Mark schemes

Q1.

(a) Tick in carbonyl box only

1

(b) Peak at 2220-2260 cm^{-1} (for C≡N) disappears

If both C≡N disappears and N-H appears without wavenumbers scores 1

M1

Peak at 3300-3500 cm^{-1} (for N-H) appears

M2

Fingerprint region different

M3

(c) Integration ratio 2:2:3

If no link between delta value and oxygen and chlorine, then can award 1 mark for correct explanation of splitting of all 3 peaks

M1

Peak at 3.95 triplet (integration 2) Cl-CH_2 next to CH_2

M2

Peak at 3.65 triplet (integration 2) O-CH_2 next to CH_2

If no explanation of splitting, then can award 1 mark for 3 correct links between delta value and oxygen and chlorine M1

M3

Peak at 3.35 singlet (integration 3) O-CH_3 no adjacent H

M4

Structure CH_3-O-CH_2CH_2Cl

M5

[9]

Q2.

B

Its ^{13}C NMR spectrum has 3 peaks.

[1]

Q3.

(a) **M1** Q, R, S, T

M1 Allow the mark for candidates who correctly name or draw the isomers.

1

M2 (Orange solution) turns green

Independent

1

(b) **M1** T

As above

1

M2 Silver mirror

Allow grey/black ppt

1

(c) **M1** P, Q, R, S

As above

1

M2 Sweet smelling (liquid)

1

M3 To react with (remove excess) acid / neutralise

Allow easier to identify the smell

1

(d) Position

Allow positional

1

(e) **M1** R & S have an O-H alcohols peak at 3230-3550 cm^{-1}

Allow value within the range

1

M2 T has C=O peak at 1680-1750 cm^{-1}

1

M3 R & S (unique) fingerprint region or below 1500 cm^{-1}

1

M4 Compare to a database / known spectra (and look for an exact match)

1

(f) All have the same M_r

Allow

same (molecular) ion M/Z peak

same molecular formula

1

[13]

Q4.

(a) **M1** Named carbonate / hydrogencarbonate / bicarbonate (or Mg / Na)

Allow any correct chemical test.

*Allow name or formula of suitable reagent in **M1***

1

M2 No (visible/observed) reaction/change/effect

1

M3 effervescence / bubbles (of gas) / fizzing

*If no reagent or incorrect reagent in **M1**, CE = 0 and no marks for **M2** or **M3***

*In **M3** ignore reference to name/formula of correct gas, but penalise reference to name/formula of incorrect gas*

*In **M3** allow reference to limewater going cloudy as an alternative*

*Penalise incorrect formula of correct reagent (or incomplete reagent) in **M1**, but mark on for **M2** and **M3***

Where there is no reaction, ignore "nothing (happens)" or "no observation"

1

OR

M1 universal indicator

M2 neutral / no change / pH7

M3 orange / red / pH < 7 / acidic

*If use of named alcohol in **M1**, allow no reaction for **M2** and sweet smell for **M3***

Allow use of other suitable indicators (e.g. litmus)

(b) **M1** Tollens' (reagent) OR ammoniacal silver nitrate OR a description of making Tollens'

1

M2 No (visible/observed) reaction/change or stays colourless

1

M3 silver mirror or black solid / precipitate

1

OR

M1 Fehling's (solution) or Benedict's solution

M2 no (visible/observed) reaction/change or stays blue

M3 red <u>solid / precipitate</u> (credit orange or brown)

OR

M1 acidified potassium dichromate or $K_2Cr_2O_7/H_2SO_4$ ***or*** $K_2Cr_2O_7/H^+$ ***or*** acidified $K_2Cr_2O_7$

M2 no (visible/observed) reaction/change or stays orange

M3 (orange to) <u>green</u> solution ***or*** goes <u>green</u>

OR

M1 acidified potassium manganate(VII) or $KMnO_4/H_2SO_4$ ***OR*** $KMnO_4/H^+$ ***OR*** acidified $KMnO_4$

M2 no (visible/observed) reaction/change or stays purple

M3 (purple to) colourless solution **OR** goes colourless

Allow any correct chemical test.

*If no reagent or incorrect reagent in **M1**, **CE = 0** and no marks for **M2** or **M3***

*Allow name or formula of suitable reagent in **M1***

*Penalise incorrect formula of correct reagent in **M1**, but mark on for **M2** and **M3***

*For Tollens' reagent: for **M1** ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, or "Tolling's reagent", but mark **M2** and **M3**; for **M3** allow silver precipitate/deposit*

*For Fehling's/Benedict's solution: for **M1** Ignore $Cu^{2+}(aq)$ or $CuSO_4$ or "Fellings" on their own, but mark **M2** and **M3***

*For acidified potassium dichromate(VI): if "dichromate" or "(potassium) dichromate(IV)" or incorrect formula or no acid, penalise **M1** but mark **M2** and **M3**; for **M3** ignore dichromate described as "yellow" or "red".*

*For acidified potassium manganate(VII): If "manganate" or "(potassium manganate(IV)" or incorrect formula or no acid, penalise **M1** but mark **M2** and **M3**.*

*Credit alkaline / neutral $KMnO_4$ for possible full marks but **M3** gives brown precipitate or solution goes green*

Where there is no reaction, ignore "nothing (happens)" or "no observation"

[6]

Q5.

B

4-hydroxybutanone

[1]

Q6.

(a) **Must be a single test-tube reaction**

If incorrect reagent then no marks

M1 Reagent: acidified potassium dichromate ***OR*** **$K_2Cr_2O_7/H_2SO_4$** ***OR*** **$K_2Cr_2O_7/H^+$** ***OR*** **acidified $K_2Cr_2O_7$**

*For acidified potassium dichromate: if "dichromate" or "(potassium) dichromate(IV)" or incorrect formula or no acid, penalise **M1** but mark on - ignore dichromate described as "yellow" or "red".*

1

M2 ….-1-ol (orange to) green solution ***OR*** **goes green**

1

M3 ….-2-ol no (visible/observed) reaction/change or NVR or stays orange

1

OR

M1 Reagent: acidified potassium manganate(VII) or $KMnO_4/H_2SO_4$ ***OR*** **$KMnO_4/H^+$** ***OR*** **acidified $KMnO_4$**

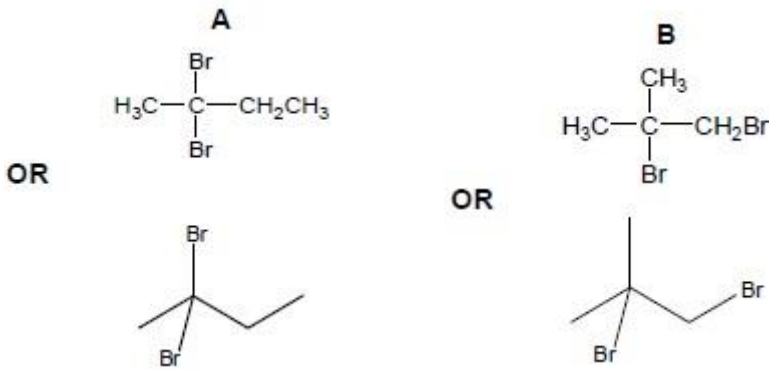
M2….-1-ol (purple to) colourless solution ***OR*** **goes colourless**

M3….-2-ol no (visible/observed) reaction/change or stays purple

*For acidified potassium manganate(VII): If "manganate" or "(potassium manganate(IV)" or incorrect formula or no acid, penalise **M1** but mark on*

*Credit alkaline / neutral KMnO4 for possible full marks but **M2** gives brown precipitate or solution goes green*

(b)



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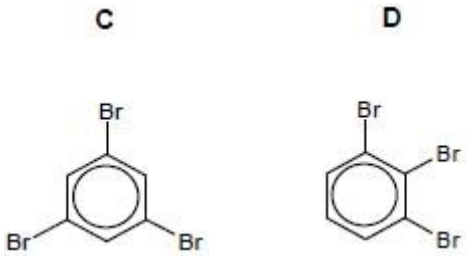
(c)



Allow Kekulé structures

Penalise missing aromatic ring each time

2

(d) **F**

G

E

1

[8]

Q7.

(a) Cyclopentanone

Allow cyclopentan -1-one but no other numbers

Ignore spaces, commas and hyphens

1

(b)

This question is marked using Levels of Response. Refer to the Mark Scheme Instructions for Examiners for guidance.	
Level 3 **5-6 marks**	**All stages are covered and each stage is generally correct and virtually complete.** Answer is well structured with no repetition or irrelevant points. Accurate and clear expression of ideas with no errors in use of technical terms.
Level 2 **3-4 marks**	**All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR two stages are covered and are generally correct and virtually complete.** Answer shows some attempt at structure Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. Some minor errors in use of technical terms
Level 1 **1-2 marks**	**Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete.** Answer includes isolated statements and these are presented in a logical order. Answer may contain valid points which are not clearly linked. Errors in the use of technical terms.
0 marks	Insufficient correct chemistry to gain a mark.

Indicative Chemistry content

Stage 1: boiling points
1a) **Y** has a higher bp
1b) **Y** has H-bonds between molecules and **X** has dip-dip imf
1c) More energy required to overcome H-bonds

Mention of covalent bond breaking loses 1c

Stage 2: ^{13}C NMR
2a) Both have 3 peaks/absorptions in their ^{13}C NMR
2b) **X** has peaks at 20-50 **OR** 190-220ppm
2c) **Y** has peaks at 50-90 **OR** 90-150ppm

(Ignore peaks at 5-40ppm - present in both)

Stage 3: ir
3a) **X** has a peak (for C=O) at 1680-1750 cm^{-1}
3b) **Y** has peak (for O−H) at 3230-3550 cm^{-1}
OR peak (for C=C) at 1620-1680 cm^{-1}
3c) They would have different fingerprint regions (below 1500 cm^{-1})

6

[7]

Q8.

B

[1]

Q9.

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

	How to choose the level		**Requirements for communication for higher mark**	**Stages**
Level 3 5-6 marks	All three stages are covered and explanation of each stage is generally correct and virtually complete – **leads to all four compounds being distinguished**		• Answer communicates whole process coherently with logical progression • Chemical tests (appear to) start with all compounds rather than selected compounds • Chemical tests reagents and observations are complete and correct • Chemical tests leave two compounds to be distinguished by spectroscopy • Enough detail is given about the spectroscopy to distinguish these two compounds	**Stage 1** Carries out a test-tube reaction to identify a compound (or to split the compounds into two groups). 1a reagent 1b observation with correct deduction **Stage 2** Carries out a second test-tube reaction to identify a second compound. 2a reagent 2b observation with correct deduction **Stage 3** Uses spectroscopy to distinguish two compounds. 3a suitable
Level 2 3-4 marks	All three stages are covered but the explanations of each stage may be incomplete or may contain	Two stages covered and explanations are generally correct and virtually complete	• Answer is mainly coherent • Chemical tests reagents and observations are complete and correct • Enough detail is given about the	

	inaccuracies		spectroscopy to distinguish these two compounds (if spectroscopy included)	technique 3b data that will distinguish compounds
Level 1 1-2 marks	Two stages covered but the explanations of each stage may be incomplete or may contain inaccuracies	One stage covered and explanation is generally correct and virtually complete	• Chemical tests reagents and observations are complete and correct (if awarded level 1 for one chemical test stage) • Enough detail is given about the spectroscopy to distinguish these two compounds (if spectroscopy included)	
0 marks	Nothing valid to warrant a mark			

<u>Possible test tube reactions</u>

Tollens' reagent [or Fehling's / Benedict's]

Identifies butanal – silver mirror (or black ppt) [or orange/brick/red ppt with Fehling's]

(No reaction with other compounds)

Acidified potassium dichromate

Reacts with butanal and butan-2-ol – goes green

(No reaction with other compounds)

Sodium *(not on specification but may be mentioned)*

Reacts with butan-2-ol and 2-methylpropan-2-ol – fizzes

(No reaction with other compounds)

Examples of incomplete/incorrect reagents include "Tolling's solution", no acid with potassium dichromate, wrong oxidation state for Cr in potassium dichromate if stated.

Examples of incomplete/incorrect observations include silver precipitate with Tollens', green ppt with acidified potassium dichromate

<u>Possible spectroscopic methods for a pair</u>

IR (infra-red) spectroscopy

If different functional groups: need to identify wavenumber and bond of key functional group signal (e.g. (alcohol) O-H 3230-3550 or C=O 1680-1750 (cm^{-1})).

If same functional group, need idea of using fingerprint region to look for match to known compounds / comparing region to samples in a database

Mass spectrometry

If different, can use different M_r values with values of M_r given butanone 72(.0), 2-methylpropan-2-ol = 74(.0), butan-2-ol = 74(.0), butanal = 72(.0)

If compounds have same M_r, then would have to use idea that fragmentation patterns would be different *(not on specification but may be mentioned)*

[6]

Q10.

A

[1]

Q11.

C

[1]

Q12.

This question is marked using Levels of Response. Refer to the Mark Scheme Instructions for Examiners for guidance.

Level 3 (5 – 6 marks)
All stages are covered and each stage is generally correct and virtually complete.
Answer is communicated coherently and shows a logical progression from Stage 1 to Stages 2 and 3 to distinguish all the compounds with results for all remaining compounds stated.
Describing subsequent organic test on product (unnecessary) - limits to lower mark in level

Level 2 (3 – 4 marks)
All stages are covered but stage(s) may be incomplete or may contain inaccuracies
OR two stages are covered and are generally correct and virtually complete.
Answer is communicated mainly coherently and shows a logical progression from Stage 1 to Stages 2 and 3.
Describing subsequent organic test on product (unnecessary) - limits to lower mark in level

Level 1 (1 – 2 marks)
Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete.
Answer includes isolated statements but these are not presented in a logical order.

Level 0 (0 marks)
Insufficient correct chemistry to gain a mark.

Indicative chemistry content

Stage 1: An initial test to separate into two groups (2 groups of 2 OR 1 group of 3 and 1 group of 1)

Stage 2: A second test to distinguish within a group or to separate into two further groups

Stage 3: A third test leads to a set of results/observations which distinguishes between all 4 compounds

Tests must include reagent and observation which identifies compound(s)

⁻COOH

a) $NaHCO_3$ / Na_2CO_3 (or correct alternative)
b) effervescence /gas turns limewater milky
c) K and /or M but not L and/or N

-OH and -CHO

d) acidified $K_2Cr_2O_7$
e) solution turns green
f) K and/or L and/or N but not M

-CHO

g) Fehlings OR Tollens
h) red ppt OR silver mirror
i) N only but not K and/or L and/or M

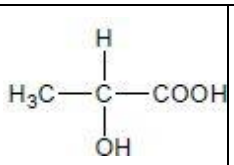
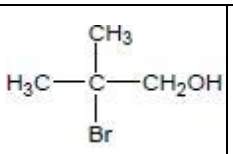
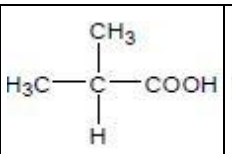
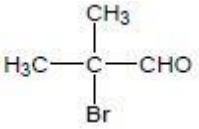
-Br

j) Silver nitrate
k) cream ppt
l) L and/or N but not K and/or M

Isolated tests on individual compounds - max LEVEL 2
Isolated tests not linked to any compound – max LEVEL 1
Penalise observation if deduction wrong, but allow observation if deduction incomplete

Alternative tests

-COOH	**-COOH**	**-OH only**
a) named alcohol & H_2SO_4 b) sweet smell (of ester) c) K and /or M but not L and/or N	a) named indicator b) correct colour c) K and /or M but not L and/or N	m) named carboxylic acid & H_2SO_4 n) sweet smell (of ester) o) K and/or L but not M and /or N

					
Test	**Tests for**	**K**	**L**	**M**	**N**
a) $NaHCO_3$ / Mg / Indicator	K M	✓	✗	✓	✗
d) $K_2Cr_2O_7$ / H^+	K L N	✓	✓	✗	✓
g) Fehlings / Tollens	N	✗	✗	✗	✓
j) $AgNO_3$ see Note *	L N	✗	✓	✗	✓
a) named alcohol &	K M	✓	✗	✓	✗

H_2SO_4					
m) named carboxylic acid & H_2SO_4	K L	✓	✓	✗	✗

Note * allow NaOH then HNO_3, $AgNO_3$ as one test; but treat NaOH, $AgNO_3$ without acid as incomplete,so can mark on.

[6]

Q13.

C

[1]

Q14.

A

[1]

Q15.

(a)

1×AO1

1

(b) **S**

1

R

1

Q

1

(c) (Isomer **T**)

signals due to OH (alcohol) at 3230−3350 and C=O at 1680−1750

1

OH and C=O (functional groups) separated in molecule.

Allow not a carboxylic acid.

1

(Isomer U)

(only) signal for OH (alcohol) at 3230−3350

1

2 × OH groups present / diol / OH & cyclo(ether) structure.

Allow OH but not C=O.

1

(Isomer V)

signals due to OH (acid) at 2500−3000 (and C=O at 1680−1750)

carboxylic acid group / −COOH present.

1
1

(d) 2:2:2:3:3

Any order.

1

(e) (The quartet at δ=3.5 is for a CH_2 group) next to **−O−CH$_2$ OR** shifted significantly downfield by electronegative O

1

(is a quartet) because of an adjacent CH_3 group / couple with 3 adjacent protons

1

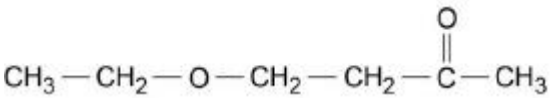
(singlet at δ=2.2 is for a CH_3 group) attached to  C**H$_3$ OR** shifted downfield by electronegative C=O

1

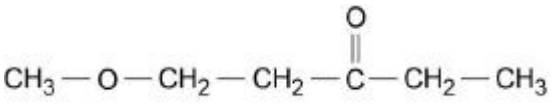
(is a singlet) because there are no adjacent protons / no coupling.

1

(f)



Allow 1 mark for:



2

[17]

Q16.

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

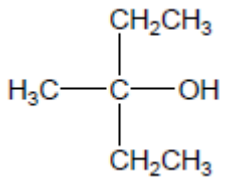
M5 **1**

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]