# A-Level Chemistry

## Identification of Functional Groups

### Mark Scheme

**Time available: 64 minutes**
**Marks available: 57 marks**

**1.**

(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]**

**2.** (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 solid / precipitate (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) green solution ***or*** goes green

***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 <u>brown precipitate</u> or solution goes <u>green</u>*

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

**[6]**

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

<table>
<tr><th></th><th colspan="2">How to choose the level</th><th>Requirements for communication for higher mark</th><th>Stages</th></tr>
<tr><td>Level 3<br>5-6 marks</td><td>All three stages are covered and explanation of each stage is generally correct and virtually complete – leads to all four compounds being distinguished</td><td></td><td>• Answer communicates whole process coherently with logical progression<br>• Chemical tests (appear to) start with all compounds rather than selected compounds<br>• Chemical tests reagents and observations are complete and correct<br>• Chemical tests leave two compounds to be distinguished by spectroscopy<br>• Enough detail is given about the spectroscopy to distinguish these two compounds</td><td rowspan="4">Stage 1<br>Carries out a test-tube reaction to identify a compound (or to split the compounds into two groups).<br>1a reagent<br>1b observation with correct deduction<br>Stage 2<br>Carries out a second test-tube reaction to identify a second compound.<br>2a reagent<br>2b observation with correct deduction<br>Stage 3<br>Uses spectroscopy to distinguish two compounds.<br>3a suitable technique<br>3b data that will distinguish compounds</td></tr>
<tr><td>Level 2<br>3-4 marks</td><td>All three stages are covered but the explanations of each stage may be incomplete or may contain inaccuracies</td><td>Two stages covered and explanations are generally correct and virtually complete</td><td>• Answer is mainly coherent<br>• Chemical tests reagents and observations are complete and correct<br>• Enough detail is given about the spectroscopy to distinguish these two compounds (if spectroscopy included)</td></tr>
<tr><td>Level 1<br>1-2 marks</td><td>Two stages covered but the explanations of each stage may be incomplete or may contain inaccuracies</td><td>One stage covered and explanation is generally correct and virtually complete</td><td>• Chemical tests reagents and observations are complete and correct (if awarded level 1 for one chemical test stage)<br>• Enough detail is given about the spectroscopy to distinguish these two compounds (if spectroscopy included)</td></tr>
<tr><td>0 marks</td><td colspan="2">Nothing valid to warrant a mark</td><td></td></tr>
</table>

**Possible test tube reactions**

**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

**Possible spectroscopic methods for a pair**

**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]**

**4.** (a) Aldehyde/propanal has dipole-dipole forces (between molecules)

*If any 'covalent bonds broken' CE=0 for clip.*

*Ignore Van der Waal forces*

**M1**

Alcohol/propan-1-ol AND Carboxylic acid/ propanoic acid have hydrogen bonding (between molecules).

*Ignore reference to energy*

**M2**

The forces between the molecules in aldehyde are weaker (than those in alcohol and acid so it will evaporate first.)

*M3 only awarded following correct M1 OR M2*

*Allow converse for M3*

**M3**

(b) Keep the temperature of the reaction mixture below the boiling point of propan-1-ol/below 97 °C

*Allow temperature in range 49-96 inclusive*

*Allow description of cooling the vessel*

**M1**

Cool the distillate / collecting vessel

*Ignore reference to oxidising agents*

*Penalise lid / sealed container*

**M2**

(c) Add named carbonate/hydrogencarbonate OR magnesium to a sample of the distillate.

*Incorrect chemical CE=0*

*Allow formula (mark on for incorrect formula)*

*Allow blue litmus or correct named indicator*

**M1**

Effervescence/fizz/bubbles would confirm presence of acid or converse

*Blue litmus turns red confirms acid present or converse*

*Allow gas/$CO_2$ produced which turns lime water cloudy OR gas/$H_2$ produced which burns with a squeaky pop*

**M2**

(d) (Temperature difference = 15.1 °C)

*If $\Delta T$ wrong – AE mark on otherwise can only award M2*

*If use 457 in M1, can only score M2*

q = 150 × 4.18 × 15.1 or 9467.7 J or 9.4677kJ

**M1**

amount ethanol burned = 0.457/46.0 = $9.93 \times 10^{-3}$ mol

*If use 457 in M2 can score 2 for - 0.953 kJ mol-1*

**M2**

Heat change per mole = (M1/1000)/M2 = 952.99 kJ mol-1

$\Delta H$ = – 953 kJ $mol^{-1}$ must be 3sfs and must be negative

(allow range -953 to -954)

*BEWARE if they miss conversion to kJ and also miss conversion to g, they get answer = - 953 which scores 1*

*+953 can score M1 and M2*

*Allow -950 or -960 for rounding to 2sf*

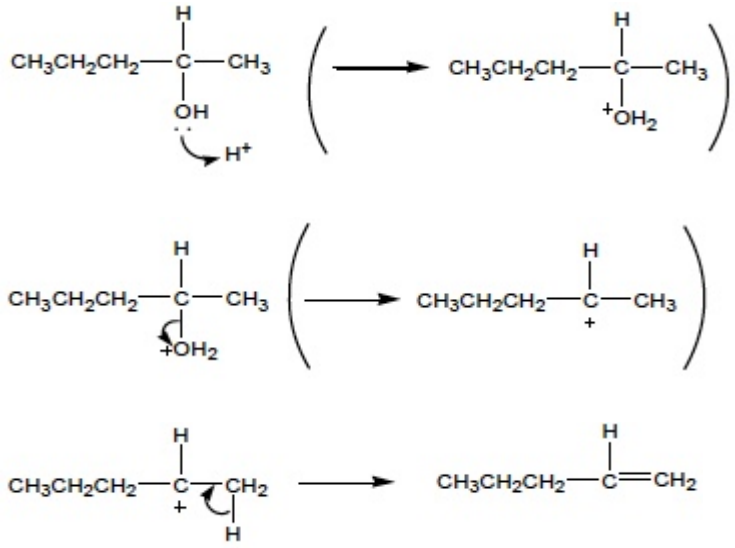
**M3**

(e) Elimination

*Penalise base elimination*

**M1**

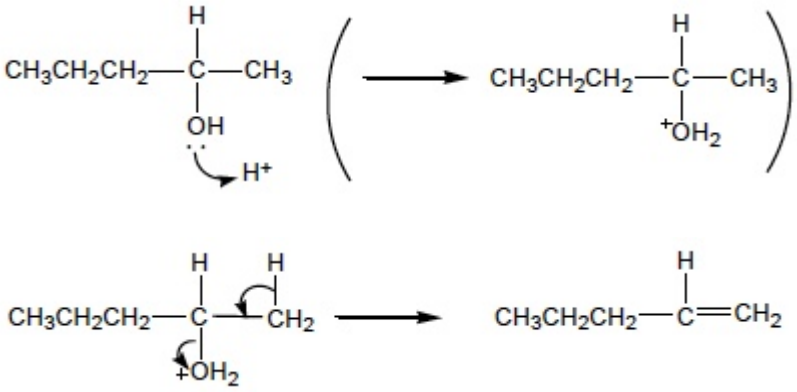
Mechanism : Either (E1)



*M2 for protonation of alcohol, i.e. lp plus arrow to $H^+$ or to H of H–O– in $H_2SO_4$ and from H-O bond to O*
*M3 for protonated alcohol plus arrow showing loss of water*
*M4 for arrow showing loss of $H^+$*
*From correct carbocation (E1)*
*wrong alcohol used / alkene formed loses M4*

**3**

OR (E2)



*M2 for protonation of alcohol, i.e. lp plus arrow to $H^+$ or to H of H–O– in $H_2SO_4$ and from H-O bond to O*
*M3 for protonated alcohol plus arrow showing loss of water*
*M4 for arrow showing simultaneous loss of $H^+$*
*wrong alcohol used / alkene formed loses M4*

**3**

(f) *E*-pent-2-ene

*Allow trans*

**M1**

C=C bond cannot rotate **and**

Each carbon in the double bond has (2) different groups attached.

*Allow (two) different groups on each/either side of the double bond.*

**M2**

**[16]**

**5.** 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

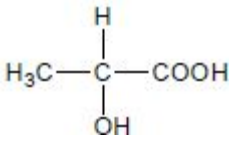
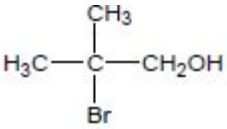
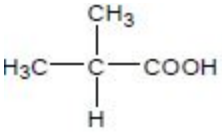
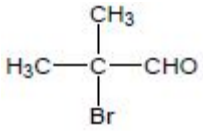
-Br

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 & $H_2SO_4$<br>b) sweet smell (of ester)<br>c) K and /or M but not L and/or N | a) named indicator<br>b) correct colour<br>c) K and /or M but not L and/or N | m) named carboxylic acid & $H_2SO_4$<br>n) sweet smell (of ester)<br>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 & $H_2SO_4$ | K M | ✓ | ✗ | ✓ | ✗ |
| 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]**

**6.**

(a) Bromine (water)

**1**

Colour change from <u>orange to colourless</u>

**1**

(b) Add sodium hydrogencarbonate (or alternative named carbonate)

*Allow suitable correct alternative test e.g.*

*Test the pH with <u>named indicator</u> (e.g. Universal Indicator)*

**1**

Propanoic acid will produce effervescence / bubbles

*Propanoic acid would turn Universal Indicator red*

**1**

(c) Tollen's reagent

**1**

(Colourless solution to) silver mirror

**1**

**OR**

Fehling's solution

(Blue solution to) brick red <u>precipitate</u>

(d) Absorption at 1680–1750 $cm^{-1}$ caused by C=O

**1**

<u>No</u> absorption at 1620−1680 $cm^{-1}$ caused by C=C

**1**

No absorption at 3230–3550 $cm^{-1}$ due to −OH (alcohol)

**1**

No absorption at 2500–3000 $cm^{-1}$ due to −OH (acid)

**1**

**[10]**