M1.C

[1]

M2.B

[1]

M3.D

[1]

M4.C

[1]

M5.D

[1]

M6.B

[1]

M7.D

[1]

M8.C

[1]

M1.(a) Reagent

Acidified
$K_2Cr_2O_7$

Acidified
$KMnO_4$

I_2 / NaOH

Named
RCOOH with HCl or H_2SO_4

Named
RCOCl

Allow names including potassium permanganate
Wrong or no reagent CE = 0

1

P (ketone)
no reaction
no reaction
Yellow ppt
no reaction
no reaction

Penalise incorrect formulae or incomplete reagent, such as $K_2Cr_2O_7$ or acidified dichromate, but mark on.

1

S (2° alcohol)
(orange to) green
(purple to) colourless
no reaction
fruity or sweet smell
Misty fumes

Allow no change or nvc but penalise <u>nothing or no observation</u>
If 2 reagents added sequentially or 2 different reagents used for P and S then CE = 0

1

(b) Tollens'
silver mirror / solid

1

Fehling's / Benedicts
red ppt

1

(c) **G**
P

If not P then no marks for clip

1

5 OR five

1

(d) $C_4H_{12}Si$

Must be molecular formula
Wrong substance CE = 0 for clip

1

Any **two** from

- One or single peak OR all (four) carbon atoms are equivalent or one environment

1

- upfield from others or far away from others or far to right
- non toxic OR inert
- low boiling point or volatile or easy removed from sample

Ignore and don't credit single peak linked to 12 equivalent H or has a peak at δ = 0
but use list principle for wrong statements

1
1

(e) Figure 1 is **R**

*If not **R** cannot score M2*

M1

1

90−150 (ppm) or value in range is (two peaks for) C = C / alkene

M2

1

Figure 2 is **T**

*If not **T** cannot score M4 or M5*

M3

1

50-90 (ppm) or value in range is C—O or alcohol or ether

M4

1

two peaks (so not S which would have only one)

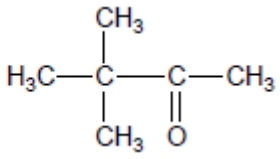
M5

1

(f)

U

$C_6H_{12}O_6$

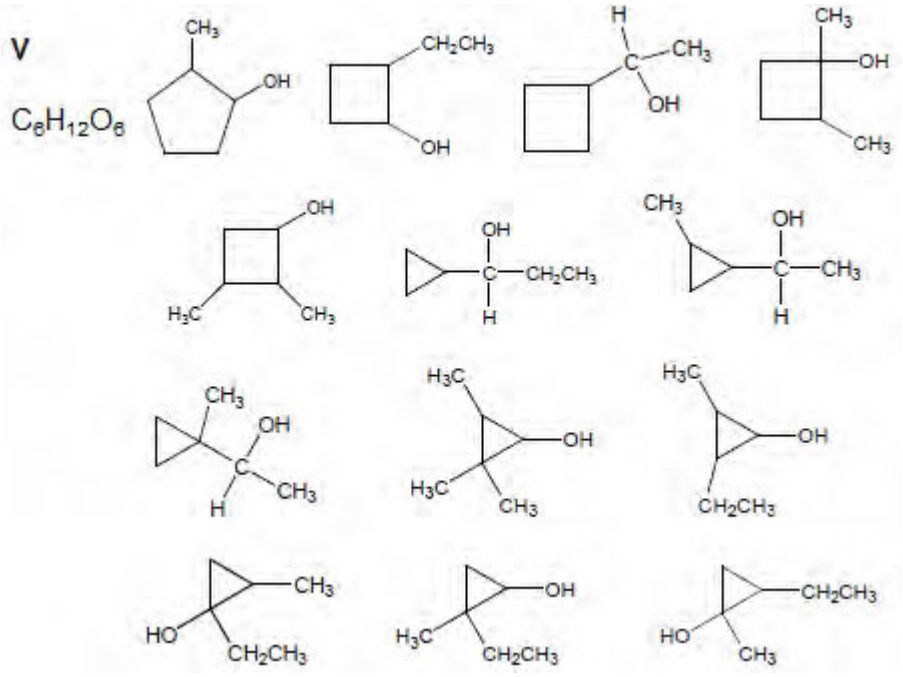


1

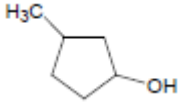
Answers include

V

$C_6H_{12}O_6$



*Not allow **S***



*because **V** must be an isomer of **S***

[17]

M2.6 / six

[1]

M3.(a) (i) Single / one (intense) peak / signal ***OR*** all H or all C in same environment ***OR*** 12 equiv H or 4 equiv C

Do not allow non-toxic or inert (both given in Q)

Any 2 from three

Ignore peak at zero

OR

Upfield / to the right of (all) other peaks ***OR*** well away from others ***OR*** doesn't interfere with other peaks

Ignore cheap

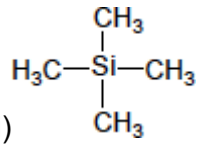
Ignore non-polar

OR

Low bp ***OR*** volatile ***OR*** can easily be removed

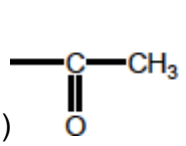
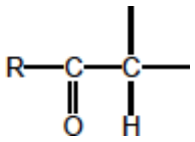
Ignore mention of solubility

2

(ii) 

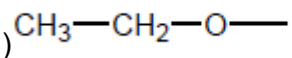
Allow $Si(CH_3)_4$

1

(b) (i)  or with sticks or 

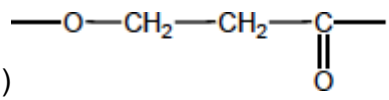
Ignore any group joined on other side of CO
Ignore missing trailing bond
Ignore charges

1

(ii)  or with sticks

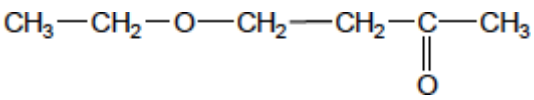
Ignore any group joined on other side of −O−
Ignore missing trailing bond
Ignore charges as if MS fragment

1

(iii)  or with sticks

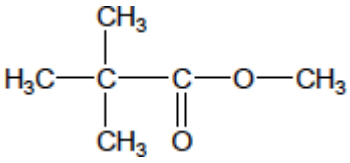
Ignore missing trailing bonds
Ignore charges as if MS fragment

1

(iv) 

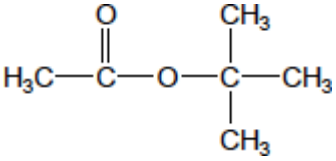
1

(c) (i) Check structure has 6 carbons



Allow $(CH_3)_3CCOOCH_3$ or $(CH_3)_3CCO_2CH_3$

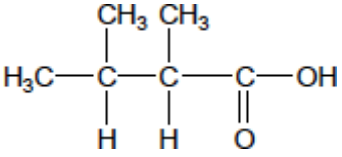
1



Allow $CH_3COOC(CH_3)_3$ or $CH_3CO_2C(CH_3)_3$

1

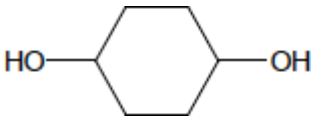
(ii) Check structure has 6 carbons



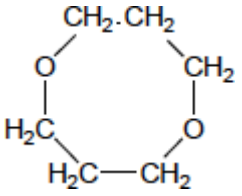
Allow $(CH_3)_2CHCH(CH_3)COOH$ or $(CH_3)_2CHCH(CH_3)CO_2H$
Penalise C_3H_7

1

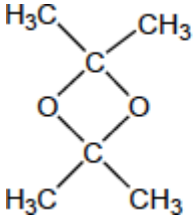
(iii) Check structure has 6 carbons



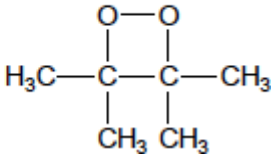
OR



Allow



OR



1

[11]

M4.(a) (i) $CDCl_3$ or CD_2Cl_2 or C_6D_6 or CCl_4

Not D_2O Allow CD_3Cl

1

(ii) 4 **or four**

1

(iii) Triplet or 3 or three

1

(iv) 1,4-dichloro-2,2-dimethylbutane

Do not penalise different or missing punctuation or extra spaces.

Spelling must be exact and order of letters and numbers as here.

1

(b) (i) 3 or three

1

(ii) 190-220 (cm^{-1})

Allow a single number within the range.

***OR** a smaller range entirely within this range.*

1

(iii) hexan**e**-2,5-dione

Do not penalise different or missing punctuation or extra spaces.

Spelling must be exact and order of letters and numbers as here.

NB so must have middle e

1

[7]

M5.IR

Extended response

Absorption at 3360 cm^{-1} shows OH alcohol present

Deduction of correct structure without explanation scores maximum of 4 marks as this does not show a clear, coherent line of reasoning.

M1

1

NMR

There are 4 peaks which indicates 4 different environments of hydrogen

Maximum of 6 marks if no structure given OR if coherent logic not displayed in the explanations of how two of OH, CH_3 and CH_2CH_3 are identified.

M2

1

The integration ratio = 1.6 : 0.4 : 1.2 : 2.4

The simplest whole number ratio is 4 : 1 : 3 : 6

M3

1

The singlet (integ 1) must be caused by H in OH alcohol

M4 **1**

The singlet (integ 3) must be due to a CH_3 group with no adjacent H

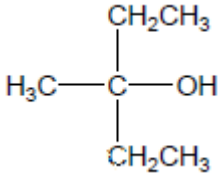
M5 **1**

Quartet + triplet suggest CH_2CH_3 group

M6 **1**

Integration 4 and integration 6 indicates two equivalent CH_2CH_3 groups

M7 **1**



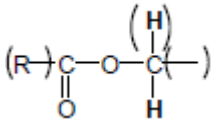
M8 **1**

[8]

M6.(a) M1 Ester **1**

If Ester 2, can score M3 only.

1

M2 peak at δ = 4.1 due to 

When marking M2 and M3, check any annotation of structures in the stem at the top of the page.

1

M3 (δ = 4.1 peak is) quartet as adjacent / next to / attached to CH_3 **1**

M4 Other spectrum quartet at δ = 2.1-2.6 (or value in this range) **1**

(b) M1 Quaternary (alkyl) ammonium salt / bromide **1**

M2 CH_3Br or bromomethane

Penalise contradictory formula and name. **1**

M3 Excess (CH_3Br or bromomethane)

Mention of acid eg H_2SO_4 OR alkali eg NaOH loses both M2 and M3. **1**

M4 Nucleophilic substitution

Can only score M3 if reagent correct.

Ignore alcohol or ethanol (conditions) or Temp. **1**

(c)

	Bromine (penalise Br but mark on)	Acidified $KMnO_4$ (Penalise missing acid but mark on)

Wrong reagent = no marks.

If bromine colour stated it must be red, yellow, orange, brown or any combination, penalise wrong starting colour. **1**

Benzene	no reaction / colour remains	no reaction / colour remains / no (visible)

	/ no (visible) change	change

Ignore 'clear', 'nothing'.
Allow colour fades slowly.
Allow 'nvc' for no visible change.

1

cyclohexene	(Bromine) decolourised	(Acidified $KMnO_4$) decolourised

1

[11]

M7.C

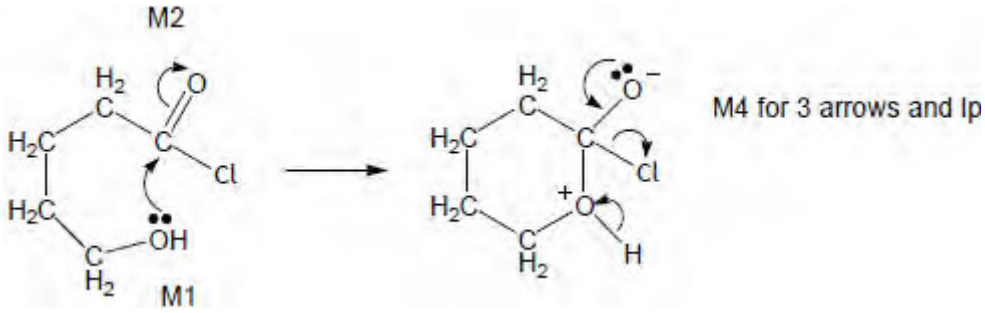
[1]

M1.(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 <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

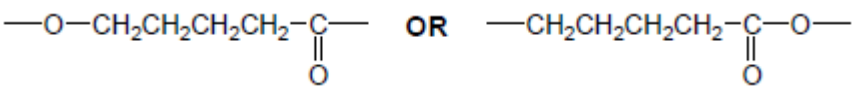
If values not specified as a or b then assume first is a.

1

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

1

(ii)

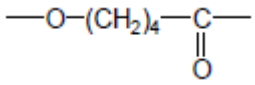


Must have trailing bonds, but ignore n.

1

OR $-OCH_2CH_2CH_2CH_2CO-$ **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

K *Four (peaks)*

Ignore details of splitting.

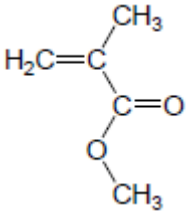
If values not specified as J or K then assume first is J.

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–.

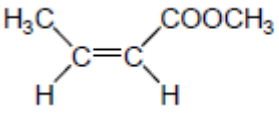
Allow $-CO_2CH_3$ etc.

Allow $CH_2C(CH_3)COOCH_3$.

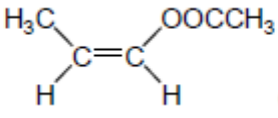
1

M

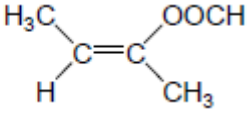
ester



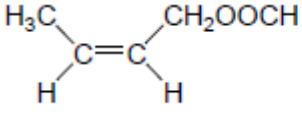
OR



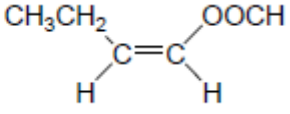
OR



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



OR



OR

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

Allow either E–Z isomer.

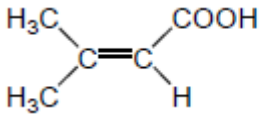
Allow CH_3– or C_2H_5– but not CH_2CH_3–.

Allow $CH_3CHCHCOOCH_3$ etc.

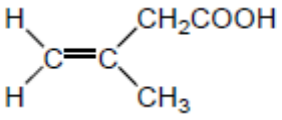
1

N

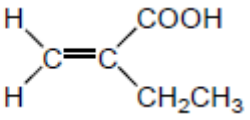
acid



OR



OR



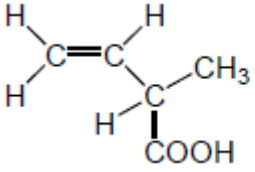
$(CH_3)_2C=CHCOOH$ $H_2C=C(CH_3)CH_2COOH$ $H_2C=C(COOH)CH_2CH_3$

Allow CH_3- or C_2H_5- but not CH_2CH_3-.

Allow $-CO_2H$.

Not cyclic isomers.

Not the optically active isomer.



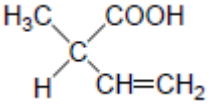
which is P anyway

Allow $(CH_3)_2CCHCOOH$ etc.

1

P

acid



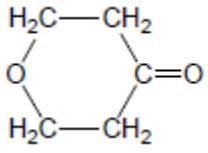
Allow $-CO_2H$.

$CH_3CH(COOH)CH=CH_2$

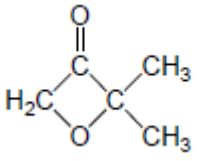
Allow $CH_3CH(CO_2H)CHCH_2$ or $CH_3CH(CO_2H)C_2H_3$.

1

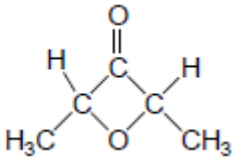
Q



OR



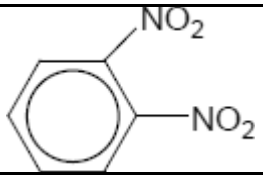
OR



Not cyclic esters.

1

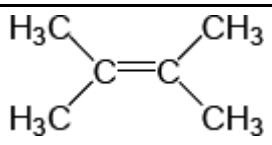
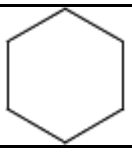
[19]

M2.(a) **F**	**G**
	

Penalize –O_2N once
Penalise missing circle once
Don't penalise attempt at bonding in NO_2

1

1

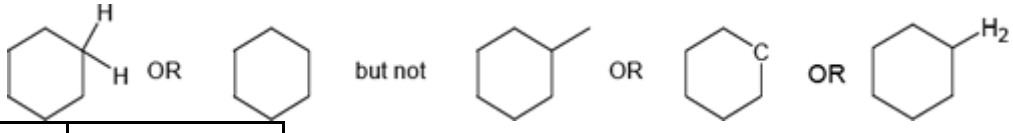
(b) **H**	**J**
	

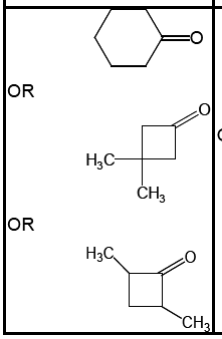
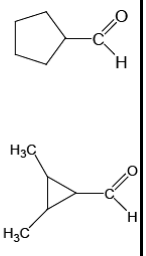
*If **both H** and **J** correct but reversed, award one mark*

1

1

A carbon in saturated ring structures should be shown as



(c) **K**	**L**
	

1

1

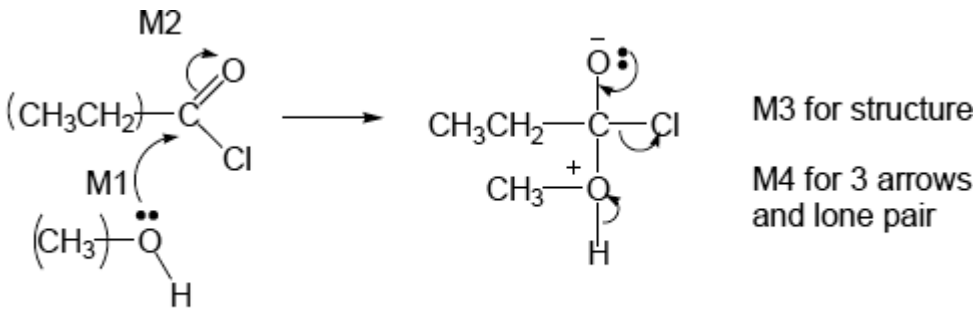
(d) ***M***	***N***
$CH_3CH_2-N(CH_2CH_3)-CH_2CH_3$ OR $CH_3-N(CH_3)-C(CH_3)_3$	$H_3C-C(CH_3)(H)-N(H)-C(CH_3)(H)-CH_3$

Allow C_2H_5 but
NOT allow C_4H_9 or C_3H_7

1

1

[8]



M3.*(a)* methyl propanoate (**NO** mark for name of mechanism)

- *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, max1 for M1*
- *M3 for correct structure <u>with charges</u> but lp on O is part of M4*
- *only allow M4 after correct/very close M3*
- *ignore Cl^- removing H^+*

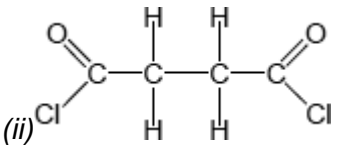
4

1

(b) (i) *pentan<u>e</u>-<u>1,5</u>-diol*

Second 'e' and numbers needed

Allow <u>1,5</u>-pentan<u>e</u>diol but this is not IUPAC name

(ii) 

Must show ALL bonds

1

(iii) *All three marks are independent*

M1 (base or alkaline) Hydrolysis (allow close spelling)

1

Allow (nucleophilic) addition-elimination or saponification

M2 <u>δ+ C</u> in polyester

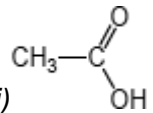
1

M3 reacts with OH^- or hydroxide ion

1

Not reacts with NaOH

1

(c) (i) 

Allow CH_3COOH or CH_3CO_2H

1

(ii) *(nucleophilic) <u>addition-elimination</u>*

Both addition and elimination needed and in that order

OR

(nucleophilic) addition followed by elimination

*Do **not** allow electrophilic addition-elimination / esterification*

Ignore acylation

1

*(iii) any **two** from: ethanoic anhydride is*

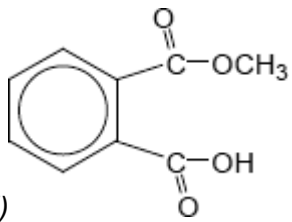
- *less corrosive*
- *less vulnerable to hydrolysis*
- *less dangerous to use,*
- *less violent/exothermic/vigorous reaction OR more controllable rxn*
- *does not produce toxic/corrosive/harmful fumes (of HCl) OR does not produce HCl*
- *less volatile*

***NOT** COST*

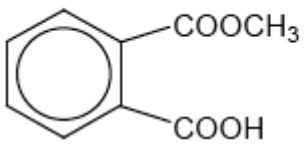
List principle beyond two answers

2

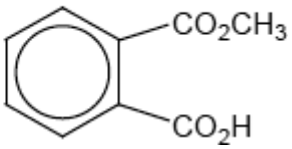
(d)



Allow



or



1

(e) (i) ester

*Do **not** allow ether*

Ignore functional group/linkage/bond

1

(ii) 12 or twelve (peaks)

1

(iii) *160 – 185*

Allow a number or range within these limits

Penalize extra ranges given

Ignore units

1

(f) (i) sulfuric acid	*sodium hydroxide*	✓
hydrochloric acid	*ammonia*	*X or blank*
ethanoic acid	*potassium hydroxide*	✓
nitric acid	*methylamine*	*X or blank*

4 correct scores 2

3 correct scores 1

2 or 1 correct scores 0

2

(ii) *<u>Pink to colourless</u>*

Allow 'red' OR 'purple' OR 'magenta' instead of 'pink'

*Do **not** allow 'clear' instead of 'colourless'*

1

[21]

M4.*(a)* *(i)* *Single / one (intense) peak / signal **OR** all H or all C in same environment **OR** 12 equiv H or 4 equiv C*

Do not allow non-toxic or inert (both given in Q)

Any 2 from three

Ignore peak at zero

OR

*Upfield / to the right of (all) other peaks **OR** well away from others **OR** doesn't interfere with other peaks*

Ignore cheap

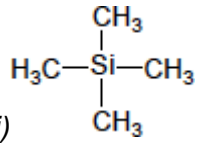
Ignore non-polar

OR

*Low bp **OR** volatile **OR** can easily be removed*

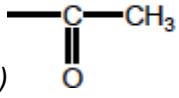
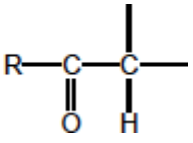
Ignore mention of solubility

2

(ii) 

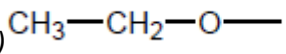
Allow $Si(CH_3)_4$

1

(b) (i)  or with sticks or 

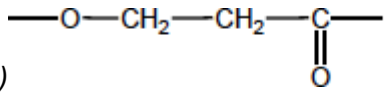
Ignore any group joined on other side of CO
Ignore missing trailing bond
Ignore charges

1

(ii)  or with sticks

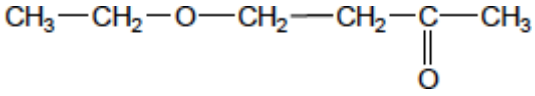
Ignore any group joined on other side of −O−
Ignore missing trailing bond
Ignore charges as if MS fragment

1

(iii)  or with sticks

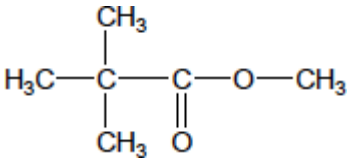
Ignore missing trailing bonds
Ignore charges as if MS fragment

1

(iv) 

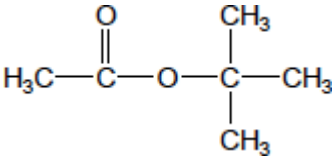
1

(c) (i) *Check structure has 6 carbons*



Allow $(CH_3)_3CCOOCH_3$ or $(CH_3)_3CCO_2CH_3$

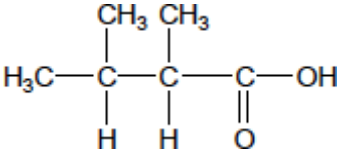
1



Allow $CH_3COOC(CH_3)_3$ or $CH_3CO_2C(CH_3)_3$

1

(ii) Check structure has 6 carbons

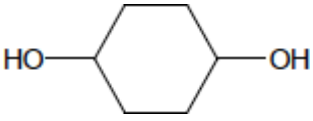


Allow $(CH_3)_2CHCH(CH_3)COOH$ or $(CH_3)_2CHCH(CH_3)CO_2H$

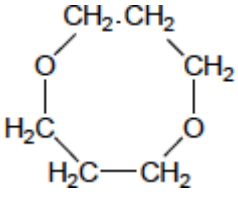
Penalise C_3H_7

1

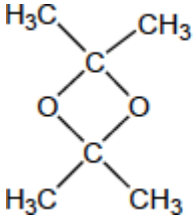
(iii) Check structure has 6 carbons



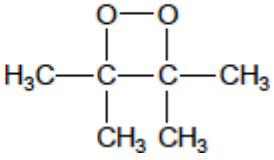
OR



Allow



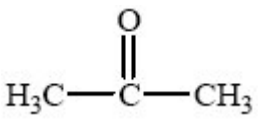
OR



1

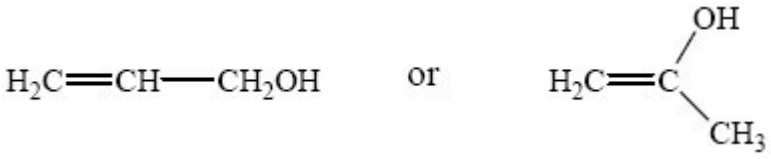
[11]

M1. (a) A



allow CH_3COCH_3

1



B

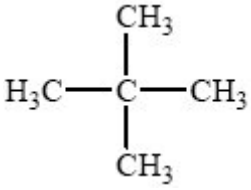
must show C=C

Penalise sticks once per pair

1

(b) C $CH_3CH_2CH_2CH_2CH_3$

1



D

NOT cyclopentane which is only C_5H_{10}

Penalise sticks once per pair

1

(c) E $CH_3CH_2COOCH_3$

Allow $C_2H_5CO_2CH_3$

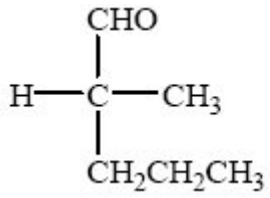
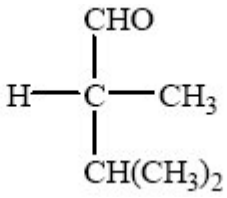
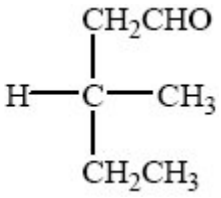
1

F $CH_3COOCH_2CH_3$

Allow $CH_3CO_2CH_2CH_3$ or $CH_3CO_2C_2H_5$

Penalise sticks once per pair

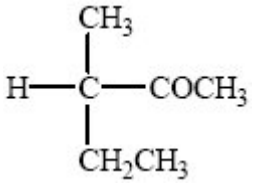
1

(d) G  **OR**  **OR** 

allow C_3H_7 allow C_3H_7 allow C_2H_5

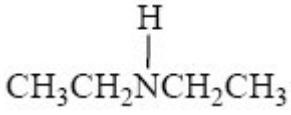
not C_5H_{11} nor C_4H_9
Penalise sticks once per pair

1

H 

allow C_2H_5

1

(e) I 

allow C_2H_5

1

J 

NOT C_3H_7
Penalise sticks once per pair

1

[10]

M2. (a) GLC or distillation

1

(b) C=O

1

(c) (i) Cl has two isotopes

1

(ii) $CH_3\overset{+}{C}=O$

1

$C_4H_7ClO^{+\cdot} \rightarrow CH_3\overset{+}{C}=O + C_2H_4Cl^{\cdot}$

1

(d) (i) e.g. $CDCl_3$ or CCl_4

1

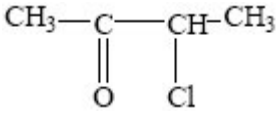
(ii) $Si(CH_3)_4$

1

(e) 0 and 3

1

(f)



1

(g) $CH_3CH_2CH_2COCl$ or $(CH_3)_2CHCOCl$

1

[10]

M3. (a) chromatography (allow GLC TLC GC HPLC)
allow any qualification

1

(b) 5

1

Allow 320(.0) or 322(.0)

1

(c) Use of excess air/oxygen or high temperature (over 800 °C) or remove chlorine-containing compounds before incineration

1

(d) (i) $Si(CH_3)_4$ allow SiC_4H_{12}

allow displayed formula and do not penalise sticks

Not TMS

1

(ii) 3

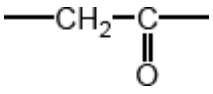
1

[6]

M4.(a) OH alcohols

1

(b) (i) 2.6



Ignore any group on RHS

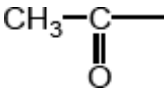
*Must clearly indicate relevant **two** H on a C next to C=O*

On LHS, penalise H or CH or CH_2 or CH_3

Ignore missing trailing bonds or attached R groups

1

(ii) 2.2



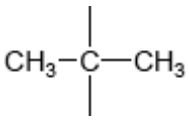
Ignore all groups on RHS

*Must clearly indicate relevant **three** H on C next to C=O*

Ignore missing trailing bonds or attached R group

1

(iii) 1.2



Or in words: two <u>equivalent</u> CH_3 groups

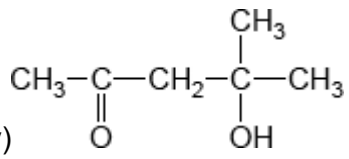
Must clearly indicate two <u>equivalent</u> methyl groups.

Penalise attached H

Ignore missing trailing bonds or attached R groups

1

(iv)



1

[5]

M5. (a) (i) Single reagent

If wrong single reagent, CE = zero

Incomplete single reagent (e.g. carbonate) or wrong formula (e.g.$NaCO_3$) loses reagent mark, but mark on

For "no reaction" allow "nothing"

Different reagents

If different tests on E and F; both reagents and any follow on chemistry must be correct for first (reagent) mark.
Reagent must react: i.e. not allow Tollens on G (ketone) – no reaction.
Second and third marks are for correct observations.
i.e. for different tests on E and F, if one reagent is correct and one wrong, can score max 1 for correct observation with correct reagent.

PCl_5 PCl_3

$SOCl_2$

1

E ester

Na_2CO_3/$NaHCO_3$ named carbonate

metal e.g.Mg

no reaction

no reaction

named indicator

no effect

No reaction

1

F acid

Na_2CO_3/$NaHCO_3$ named carbonate

Effervescence or CO_2

metal e.g.Mg

Effervescence or H_2

named indicator

acid colour

fumes

1

(ii) Single reagent

If wrong single reagent, CE = zero
Incomplete single reagent (e.g. carbonate) or wrong formula (e.g.$NaCO_3$) loses reagent mark, but mark on
For "no reaction" allow "nothing"

Different reagents

If different tests on E and F; **both** reagents and any follow on chemistry must be correct for first (reagent) mark.
Reagent must react: i.e. not allow Tollens on G (ketone) – no reaction.
Second and third marks are for correct observations.

1

i.e. for different tests on E and F, if one reagent is correct and one wrong, can score max 1 for correct observation with correct reagent.

G ketone

$AgNO_3$

no reaction

Na_2CO_3/$NaHCO_3$ named carbonate

water

no reaction

named indicator

no effect

Named alcohol

no reaction

Named amine or ammonia

no reaction

1

H Acyl chloride

$AgNO_3$

(white) ppt

Na_2CO_3/$NaHCO_3$ named carbonate

Effervescence or CO_2 or fumes or exothermic

water

fumes

named indicator

acid colour

Named alcohol

Smell or fumes

Named amine or ammonia

fumes

1

Allow iodoform test or Brady's reagent (2,4,dnph) test (both positive for G)

(iii) Single reagent

If wrong single reagent, CE = zero
Incomplete single reagent (e.g. carbonate) or wrong formula (e.g.$NaCO_3$) loses reagent mark, but mark on

For "no reaction" allow "nothing"

Different reagents

If different tests on E and F; **both** reagents and any follow on chemistry must be correct for first (reagent) mark.

Reagent must react: i.e. not allow Tollens on G (ketone) – no reaction.

Second and third marks are for correct observations.

i.e. for different tests on E and F, if one reagent is correct and one wrong, can score max 1 for correct observation with correct reagent.

1

J Primary alcohol

$K_2Cr_2O_7$/ H^+

goes green

$KMnO_4$/ H^+

decolourised / goes brown

Lucas test ($ZnCl_2$/HCl)

Penalise missing H^+ but mark on

1

K Tertiary alcohol

$K_2Cr_2O_7$/ H^+

No reaction

$KMnO_4$/ H^+

no reaction

Lucas test ($ZnCl_2$/HCl)

Rapid cloudiness

1

If uses subsequent tests e.g. Tollens/Fehlings, test must be on product of oxidation

(b) (i) 3,3-dimethylbutan-1-ol

Allow 3,3-dimethyl-1-butanol

1

4

1

Triplet on three

1

(ii) 2-methylpentan-2-ol

Allow 2-methyl-2-pentanol

1

5

1

Singlet or one or no splitting

1

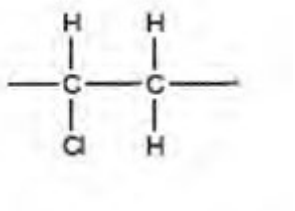
[15]

M6. (a) Benzene-1,2-dicarboxylic acid

Allow 1,2-benzenedicarboxylic acid

1

(b)



Must show all bonds including trailing bonds
Ignore n

1

(c) (i) $2\ C_2H_5OH$

NB Two ethanols

1

H_2O

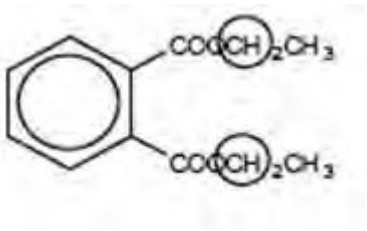
but only one water

1

(ii) 6 or six

1

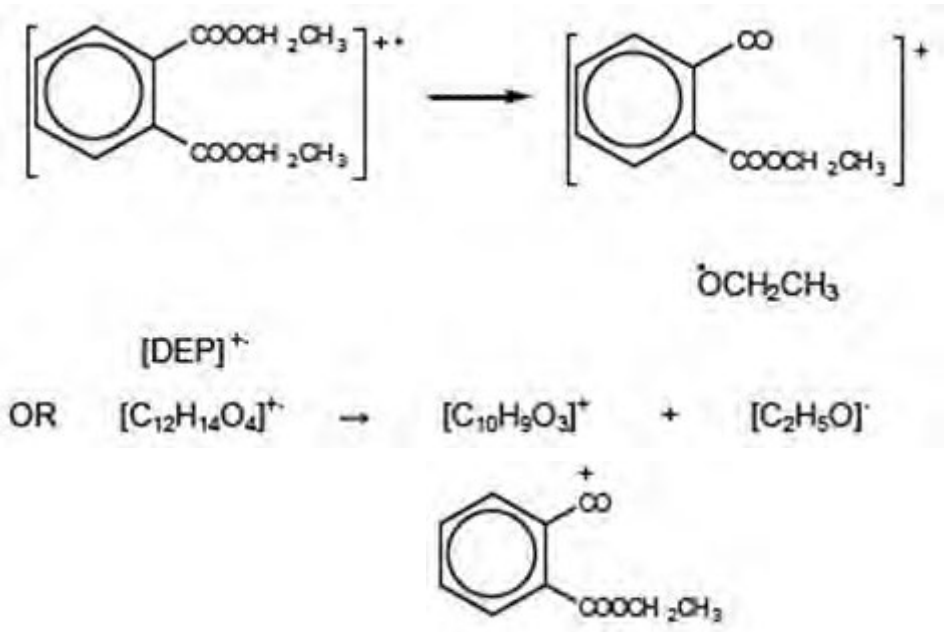
(iii)



Ignore overlap with O to the left or H to the right, but must only include this one carbon. either or allow both (as they are identical)

1

(d)



Allow + on C or O in

1

Dot must be on O in radical

1

(e) (i) Rate = *k*[DEP]

Must have brackets but can be ( )

1

(ii) Any **two** of

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

Not just repetition

Ignore animal testing

2 max

[11]