus two C=O plus two N-H, such as



Trailing bonds are required

1

(iv) Non polar OR no polar groups / bonds (for attack by water / acids / alkalis / nucleophiles or for hydrolysis)

C-C bonds are strong

1

[7]

Q16.

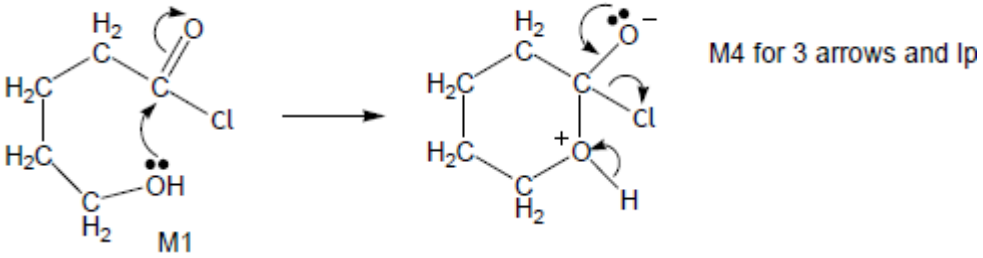
(a) (i) (nucleophilic) addition-elimination

Not electrophilic addition-elimination

Ignore esterification

1

M2



M3 for structure

- *If wrong nucleophile used or O–H broken in first step, can only score M2.*
- *M2 not allowed independent of M1, but allow M1 for correct attack on C+*
- *+ rather than δ+ on C=O loses M2.*
- *If Cl lost with C=O breaking lose M2.*
- *M3 for correct structure with charges but lone pair on O is part of M4.*
- *Only allow M4 after correct / very close M3.*
- *Ignore HCl shown as a product.*

4

a 20-50 (ppm) or single value or range entirely within this range

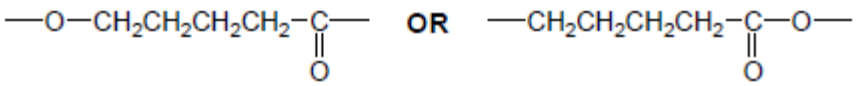
If values not specified as a or b then assume first is a.

1

b 50-90 (ppm) or single value or range entirely within this range

1

(ii)

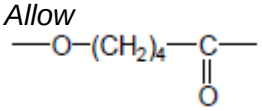


Must have trailing bonds, but ignore n.

1

OR –OCH₂CH₂CH₂CH₂CO– **OR** –CH₂CH₂CH₂CH₂COO–

Allow



but not - C_4H_8–

one unit only

Condensation

1

(b)

	Tollens'	Fehling's / Benedicts	Acidified potassium dichromate

Penalise wrong formula for Tollens or missing acid with potassium dichromate but mark on.

1

J	No reaction / no (visible) change / no silver mirror	No reaction / no (visible) change / stays blue / no red ppt	No reaction / no (visible) change / stays orange / does not turn green

Ignore 'clear', 'nothing'.

Penalise wrong starting colour for dichromate.

1

K	Silver <u>mirror</u> / grey <u>ppt</u>	Red <u>ppt</u> (allow brick red or red-orange)	(orange) turns green

1

J Two (peaks)

Allow trough, peak, spike.

1

K Four (peaks)

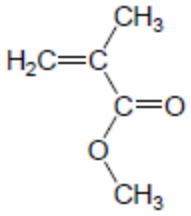
Ignore details of splitting.

If values not specified as J or K then assume first is J.

1

(c) If all the structures are unlabelled, assume that the first drawn ester is L, the second ester is M; the first drawn acid is N, the second P. The cyclic compound should be obvious.

L
ester



OR $H_2C=C(CH_3)COOCH_3$

All $C_5H_8O_2$ L to P must have C=C.

Allow CH_3–.

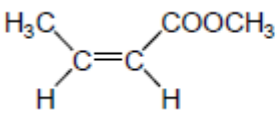
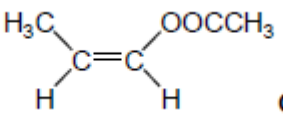
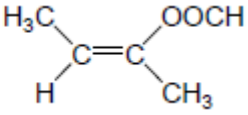
Allow $-CO_2CH_3$ etc.

Allow $CH_2C(CH_3)COOCH_3$.

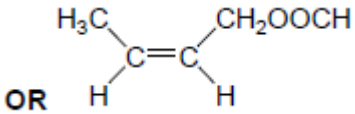
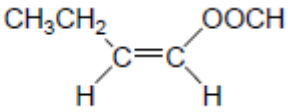
1

M

ester

$CH_3CH=CHCOOCH_3$ $CH_3CH=CHOOCCH_3$ $CH_3CH=C(CH_3)OOCH$

$CH_3CH=CHCH_2OOCH$ $CH_3CH_2CH=CHOOCH$

Allow either E–Z isomer.

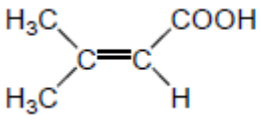
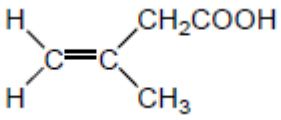
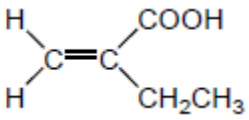
Allow CH_3– or C_2H_5– but not CH_2CH_3–.

Allow $CH_3CHCHCOOCH_3$ etc.

1

N

acid

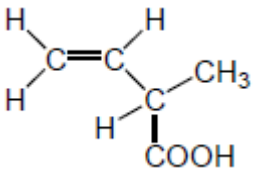
$(CH_3)_2C=CHCOOH$ $H_2C=C(CH_3)CH_2COOH$ $H_2C=C(COOH)CH_2CH_3$

Allow CH_3– or C_2H_5– but not CH_2CH_3–.

Allow $-CO_2H$.

Not cyclic isomers.

Not the optically active isomer.

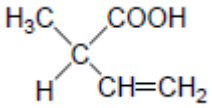

which is P anyway

Allow $(CH_3)_2CCHCOOH$ etc.

1

P

acid



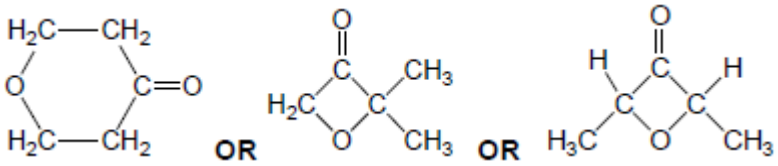
Allow −CO_2H.

$CH_3CH(COOH)CH=CH_2$

Allow $CH_3CH(CO_2H)CHCH_2$ or $CH_3CH(CO_2H)C_2H_3$.

1

Q



Not cyclic esters.

1

[19]

Q17.

(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

(ii) $C_{12}H_{22}O_{11} + H_2O \longrightarrow 4CH_3CH(OH)COOH$

Allow $4C_3H_6O_3$

OR

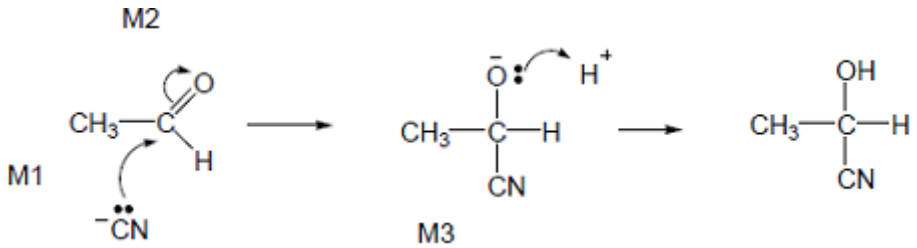
$C_{12}H_{22}O_{11} + H_2O \longrightarrow 2CH_3CH(OH)COOH + C_6H_{12}O_6$

Allow $2C_3H_6O_3$

1

(b) (i) Nucleophilic addition

M4 for lp, arrow and H+



- *M1 lp <u>and minus</u> 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 δ+ 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) <u>Equal</u> mixture of enantiomers / (optical) isomers

1

(iii) (Plane) polarized light

If missing no further mark.

1

(Polarised light) <u>rotated</u> by single enantiomer but unaffected by racemate

Both needed; not allow bend, twist etc.

1

(c) (i) $CH_3CH(OH)COOH + NaOH \rightarrow CH_3CH(OH)COONa + H_2O$
OR $CH_3CH(OH)COOH + OH^- \rightarrow CH_3CH(OH)COO^- + H_2O$

Not ambiguous mol formulae for product - must show COONa or CO_2Na or COO^- or CO_2^-

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 $H^+ + A^- \rightarrow HA$

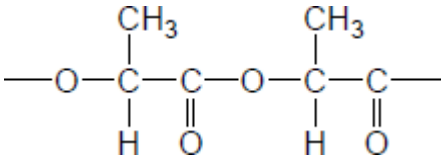
Ignore reaction of H^+ with OH^-
Ignore reference to equilibrium unless it is shown.

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

Ignore H^+ or pH remains constant.

Max 2

(d) (i)



No marks if ester link missing

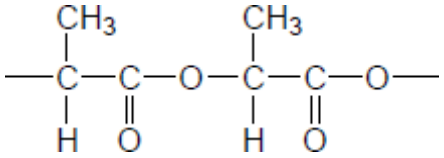
Correct ester link
allow –COO–

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

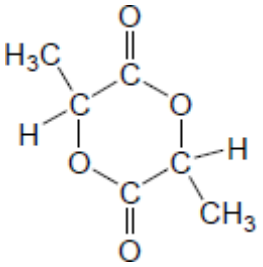
1

(ii) (Poly)ester ie allow ester

Not terylene.
Ignore spaces and brackets in answer.

1

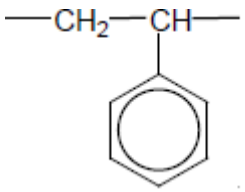
(iii)



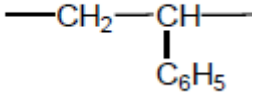
Allow any <u>cyclic $C_6H_8O_4$</u>

1

(iv)



OR



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

[22]