# A-Level Chemistry

## Infrared Spectroscopy

### Mark Scheme

**Time available: 64 minutes**
**Marks available: 61 marks**

**1.**

(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]**

**2.**

(a) M1 have the same molecular formula
or are $C_3H_6O$
or both have the same number/amount of each type of atom or same amount of each element
or are isomers

*Not just the same atoms;*

**1**

M2 identical / exactly the same / same precise (relative) molecular mass / formula mass / $M_r$

*Same (relative) molecular mass / formula mass / $M_r$ is NOT enough got score M2*

*Allow same accurate (relative) molecular mass / formula mass / $M_r$*

*Ignore reference to number of decimal places*

**1**

(b) M1 prop-2-en-1-ol

*Must refer to this compound clearly by name or structure (not to alcohol alone); ignore minor slips in name/structure*

**1**

M2 O(-)H (alcohol) and 3230–3550 ($cm^{-1}$), or
C=C and 1620–1680 ($cm^{-1}$)

*Marked independently from M1*

*Could score from bond labelled on correct signal on spectrum*

*Allow any value within these ranges*

*If additional incorrect signals given penalise M2*

*Ignore signals below 1500 $cm^{-1}$ and C-H signals*

**1**

(c) (i) Determine the level by looking at the chemical content. (**NB** - If there is clear breakage of covalent bonds then max level 2 (max 3 marks).

(ii) The mark within that level is then determined by looking at how coherent and logical the answer is and by use of terminology; start at the higher mark and penalise poor terminology/explanation; examples of terminology that would reduce the mark to the lower one:

- reference to van der Waals 'bonds' or dipole-dipole 'bonds in relevant compounds that are being credited
- uncertainty about whether hydrogen bonds are the O-H bonds within or are forces/bonds between molecules (if the alcohol is being credited)
- use of 'vdw' or 'dip-dip' unless these terms 'van der Waals' for 'dipole-dipole' have been used elsewhere in answer (note that IMF and H-bond would not be penalised)

(iii) If the answer does not achieve level 1, then 1 mark maximum could be scored for any correct point from the list of indicative content

**Level 3**

- **Relative order** of boiling points of **all three** compounds
- Strongest intermolecular force of **all three** compounds identified
- Answer explains this coherently and logically and uses correct terminology for all **three** compounds

**5-6 marks**

**Level 2**

- **Relative** boiling points of **two** compounds correctly compared
- Strongest intermolecular force for these **two** compounds correctly identified
- Answer explains this coherently and logically and uses correct terminology for **these two** compounds

**3-4 marks**

**Level 1**

- **One** compound with the **highest** or **lowest** boiling point is correctly identified
- Strongest intermolecular force for that **one** compound identified
- Answer explains this coherently and logically and uses correct terminology for **this one** compound
- Allow 1 mark for individual correct point from indicative content on the right if no other mark scored

**1-2 marks**

**Level 0**

None of the indicative chemistry content given.

**0 marks**

***Indicative chemistry content:***

*• Correct order (highest to lowest) = prop-2-en-1-ol > propanal > butane*

*• Prop-2-en-1-ol has hydrogen bonds*

*• Propanal has (permanent) dipole-dipole forces*

*• Butane has van der Waals' forces*

*• Strength of intermolecular forces:*
*hydrogen bonds > dipole-dipole > van der Waals*

*(Note - actual values for reference are prop-2-en-1-ol 97°C, propanal 46°C and butane −1°C)*

**[10]**

**3.** (a) OH AND alcohol

***IGNORE*** *hydroxy(l)*

**1**

(b) **A** = butan-2-ol / $CH_3CH(OH)CH_2CH_3$

*If formulae given then must be unambiguous*

*If both formula and name given then formula must match name for mark to be awarded*

**1**

**B** = butan-1-ol / $CH_3CH_2CH_2CH_2OH$

**1**

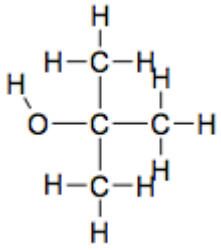
Product from **A / P** is a <u>ketone</u>
**AND**
Product from **B / Q** is an <u>aldehyde</u>

*Penalise reference to incorrect class of alcohol*

**1**

(c) Type of Bond: C=C

**1**



*Must show all bonds in Isomer **C** including O–H bond*

**1**

Reagent: conc. $H_2SO_4$ / conc. $H_3PO_4$

*If incorrect attempt at correct reagent, mark on*

*Apply list principle for reagents and conditions marks*

*Conc required - may appear on conditions line*

*NOT (aq) For M3 even if seen on conditions line*

*ALLOW*

*Reagent = $Al_2O_3$*

*Condition = 'passing vapour over hot solid' owtte*

**1**

Conditions: 180 °C / High temp / Hot / Reflux /

*ALLOW stated temp in range 100-300 °C/373-573 K*

*IGNORE 'heat'*

*M4 dependent on correct reagent in M3*

**1**

(d) (i) S = aldehyde/CHO **AND** T = carboxylic/COOH/$CO_2H$

**1**

T forms hydrogen bonds

**1**

(Which are) stronger than / need more energy to break than forces <u>between molecules/IMFs</u> in S ora (or reverse argument)

*If implication of breaking covalent bonds max M1 only*

**1**

(ii) (No oxidation has occurred as..)

(Still) contains peak at 3230−3550 cm-1 due to O−H/alcohol

Does not contain peak at 2500−3000 cm-1 due to O−H/carboxylic acid

Does not contain peak at 1680−1750 cm-1 due to C=O

*Must have wavenumber range (or value within range) and bond or functional group to score each mark.*

**Any 2**

**[13]**

**4.** (a) (i) $CH_2O$

*Atoms in any order*

*Accept a clear indication that $C_6H_{12}O_6$ yields $CH_2O$ as the answer*

**1**

(ii) No peak / no absorption / no C=O in the **range 1680 to 1750** ($cm^{-1}$) (suggesting no evidence of C=O)

*Allow the words "dip", "spike", "low transmittance" and "trough" as alternatives for absorption*

*Ignore references to other wavenumbers*

**1**

(b) M1 $C_6H_{12}O_6 \longrightarrow$ **2**$CH_3CH_2OH$ + **2**$CO_2$

*Penalise ($C_2H_6O$)*

*Allow multiples of the equation in **M1***

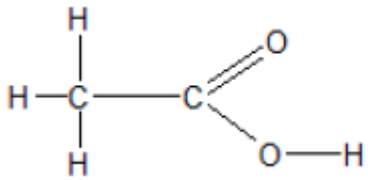
Either order
M2 (enzymes from) yeast or zymase

M3 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 K

*For **M2** and **M3***
*Ignore "aqueous"*
*Ignore "anaerobic / absence of oxygen"*
*Ignore "controlled pH"*
*Ignore "warm"*

**3**

(c) (i) Displayed formula for $CH_3COOH$




*All bonds must be drawn out, but ignore bond angles*

**1**

(ii) $O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$

*Ignore state symbols*

*Negative charge on electron not essential*

*Accept multiples*

*Accept electrons subtracted from RHS*

**1**

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

($C_2H_6O$ or $C_2H_5OH$)

*Ignore state symbols*

*Negative charge on electron not essential*

*Accept multiples*

*Accept electrons subtracted from LHS*

**1**

(iv) M1 <u>Acidified potassium or sodium dichromate</u>

*For **M1**, it must be a whole reagent and / or correct formulae*

***OR*** $H_2SO_4$ / $K_2Cr_2O_7$ OR $H^+$ / $K_2Cr_2O_7$ etc.

*Do not penalise incorrect attempt at formula if name is correct or vice versa*

***OR*** correct combination of formula and name

*If oxidation state given in name, it must be correct, but mark on from an incorrect attempt at a correct reagent.*

**M2 (requires an attempt at M1**)
<u>orange to green</u>

*Credit **acidified** potassium chromate(VI) / <u>$H_2SO_4$ + $K_2CrO_4$</u>*

Possible alternative
M1 (acidified) potassium manganate(VII) ***OR*** $KMnO_4$ / $H_2SO_4$
M2 <u>purple to colourless</u>

*Other alternatives will be accepted but **M2** is dependent on **M1** in every case*
***M2** requires an attempt at a correct reagent for **M1***
*Ignore reference to states*

**2**

(d) (i) An activity which has no net / overall (annual) carbon emissions to the atmosphere / air

*The idea that the carbon / $CO_2$ given out equals the carbon / $CO_2$ that was taken in from the atmosphere / air*

***OR***

An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere / air.

*Answer must refer to the atmosphere or air*

***OR***

There is no change in the total amount of carbon dioxide / carbon /greenhouse gas present in the atmosphere / air

**1**

(ii) Renewable / sustainable ONLY

*Ignore references to global warming or greenhouse gases*

**1**

(iii) **Any one statement about this process from**

Subject to weather / climate

*Ignore "batch"*

***OR***

Depletes food supply OR the land use for (specified) food

***OR***

Requires use of / uses more fossil fuels

***OR***

Not carbon-neutral OR $CO_2$ produced during a named process (eg harvest, transport etc.)

***OR***

Slow process / slow rate of reaction / takes a long time (to grow crops)

***OR***

This route leads to the production of a mixture of water and ethanol / impure ethanol that requires separation / further processing

**1**

**[13]**

**5.** (a) (i) C

**1**

(ii) A

**1**

(iii) D

**1**

(iv) B

**1**

(b) **M1** $Br_2$ ***OR*** bromine (water) ***OR*** bromine (in $CCl_4$ / organic solvent)

*If M1, has no reagent or an incorrect reagent, CE=0*

*Ignore "acidified"*

*For M1 penalise Br (or incorrect formula of other correct reagent), but mark on*

*For M1, it must be a whole reagent and/or correct formulae*

**Either order**

*If oxidation state given in name, it must be correct.*

**M2** cyclohexane ***OR* A** or the alkane: remains orange / red / yellow / brown / the same ***OR*** no reaction ***OR*** reference to colour going to cyclohexane layer

*For M2 credit "no change"*

*Ignore "nothing"*

*Ignore "nothing happens"*

*Ignore "no observation"*

**M3** cyclohexene ***OR* D** or the alkene: decolourised / goes colourless / loses its colour

*For M3, ignore "goes clear"*

**Alternatives** : potassium manganate(VII)

**M1** $KMnO_4$ in acid **M2** purple **M3** colourless

**M1** $KMnO_4$ in alkali / neutral **M2** purple **M3** brown solid

Give appropriate credit for the use of iodine and observations

*No credit for combustion observations*

**3**

(c) **M1** acidified potassium or sodium dichromate

*For M1, it must be a whole reagent and/or correct formulae*

***OR*** eg $H_2SO_4$ / $K_2Cr_2O_7$ ***OR*** $H^+$/ $K_2Cr_2O_7$

***OR*** correct combination of formula and name

*If oxidation state given in name, it must be correct.*

**M2** oxidation ***OR*** oxidised ***OR*** redox

*Do not penalise incorrect attempt at formula if name is correct or vice versa*

**M3** secondary / $2^o$ (alcohol)

*Credit acidified potassium chromate(VI) / $H_2SO_4 + K_2CrO_4$*

**3**

(d) **M1** (free-) radical substitution (mechanism)

*M1 both words required*

**M2** $Br_2 \longrightarrow 2Br\bullet$

*Penalise absence of dot once only.*

**M3** $Br\bullet + CH_4 \longrightarrow \bullet CH_3 + HBr$

*Penalise + or – charges every time*

**M4** $Br_2 + \bullet CH_3 \longrightarrow CH_3Br + Br\bullet$

*Accept dot anywhere on methyl radical*

*Accept a correct termination step for 1 mark if neither M3 nor M4 are scored; otherwise ignore termination steps*

*Mark independently*

*NB If $Cl_2$ is used, penalise every time ( this may be for M2, M3 and M4)*

*If cyclohexane is used, penalise every time (this may be for M3 and M4)*

**M5 Condition**

ultra-violet / uv / sun light

***OR*** high temperature

***OR*** 125 °C ≤ T ≤ 600 °C

***OR*** 400 K ≤ T ≤ 870 K

*For M5 ignore "heat"*

**5**

**[15]**