M1.D

[1]

M2.B

[1]

M3.D

[1]

M4.D

[1]

M5.D

[1]

M6.B

[1]

M7.D

[1]

M1. (a) nucleophilic addition

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

1

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]

M2. D

[1]

M3. B

[1]

M4.(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 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

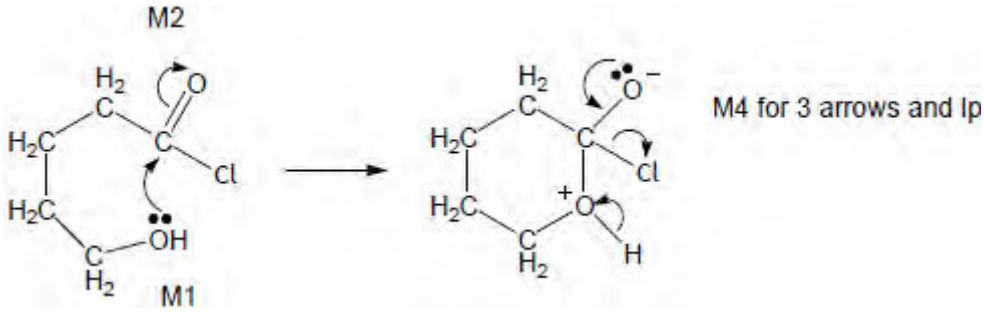
[7]

M5.(a) (i) (nucleophilic) addition-elimination

Not electrophilic addition-elimination

Ignore esterification

1



M3 for structure

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

4

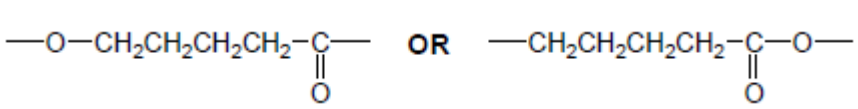
a 20-50 (ppm) or single value or range entirely within this range

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

1

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

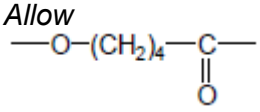
1

(ii)  **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*	*(orange) turns green*

		red-orange)	

1

J *Two (peaks)*

Allow trough, peak, spike.

1

K *Four (peaks)*

Ignore details of splitting.

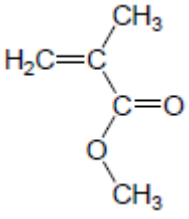
If values not specified as J or K then assume first is J.

1

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

L

ester



OR *$H_2C=C(CH_3)COOCH_3$*

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

Allow CH_3–.

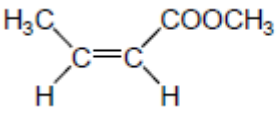
Allow $-CO_2CH_3$ etc.

Allow $CH_2C(CH_3)COOCH_3$.

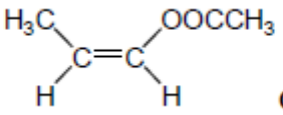
1

M

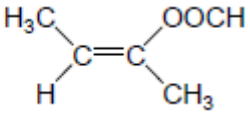
ester



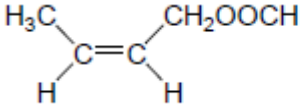
OR



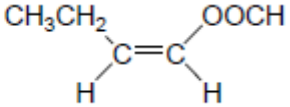
OR



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



OR



OR

$CH_3CH=CHCH_2OOCH$ *$CH_3CH_2CH=CHOOCH$*

Allow either E–Z isomer.

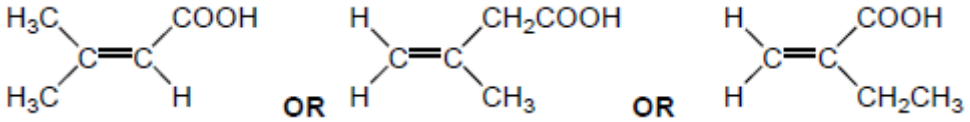
Allow CH_3– or C_2H_5– but not CH_2CH_3–.

Allow $CH_3CHCHCOOCH_3$ etc.

1

N

acid



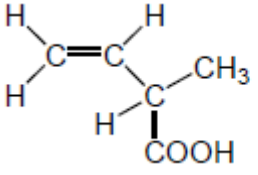
$(CH_3)_2C=CHCOOH$ *$H_2C=C(CH_3)CH_2COOH$* *$H_2C=C(COOH)CH_2CH_3$*

Allow CH_3– or C_2H_5– but not CH_2CH_3–.

Allow $-CO_2H$.

Not cyclic isomers.

Not the optically active isomer.



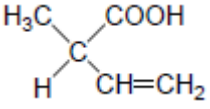
which is P anyway

Allow $(CH_3)_2CCHCOOH$ etc.

1

P

acid



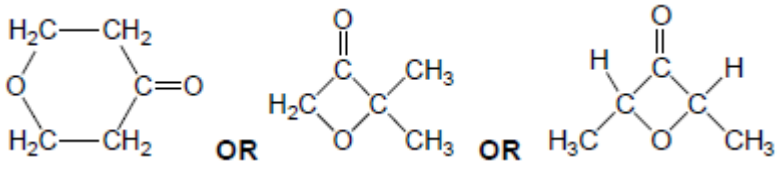
Allow $-CO_2H$.

$CH_3CH(COOH)CH=CH_2$

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

1

Q



Not cyclic esters.

1

[19]

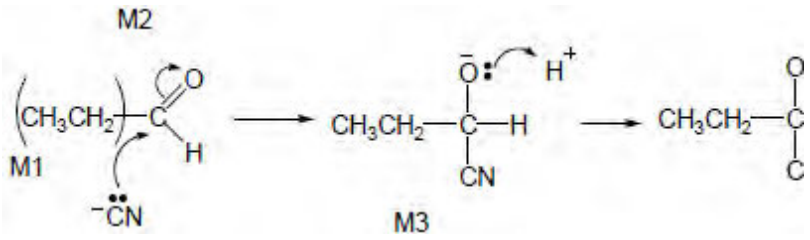
M6.*D*

[1]

M7.*(a)* <u>*Nucleophilic addition*</u>

1

M4 for lp, arrow and H+

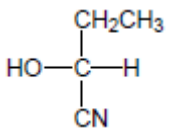


Allow C_2H_{5-} for CH_3CH_{2-}

- *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.*
- *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



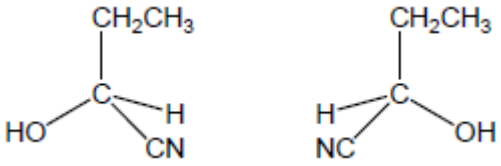
M1 for correct structure of product of part (a).

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

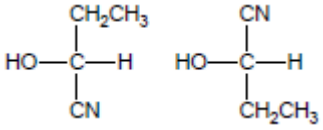
Penalise wrongly bonded, OH or CN or CH_2CH_3 once only in clip.

1

M2

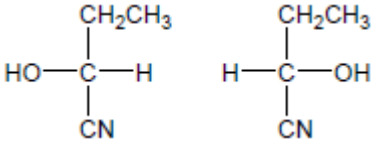


M2 cannot be gained by simply swapping two or more groups with no attempt to show a mirror image., e.g. do not allow M2 for



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

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

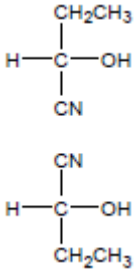


ie vertical groups same and horizontal swapped as if there was a mirror between them

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.



1

(ii) M1 (Plane) <u>polarized light</u>

M2 only scores following correct M1

1

M2 <u>Rotated</u> in <u>opposite</u> 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) <u>2-hydroxybutane(-1-)nitrile</u>

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

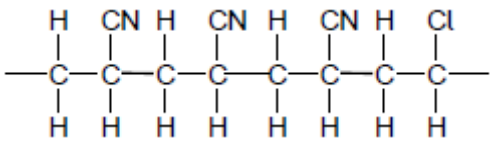
$H_2C{=}CH{-}CH_3 + NH_3 + 3O_2 \longrightarrow H_2C{=}CH{-}CN + 3H_2O_2$

OR doubled.

Allow C_3H_6 and CH_2CHCN or C_3H_3N on this occasion only.

1

(ii)

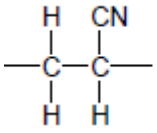
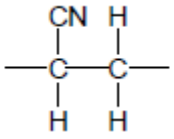
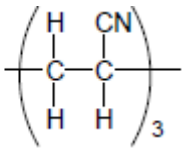


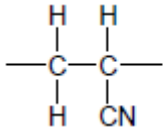
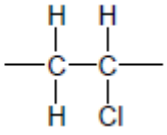
Ignore n.

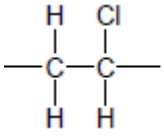
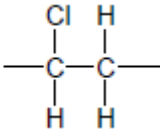
Must show trailing bonds.

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

Must contain, in any order,

3 of  or 3 of  or 

Allow  or 

and one of  or 

Allow –$CH_2CH(CN)CH_2CHCl$– etc.

1

(iii) Addition (polymerization)

Allow self-addition.

Do not allow additional.

1

[15]

M1.D

[1]

M2. (a) **X** (O–H) (alcohols)

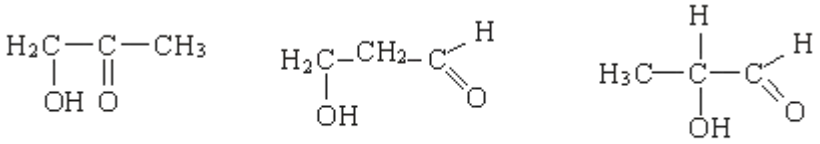
penalise acid or missing "alcohol"

1

Y C=O

allow carbonyl

1

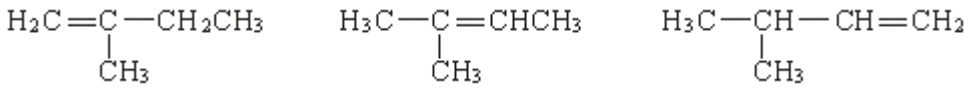


A

NOT acid

4

(b)

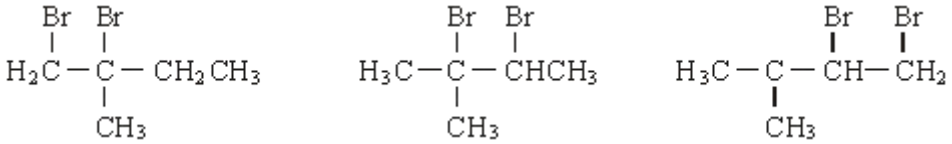


Allow conseq dibromocompounds following incorrect unbranched alkenes

NOT allow dibromocompound consequent on a duplicate alkene

NOT allow monobromocompounds if HBr added

3



3

6:3:1 either next to correct structure or to none

1

Allow a mark for identifying correct dibromocompound with three peaks even if integration ratio is wrong

1

if 6:3:1 missing or wrong, no marks for splitting

Only award a mark for splitting if it is clear which integration number it refers to

6 singlet or drawn

1

3 doublet or drawn

1

1 quartet/quadruplet or drawn

1

(max 10 marks)

[16]

M3. D

[1]

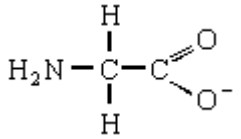
M4. (a) 2-amino(e) propanoic acid **(1)**

1

(b) (i) molecules with same structure / structural formula **(1)**
but with bonds **(atoms or groups)** arranged differently in space (3D) **(1)**

(ii) Plane polarised light **(1)**
Rotated (equally) in opposite directions **(1)**

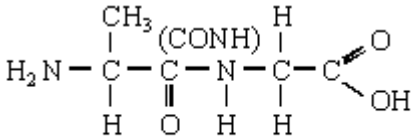
4

(c)  **(1)**

allow $H_2NCH_2COO^-$

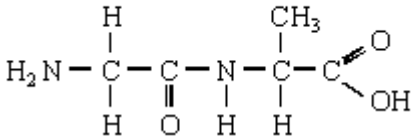
Penalise NH_2^- and OH^- once per paper
but CH_3– is allowed

1



(1)

(d)

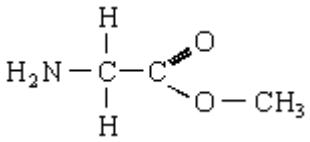


(1)

Not anhydrides; not repeating units

2

(e)



(1)

or $H_2NCH_2COOCH_3$

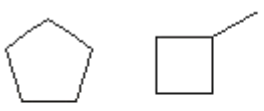
1

[9]

M5. (a) **A** any C_5 alkene

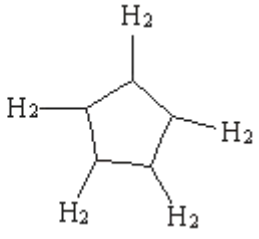
1

B



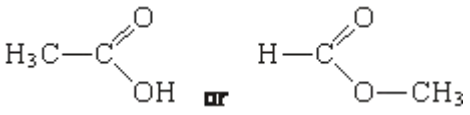
etc

penalise



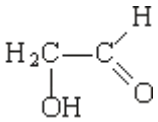
1

(b) **C**



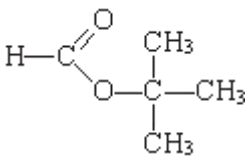
or CH_3COOH or $HCOOCH_3$ **1**

D



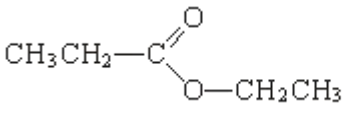
or $HOCH_2CHO$ **1**

(c) **E**



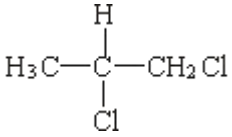
1

F



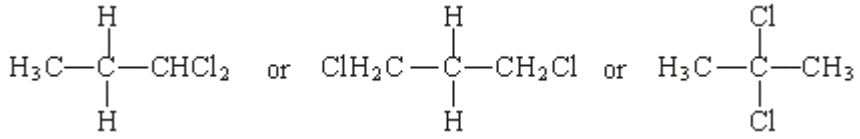
1

(d) **G**



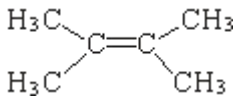
1

H



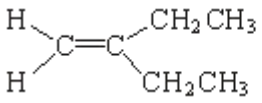
1

(e) **I**



1

J

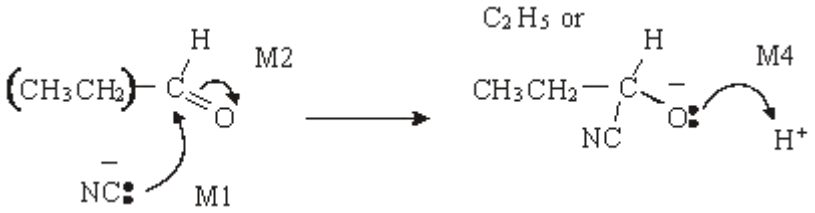


(allow C_2H_5) **NOT** hex-3-ene

1

[10]

M6. (a) necleophilic addition;



1

M3 structure;

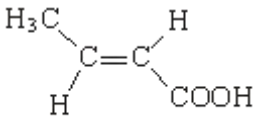
(be lenient on position of charge on CN–)
(M2 not allowed independent of M1,
but allow M1 for correct attack on C+
if M2 show as independent first.)
(+on C of C=O loses M2 but ignore δ+ if correct)
(M4 for arrow and lone pair (only allow for correct M3 or close))

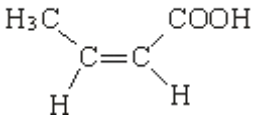
4

(b) (i) 2-hydroxybutanoic acid

1

(ii)



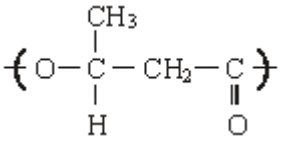


1

geometric(al) or cis-trans

1

(c) (i)



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

1

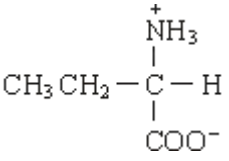
(ii) can be hydrolysed

OR

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

1

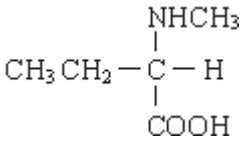
(d) (i)



(allow $-NH_3^+$)

1

(ii)



(or zwitterions product)

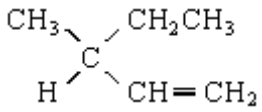
1

(iii) nucleophilic substitution;

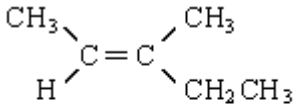
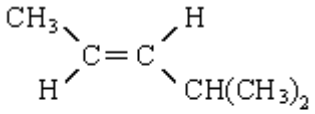
1

[14]

M1. (a) *Structure of* **P**:


(1)

Structures of **Q** and **R**:


and


NOT C_3H_7

(1) **(1)**

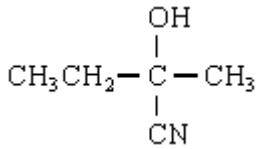
Q and R in any order

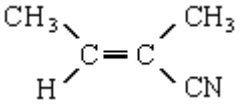
3

(b) (i) *Racemic mixture*: <u>equal</u> mixture of optical isomers / enantiomers
OR in explanation

Explanation: planar (>C=O) **(1)**
attack from either side is equally likely **(1)**

(ii) *Reagent **S***: HCN or (KCN / HCl **or** H_2SO_4) **(1)**

*Compound **T***:  **(1)**

*Compound **U***:  **(1)**

6

[9]

M2.B

[1]

M3. D

[1]

M4. (a) (i) 0.86 **(1)**

(ii) total moles = 0.86 + 0.43 +0.085 = 1.375 **(1)**

$\therefore$ mole fraction of H_2 = $\frac{0.86}{1.375}$ = 0.625 **(1)**

(0.62 - 0.63)

Conseq on (i)

(iii) pp = mole fract^{n} × total P **(1)**
= 0.625 × 1.75 × 10^4
= 1.09 × 10^4 (kPa) **(1)**
or 1.1(0)
Ignore units
Conseq on (ii)

5

(b) (i) $K_p = \frac{P_{CH3OH}}{P^2_{H_2} \times P_{CO}}$ **(1)**
Penalise [ ]

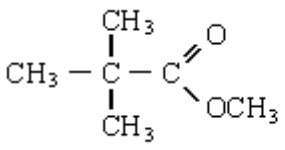
(ii) $K_p = \frac{2710}{(12300)^2 \times (7550)}$ = 2.37 (2.4) × 10^{-9} **(1)**
OR 2.37 × 10^{-15}

Units: kPa^{-2} **(1)**
or Pa^{-2}

not conseq to wrong K_p expression

3

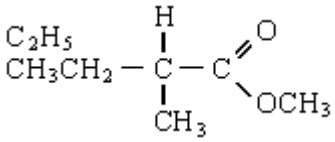
(c) *Isomer **E**:*



(1)

allow $(CH_3)_3CCOOCH_3$ or $(CH_3)_3CCO_2CH_3$

*Isomer **F**:*



(1)

2

[10]