AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.3.8 ALDEHYDES AND KETONES

SCORE	PERCENTAGE
/323	%

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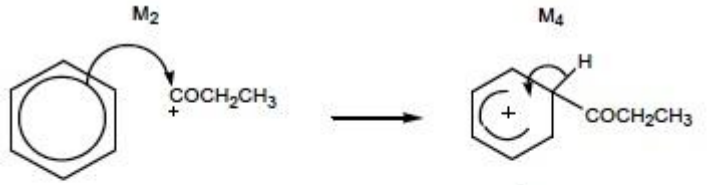
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Q1.

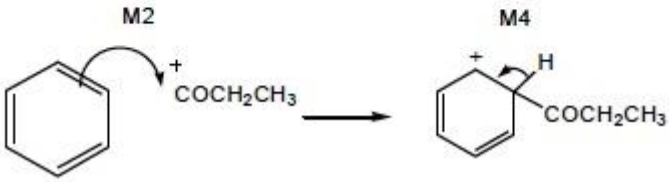
(a) $AlCl_3 + CH_3CH_2COCl \longrightarrow CH_3CH_2-\overset{+}{C}=O + AlCl_4^-$

Allow + on C or O in equation –
But must be on C in mechanism

M1



OR Kekule



M2 Arrow from inside hexagon to C or + on C

1

M3 Structure of intermediate
• horseshoe centred on C1 and must not extend beyond C2 and
C6, but can be smaller
• + in intermediate not too close to C1 (allow on or "below" a line
from C2 to C6)

1

M4 Arrow from bond into hexagon (Unless Kekule)
• Can allow M4 arrow independent of wrong M3 structure
• + on H in intermediate loses M3 not M4
• Ignore Cl^- and $AlCl_4^-$
- used in M4

1

(b) Either...

1-phenylpropan-1-ol

1

$NaBH_4$ / $LiAlH_4$

1

Nucleophilic addition

1

Or...

1-phenylpropan-1-ol

1

H_2 with Ni/Pd/Pt

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1

Addition/hydrogenation

1

Both numbers needed for names
Ignore solvents

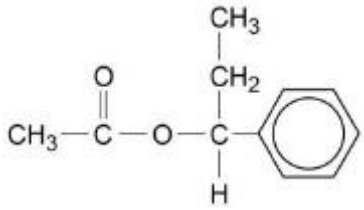
(c) Misty fumes / steamy fumes

Allow sweet/fruity smell / white fumes
Not smoke

1

(Nucleophilic) addition-elimination

1



1

[10]

Q2.

B

[1]

Q3.

(a) 2-hydroxyhexanenitrile

1

(b) (Plane) polarised light

1

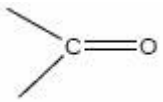
Enantiomers would <u>rotate</u> light in opposite directions

not different alone

1

(c) <u>planar</u> carbonyl group or

<u>planar</u>



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

1

Attack from either side

1

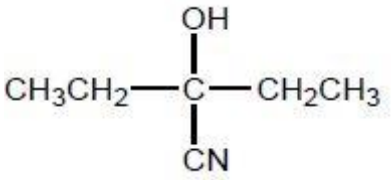
With <u>equal</u> probability

OR produces <u>equal</u> amounts (of the two isomers/enantiomers)

1

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(d)



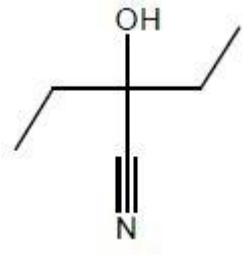
Does not contain a chiral centre

OR does not contain C attached to 4 different groups

OR contains two identical/ethyl groups

OR symmetrical (product)

Allow C_2H_5 or skeletal



M2 dependent on correct M1 (No structure = 0)

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

[8]

Q4.

D

[1]

Q5.

B

[1]

Q6.

B

[1]

Q7.

(a) $CH_3CH_2COCH_3 + 2[H] \longrightarrow CH_3CH_2CH(OH)CH_3$

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer is communicated coherently and shows a logical progression from

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stage 1 to stage 2 then stage 3.

Level 3
5 – 6 marks

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression from stage 1 to stage 3.

Level 2
3 – 4 marks

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

Level 1
1 – 2 marks

Insufficient correct chemistry to gain a mark.

Level 0
0 marks

Indicative Chemistry content

Stage 1: Formation of product
- Nucleophilic attack
- Planar carbonyl group
- H^- attacks from either side (stated or drawn)

Stage 2: Nature of product
- Product of step 1 shown
- This exists in two chiral forms (stated or drawn)
- Equal amounts of each enantiomer / racemic mixture formed

Stage 3: Optical activity
- Optical isomers / enantiomers rotate the plane of polarised light equally in
- With a racemic / equal mixture the effects cancel

6

[7]

Q8.

(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) $CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$

1

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(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

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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]

Q9.

B

[1]

Q10.

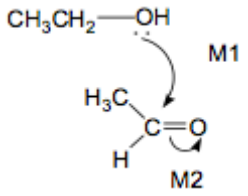
(a) (i) Nucleophilic addition

Any extra loses the mark

Allow minor spelling errors e.g. nucleophyllic

1

(ii)



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+ produced

+ rather than δ+ 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) Ethan**al** 0.33

1

Ethan**ol** 4.16

Allow 4.2 for ethanol

1

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(ii) $K_c = \dfrac{[acetal][H_2O]}{[CH_3CHO][CH_3CH_2OH]^2}$ or with names

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

Ignore slips in acetal structure or formula $C_6H_{14}O_2$

If K_c wrong, allow M4 only for units conseq to their K_c

If volume omitted (gives 2.93×10^{-2}) may only score M1 and M4

If volume used = 310 cm^3 allow M2 then award M3 for 9.08 – 9.23 only and M4 for mol^{-1} cm^3 only

Treat error in converting 310 cm^3 to dm^3 as AE

M1
M2

9.1×10^{-3}

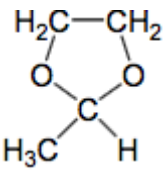
Allow range 9.08×10^{-3} – 9.23×10^{-3}

M3

$mol^{-1}dm^3$

Not $moles^{-1}dm^3$

M4

(d) 

1

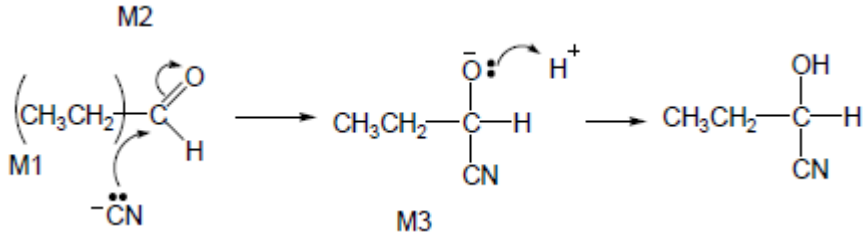
[12]

Q11.

(a) Nucleophilic addition

1

M4 for lp, arrow and H+



Allow C_2H_5- for CH_3CH_2-

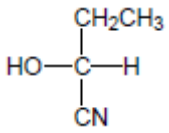
- *M1 and M4 include lone pair and curly arrow.*
- *Allow: CN^- but arrow must start at lone pair on C.*
- *M2 not allowed independent of M1, but allow M1 for correct attack on C+.*
- *+ rather than δ+ on C=O loses M2.*
- *Penalise incorrect partial charges.*

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- *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



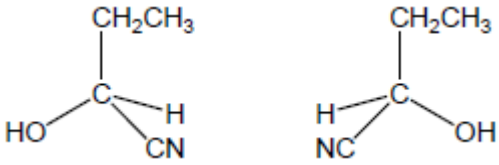
M1 for correct structure of product of part (a).

Allow C_2H_{5-} for CH_3CH_{2-}.

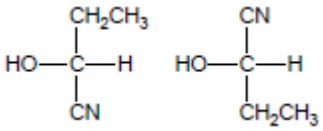
Penalise wrongly bonded, OH or CN or CH_2CH_3 once only in clip.

1

M2

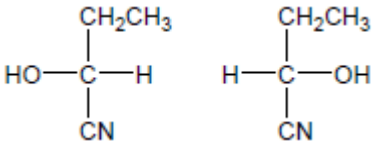


M2 cannot be gained by simply swapping two or more groups with no attempt to show a mirror image., e.g. do not allow M2 for



because these do not <u>show</u> the enantiomers as mirror images.

Students must <u>show</u> an attempt at mirror images, eg allow



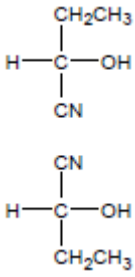
ie vertical groups same and horizontal swapped as if there was a mirror between them

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.

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1

(ii) M1 (Plane) polarized light

M2 only scores following correct M1

1

M2 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

$[CN^-]$ very low

Allow (very) few cyanide ions.

Mark independently.

1

(e) (i) $H_2C{=}CH{-}CH_3 + NH_3 + \frac{3}{2}O_2 \longrightarrow H_2C{=}CH{-}CN + 3H_2O$

OR

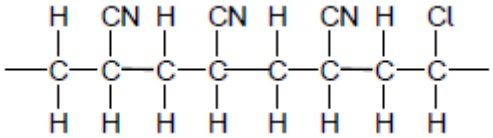
$H_2C{=}CH{-}CH_3 + NH_3 + 3O_2 \longrightarrow H_2C{=}CH{-}CN + 3H_2O_2$

OR doubled.

Allow C_3H_6 and CH_2CHCN or C_3H_3N on this occasion only.

1

(ii)



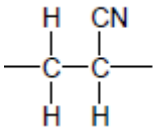
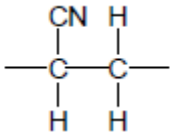
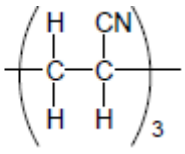
Ignore n.

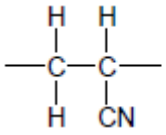
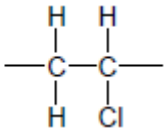
Must show trailing bonds.

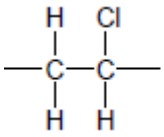
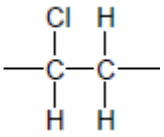
Do not penalise C–NC bond here on this occasion.

Must contain, in any order,

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3 of  or 3 of  or 

Allow  or 

and one of  or 

Allow –CH₂CH(CN)CH₂CHCl− etc.

1

(iii) Addition (polymerization)

Allow self-addition.

Do not allow additional.

1

[15]

Q12.

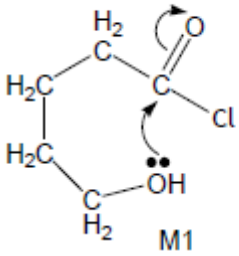
(a) (i) (nucleophilic) addition-elimination

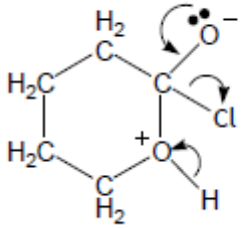
Not electrophilic addition-elimination

Ignore esterification

1

M2





M4 for 3 arrows and lp

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 <u>with charges</u> 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

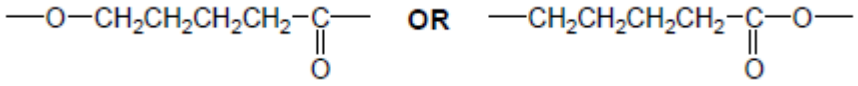
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If values not specified as a or b then assume first is a.

1

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

1

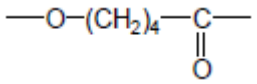
(ii)  **OR**

Must have trailing bonds, but ignore n.

1

OR –$OCH_2CH_2CH_2CH_2CO$– **OR** –$CH_2CH_2CH_2CH_2COO$–

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

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K Four (peaks)

Ignore details of splitting.

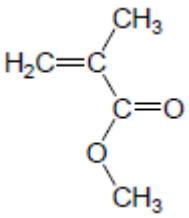
If values not specified as J or K then assume first is J.

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–.

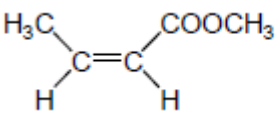
Allow $-CO_2CH_3$ etc.

Allow $CH_2C(CH_3)COOCH_3$.

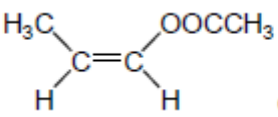
1

M

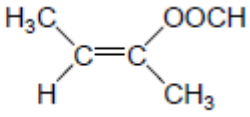
ester



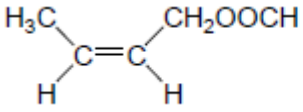
OR



OR

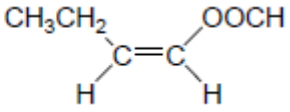


$CH_3CH=CHCOOCH_3$ $CH_3CH=CHOOCCH_3$ $CH_3CH=C(CH_3)OOCH$



OR

OR



$CH_3CH=CHCH_2OOCH$ $CH_3CH_2CH=CHOOCH$

Allow either E–Z isomer.

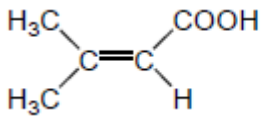
Allow CH_3− or C_2H_5– but not CH_2CH_3–.

Allow $CH_3CHCHCOOCH_3$ etc.

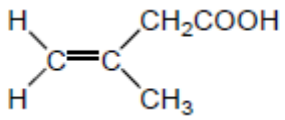
1

N

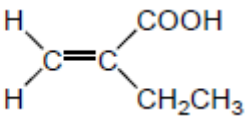
acid



OR



OR



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

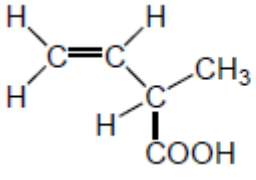
Allow CH_3− or C_2H_5– but not CH_2CH_3–.

Allow $-CO_2H$.

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Not cyclic isomers.

Not the optically active isomer.



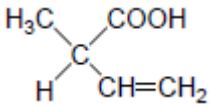
which is P anyway

Allow $(CH_3)_2CCHCOOH$ etc.

1

P

acid



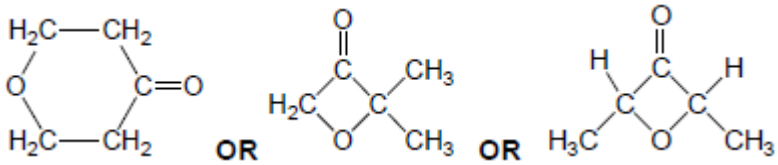
Allow $-CO_2H$.

$CH_3CH(COOH)CH=CH_2$

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

1

Q



Not cyclic esters.

1

[19]

Q13.

(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

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

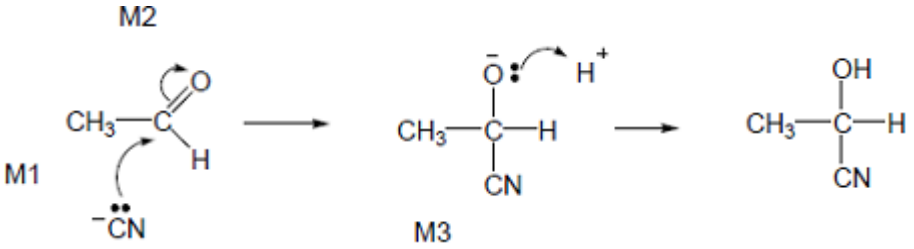
Allow $2C_3H_6O_3$

1

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(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 $CH_3CH(OH)COOH + OH^- \rightarrow CH_3CH(OH)COO^- + H_2O$

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

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M3 added acid reacts with / is removed by lactate ion or A^- or sodium lactate or salt
OR equation $H^+ + A^- \rightarrow HA$

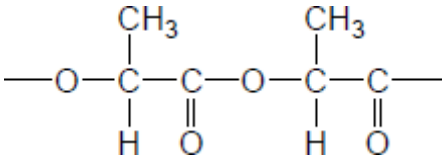
Ignore reaction of H^+ with OH^-
Ignore reference to equilibrium unless it is shown.

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

Ignore H^+ or pH remains constant.

Max 2

(d) (i)



No marks if ester link missing

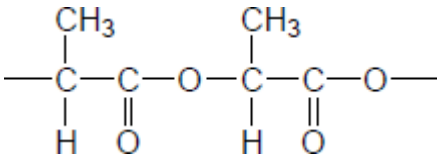
Correct ester link
allow –COO–

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

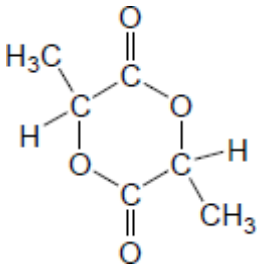
(ii) (Poly)ester ie allow ester

Not terylene.

Ignore spaces and brackets in answer.

1

(iii)

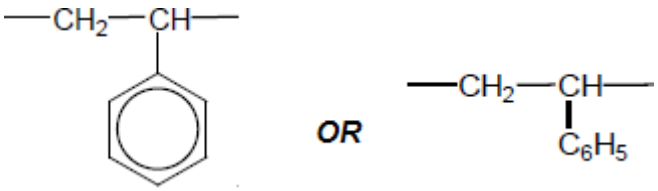


Allow any <u>cyclic $C_6H_8O_4$</u>

1

(iv)

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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 *<u>lower</u> temperature.*

1

[22]

Q14.

Dichromate(VI) will also oxidise / give a positive test with alcohols

Allow 'dichromate'.

Allow 'dichromate(VI) will oxidise other organic molecules / functional groups'.

[1]

Q15.

(a) Yes, because it is oxidised to ethanal / CH_3CHO
OR it is oxidised to a compound that contains CH_3CO group

Ignore 'primary alcohols are oxidised to aldehydes'.

Need 'yes' and an explanation to be awarded the mark.

1

(b) M_r CHI_3 = 393.7 **(M1)**

Allow if clearly shown in a calculation.

Allow 394

1

Moles CHI_3 = 10 / 393.7 = 2.54×10^{-2} **(M2)**

Allow a consequential answer on an incorrect M_r.

*2.54×10^{-2} scores **M1** and **M2**.*

1

Moles I_2 = 7.62×10^{-2} **(M3)**

*Allow 3 × **M2**.*

1

Mass I_2 = $7.62 \times 10^{-2} \times 253.8$ = 19.34g **(M4)**

*Allow **M3** × 253.8 or **M3** × 254*

1

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Scaling 19.34 / 0.832 = 23.2g **(M5)**

*Allow **M4** / 0.832*

Lose this mark if the answer is not given to 3 significant figures.

*Answer without working scores **M5** only.*

Allow any chemically correct alternative method.

Calculations which combine several steps in one expression can score the marks for all of these individual steps.

1

(c) Remove soluble impurities

Allow 'remove excess sodium hydroxide / iodine'.

Allow 'remove excess sodium methanoate / sodium iodide'.

Allow 'remove excess reagents'.

1

(d) Will not dissolve solid / solid is insoluble in water

Allow 'will not react with solid'.

1

[8]

Q16.

(a) Sn / HCl ***OR*** Fe / HCl not conc H_2SO_4 nor any HNO_3

Ignore subsequent use of NaOH

Ignore reference to Sn as a catalyst with the acid

Allow H_2 (Ni / Pt) but penalise wrong metal

But NOT $NaBH_4$ $LiAlH_4$ Na / C_2H_5OH

1

Equation must use molecular formulae

$C_6H_4N_2O_4 + 12\,[H]$

12[H] and $4H_2O$ without correct molecular formula scores 1 out of 2

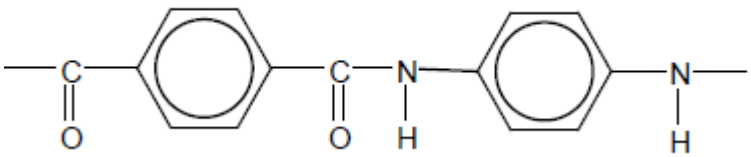
1

$\rightarrow C_6H_8N_2 + 4H_2O$

Allow .... + $6H_2$ if H_2 / Ni used

Allow −CONH− or −COHN− or −C_6H_4−

1



Mark two halves separately: lose 1 each for

- *error in diamine part*
- *error in diacid part*
- *error in peptide link*

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- *missing trailing bonds at one or both ends*
- *either or both of H or OH on ends*

Ignore n

2

(b) H_2 (Ni / Pt) but penalise wrong metal

NOT Sn / HCl, $NaBH_4$ etc.

1

CH_2

1

In benzene 120°

1

In cyclohexane 109° 28' or 109½°

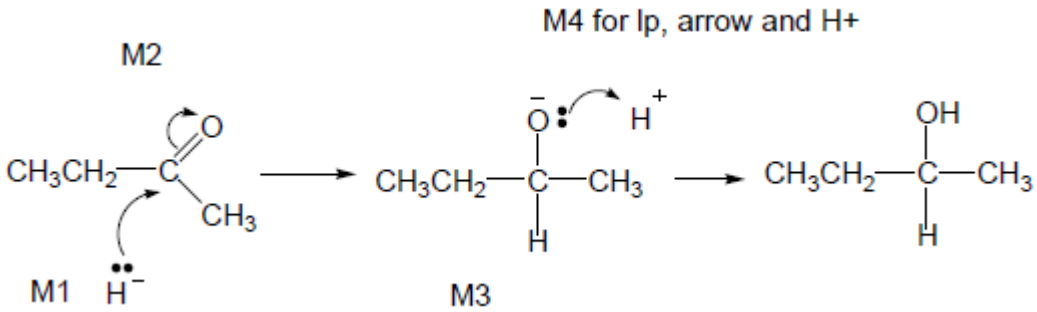
Allow 108° - 110°

If only one angle stated without correct qualification, no mark awarded

1

(c) (i) Nucleophilic addition

1



- *M2 not allowed independent of M1, but 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 C_2H_5*
- *M1 and M4 include lp and curly arrow*
- *Allow M4 arrow to <u>H</u> in H_2O (ignore further arrows)*

4

(ii) M1 Planar C=O (bond / group)

Not just planar molecule

1

M2 Attack (equally likely) from either side

Not just planar bond without reference to carbonyl

1

M3 (about product): Racemic mixture formed ***OR*** 50:50 mixture or each enantiomer equally likely

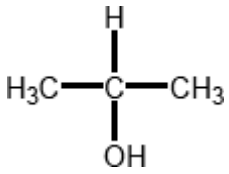
1

[17]

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Q17.

L



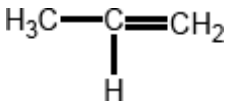
Allow $(CH_3)_2CHOH$ or $CH_3CH(OH)CH_3$

Allow name propan–2–ol

Penalise contradiction of name and structure

1

M



Allow $CH_3CH=CH_2$

Allow name propene

ignore -1- but penalise other numbers

Penalise contradiction of name and structure

1

Step 1 $NaBH_4$ or $LiAlH_4$

Zn/HCl or Sn/HCl

or H_2/Ni or H_2/Pt

Ignore name if formula is correct

ignore solvent

ignore acid (for 2nd step) but penalise acidified $NaBH_4$

Apply list principle for extra reagents and catalysts.

M1

1

(nucleophilic) addition

Addition (not nucleophilic)

Penalise electrophilic

Ignore reduction

M2

1

Step 2 conc H_2SO_4 or conc H_3PO_4 or Al_2O_3

Apply list principle for extra reagents and catalysts.

M3

1

elimination

Independent from M3

penalise nucleophilic or electrophilic

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ignore dehydration

M4
1

Step 3 HBr

Apply list principle for extra reagents and catalysts.

M5
1

electrophilic addition

Independent from M5

M6
1

[8]

Q18.

(a) (i) Green

Ignore shades of green.

1

(ii) Excess acidified potassium dichromate(VI)

1

Reflux (for some time)

1

In the diagram credit should be given for

- a vertical condenser

Lose M3 and M4 for a distillation apparatus.

1

- an apparatus which would clearly work

Do not allow this mark for a flask drawn on its own.

Penalise diagrams where the apparatus is sealed.

1

(iii) Distillation

1

Immediately (the reagents are mixed)

1

(b) Keep away from naked flames

Allow heat with water-bath or heating mantle.

If a list is given ignore eye protection, otherwise lose this mark.

1

(c) (i) Tollens' or Fehling's reagents

*Incorrect reagent(s) loses **both** marks.*

Accept mis-spellings if meaning is clear.

1

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Silver mirror / red ppt. formed

Accept 'blue to red' but not 'red' alone.

1

(ii) Sodium carbonate (solution) / Group II metal

Allow indicator solutions with appropriate colours.

Accept any named carbonate or hydrogen carbonate.

1

Effervescence / evolves a gas

Accept 'fizzes'.

1

(d) Propanoic acid

If this mark is lost allow one mark if there is reference to stronger intermolecular forces in the named compound.

Lose M1 and M3.

1

Contains hydrogen bonding

1

Some comparison with other compounds explaining that the intermolecular forces are stronger in propanoic acid

1

[15]

Q19.

(a) (i) $C_6H_6 + CH_3CH_2COCl \rightarrow C_6H_5COCH_2CH_3 + HCl$

OR

$C_6H_6 + CH_3CH_2CO^+ \rightarrow C_6H_5COCH_2CH_3 + H^+$

allow C_2H_5

penalise $C_6H_5–CH_3CH_2CO$

allow + on C or O in equation

1

Phenylpropanone

OR ethylphenylketone **OR** phenylethylketone

Ignore 1 in formula, but penalise other numbers

1

$AlCl_3$

can score in equation

1

$CH_3CH_2COCl + AlCl_3 \rightarrow CH_3CH_2CO^+ + AlCl_4^-$

allow C_2H_5

allow + on C or O in equation

1

$AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$

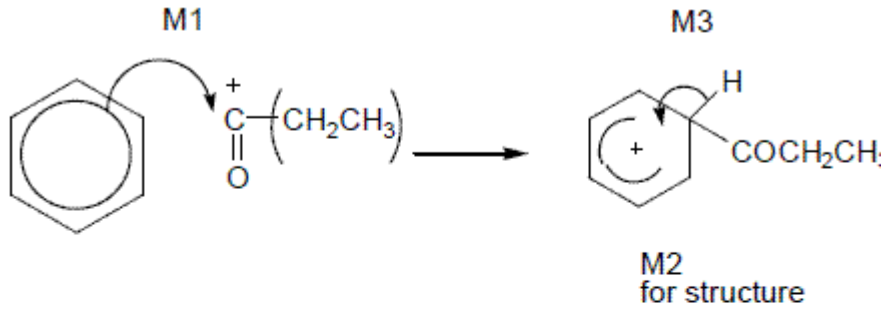
1

(ii) electrophilic substitution

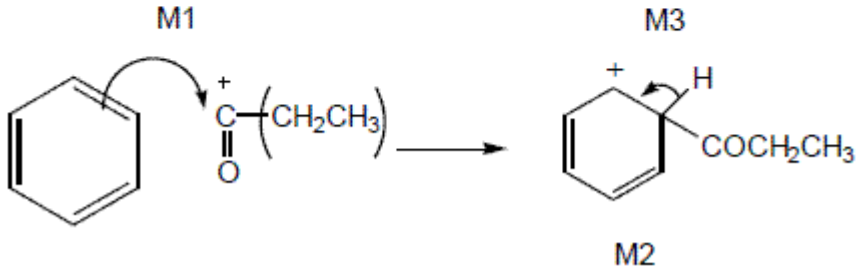
can allow in (a)(i) if no contradiction

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1



OR



M1 arrow from circle or within it to C or to + on C
horseshoe must not extend beyond C2 to C6 but can be smaller
+ not too close to C1
M2 penalise C_6H_5–CH_3CH_2CO (even if already penalized in (a)(i))
M3 arrow into hexagon unless Kekule
allow M3 arrow independent of M2 structure
ignore base removing H in M3

3

(b) (i) $CH_3CH_2\underline{CHO} + HCN \rightarrow CH_3CH_2CH(OH)CN$ **OR** $C_2H_5CH(OH)CN$

aldehyde must be –CHO brackets optional

1

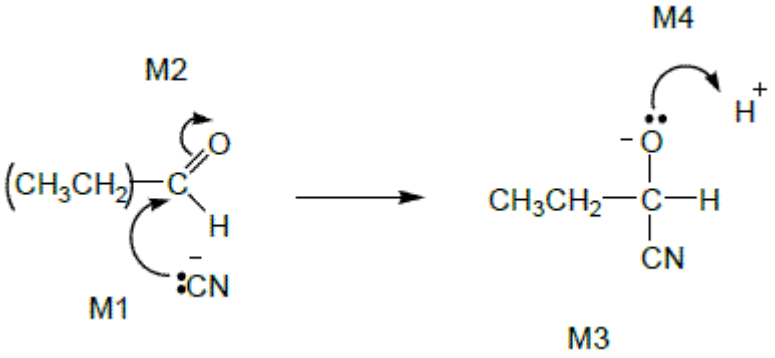
2-hydroxybutanenitrile **OR** 2-hydroxybutan<u>o</u>nitrile

no others

1

(ii) nucleophilic addition

1



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M1 includes lp and arrow to Carbonyl C and minus charge (on either C or N)
Not allow M2 before M1, but allow M1 to C^+ after non-scoring carbonyl arrow
Ignore δ+, δ– on carbonyl group, but if wrong way round or full + charge on C lose M2
M3 for correct structure including minus sign. Allow C_2H_5
M4 for lp and curly arrow to H^+

4

(iii) (propanone) slower ***OR*** <u>propanal</u> faster

1

inductive effects of alkyl groups
OR
C of C=O less δ+ in propanone
OR
alkyl groups in ketone hinder attack
OR
easier to attack at end of chain
if wrong, no further marks

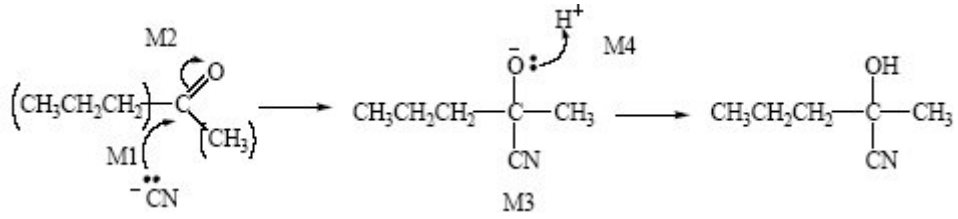
1

[18]

Q20.

(a) <u>nucleophilic addition</u>

1



Attack by HCN loses M1 and M2
M2 not allowed independent of M1, but
allow M1 for correct attack on C+
+C=O loses M2
M2 only allowed if correct carbon attacked
allow minus charge on N i.e. :CN^-

4

M3 for completely correct structure not including lp
allow C_3H_7 in M3

M4 for lp and arrow
allow without –

1

2-hydroxy-2-methylpentan(e)nitrile
allow 2-hydroxy-2-methylpentanonitrile

(b) <u>Product</u> from **Q** is a racemic mixture/<u>equal amounts</u> of enantiomers
if no reference to products then no marks;

1

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racemic mixture is inactive or inactive explained

*not **Q** is optically active or has a chiral centre etc*

1

Product from **R** is inactive (molecule) or has no chiral centre

1

[9]

Q21.

(a) $CH_3COCl + AlCl_3 \rightarrow CH_3\overset{+}{C}O + \overset{-}{AlCl_4}$

(1) equation (1)

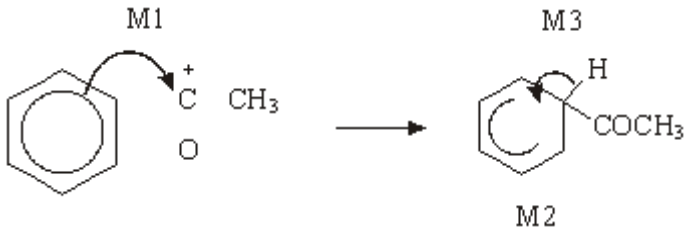
2

penalise wrong alkyl group once at first error
position of + on electrophile can be on O or C or outside [ ]
penalise wrong curly arrow in the equation or lone pair on $AlCl_3$ else ignore

Electrophilic substitution

NOT F/C acylation

1



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

M1 arrow from within hexagon to C or to + on C

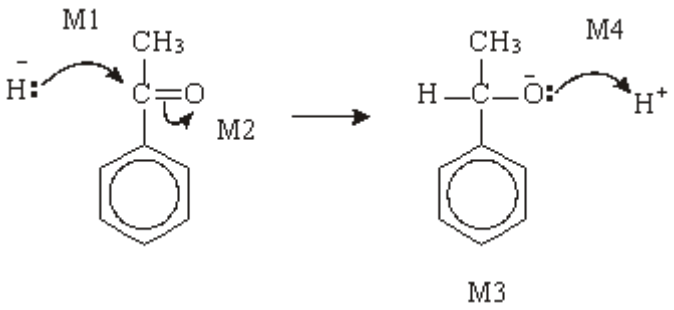
+ must be on C of $\overset{+}{R}CO$

3

(b) Nucleophilic addition

NOT reduction

1



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M2 not allowed independent, but can allow M1 for attack of H^- on C+ formed

4

1–phenylethan(–1–)ol or (1–hydroxyethyl)benzene

1

(c) dehydration or elimination

1

(conc) H_2SO_4 or (conc) H_3PO_4

allow dilute and Al_2O_3

Do not allow iron oxides

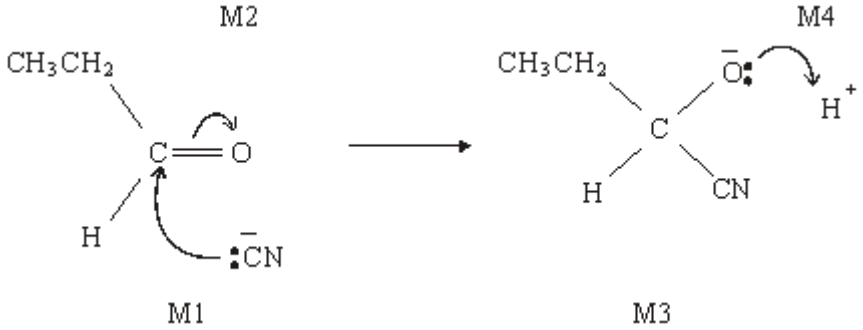
1

[14]

Q22.

(a) nucleophilic addition

1

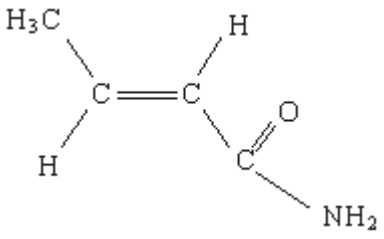


4

(b) (i) 2-hydroxybutanenitrile

1

(ii)

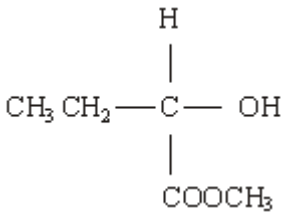


(allow 1 for amide even if not C_4H_7NO, i.e. $RCONH_2$)

(if not amide, allow one for any isomer of C_4H_7NO which shows geometric isomerism)

2

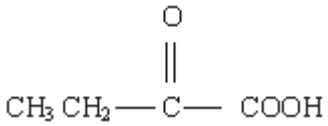
(c) (i)



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1

(ii)



1

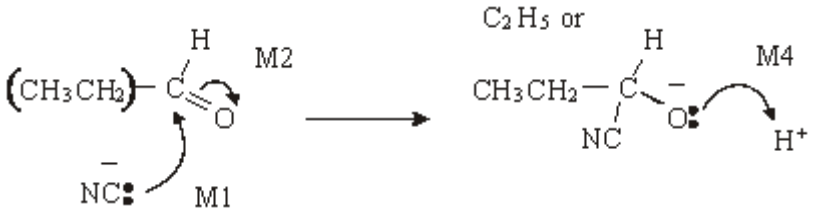
(iii) $CH_3CH=CHCOOH$

1

[11]

Q23.

(a) necleophilic addition;



1

M3 structure;

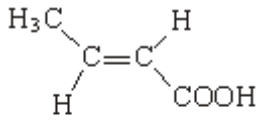
(be lenient on position of charge on CN–)
(M2 not allowed independent of M1,
but allow M1 for correct attack on C+
if M2 show as independent first.)
(+on C of C=O loses M2 but ignore δ+ if correct)
(M4 for arrow and lone pair (only allow for correct M3 or close))

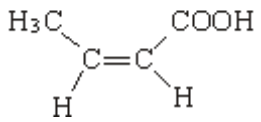
4

(b) (i) 2-hydroxybutanoic acid

1

(ii)





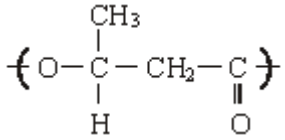
1

geometric(al) or cis-trans

1

(c) (i)

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(one unit only) (ignore brackets or n) (trailing bonds are needed)

1

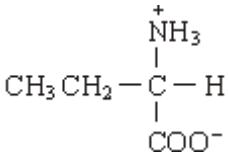
(ii) can be hydrolysed

OR

can be reacted with/attacked by acid/base/nucleophiles/H_2O/OH^-;

1

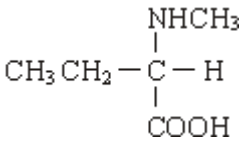
(d) (i)



(allow $-NH_3^+$)

1

(ii)



(or zwitterions product)

1

(iii) nucleophilic substitution;

1

[14]

Q24.

D

[1]

Q25.

(a) (i)

Reagent	Tollens	Fehlings or Benedicts	$K_2Cr_2O_7/H^+$ or acidified	$KMnO_4/H^+$	I_2/NaOH
Propanal	silver (mirror)	red ppt or goes red *(not red solution)*	goes green	goes colourless	No reaction
Propanone	no reaction	no reaction	no reaction	no reaction	Yellow (ppt)

(penalise incomplete reagent e.g. $K_2Cr_2O_7$ or $Cr_2O_7^{2-}/H^+$ then mark on)

3

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(ii) propanal 3 peaks
ignore splitting even if wrong

1

propanone 1 peak

1

(b) **X** is CH_3CH_2COOH or propanoic acid if both name and formula given, both must be correct, but

1

Y is $CH_3CH(OH)CH_3$ or propan-2-ol allow propanol with correct formula

1

Mark the type of reaction and reagent/condition independently.
The reagent must be correct or close to score condition

Step 1 Oxidation

$K_2Cr_2O_7/H^+$ or other oxidation methods as above
allow $Cr_2O_7^{2-}H^+$ if penalised above (ecf)
reflux (not Tollens/Fehlings) or heat or warm

1

Step 2	reduction or nucleophilic addition	reduction or nucleophilic addition	reduction or hydrogenation	1
	$NaBH_4$	$LiAlH_4$	H_2	1
	in (m)ethanol or water or ether or dry	ether or dry	Ni / Pt etc	1

Step 3 esterification or (nucleophilic) addition-elimination or condensation

1

(conc) H_2SO_4 or HCl

1

warm (allow without acid reagent if **X** and **Y** given as reagents)

1

or reflux or heat

1

[15]

Q26.

(a) (i) An appropriate alkene; $CH_3CH_2CHCH_2$ or $(CH_3)_2CCH_2$

1

Isomer 1

1

Isomer 2

1

Position isomerism

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1

Mechanism

electrophilic attack and electron shift to Br (Unless H^+ used)

1

carbocation

1

reaction with carbocation

[Allow mechanism marks for the alkene $CH_3CHCHCH_3$]
[Allow one mark if mechanism for minor product given]

1

(ii) An appropriate carbonyl; CH_3CH_2CHO

1

Mechanism nucleophilic attack and electron shift to O

1

anion intermediate

1

reaction with anion

[Allow mechanism marks for the carbonyl $(CH_3)_2CO$]

1

Isomer 1

1

Isomer 2

1

Optical isomerism

NB Isomer structures must be tetrahedral
NB Penalise "stick" structures once in part (a)

1

(b) QoL
Large charge on carbonyl carbon atom due to bonding to O and Cl

1

Nucleophiles have electron pairs which can be donated

1

Equation Species

1

Balanced

1

[18]

Q27.

A

[1]

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Q28.

C

[1]

Q29.

(a) (i) Potassium (OR sodium) dichromate(VI) OR <u>correct</u> formula OR potassium manganate(VII)

(Oxidation state not needed, but must be correct if included)

(Penalise errors in the formula or oxidation state, but mark conditions)

1

Acidified OR H_2SO_4 / HCl (*NOT with $KMnO_4$*) / H_3PO_4 / HNO_3

(Ignore heat or reflux)

(Credit "acidified" as part of reagent)

1

Oxidation or redox

1

(ii) $NaBH_4$ OR $LiAlH_4$ OR H_2/Ni

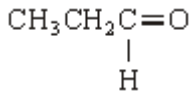
1

$CH_3COCH_3 + 2[H] \rightarrow CH_3CH(OH)CH_3$

(Credit H_2 in the equation if H_2 has been chosen as reagent)

1

(b) (i)



(Structure must show aldehyde structure)

(Credit C_2H_5 as alternative to CH_3CH_2)

(ii)

M1	Tollens' reagent OR ammoniacal silver nitrate OR $AgNO_3 + NH_3$	OR Fehling's solution	OR <u>acidified</u> potassium dichromate

1

M2	stays colourless	stays blue	stays orange

1

(Provided reagent is correct, credit "no reaction", "no change", "nothing", "no observation" for M2)

M3	silver <u>mirror</u> / <u>deposit</u> OR black / grey <u>precipitate</u>	red / brown / orange <u>precipitate / solid</u>	goes green

1

(Credit other correct reagents and observation)

(For M1, penalise $AgNO_3$ alone, penalise $Ag(NH_3)_2^+$,

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penalise "potassium dichromate", etc., but, in each case, mark on and credit correct M2 and M3)

(If totally wrong reagent or no reagent, CE = no marks for M1,M2 or M3)

1

[9]

Q30.

(a) Pentan-2-one

1

(b) (i) 1680 – 1750 (cm^{-1})

1

(ii) 3230 – 3550 or 1000 – 1300 (cm^{-1})

1

(iii) 4

1

(c)

Reagent	$K_2Cr_2O_7/H^+$	$KMnO_4/H^+$	Na	CH_3COOH/H_2SO_4
with **C**	no reaction	no reaction	no reaction	no reaction
with **D**	goes green	goes colourless	effervescence	smell

1 **1** **1**

(penalise incomplete reagent e.g. $K_2Cr_2O_7$ or $Cr_2O_7^{2-}/H^+$ then mark on)

(d)

Reagent	Tollens	Fehlings or Benedicts
with **E**	silver (mirror)	red ppt or goes red *(not red solution)*

1 **1**

[9]

Q31.

B

[1]

Q32.

(a) (i) propyl methanoate **(1)**

not propanyl

- *A wrong reagent or no reagent scores zero*
- *An incomplete reagent such as silver nitrate for Tollens, or potassium dichromate loses the reagent mark, but can get both observation marks*
- *penalise observations which just say colour change occurs or only state starting colour*

(ii) *Reagent*: $NaHCO_3$ **(1)**

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*Observation with **C***: no reaction **(1)**
*Observation with **D***: effervescence **(1)**
*for **C** and **D** NOT Tollens*

Test	an identified (hydrogen) carbonate	acidified $K_2Cr_2O_7$	acidified $KMnO_4$	correct metal	UI or stated indicator	PCl_5
Observation with C	no reaction	goes green	goes colourless	no reaction	no change	no reaction
observation with D	bubbles or CO_2	no change	no change	bubbles or H_2	red or correct colour pH 3 – 6.9	(misty) fumes

4

(b) (i) *Reagent*: pentan-2-one **(1)**
or 2-pentanone
but not pent-2-one or pentyl

(ii) *Reagent*: Tollen's or Fehling's **(1)**

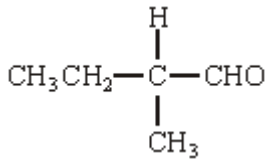
*Observation with **E***: no reaction **(1)**

*Observation with **F***: silver mirror or red ppt **(1)**

for **E** and **F**

Test	Tollens	Fehlings or Benedicts	iodoform or I_2/NaOH	acidified $K_2Cr_2O_7$	Schiff's
observation with E	no reaction	no reaction	yellow (ppt)	no change	no reaction
observation with F	silver or mirror or grey or ppt	red or ppt not red solution	no reaction	goes green	goes pink

4

(c) 

(1)
must be aldehyde. Allow C_2H_5 for CH_3CH_2 otherwise this is the only answer

1

[9]

Q33.

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(a) $K_2Cr_2O_7/H_2SO_4$ reuced by

$CH_3CH_2CH_2CH_2OH$ **(1)**

oxidised to $CH_3(CH_2)_2CHO$ **(1)**
and $CH_3(CH_2)_2COOH$ **(1)**

$CH_3CH_2CH_2CHO$ **(1)**

oxidised to $CH_3(CH_2)_2COOH$ **(1)**

Equation: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ **(1)**

Note: Deduct one if all three compounds given as reducing agents.

6

(b) Tollens' reduced by
$CH_3CH_2CH_2CHO$ **(1)**

oxidised to $CH_3(CH_2)_2COOH$ **(1)**

Equation $[Ag(NH_3)_2]^+ + e^- \rightarrow Ag + 2NH_3$ **(1)**

3

(c) $CH_3CH_2CH_2CH_2OH$ **(1)**

Product $CH_3CH_2CH_2CH_2OOCCH_3$ **(1)**

$(CH_3)_3COH$

Product $(CH_3)_3COOCCH_3$ **(1)**

4

(d) $CH_3CH_2CH_2OH$ has five peaks **(1)**

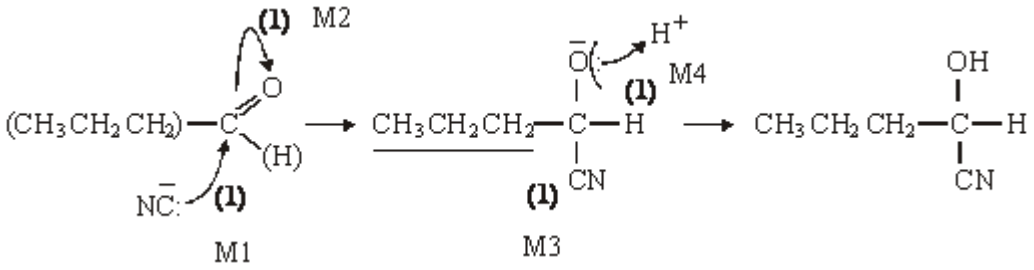
$(CH_3)_3COH$ has two peaks **(1)**

2

[15]

Q34.

(a) *Mechanism*



Allow C_3H_7 if structure shown elsewhere
penalise HCN splitting if wrong

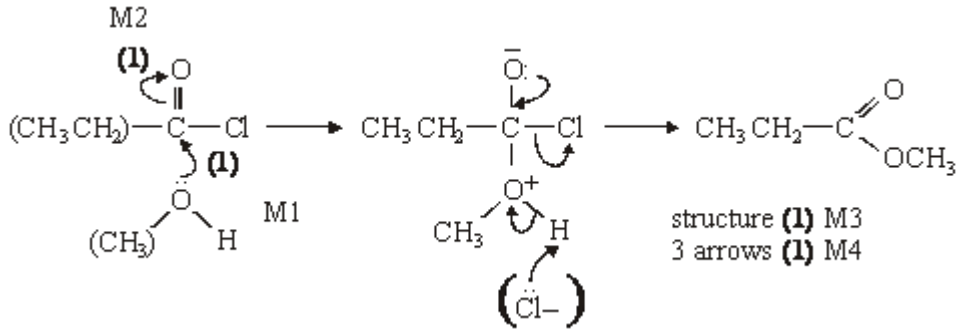
Name of product: 2-hydroxypenta(neo)nitrile **(1)**

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or 1-cyanobutan-1-ol

5

(b) *Mechanism*

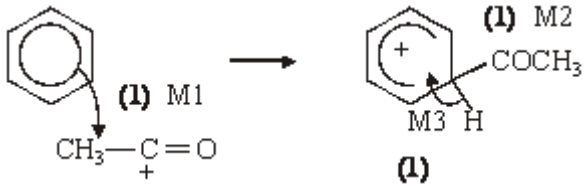


Name of organic product: methylpropanoate **(1)**

5

(c) (i) ([] CH_3CO [])$^+$ **(1)**

(ii)



4

Notes

(abc) extra curly arrows are penalised

(a) be lenient on position of negative sign on : CN^- but arrow must come from lp

(a)/(b) C=O alone loses M2 but can score M1 for attack on C+, similarly C—Cl

(a) allow 2-hydroxypentanonitrile or 2-hydroxypenta(ne)nitrile ... pentylnitrile

(b) in M4, allow extra: Cl^- attack on H, showing loss of H^+

(c) (i) allow formula in an "equation"(balanced or not)
be lenient on the position of the + on the formula

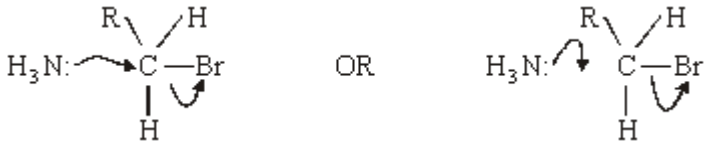
(ii) for M1 the arrow must go to the C or the + on the C
don't be too harsh about the horseshoe, but + must not be close to the saturated C
M3 must be final step not earlier; allow M3 even if structure (M2) is wrong

[14]

Organic points

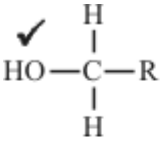
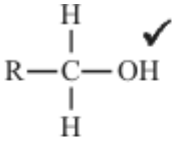
(1) Curly arrows: must show movement of a pair of electrons,
i.e. from bond to atom or from lp to atom / space
e.g.

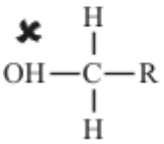
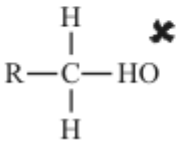
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(2) Structures

penalise sticks (i.e. ) once per paper

 or  or $-NH_2$ ✓

 or  H_2N- ✓

etc

Penalise once per paper

allow CH_3- or $-CH_3$ or  or CH_3
or H_3C-

Q35.

A

[1]

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Q1.

(a) This was a straightforward question on a familiar topic and many good students (46.5%) scored full marks. However, some drew structures, such as the horseshoe in the mechanism, with insufficient care and consequently failed to gain marks. Others omitted charges on the ions in the equation (especially on $AlCl_4^-$), or in the mechanism did not draw the + on the carbonyl carbon in the electrophile.

(b) In this question, although some students struggled with the name, a number failed to gain the mark due to a failure to label 1-phenyl in an otherwise correct name. Most identified a correct reagent but “electrophilic addition” and “reduction” were frequent wrong answers for the name of the mechanism.

(c) This question was generally answered well, especially the name of the mechanism and the structure of the ester. A common error was to give the name of the product, i.e. ‘HCl gas’, rather than an observation as required, or alternatively to describe this as a ‘white precipitate’.

Q2.

A was the commonest incorrect response to this question which had a 47% success rate. This suggests there were many students who recognised that the answer is an aldehyde, but who then missed a possible isomer. Drawing out possible structures in a logical sequence is the key here. Students are advised to start with a 5C chain, then 4C and find possible positions for the fifth C (carbon 2 or carbon 3), and finally a 3C chain and find positions for the remaining two carbons (both on carbon 2).

Q3.

(a) As usual, naming nitriles proved difficult for some, but 56% of students gave the correct answer.

(b) Although this question was answered well by most, an appreciable number of students were careless with language and appeared to say that the enantiomers themselves rotate, or that the plane polarised light is ‘refracted’ or ‘bent’ rather than ‘rotated in opposite directions’.

(c) The first mark was less commonly scored than expected as many students wrote about a planar molecule or a planar bond rather than planar carbonyl group; the other two marks were frequently awarded.

(d) A significant number were not able to deduce the correct product and many incorrect products were seen. These included the cyanohydrin formed from pentanal. This showed a lack of care in reading the question.

Q10.

Both parts of question (a) were answered very well and it was good to see the correct use of curly arrows. Part (b)(i) was well done but in (b)(ii) many students simply stated what stereoisomers do to plane polarised light and so failed to answer the question. Part (c)(i) was answered extremely well and the K_c expression in part (c)(ii) was also answered well. The calculation was well done but a frequent error was to use amounts, in moles, rather than concentrations by not using the volume. Better students answered part (d) correctly

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while others showed only one hydroxyl group from the diol reacting and so produced an answer for the acetal which did not match the given molecular formula.

Q11.

In part (a), the nucleophilic addition mechanism was very well done; common errors included missing the charge on the nucleophile or on the intermediate structure and showing a bond between the carbonyl carbon and the N of CN in the intermediate. In part (b)(i), students were not used to drawing 3D structures, and credit was given where attempts showed a pair of mirror images. Again there were some problems with wrongly bonded OH, CN and CH_2CH_3 groups in these structures. The method needed to distinguish between two enantiomers was well known, although to gain M2 polarised light had to be 'rotated' not turned or reflected, and rotated in 'opposite' directions not just different directions. A few students suggested wrongly that the molecules polarised the light or that the molecules themselves were rotated. The name in part (c) was well answered but part (d) was answered poorly. There was confusion of K_a, the acid dissociation constant, with a rate constant, and many students missed the link to low concentrations of cyanide ions from the weak acid HCN and focused mainly on the rate of the dissociation of the acid. Parts (e)(i) and (e)(iii) were answered well but responses to part (e)(ii) sometimes included the C=C bond or the CN group as part of the polymer chain.

Q12.

The nucleophilic addition-elimination mechanism in part (a)(i) presented a real challenge to many students, who were confused by the cyclic nature of the product, failed to identify the correct nucleophile and suggested either separate nucleophiles such as H_2O, CH_3OH and OH^- or alternatively loss of the proton from the OH group before nucleophilic attack. Most students gave the correct range for the carbon atom labelled **b**, but often the range for the carbon atom labelled **a** was given as 160–185 as for a carbonyl carbon. In part (a)(ii), the repeating unit for the polyester was answered well although some students gave twice the repeating unit.

The distinguishing test in part (b) was well done, although a significant number of students thought that substance **K** was an acid and wrongly suggested $NaHCO_3$ or Na_2CO_3 to distinguish between the compounds. It was common for students to fail to see the symmetry of **J** and so to predict, incorrectly, three peaks in its proton n.m.r. spectrum. Five peaks was a common incorrect answer for **K**, suggesting that students had misread the question and given the ^{13}C n.m.r. result.

Part (c) of this question proved to be very challenging and fewer than 10% of students scored full marks. Isomer **Q** was found particularly difficult where many students omitted one of the O atoms from their suggested structure. Other common errors included missing the double bond in **L**, giving the structure of **P** as the structure of **N** (which suggests a failure to recognise that optical isomerism is a form of stereoisomerism) or writing an unbranched carbon chain for the acid **N**. Answers to part (c) were often very badly presented, with a great deal of crossing out, duplication of answers and poor labelling of structures.

Q13.

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

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(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 $C_6H_8O_4$. 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.

Q14.

In this Question, many students stated that Tollens' Reagent is specific to aldehydes and were allowed the mark. This answer did little more than reword the question. A specific reference to potassium dichromate(VI) was needed to earn the mark.

Q15.

In this part (a), many students gave the answer 'primary alcohols are oxidised to aldehydes'. Since ethanol is the only primary alcohol which will give a positive triiodomethane test this answer missed the point, and teachers were told to ignore that answer in the Marking Guidelines. However, sometimes teachers wrongly allowed a mark for this answer. This was another question where answers that included a disqualifier, such as 'ethanol is oxidised to ethanal, CH_3CO', were often incorrectly allowed a mark despite the absence of 'Yes' and use of an incorrect formula for ethanal.

The calculation in this part (b) was answered well. Many teachers did not penalise students who did not give their final answer to 3 significant figures. Some did not always give credit for alternative methods, such as employing the scaling to 100% yield at the start of the calculation. The omission of the word 'soluble' in this part (c) often went unpunished while part (d) was answered well.

Q16.

In part (a), many students thought $NaBH_4$ or $LiAlH_4$ could be used as the reducing agent. Most did not give the molecular formulae in the equation but could balance it correctly; the repeating unit of the polymer was very well done.

Similarly, in part (b), $NaBH_4$ was often suggested as the reducing agent and the empirical formula was frequently wrong. Students found the bond angles difficult, with many failing to deduce that there is a tetrahedral arrangement around a C atom in cyclohexane and appearing simply to guess any angle. Only the most able scored both marks for the bond angles.

There was a good spread of marks in the mechanism with over 40% gaining full marks. In part (c)(ii), most realised that the product was a racemic mixture and that it was produced as a result of attack on the ketone from both sides, but often this was thought to be by an electrophile or an H^+ ion. Some thought that a carbocation intermediate was attacked.

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Q17.

This three–step synthesis was slightly easier than the three–step synthesis in last year's paper. The question discriminated very well; there were many excellent answers and some very poor ones, too. Many students were able to see their way through this synthetic route and had clearly learned reagents and types of mechanism very thoroughly. Others struggled to get started. Common errors included giving L as propan–1–ol, naming M as prop–2–ene, omitting the concentrated condition from sulfuric acid and calling the mechanism in step 2 dehydration rather than elimination.

Q18.

The colour change in part (a)(i) was well known but most candidates failed to score both marks for the conditions for the reaction in part (a)(ii). Many markers treated the word 'excess' as an optional extra and awarded a mark to candidates who just repeated information in the stem of the question. Most candidates were able to draw an acceptable diagram for reflux. The usual mistake was to seal the condenser and many markers failed to punish this serious error.

Part (a)(iii) was poorly answered, even by the better candidates. Distillation was often appreciated but the concept of removal of the aldehyde immediately when it is formed was rarely seen. Some centres were very generous indeed when marking this question.

The tests in part (c) were well known and better candidates scored all four marks. Some candidates lost a mark by giving an incorrect formula for a reagent. Centres are reminded that if the candidate chooses an incorrect test reagent the mark for the observation cannot be awarded.

Most candidates could make some progress in part (d), and the presence of hydrogen bonding in the acid and alcohol were known to the better candidates. Some centres were very generous when marking this question. The final mark was often given for references to stronger van der Waals forces in the carboxylic acid.

Q19.

As is usual, mechanism questions such as this discriminate well. In part (a)(i), 13% of the candidates gained all five marks whereas a similar number scored only one mark. Many candidates omitted the name of the product in an otherwise perfect answer. In part (a)(ii), two fifths of the candidates gained full marks.

In part (b)(i), a number of candidates lost a mark because they gave the formula of the aldehyde propanal as CH_3CH_2COH rather than as CH_3CH_2CHO. For clarification of acceptable formulae styles, candidates and teachers are advised to consult the document "General principles applied to marking CHEM4 papers by CMI+ January 2011" which is available with the Mark Scheme for this paper.

The mechanism in part (b)(ii) was well known and two fifths of candidates gained full marks.

Part (b)(iii) was a How Science Works question where candidates were not required to know the answer, but were expected to apply understanding gained from other areas of the specification. The inductive effect of alkyl groups is part of the explanation of the relative stability of carbocations. A similar effect using two alkyl groups will reduce the δ+ nature of the carbonyl carbon in propanone more than the single alkyl group does for the carbonyl carbon in propanal. Hence it can be predicted that the nucleophile will attack propanal more easily than propanone. About a third of the candidates gained both marks; most of these gave an answer based on inductive effects as above, but others correctly discussed steric effects and this answer was also accepted.

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Q20.

In part (a), large numbers of candidates were able to write a correct mechanism for the nucleophilic addition of HCN to ketone **Q**. By contrast, most found it difficult to name the product correctly and so only 15% scored full marks overall. In part (b) many answers discussed the optical activity of the original ketones **Q** and **R** rather than that of the products of their reactions with HCN. Many also thought that both ketones produced racemic mixtures.

Q21.

Part (a) was well answered and many candidates scored highly. The mechanism in part (b) proved more difficult and some candidates tried to use BH_4^- instead of H^- as expected. The name of the product proved very difficult for most candidates and many made no attempt to answer the question. In part (c), many confused Reaction 3, which is a dehydration or an elimination of water, with the removal of hydrogen from ethylbenzene using iron oxides.

Q22.

As usual, better candidates find organic mechanisms straightforward and many good answers were seen to part (a). In part (b)(i) the name 2–hydroxybutanenitrile, was usually given correctly. The abbreviation 2–hydroxybutanitrile was not allowed.

The structure of the isomer of C_4H_7NO was found difficult. It was possible to score one mark for a structure with the correct molecular formula which showed geometric isomerism. Sadly many candidates did not recognise that an acyl chloride reacts with ammonia form an amide.

In part (c), there were many pentavalent carbons shown in the structures drawn, especially in part (ii). The elimination of water in part (iii) to form an alkene was the least well-known reaction.

Q23.

The name of the mechanism was well answered in part (a) but the actual mechanism itself was much more discriminating. Too many candidates are still careless in their drawing of curly arrows and fail to start every arrow either at a bond or a lone pair. Attack by the cyanide ion must show a lone pair on the carbon atom as the source of the curly arrow. The carbonyl group carbon has a δ+ charge not a full positive charge as suggested by several. Part (b) was less well done. Although many answered part (b)(i) correctly, several omitted the number 2 in the name or failed to count the number of carbons carefully. Part (b)(ii) was misread by many, who simply drew the two optical isomers of **Q** rather than the two geometrical isomers of the dehydration product of **Q**. The repeating unit was usually correct in part (c) although some gave an extra oxygen in their structure and others gave more than the single repeating unit requested. The zwitterion in part (d)(i) was generally well known, but many drew incorrectly a quaternary ammonium salt in part (d)(ii).

Q25.

Part (a) was answered well. Most candidates were able to describe a correct chemical test to distinguish between the aldehyde, propanal, and the ketone, propanone. However, many thought that propanone had two peaks in its proton n.m.r. spectrum.

In part (b), better candidates had no difficulty in identifying propanoic acid as **X** and propan-2-ol as **Y** and in giving correct descriptions of oxidation in Step 1, reduction in Step 2 and esterification in Step 3. Weaker candidates lost marks for incorrect reagents or for

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wrong or missing conditions in the reactions.

Q26.

Part (a)(i) was well answered. Many candidates chose a correct alkene, gave two structural isomers formed in the reaction with HBr and named the type of structural isomerism. Candidates who chose an incorrect alkene were able to score three marks for a correct mechanism. In (a)(ii) choosing a carbonyl compound with the molecular formula C_3H_6O which forms two isomers when HCN is added proved more difficult and many candidates gave the incorrect carbonyl $(CH_3)_2CO$. Marks were again allowed for a correct mechanism even when the carbonyl was incorrect. Candidates were only allowed to score a mark for stating that the isomers formed were optically active if the isomers given had an asymmetric carbon. As square planar molecules are not optically active, structure marks were only awarded when isomers were shown as tetrahedral arrangements. Almost all candidates were able to write an equation for a nucleophilic addition-elimination reaction of ethanoyl chloride but equations involving NH_3 were only given full marks if NH_4Cl rather than HCl was given as a product. Many candidates omitted to state the polarising effects of both the oxygen and the chlorine atoms when explaining why the reactions occur readily. Most also failed to state that nucleophiles are able to react because they have a lone electron pair which they can donate.

Q29.

This was a relatively high scoring question. In part (a), many correct answers were seen, although answers to part (a)(ii) often included unbalanced equations or an incorrect formula for propanone. The intended answer in (a)(ii) was $NaBH_4$, but due credit was given to those candidates who chose to use Ni/H_2 and ignored the requirement to use [H] in the equation. The structure of propanal was generally well known and the choice of a suitable reagent for the test to distinguish propanone from propanal caused few problems; Tollens' reagent being the most common choice. Many candidates received full credit for part (b)(ii), but some credit was withheld when an incomplete reagent was used e.g. $[Ag(NH_3)_2]^+$ or the results were recorded the wrong way around.

Q30.

Compound **C** was named correctly by the more able, but the requirement for the number 2 was not appreciated by the weaker candidates. Part (b) was answered well by most, although some did not distinguish between the O-H absorption in alcohols such as compound **D** and the O-H absorption in carboxylic acids. A surprising number of candidates gave the answer 5 in part (c) rather than the expected 4. Answers to part (d) were disappointing even from otherwise good candidates. It seemed that as soon as the ketone **C** was seen, then tests using Fehlings or Tollens' solutions were suggested, without the candidates noticing that **D** was an alcohol and not an aldehyde. Those who chose a correct test usually scored well. Answers to part (e) were better.

Q32.

This question discriminated well and better candidates were able to score full marks. Weaker candidates were unable to recognise the ester **C** and acid **D** in part (a) and hence could not distinguish correctly between them. As expected, methyl propanoate was a common wrong answer in part (a)(i) and only the better candidates named **E** correctly as pentan-2-one. Reagents distinguishing between the ketone **E** and the aldehyde **F** were better known, but the term "chain isomer" was missed by many who failed to draw a correct structure for 2-methylbutanal, the only possible answer.

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Q33.

Although many candidates were able to identify which of the three organic compounds would reduce acidified potassium dichromate(VI), as required in part (a), only a relatively small number gave a correct half-equation for the reduction of dichromate(VI) ions. In part (b), many candidates correctly identified the aldehyde as the compound which reduces Tollens' reagent. Some also gave the correct silver complex present in Tollens' reagent but few gave a correct half-equation for the reduction of this species to silver metal. The formation of two esters by the reactions of the two alcohols with ethanoic acid was quite well known and many correct equations for their formation were given in answers to part (c). Part (d) proved, as expected, to be more challenging and only the best candidates were able to deduce correctly the number of peaks in the proton n.m.r. spectra of the two compounds given.

Q34.

In organic mechanisms, a curly arrow must start at a lone pair or at a bond. This idea was still forgotten by some candidates. In part(a), several used a lone pair on the nitrogen atom rather than one on the carbon of the cyanide ion. A few confused the nucleophilic addition in part (a) with the addition-elimination in part (b) and tried in part (a) to reform a carbon to oxygen double bond. An appreciable number thought that the name of the product was a propanenitrile instead of 2-hydroxypentanenitrile. In both parts (a) and (b) the C=O bond should not be shown breaking before the nucleophile attacks. The ester was often correctly named as methyl propanoate but many other suggestions were also seen. Part (c) discriminated well. Only the better candidates were able to identify the correct electrophile, join it correctly to the benzene ring, draw the correct intermediate and show the loss of H^+ correctly.

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