AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.3.12 POLYMERS

SCORE	PERCENTAGE
/130	%

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Q1.

B

[1]

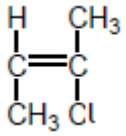
Q2.

C

[1]

Q3.

(a)

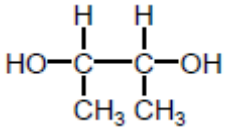


1

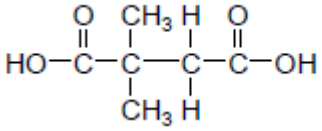
Addition

1

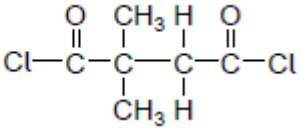
(b)



1



OR



1

(c) **Q** is biodegradable

1

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

1

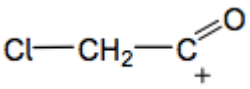
Therefore, can be attacked by nucleophiles (leading to breakdown)

1

[7]

Q4.

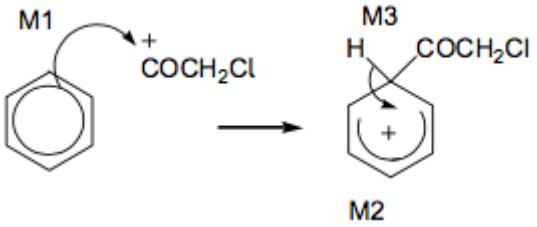
(a) (i)



Allow $[ClCH_2CO]^+$

1

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(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

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White precipitate (immediately formed)

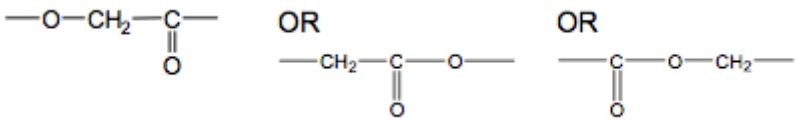
White precipitate (immediately formed)

Indicator turns to correct acid colour

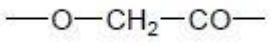
Fruity or sweet smell or misty fumes
Fizzing or effervescence (not just gas produced)
White smoke

1

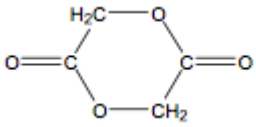
(c) (i)



One unit only
Must have trailing bonds
Ignore n and brackets

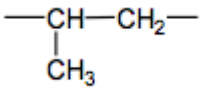
allow 

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]

Q5.

(a) (i) 2-hydroxypropanoic acid
OR

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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

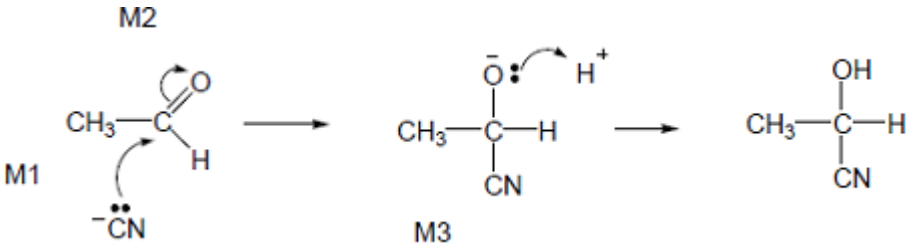
$C_{12}H_{22}O_{11} + H_2O \longrightarrow 2CH_3CH(OH)COOH + C_6H_{12}O_6$

Allow $2C_3H_6O_3$

1

(b) (i) Nucleophilic addition

M4 for lp, arrow and H+



- *M1 lp 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 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) 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

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

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

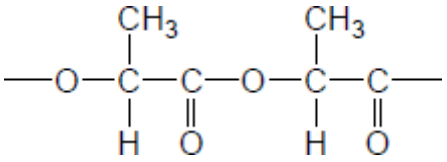
Ignore reaction of H^+ with OH^-
Ignore reference to equilibrium unless it is shown.

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

Ignore H^+ or pH remains constant.

Max 2

(d) (i)



No marks if ester link missing

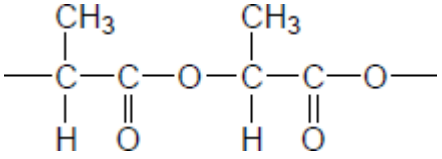
Correct ester link
allow –COO–

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

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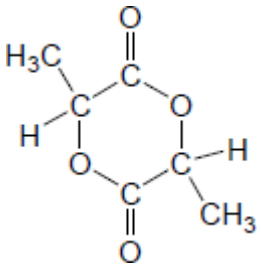
(ii) (Poly)ester ie allow ester

Not terylene.

Ignore spaces and brackets in answer.

1

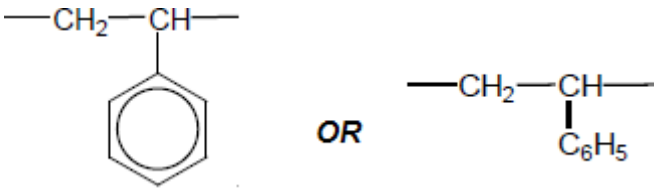
(iii)



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*

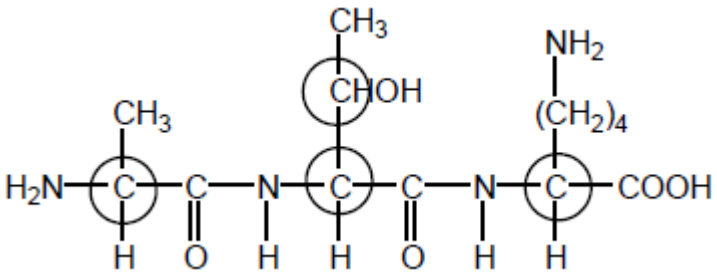
***OR** lower temperature.*

1

[22]

Q6.

(a) (i)

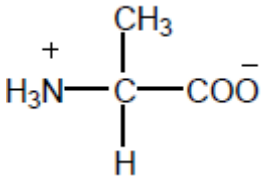


These four only

1

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(ii)



Allow − NH_3 and NH_3

1

(iii) 2-amino-3-hydroxybutanoic acid

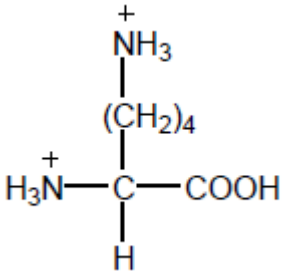
Ignore 1 in butan-1-oic acid

Do not penalise commas or missing hyphens

Penalise other numbers

1

(iv)



Allow –NH_3 and NH_3

1

(b) (i) Condensation

Allow polyester

1

(ii) propan**e**-1,3-diol

Must have e

*Allow 1,3-propan**e**diol*

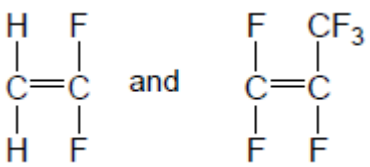
1

(c) (i) Addition

Not additional

1

(ii)



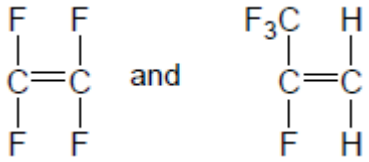
Allow monomers drawn either way round

Allow bond to F in CF_3

1

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OR



1 for each structure within each pair

1

(d) c

If wrong, CE = 0

1

C-C or C-F bonds too strong

1

[11]

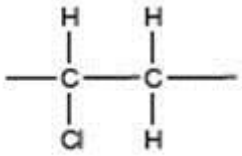
Q7.

(a) Benzene-1,2-dicarboxylic acid

Allow 1,2-benzenedicarboxylic acid

1

(b)



Must show all bonds including trailing bonds
Ignore n

1

(c) (i) 2 C_2H_5OH

NB Two ethanols

1

H_2O

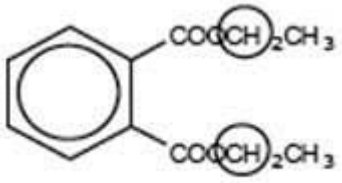
but only one water

1

(ii) 6 or six

1

(iii)



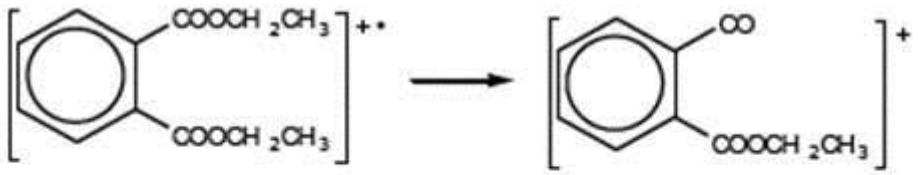
Ignore overlap with O to the left or H to the

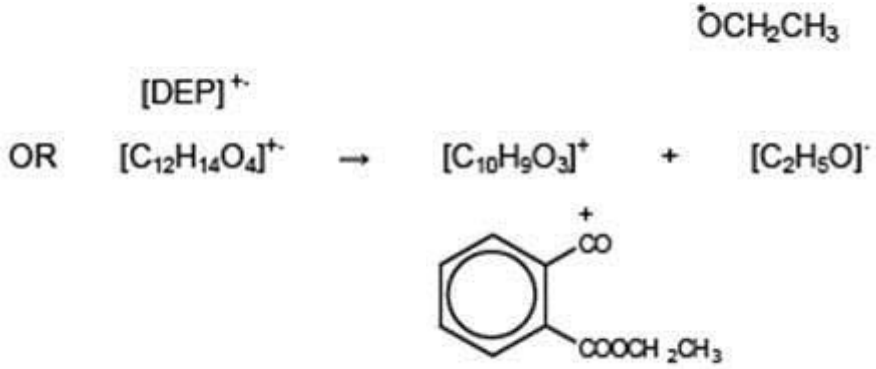
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right, but must only include this one carbon.
either or allow both (as they are identical)

1

(d)





Allow + on C or O in

1

Dot must be on O in radical

1

(e) (i) Rate = *k*[DEP]
Must have brackets but can be ( )

1

(ii) Any **two** of

- experiment repeated/continued <u>over a long period</u>
- repeated by independent body/other scientists/avoiding bias
- investigate breakdown products
- results made public

Not just repetition
Ignore animal testing

2 max

[11]

Q8.

(a) **M1** $CH_3CH_2CH_2COOH$
not C_3H_7COOH

1

M2 CH_3CH_2OH or C_2H_5OH

1

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M3 $CH_3CH_2CH_2COOCH_2CH_3 + H_2O$

allow $C_3H_7COOC_2H_5$
penalise M3 for wrong products and unbalanced equation

1

M4 H_2SO_4 or HCl or H_3PO_4 conc or dil or neither

not HNO_3

1

(b) **M1** $CH_3CH_2CH_2CH_2OH$

1

not C_4H_9OH

M2 $(CH_3CO)_2O$

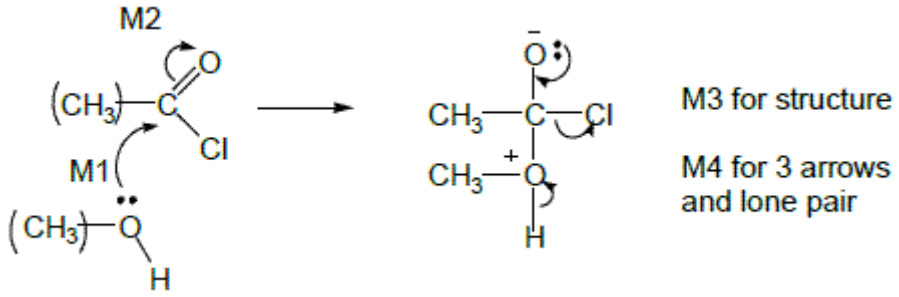
1

M3 → $CH_3COOCH_2CH_2CH_2CH_3 + CH_3COOH$

allow $CH_3COOC_4H_9$
penalise M3 for wrong products and unbalanced equation

1

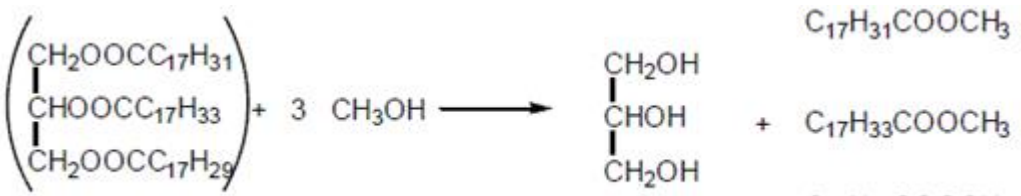
(c) (nucleophilic) addition-elimination



not acylation alone
M2 not allowed indep of M1 but allow M1 for correct attack on C+
+C=O loses M2
only allow M4 after correct or v close M3
ignore Cl^- removing H^+

5

(d)



(1) (1) (1)

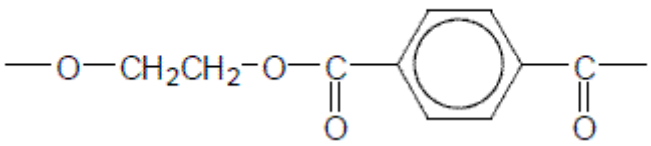
ignore errors in initial triester
First mark for $3CH_3OH$
Third mark for all three esters

3

(e)

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not – C_2H_4 –



First mark for correct ester link second mark for the rest including trailing bonds

If ester link wrong, lose second mark also

2

Adv reduces landfill
saves raw materials
lower cost for recycling than making from scratch
reduces CO_2 emissions by not being incinerated

not allow cost without qualification
ignore energy uses

1

Disad difficulty/cost of collecting/sorting/processing
product not suitable for original purpose, easily contaminated

not allow cost without qualification
ignore energy uses

1

[19]

Q9.

(a) (i) **W** 3

1

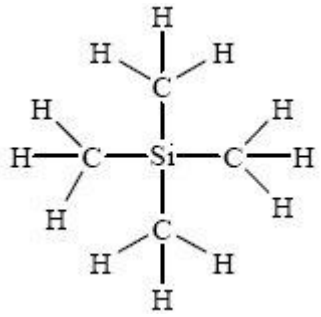
X 4

1

Y 2

1

(ii)



displayed formula shows ALL bonds

1

(b) (i) NO_2^+

allow + anywhere
can score in equation

1

$HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$

1

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OR

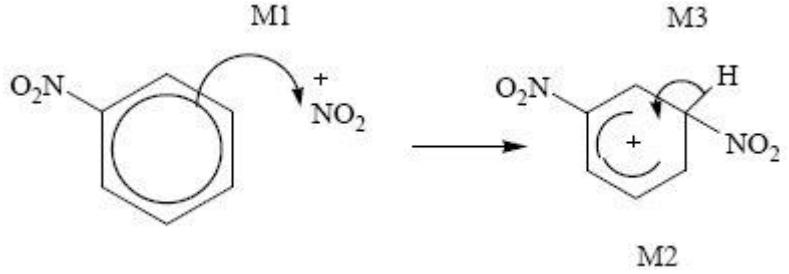
$HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$

or use two equations via $H_2NO_3^+$

(ii) electrophilic substitution

Not Friedel Crafts

1



Allow Kekule structures

+ must be on N of $^+NO_2$ (which must be correct)

both NO_2 must be correctly positioned and bonded to gain M2

M1 arrow from circle or within it to N or to + on N

horseshoe must not extend beyond C2 to C6 but can be smaller

+ not too close to C1

M3 arrow into hexagon unless Kekule

allow M3 arrow independent of M2 structure

ignore base removing H in M3

3

(c) (i) H_2/Ni or H_2/Pt or Sn/HCl or Fe/HCl (conc or dil or neither)

allow dil H_2SO_4

ignore mention of NaOH

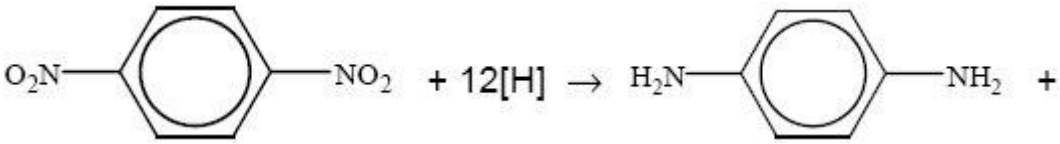
Not $NaBH_4$

Not $LiAlH_4$

Not Na/C_2H_5OH

not conc H_2SO_4 or any HNO_3

1



$4H_2O$

Or $6H_2$

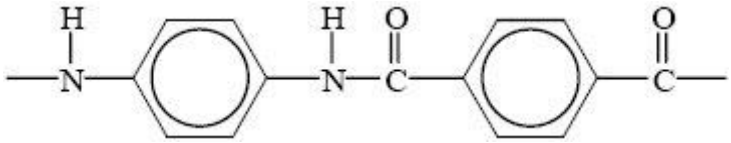
allow $C_6H_4(NO_2)_2$ etc ,

allow NO_2– NH_2–

i.e. be lenient on structures, the mark is for balancing equ

1

(ii)



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allow –CONH

ignore [ ]$_n$ as in polymer

1st mark for correct peptide link
2nd mark for the rest correct including trailing bonds

2

(iii) **M1** Kevlar is <u>biodegradeable</u> but polyalkenes not

allow Kevlar is <u>more</u> biodegradeable

1

M2 Kevlar has <u>polar</u> bonds/is a (poly) amide/has peptide link

comment on structure of Kevlar

1

M3 can be hydrolysed/attacked by nucleophiles/acids/ bases/enzymes

1

M4 polyalkenes <u>non polar</u>/has <u>non-polar</u> bonds

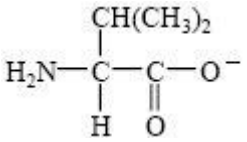
comment on structure of polyalkenes but not just strong bonds

1

[18]

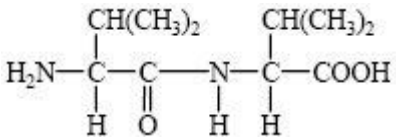
Q10.

(a) (i)



1

(ii)



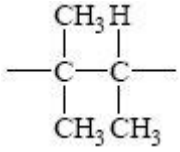
1

(iii) <u>hydrogen</u> bonding (do not allow H-bonding) QWC

do not penalise any error twice.

1

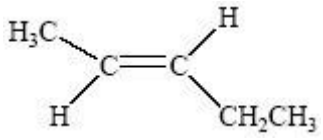
(b) (i)



1

(ii)

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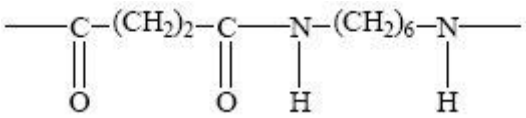


1

(iii) Isomer must be saturated or must not contain a double bond

1

(c)



2

(d) (i) heat/reflux with aqu NaOH

1

poly(alkene) is inert/ no reaction

1

polyamide is hydrolysed (or undergoes hydrolysis) to form acid salt and alcohol QWC

1

(ii) e.g combustion

1

heat energy produced

1

toxic gases produced

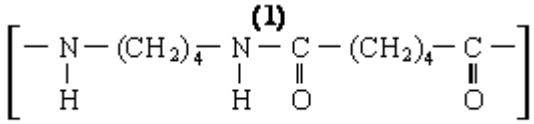
1

[14]

Q11.

(a) 1, 4-diaminobutane or butane -1, 4-diamine **(1)**
A: $BrCH_2CH_2Br$ **or** $ClCH_2CH_2Cl$ **(1)**
B: $NC\ CH_2CH_2CN$
Step 1: Br_2 or Cl_2 **(1) (ignore aq)**
Step 2: KCN **(1) (NOT HCN)**
Step 3: H_2 / Ni **or** $LiAlH_4$ **or** Na / C_2H_5OH **(1) (NOT $NaBH_4$)**
Hydrogenation only for H_2 / Ni, **or** nucleophilic addition only for $LiAlH_4$**(1)**
OR reduction or addition

7



(1)

(b)

(1)

QL hydrogen bonding **(1)**

Polarity of H-bonding shown or discussed **(1)**

4

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(c) Polyamides / peptide link can be hydrolysed **(1)**

OR polyalkenes cannot be hydrolysed

QL $\underline{OH^-\text{ attacks}}$ peptide link or $C^{\delta+}$ **(1)**

poly(ethene) non-polar **(1)**

3

[14]

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Q1.

A was the commonest incorrect response suggesting that students failed to realise that hydrogen must be directly attached to an electronegative atom in order to take part in hydrogen bonding. 51.2% of students gained this mark.

Q4.

Apart from the occasional suggestion of $AlCl_4^-$ as the electrophile, part (a)(i) was answered well as was the mechanism in (a)(ii). Marks are still lost by some students who draw curly arrows that lack the precise start and end positions required to gain the mark. About a third of students scored full marks in part (b). The vast majority of incorrect answers involved oxidation: using Tollens or Fehling's or acidified potassium dichromate solution. Students should be reminded that when asked to give an observation, those who write the word "nothing" or "no observation" will not gain a mark.

Part (c)(i) was answered well although a few students drew more than one repeating unit. Part (c)(ii) was also answered well. About a third of students did not answer part (d)(i) correctly. Part (d)(ii) proved a good differentiator with many gaining a mark for noting that PGA is biodegradable, but only the best students were able to link this to the presence of polar bonds in PGA. Some students included the term polar but applied it to the whole molecule and not a specific bond.

Q5.

Parts (a), (b)(i) and (b)(ii) were answered well. In part (b)(iii), students often correctly identified that polarised light could be used but then failed to gain the marks because they did not mention the effect of a racemic mixture on the light. Another concern was that answers appeared to suggest that the light caused the molecules themselves to rotate.

Parts (c)(i) and (c)(ii) were answered well but very few students scored full marks for part (c)(iii) where explanations were often muddled or referred to unspecified equilibria.

Part (d) was generally well attempted, with the main errors being in part (d)(i), where many gave three or more repeating units or failed to show an ester linkage, in part (d)(iv), where many gave the formula of the polymer or missed this part out completely, and in part (d)(v), where hydrogen bonding was often offered as an explanation.

Part (d)(iii) contained an unfortunate typographical error, which was identified after the examination had taken place. The end of the first sentence should have read "...from two lactic acid molecules" rather than ".....from two PLA molecules". AQA apologises for this error. The expected answer was given by about a quarter of the students. To ensure that students were not disadvantaged, a mark was also awarded to those students who drew any correct cyclic compound with molecular formula C6H8O4. The number of students who did not attempt this question was low and in line with other question parts on this paper. The most common errors involved attempts to draw a cyclic compound but with one or more carbons having fewer than four bonds or oxygens with fewer than two bonds.

Q6.

Part (a)(i) was only answered correctly by 28% of students but the rest of part (a) was well done including the name in part (a)(iii) although some had the prefixes in the wrong order or had the numbers reversed.

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Part (b)(ii) was not well done. The ‘e’ is required in the names of diols, triols etc as in the example here, propane-1,3-triol.

There were very few wrong answers in part (c).

Many students scored 1 mark in part (d) for identifying the correct compound as ‘c’, but the explanations were almost always incorrect. The C-F bond in the copolymer is polar but is not hydrolysed because it and all other bonds in the compound are strong.

Q7.

There were very few correct answers to part (a), but part (b) was well answered, although some misread the question here and tried to use benzene-1,2-dicarboxylic acid or tetrachloroethene.

Part (c)(i) was quite well done although many wrong answers included CH_2CH_3OH for ethanol or two moles of water.

In part (d), many candidates missed the +. from the molecular ion or put the . on the radical in the wrong place. Several of those who chose to write a formula for the benzene ring in DEP, rather than use the structure given, lost the mark if they gave C_6H_6 rather than C_6H_4 in the formula for the molecular ion and fragment ion.

A surprising number of candidates wrote a chemical equation or included $[H_2O]$ in the rate equation in part (e)(i). Not many candidates scored both marks in part (e)(ii), with many simply referring to more repeats.

Q8.

A few candidates were unsure of the names of the esters involved and confused butyl ethanoate with ethyl butanoate. In parts (a) and (b) a common error was the failure to balance the equations due to the omission of water or ethanoic acid respectively. Weaker candidates were also unsure of the structure of ethanoic anhydride.

The mechanism in part (c) was well answered although several omitted to give its name. The reaction in part (d) proved unfamiliar to many candidates; some attempted to answer the question in terms of alkaline hydrolysis of the ester to form soap rather than the reaction with methanol to form the mixture of methyl esters which make up biodiesel. The repeating unit was well answered in part (e).

Q9.

Part (a)(i) was answered well by most candidates who showed a good understanding of the numbers of peaks in ^{13}C spectra. By contrast, large numbers did not draw a displayed formula in part (a)(ii). The topic of electrophilic substitution involving nitration in part (b) was familiar to most candidates and high marks were frequently scored. However, many marks were lost by careless drawing of intermediate structures with incorrect positioning of + charges in the mechanism and also by a failure to give the name of the mechanism. Similarly, an equation for the reduction of a nitro compound to an amine should be very familiar to candidates but only about a quarter gained both marks in part (c)(i) where two such nitro groups were involved. The repeating unit of Kevlar was much better known and both marks were gained by three-fifths of candidates.

In part (c)(iii), many candidates discussed the polarity of bonds in Kevlar but failed to note that the bonds in polyalkenes are non-polar and therefore lost the final mark.

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Q11.

This question was found difficult by many candidates. The synthetic route in part (a) ended with butane-1,4-diamine and many candidates were able to deduce that Compound **B** was
$NC–CH_2CH_2–CN$ which would be reduced or hydrogenated to produce butane-1,4-diamine. To form $NC–CH_2CH_2–CN$ in two steps from ethene was found more difficult. The use of hydrogen bromide or even hydrogen were suggested as reagents with ethene by many candidates who forgot that a CN group was required at both ends of the molecule. An appreciable number of candidates also wrote equations and mechanisms in this question, when only reagents and structures were required. This used up precious minutes of their exam time for no reward.

In part (b), the repeating unit of the polyamide was deduced well, although some candidates drew nylon (6,6) rather than the polymer required. A brief statement to show that the chains were linked by hydrogen bonding was then all that was required. Details of the secondary structure of peptides was not necessary. Part (b) was worth 4 marks in total so candidates should be aware that they should spend only about 4 minutes on their answer.

In part (c) many answers contained details of the type of polymerisation involved in the formation of these polymers rather than the explanation that the non-polar polyalkenes are not attacked by hydroxide ions and are therefore not hydrolysed.

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