AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.3.6 ORGANIC ANALYSIS

SCORE	PERCENTAGE
/267	%

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Q1.

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 technique 3b data that will distinguish compounds
Level 2 3-4 marks	All three stages are covered but the explanations of each stage may be incomplete or may contain inaccuracies	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 spectroscopy to distinguish these two compounds (if spectroscopy included)	
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	

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			given about the spectroscopy to distinguish these two compounds (if spectroscopy included)	
0 marks	Nothing valid to warrant a mark			

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]

Q2.

(a) Aldehyde/propanal has <u>dipole-dipole</u> 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.)

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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 ΔT 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 = 9.93×10^{-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

ΔH = – 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

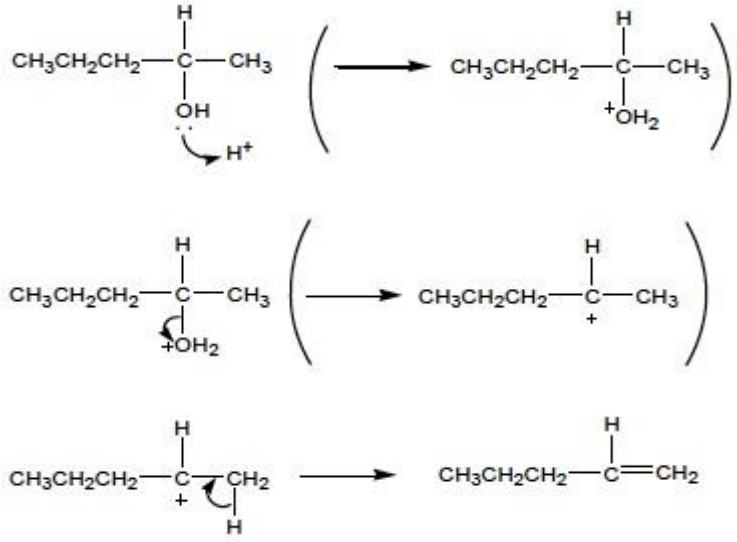
(e) Elimination

Penalise base elimination

M1

Mechanism : Either (E1)

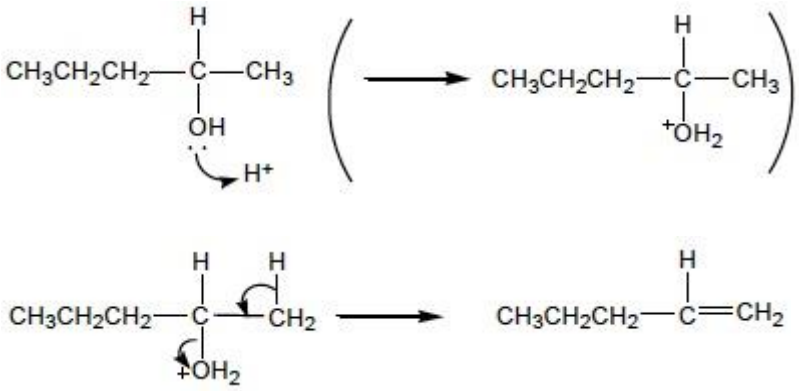
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M2 for protonation of alcohol, i.e. lp plus arrow to H^+ or to H of H–O– in H_2SO_4 and from H-O bond to O
M3 for protonated alcohol plus arrow showing loss of water
M4 for arrow showing loss of H^+
From correct carbocation (E1)
wrong alcohol used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

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

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

M2

[16]

Q3.

(a) **M1** Moles of cyclohexanol = (10 × 0.96)/100.0 = 0.096

Correct answer scores all 3 marks

1

M2 Max mass of cyclohexene = 0.096 × 82.0 = 7.87(2)

= *M1 × 82.0 (process mark)*

1

M3 % yield = (5.97 / 7.87) × 100 = 76% (Allow range 75.8 – 76)

= *(5.97 / M2) × 100 (process mark)*

1

Alternative method

M1 Moles of cyclohexanol = (10 × 0.96)/100.0 = 0.096

M2 Moles of cyclohexene = 5.97/82.0 = 0.0728

M3 % yield = 0.0728 / 0.096 × 100 = 76% (allow range 75.8 – 76)

= *(M2 / M1) × 100*

Allow 1/3 for 62(.2)%

(b) Add bromine (water)

If M1 not correct then only allow M2 if reagent involves bromine (water)

1

Would turn (from orange to) colourless / decolourise

Do not allow incorrect starting colour, but allow brown/red/yellow

Not discolour.

Ignore clear

1

(c) Na_2CO_3 would neutralise/react with/remove (phosphoric) acid/H_3PO_4/H^+

1

(d) avoid pressure build-up / release pressure / release CO_2/air/gas / prevent stopper blowing out

Ignore explosion

Do not allow an incorrect named gas

Allow idea that build-up of gas/CO_2 would lead to increased pressure/stated effect of increased pressure

1

(e) Does not dissolve in/react with the cyclohexene

Allow remains a solid/is inert in cyclohexene

Allow organic product/organic compound formed/ organic

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layer/distillate instead of cyclohexene

Do not allow if answer implies cyclohexanol

Do not allow if answer says does not react with products

Ignore references to filtration

Do not allow insoluble/unreactive unless qualified by implied reference to cyclohexene

1

(f) If diagram drawn:

M1 diagram of basic set up to include flask or tube with side-arm/Buchner flask, flat-bottomed funnel/Buchner funnel, filter paper

M2 apparatus should work, flow through, air-tight connection between flask and funnel, arrow/label/description (to vacuum pump)

Do not allow "standard" Y-shaped funnel

1

If description given:

M1 Buchner funnel/flat-bottomed funnel containing filter paper

M2 Buchner flask/side-arm flask connected to vacuum pump

Do not allow just "funnel"

Penalise M2 if described apparatus would not actually work.

1

(g) Cyclohexene is less polar than cyclohexanol / cyclohexanol is more polar than cyclohexene

It = cyclohexene

Allow cyclohexene is non-polar and cyclohexanol is polar

1

Cyclohexene has a greater affinity/attraction for the mobile phase/hexane / cyclohexanol has a greater affinity/attraction for the stationary phase/silica

Allow cyclohexanol held in the stationary phase for longer

Allow cyclohexene is more soluble in the mobile phase/hexane or converse for cyclohexanol

Allow references to hydrogen bonds between cylcohexanol and silica

1

(h) Would be no peak at 3230 – 3550 cm^{-1} due to O—H((alcohol))

OR

There would be no additional peaks in the fingerprint region compared to a pure sample / fingerprint region exactly matches cyclohexene

Need wavenumber and bond for mark

1

[13]

Q4.

This question is marked using levels of response. Refer to the Mark Scheme

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Instructions for Examiners for guidance on how to mark this question.

Level 3 (5 – 6 marks)
All stages are covered, three correct structures are given and each stage is generally correct and virtually complete. Answer communicates reasoning coherently and shows a logical progression through the identification of structures including explaining about stereoisomerism.

Level 2 (3 – 4 marks)
Two stages are covered or parts of three stages (if two stages are covered, they must be complete for 4 marks)

Level 1 (1 – 2 marks)
One stage covered or parts of two stages (if one stage is covered, it must be complete for 2 marks)

Level 0 (0 marks)
No relevant correct chemistry to warrant a mark.

Indicative chemistry content

Stage 1 – deduces which compounds are saturated/unsaturated
1a states that A & B are unsaturated / do contain C=C / alkenes (this can be obtained from the structures)
1b as they decolourise bromine water
1c states that C is saturated / does not contain C=C / is (cyclo)alkane (this can be obtained from the structures)
1d as it does not decolourise bromine water

Stage 2 – deduces the structures
2a suggests suitable name/structure for **A**
- pent-1-ene,
- 2-methylbut-1-ene,
- 3-methylbut-1-ene,
- 2-methylbut-2-ene

2b **B** = pent-2-ene (name / structure)
2c suggests a suitable name / structure of **C** (cyclopentane, methylcyclobutane, any dimethylcyclopropane)

Stage 3 – can explain the stereoisomerism
3a explains what stereoisomerism is in terms of molecules with the same structural formula but a different arrangement of atoms / bonds / groups in space
3b explains how it arises by discussing that C=C cannot rotate,
3c explains how it arises by discussing that each C in C=C has two different groups (ignore reference to Mr in this context) or by drawing the E and Z isomers of **B**

Note
- compounds may be identified by name or structure (but if both given and there is error in one, then award lower mark in whichever level the answer fits, i.e. it penalises the mark within a level, but not the overall level itself).

[6]

Q5.

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

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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

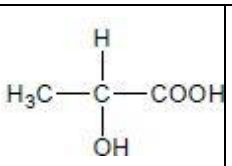
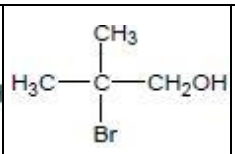
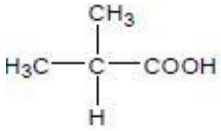
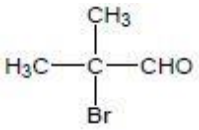
-Br
- j) Silver nitrate
- k) cream ppt
- l) L and/or N but not K and/or M

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

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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 & 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]

Q6.

(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

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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]

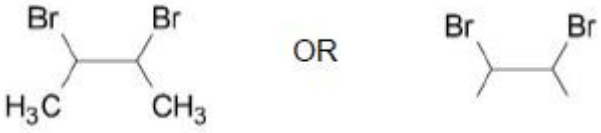
Q7.

(a) 2,3-dimethylbutane(-1,4-)dioic acid

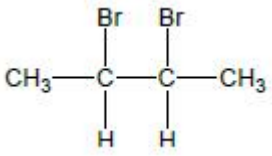
Penalise other numbers.
Ignore hyphens, commas, spaces.

1

(b)



Allow displayed formula



1

Step 1:

HBr

1

Electrophilic addition

1

Step 2:

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KCN

Not HCN, not KCN with acid.

1

Nucleophilic substitution

1

Step 3:

Hydrolysis

1

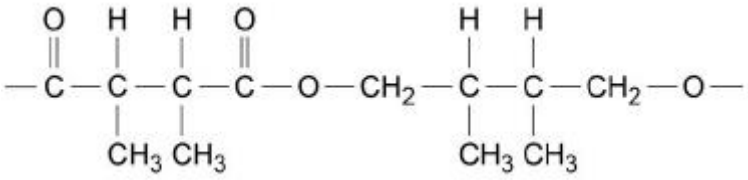
(c)

	Mark
Reagent	1
Observation with **F**	1
Observation with **G**	1

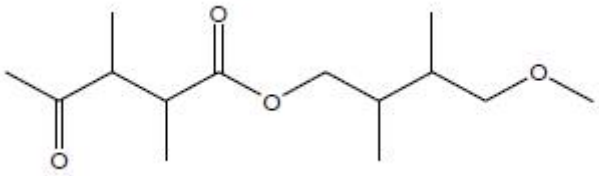
$K_2Cr_2O_7$ & H_2SO_4 (allow acidified)	**Mg**	**Na_2CO_3 or $NaHCO_3$**
F: no visible change	**F:** effervescence	**F:** effervescence
G: orange to green	**G:** no visible change	**G:** no visible change

Named alcohol and conc. sulfuric acid	**Named carboxylic acid and conc. sulfuric acid**
F: pleasant smell	**F:** no visible change
G: no visible change	**G:** pleasant smell

(d)



OR



Two ester groups.

1

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One unit only.
Must have trailing bonds.
Ignore n and brackets.

1

(e) Mass of **G** = (1.11 × 10^3) cm^3 × 1.04 g cm^{-3} = 1154 g

65.1 scores 4 marks.

1

Amount of **G** $\frac{1154}{Mr = 118}$ = 9.78 mols

1

Amount of **F** (actual) = $\frac{930}{Mr = 146}$ =

6.37 mol

OR

Expected mass of **F** = 9.78 × (M_r =)

146 = 1428 g

1

% yield = $\frac{6.37}{9.78}$ × 100 = 65.1(%)

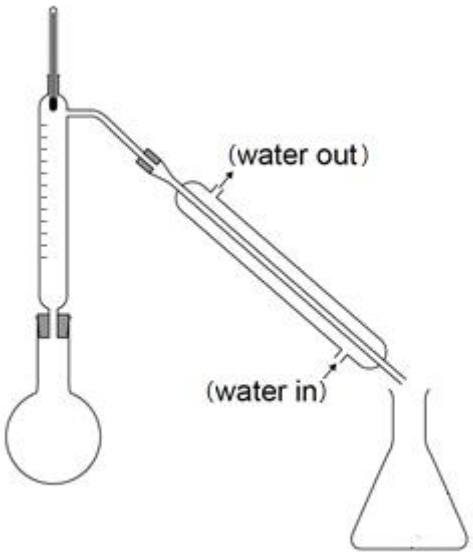
OR

% yield = $\frac{930}{1428}$ × 100 = 65.1(%)

M4 answer must be to 3 significant figures.

1

(f) Fractional distillation



A rough labelled sketch illustrating these points scores the marks.

1

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Apparatus for fractional distillation must clearly work with fractionating column.

1

Fractionating column and thermometer.

1

Condenser / water jacket.

Ignore heat source.

1

[20]

Q8.

(a) 2,2,4-trimethylpentane

This answer only but ignore punctuation

1

(b) M1 (fractional or simple) distillation

Incorrect process in M1 CE=0

If M1 blank, mark on for M2 and M3 (ignore boiling, condensing)

1

M2 idea that isooctane / the one with the lower boiling point boils (first) (or reaches top of column first)

Ignore reference to octane boiling and being collected at higher temperature

If temperature referred to, should be between 99 and 124°C

"it" refers to isooctane

M2 – allow vaporises/evaporates first

1

M3 idea that isooctane condenses / liquefies and collected

Penalise M2 and M3 if octane boils first

In M2 and M3 – if no specific reference to individual alkanes, could score one mark for M2 + M3 combined if M2 and M3 both otherwise correct

M2 and M3 must refer to a laboratory apparatus (not to an industrial process)

1

(c) $C_8H_{18} + 12½O_2 \longrightarrow 8CO_2 + 9H_2O$

Accept multiples; ignore state symbols

Accept any correct structural representation of isooctane

1

(d) M1 Alternative route/mechanism/pathway

1

M2 With lower activation energy

Accept E_a for activation energy

1

(e) $2CO + 2NO \longrightarrow 2CO_2 + N_2$

Accept multiples; ignore state symbols

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1

(f) M1 to reduce amount of metals needed / small amount of metal needed

Relates to low amount of metal

1

M2 Increase / maximise / produce large surface area or to give catalyst a larger surface area: volume ratio or so that high(er) proportion of atoms/metal is on surface

Is related to large surface area

1

(g) M1 bromine (water or in organic solvent or CCl_4) / Br_2 (aq) / Br_2

No reagent or an incorrect reagent (e.g. bromide), CE=0;

Penalise Br (or incorrect formula of other correct reagent) but mark on for M2

It must be a whole reagent and/or correct formula

If oxidation state given in name, it must be correct

If 'manganate' or 'manganate(IV)' or incorrect formula, penalise M1 but mark on

Ignore 'acidified'

1

M2 (orange/yellow to) colourless / decolourised / loses its colour

Ignore goes clear

Ignore brown/red, but penalise other incorrect colours

1

Alternatives:

M1 = potassium manganate(VII), M2 = colourless

M1 = <u>conc</u> sulfuric acid, M2 = brown

M1 = iodine, M2 = colourless

[12]

Q9.

C

[1]

Q10.

(a) <u>OH</u> AND <u>alcohol</u>

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>

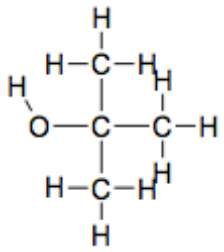
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Penalise reference to incorrect class of alcohol

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.

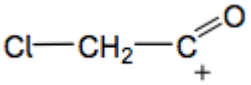
Any 2

[13]

Q11.

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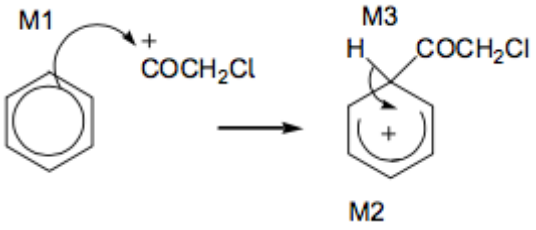
(a) (i)



Allow $[ClCH_2CO]^+$

1

(ii)



M1 for arrow from inside hexagon to C or + on C on correct electrophile

M2 for structure of intermediate

- *Horseshoe centred on C1;*
- *+ in intermediate not too close to C1 (allow on or "below" a line from C2 to C6)*

M3 for Arrow from bond to H into ring

- *Allow M3 arrow independent of M2 structure*
- *+ on H in intermediate loses M2 not M3*
- *Ignore Cl- removing H^+*

1
1
1

(b) Reagent

Water

(Aqueous) silver nitrate

NaOH followed by acidified silver nitrate

(Water +) named indicator

Named alcohol

Na_2CO_3 or $NaHCO_3$

Ammonia

1

P

No reaction

No reaction (or slow formation of ppt)

No reaction (or slow formation of ppt)

No colour change

NVC

NVC

No reaction

Do NOT award

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No observation

1

Q

Steamy /misty/ white fumes

White precipitate (immediately formed)

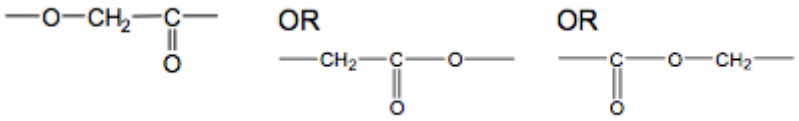
White precipitate (immediately formed)

Indicator turns to correct acid colour

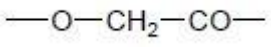
Fruity or sweet smell or misty fumes
Fizzing or effervescence (not just gas produced)
White smoke

1

(c) (i)

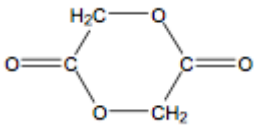


One unit only
Must have trailing bonds
Ignore n and brackets

allow 

1

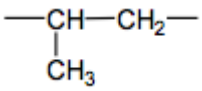
(i)



Allow CO for C=O

1

(d) (i)



One unit only
Must have trailing bonds
Ignore n and brackets

1

(ii) PGA sutures react/dissolve/break down/are biodegradable/ are hydrolysed / attacked by water or nucleophiles /no need to remove

OR Polypropene not biodegradeable/ not hydrolysed / not attacked by water/nucleophiles

1

(Ester links have) <u>polar bonds</u>

polypropene contains <u>non-polar bonds</u>

ignore intermolecular forces

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1

[12]

Q12.

(a) **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 (orange to) green solution ***OR*** goes green

M3 (solution) remains orange or no reaction or no (observed) change

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

*If incomplete / inaccurate attempt at reagent e.g. "dichromate" or "dichromate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*For **M2** ignore dichromate described as "yellow" or "red"*

*For **M3** ignore "nothing (happens)" or "no observation"*

Alternative using $KMnO_4$ / H_2SO_4

M1 acidified potassium manganate(VII) / potassium permanganate or $KMnO_4$ / H_2SO_4

OR $KMnO_4$ / H^+ ***OR*** acidified $KMnO_4$

M2 colourless solution ***OR*** goes colourless

M3 (solution) remains purple or no reaction or no (observed) change

*For **M1***

*If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*Credit alkaline $KMnO_4$ for possible full marks but **M2** gives brown precipitate or solution goes green*

3

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

M2 (stays) orange / red / yellow / brown / the same

OR no reaction ***OR*** no (observed) change

M3 decolourised / goes colourless / loses its colour / orange to colourless

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

*If incomplete / inaccurate attempt at reagent (e.g. Br), **penalise M1 only and mark on***

*No credit for combustion observations; **CE = 0***

*For **M2 in every case***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear"

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***OR* as alternatives**

Use $KMnO_4$ / H_2SO_4

M1 acidified potassium manganate(VII) / potassium permanganate ***OR*** $KMnO_4$ / H_2SO_4

OR $KMnO_4$ / H^+ ***OR*** acidified $KMnO_4$

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

M3 decolourised / goes colourless / loses its colour

Use iodine

M1 iodine or I_2 / KI or iodine solution

M2 no change

M3 decolourised / goes colourless / loses its colour

Use concentrated sulfuric acid

M1 concentrated H_2SO_4

M2 no change

M3 brown

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

For M1** penalise incorrect attempt at correct formula, but mark **M2** and **M3

With potassium manganate(VII)

*If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

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

Apply similar guidance for errors in the formula of iodine or concentrated sulfuric acid reagent as those used for other reagents.

3

(c) **M1** Any soluble chloride including hydrochloric acid (ignore concentration)

M2 white precipitate or white solid / white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 Any soluble iodide including HI

M2 yellow precipitate or yellow solid / yellow suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

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***OR* as an alternative**

M1 Any soluble bromide including HBr

M2 cream precipitate or cream solid / cream suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 NaOH or KOH or any soluble carbonate

M2 brown precipitate or brown solid / brown suspension with NaOH / KOH (white precipitate / solid / suspension with carbonate)

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

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

Allow chlorine water

*If incomplete reagent (e.g. chloride ions) or inaccurate attempt at formula of chosen chloride, or chlorine, **penalise M1 only and mark on***

*For **M2** require the word "white" and some reference to a solid. Ignore "cloudy solution" OR "suspension" (similarly for the alternatives)*

*For **M3***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear" on its own

Ignore "dissolves"

3

(d) **M1** Any soluble sulfate including (dilute or aqueous) sulfuric acid

M2 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

M3 white precipitate or white solid / white suspension

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

Accept $MgSO_4$ and $CaSO_4$ but not barium, lead or silver sulfates

*If concentrated sulfuric acid or incomplete reagent (e.g. sulfate ions) or inaccurate attempt at formula of chosen sulfate, **penalise M1 only and mark on***

*For **M3 (or M2 in the alternative)** require the word "white" and some reference to a solid.*

Ignore "cloudy solution" OR "suspension"

*For **M2 (or M3 in the alternative)***

Ignore "nothing (happens)"

Ignore "no observation"

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Ignore "clear" on its own

Ignore "dissolves"

***OR* as an alternative**

M1 NaOH or KOH

M2 white precipitate or white solid / white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

If incomplete reagent (e.g. hydroxide ions) or inaccurate attempt at formula of chosen hydroxide, ***penalise M1 only and mark on***

If ***M1*** *uses* NH_3 *(dilute or concentrated)* ***penalise M1 only and mark on***

3

[12]

Q13.

(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

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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

- <u>One or single</u> 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

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M4
1

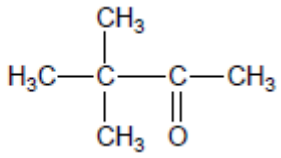
two peaks (so not S which would have only one)

M5
1

(f)

U

$C_6H_{12}O_6$

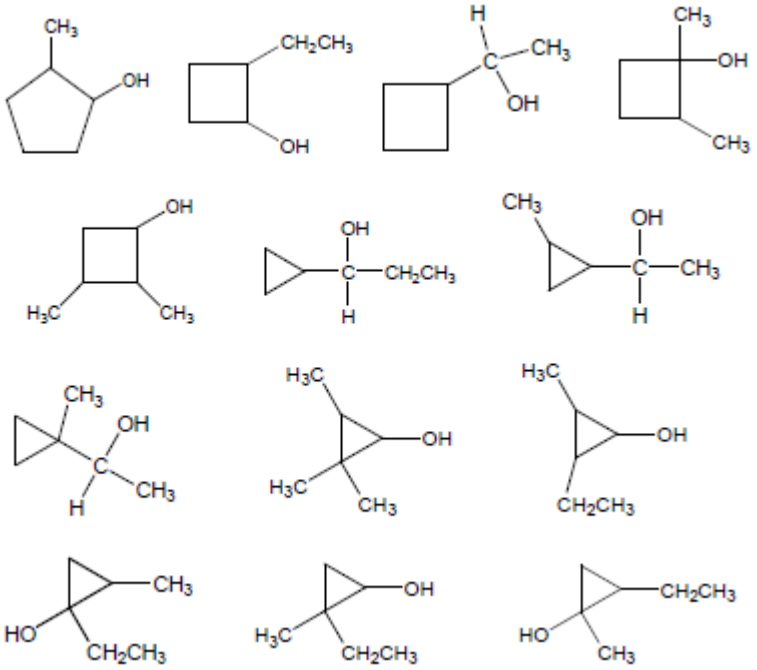


1

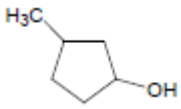
Answers include

V

$C_6H_{12}O_6$



*Not allow **S***



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

[17]

Q14.

(a) (i) **M1** (Compounds / molecules with) the <u>same structural formula</u>

*Penalise **M1** if 'same structure' or 'different structural / displayed formula'.*

M2 with <u>atoms / bonds / groups</u> arranged <u>differently in space</u>

OR <u>atoms / bonds / groups</u> with <u>different spatial arrangements / different orientation</u>

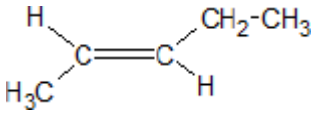
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Ignore references to 'same molecular formula' or 'same empirical formula'.

Mark independently.

2

(ii)



Credit C–H_3C

Credit C_2H_5

Penalise C–CH_3CH_2

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'.

M2 Isomer 1: decolourised / goes colourless / loses its colour

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

M3 Isomer 2: remains orange / red / yellow / brown / the same **OR** no reaction / no (observable) change **OR** reference to colour going to the cyclopentane layer

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

*If oxidation state given in name, it must be correct. If 'manganate' OR 'manganate(IV)' or incorrect formula, penalise **M1**, but mark on.*

Alternatives : potassium manganate(VII)

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

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

Credit for the use of **iodine**

M1 iodine (solution / in KI) **M2** colourless **M3** (brown) to purple (credit no change)

Credit for the use of **<u>concentrated</u> H_2SO_4**

M1 <u>concentrated</u> H_2SO_4 **M2** brown **M3** no change / colourless

Ignore 'goes clear'.

Ignore 'nothing (happens)'.

Ignore 'no observation'.

No credit for combustion observations.

3

(c) (i) (Both infrared spectra show an absorption in range) **<u>1620 to 1680</u>** (cm^{-1})

Ignore reference to other ranges (eg for C–H or C–C).

1

(ii) The <u>fingerprint</u> (region) / below 1500 cm^{-1} will be different **or** its

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fingerprinting will be different

OR

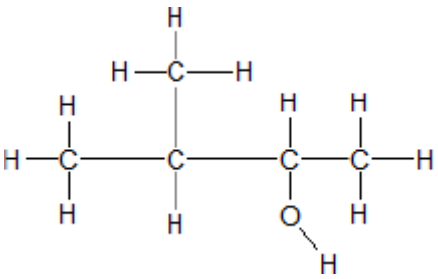
different absorptions / peaks are seen (in the region) below 1500 cm^{-1} (or a specified region within the fingerprint range)

*Allow the words 'dip' **OR** 'spike' **OR** 'low transmittance' as alternatives for absorption.*

QoL

1

(d)



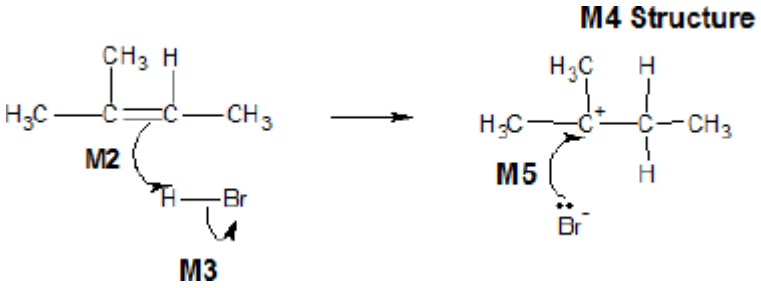
All bonds must be drawn.

Ignore bond angles.

1

(e) (i) **M1 Electrophilic addition**

***M1** both words needed.*



Penalise one mark from their total if half-headed arrows are used.

M2 must show an arrow from the double bond towards the H atom of the H–Br molecule

***M2** Ignore partial negative charge on the double bond.*

M3 must show the breaking of the H–Br bond

***M3** Penalise incorrect partial charges on H–Br bond and penalise formal charges.*

M4 is for the structure of the tertiary carbocation

*Penalise **M4** if there is a bond drawn to the positive charge.*

Penalise once only in any part of the mechanism for a line and two dots to show a bond.

M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged carbon atom of either a secondary or a tertiary carbocation

*For **M5**, credit attack on a partially positively charged*

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*carbocation structure but penalise **M4**.*

Max 3 of any 4 marks in the mechanism *for wrong organic reactant or wrong organic product (if shown) or secondary carbocation.*

Max 2 of any 4 marks in the mechanism *for use of bromine.*

Do not penalise the correct use of 'sticks".

NB The arrows here are double-headed

5

(ii) **M1** Reaction goes via intermediate carbocations / carbonium ions

***M1** is a lower demand mark for knowledge that carbocations are involved.*

M2 (scores both marks and depends on M1)

Tertiary carbocation / carbonium ion is more stable (than the secondary carbocation / carbonium ion)

OR

Secondary carbocation / carbonium ion is less stable (than the tertiary carbocation / carbonium ion)

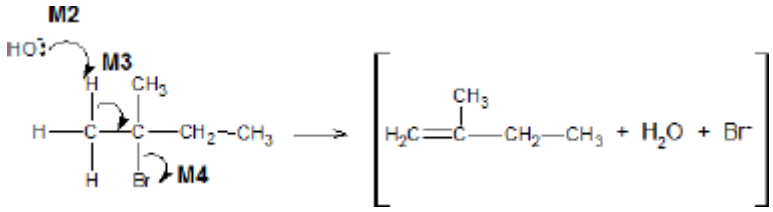
***M2** is of higher demand and requires the idea that the secondary carbocation is less stable or the tertiary carbocation is more stable. Reference to incorrect chemistry is penalised.*

A carbocation may be defined in terms of alkyl groups / number of carbon atoms, rather than formally stated.

2

(f) **M1 Elimination**

***M1** credit 'base elimination' but no other qualifying prefix.*



Penalise one mark from their total if half-headed arrows are used.

M2 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to a correct H atom

*Penalise **M2** if covalent KOH*

M3 must show an arrow from a correct C–H bond adjacent to the C–Br bond to a correct C–C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C–H bond (in **M2**)

M4 is independent provided it is from their original molecule **BUT penalise M2, M3 and M4 if nucleophilic substitution** shown

Award full marks for an E1 mechanism in which **M2** is on the correct

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carbocation

NB The arrows here are double-headed

*Penalise **M4** for formal charge on C or Br of the C–Br bond or incorrect partial charges on C–Br.*

*Penalise **M4** if an additional arrow is drawn from the Br of the C–Br bond to, for example, K^+.*

Ignore other partial charges.

*Penalise **once only** in any part of the mechanism for a line and two dots to show a bond.*

***Max 2 of any 3 marks in the mechanism** for wrong reactant or wrong organic product (if shown) or a correct mechanism that leads to the alkene 2-methylbut-2-ene.*

Credit the correct use of "sticks" for the molecule except for the C–H being attacked.

M5 hydroxide ion behaves as a base / proton acceptor / electron pair donor / lone pair donor

*Penalise **M5** if 'nucleophile'.*

5

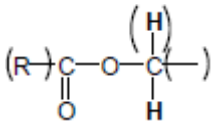
[21]

Q15.

(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

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

Ignore 'clear', 'nothing'.

Allow colour fades slowly.

Allow 'nvc' for no visible change.

1

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

1

[11]

Q16.

Identification of acid by suitable method eg named indicator, named carbonate, specified reactive metal

Ignore any reference to the smell of the ester.

1

with expected results

Do not allow the use of any instrumental method eg i.r. or n.m.r.; must be a <u>chemical</u> test.

1

Identification of alcohol by suitable method eg oxidation by acidified potassium dichromate(VI)

1

with expected results

1

[4]

Q17.

(a) M1 <u>concentrated sulfuric acid OR c(onc) H_2SO_4</u>

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

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*for **M2** or **M3***

M2 (cream solid) turns orange
OR <u>orange / red / brown fumes / gas / vapour</u>

*If <u>dilute</u> sulfuric acid **OR** "aq" <u>(alone)</u> **CE=0***

M3 (yellow solid) turns black
OR <u>purple fumes / gas / vapour</u>
OR correct reference to H_2S <u>observation (eg bad egg smell)</u>

*If H_2SO_4 / sulfuric acid given but not stated whether dilute or concentrated, penalise **M1** and mark on for **M2** and **M3***
*If incorrect formula for the acid, penalise **M1** but mark **M2** and **M3***

***OR* as an alternative**

M1 <u>concentrated ammonia</u> ***OR*** <u>c(onc) NH_3</u>

*If NH_3 / ammonia / aq ammonia given, but not stated as <u>concentrated</u> **OR** if <u>dilute</u> ammonia given, penalise **M1** but mark on for **M2** and **M3***
*Ignore "partially" and ignore "clear" in **M2***

M2 (cream solid) dissolves / solution formed

M3 precipitate remains / does not dissolve / insoluble
OR no reaction / no change / (yellow solid) turns to white solid

*If incorrect formula for ammonia, penalise **M1** but mark **M2** and **M3***

*In **M3** for ammonia.*
ignore "nothing (happens)".
ignore "no observation".

3

(b) M1 $AgNO_3$ ***OR*** silver nitrate ***OR*** any soluble silver salt

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

M2 <u>white precipitate</u> or <u>white solid / white suspension</u>

*An insoluble silver salt OR Tollens' **OR** Ag **OR** ammoniacal silver nitrate or HCl / $AgNO_3$ **CE= 0** for the clip.*

M3 remains colourless ***OR*** no reaction ***OR*** no (observed) change ***OR*** no precipitate

*For **M1***
*Credit acidified (**OR** HNO_3) silver nitrate for **M1** and mark on.*
*If silver ions or incorrect formula for silver nitrate, penalise **M1** but mark **M2** and **M3***

Credit alternative test for nitrate ions

*For **M2***
*Ignore "cloudy solution" **OR** "suspension".*

*For **M3***
Ignore "nothing (happens)".
Ignore "no observation".
Ignore "clear".

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Ignore "dissolves".

3

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

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

Either Order

M2 (stays) Orange / red / yellow / brown / the same
OR no reaction ***OR*** no (observed) change
OR reference to colour going to cyclohexane layer

*No credit for combustion observations; **CE=0***
*For **M2 in every case**.*
Ignore "nothing (happens)".
Ignore "no observation".
Ignore "clear".

M3 decolourised / goes colourless / loses its colour

With bromine (water)
***For M1**, it must be a whole reagent and / or correct formula.*
If oxidation state given in name, it must be correct.
For M1** penalise incorrect formula, but mark **M2** and **M3

***OR* as an alternative**

Use $KMnO_4/H_2SO_4$

M1 acidified potassium manganate(VII) or $KMnO_4/H_2SO_4$
OR $KMnO_4/ H^+$ ***OR*** acidified $KMnO_4$
M2 (stays) <u>purple</u> or no reaction or no (observed) change

With potassium manganate(VII)
For M1

M3 <u>purple to colourless</u> solution ***OR*** goes <u>colourless</u>

*If "manganate" or "manganate(IV)" or incorrect formula or no acid, penalise **M1** but mark **M2** and **M3***

Credit alternative test using **iodine** (for **M1**)
M2 (brown) to purple or accept no change, M3 colourless
Credit alternative test using <u>concentrated</u> $H_2 SO_4$
M2 no change, M3 brown

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

3

(d) M1 Tollens' (reagent) OR ammoniacal silver nitrate OR a description of making Tollens'
(Ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3)
M2 <u>silver mirror</u>
OR <u>black solid / precipitate</u> (Ignore silver precipitate)
M3 (stays) <u>colourless</u> or no reaction or no (observed) change

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

For M3 in every case
Ignore "nothing (happens)".
Ignore "no observation".

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Alternative using Fehling's (solution)
M1 Fehling's (solution) or Benedict's solution
(Ignore $Cu^{2+}(aq)$ or $CuSO_4$ on their own, but mark M2 and M3)
M2 Red solid / precipitate (Credit Orange or brown solid)
M3 (stays) blue or no reaction or no (observed) change

With potassium dichromate(VI)
For M1
*If "dichromate" or "(potassium) dichromate(IV)" or incorrect formula or no acid, penalise **M1** but mark **M2** and **M3***

Alternative using $K_2Cr_2O_7/H_2SO_4$
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 (Orange to) green solution OR goes green
M3 (stays) Orange or no reaction or no (observed) change

*For **M3***
Ignore dichromate described as "yellow" or "red".

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

Alternative using $KMnO_4/H_2SO_4$
M1 acidified potassium manganate(VII) or $KMnO_4/H_2SO_4$
OR $KMnO_4/H^+$ ***OR*** acidified $KMnO_4$
M2 purple to colourless solution OR goes colourless
M3 (stays) purple or no reaction or no (observed) change

*Credit alkaline / neutral $KMnO_4$ for possible full marks but **M2** gives brown precipitate or solution goes green.*

3

[12]

Q18.

(a) **If 2 stage test for one compound, award no marks for that compound, eg no mark for ROH or RX to alkene then Br_2 test. If reagent is wrong or missing, no mark for that test; if wrong but close/incomplete, lose reagent mark but can award for correct observation. In each test, penalise each example of wrong chemistry, eg $AgClr_2$**

propan-1-ol

acidified
potassium
dichromate

sodium

Named acid + conc H_2SO_4

named acyl chloride

PCl_5

M1

1

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(orange) turns green

effervescence

Sweet smell

Sweet smell /misty fumes

Misty fumes

M2
1

propanal

add Tollens or Fehlings / Benedicts

acidified
potassium
dichromate

Bradys or 2,4-dnph

if dichromate used for alcohol cannot be used for aldehyde

M3
1

Tollens: silver mirror or Fehlings/ Benedicts: red ppt

(orange) turns green

Yellow or orange ppt

M4
1

propanoic acid

Named carbonate/ hydrogencarbonate

water and UI (paper)

Named alcohol + conc H_2SO_4

sodium or magnesium

PCl_5

if sodium used for alcohol cannot be used for acid

M5
1

effervescence

orange/red

Sweet smell

effervescence

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Misty fumes

if PCl_5 used for alcohol cannot be used for acid

M6
1

1-chloro propane

NaOH then acidified $AgNO_3$

$AgNO_3$

If acidification missed after NaOH,
no mark here but allow mark for observation

M7
1

white ppt

white ppt

M8
1

(b) oxidation (of alcohol by oxygen in air)

M1
1

absorption at 1680 -1750 (due to C=O)

Must refer to the spectrum

M2
1

comparison of polarity of molecules or correct imf statement:
propanone is less polar OR propan-2-ol is more polar
OR propanone has dipole-dipole forces
OR propan-2-ol has hydrogen bonding

M3
1

about attraction to stationary phase or solubility in moving phase
Propan-2-ol has greater affinity for stationary phase or vice versa
OR propanone is more soluble in solvent/moving phase or vice versa

M4
1

[12]

Q19.

(a) **For 2 marks at least one correct reference either to M_r or value to 5 decimal places required**

QoL *(associated with the bold statement here)*

M1 Compounds 1 and 3 (butanal and butanone) have the same M_r (to 5dp)

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because **either**

It may be possible to award 2 marks if there is a clear statement about oxygen having a different precise A_r in the context of the comparison

- they contain the same number of atoms of the same / each element
- are both C_4H_8O
- have the same molecular formula

  NB The word "similar" does not mean "the same"
- contain the same number of C, H and O atoms

M2 Compound 2 (pentane) has a different M_r (to 5dp) because **either**

- it has different numbers of atoms of different elements
- is C_5H_{12} / only contains C and H
- different molecular formula
- does not contain oxygen (atom) / C=O

2

(b) **WithTollens' (reagent)**

M1 silver mirror

OR black solid/precipitate

(NOT silver (mirror) precipitate)

M2 (stays) colourless

OR no change / no reaction

OR no silver mirror

With Fehling's (solution)

M1 Red solid/precipitate

(Credit orange or brown solid)

M2 (stays) blue

OR no change / no reaction

OR no red solid

OR no (red) precipitate

N.B No mark is awarded for the reagent

If no reagent given allow 1 mark for a consistent statement of M1 and M2

For M2, ignore "nothing (happens)"

And ignore "no observation"

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2

[4]

Q20.

Test bromine (water) / iodine

Accept 'Br_2' or 'bromine in a named solvent'.

Do not accept 'Br'

Use of UV light, CE (lose next mark as well)

1

Observation orange / yellow / (red-)brown to colourless

Must have correct reagent to score this mark.

For I_2, allow red-brown / purple to colourless.

1

[2]

Q21.

(a) (i) Green

Ignore shades of green.

1

(ii) Excess acidified potassium dichromate(VI)

1

Reflux (for some time)

1

In the diagram credit should be given for

- a vertical condenser

Lose M3 and M4 for a distillation apparatus.

1

- an apparatus which would clearly work

Do not allow this mark for a flask drawn on its own.

Penalise diagrams where the apparatus is sealed.

1

(iii) Distillation

1

Immediately (the reagents are mixed)

1

(b) Keep away from naked flames

Allow heat with water-bath or heating mantle.

If a list is given ignore eye protection, otherwise lose this mark.

1

(c) (i) Tollens' or Fehling's reagents

*Incorrect reagent(s) loses **both** marks.*

Accept mis-spellings if meaning is clear.

1

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Silver mirror / red ppt. formed

Accept 'blue to red' but not 'red' alone.

1

(ii) Sodium carbonate (solution) / Group II metal

Allow indicator solutions with appropriate colours.

Accept any named carbonate or hydrogen carbonate.

1

Effervescence / evolves a gas

Accept 'fizzes'.

1

(d) Propanoic acid

If this mark is lost allow one mark if there is reference to stronger intermolecular forces in the named compound.

Lose M1 and M3.

1

Contains hydrogen bonding

1

Some comparison with other compounds explaining that the intermolecular forces are stronger in propanoic acid

1

[15]

Q22.

1-chloropropane no visible change

Accept 'small amount of precipitate' or 'precipitate forms slowly'.

1

ethanoyl chloride white precipitate

Accept 'large amount of precipitate' or 'precipitate forms immediately'.

1

[2]

Q23.

(a) Functional group (isomerism)

1

(b)

M1 Tollens' (reagent)
(*Credit ammoniacal silver nitrate* **OR** *a description of making Tollens'*)
(*Ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3*)

M2 silver mirror

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

M2 Red solid/precipitate
(*Credit orange or brown solid*)

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OR

<u>black solid/precipitate</u>
(NOT silver precipitate)

M3 (stays) colourless
or no change or no reaction

M3 (stays) blue
or no change or no reaction

Mark on from an incomplete/incorrect attempt at the correct reagent, penalising M1

No reagent, CE=0

Allow the following alternatives
M1 *(acidified) potassium dichromate(VI) (solution)*
M2 *(turns) green*
M3 *(stays) orange/no change*
OR
M1 *(acidified) potassium manganate(VII) (solution)*
M2 *(turns) colourless*
M3 *(stays) purple/no change*

For M3
Ignore "nothing (happens)"
Ignore "no observation"

3

(c) (Both have) C=O ***OR*** a carbonyl (group)

1

(d) (i) (Free-) <u>radical substitution</u> ONLY

Penalise "(free) radical mechanism"

1

(ii) **Initiation**
$Cl_2 \rightarrow 2Cl\bullet$

Penalise absence of dot once only.

First propagation
$Cl\bullet + CH_3CH_2CH_3 \rightarrow \bullet CH_2CH_2CH_3 + HCl$
OR C_3H_8

Penalise incorrect position of dot on propyl radical once only.

Penalise $C_3H_7\bullet$ once only

Second propagation
$Cl_2 + \bullet CH_2CH_2CH_3 \rightarrow CH_3CH_2CH_2Cl + Cl\bullet$

OR

C_3H_7Cl

Accept $CH_3CH_2CH_2\bullet$ with the radical dot above/below/to the side of <u>the last carbon</u>.

Termination (must make C_6H_{14})
$2 \bullet CH_2CH_2CH_3 \rightarrow C_6H_{14}$ or $CH_3CH_2CH_2CH_2CH_2CH_3$

Use of the secondary free radical might gain 3 of the four marks

4

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(e) M_r = 44.06352 (for propane)
M_r = 43.98982 (for carbon dioxide)
Mark independently

M1 a correct value for both of these M_r values.

M2 a statement or idea that two peaks appear (in the mass spectrum)

OR

two molecular ions are seen (in the mass spectrum).

2

[12]

Q24.

(a) (i) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$;
(penalise C_2H_6O once only in this question)

1

(ii) Concentrated H_2SO_4 OR concentrated H_3PO_4 OR Al_2O_3;
(penalise aqueous or dilute as a contradiction)

1

$C_2H_5OH \rightarrow C_2H_4 + H_2O$ OR $C_2H_5OH \rightarrow H_2C = CH_2 + H_2O$;
(penalise CH_2CH_2 and CH_2-CH_2 and CH_2: CH_2 for ethene)

1

(b) Nickel OR Ni OR platinum OR Pt OR palladium OR Pd;

1

Hydrogen OR H_2;

1

(c) (i) $C_{18}H_{34}O_2$ Only;

1

$C_9H_{17}O$ Only;
(empirical formula is not consequential on molecular formula)

1

(ii) (An unsaturated compound) contains (at least) one double bond

OR

Contains C=C;
(must be a positive statement)

1

(iii) M1: Bromine water

OR

Br_2(aq)

OR

Bromine

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OR

Br_2;

(penalise "bromide water", but mark on)

1

M1: decolourised or goes colourless

OR

from brown/red/orange/yellow to colourless;

(Must be "colourless" not "clear" for M2)
(chemical error if no reagent or wrong reagent, loses both marks) (credit $KMnO_4$ for M1, (purple) to colourless for M2 (if acidified) OR (purple) to brown/brown precipitate (if alkaline or unspecified) (No credit for hydrogen or iodine as reagents)

1

[10]

Q25.

(a) (i)

	The addition of $AgNO_3$	followed by concentrated	the addition of $NH_3(aq)$
Observation with NaBr(aq)	Cream or off white precipitate or solid (1)	Precipitate dissolves (1)	
Observation with NaI(aq)	Yellow precipitate or solid (1)	Precipitate insoluble or no change (1)	

(ii) Ag F is soluble;

5

(b) (i) identity: $[Ag(S_2O_3)_2]^{3-}$;

1

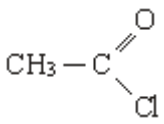
(ii) equation: $AgI + 2S_2O_3^{2-} \rightarrow [Ag(S_2O_3)_2]^{3-} + I^-$

1

(iii) use: in photography or as a fixer;

1

(c) (i) Structure



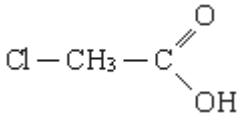
1

Observation: Vigorous or violent or exothermic reaction
or fumes or white precipitate formed immediately

1

(ii) Structure:

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1

Observation: No immediate precipiate or reaction

OR

white precipitate formed very slowly;

1

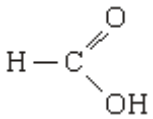
(d) (i) Silver-containing complex: $[Ag(NH_3)_2]^+$;

1

Shape: Linear;

1

(ii) Structure



1

Explanation: Methanoic acid contains an aldehyde group;

1

(iii) H_2CO_3 or CO_2 or $OC(OH)NH_2$ or $(NH_2)_2CO$ or $(NH_4)_2CO_3$

OR

$HCOONH_4$;

1

[17]

Q26.

D

[1]

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Q1.

Many students approached this question as if they already knew which compound was which. They did not appreciate the need to carry out the first test with all four compounds to start to work out which is which. Many used the test with acidified potassium dichromate(VI) but did not realise that butanal as well as butan-2-ol would react. Few successfully identified two compounds using two test tube reactions, leaving the other two compounds to be distinguished by IR spectroscopy or mass spectrometry. Many did not explain how one of these spectroscopic methods could actually be used to distinguish the final two compounds. Overall, though, the question discriminated well.

Q2.

(a) This question discriminated well: 28.3% of students correctly identified the types of intermolecular forces and noted that hydrogen bonding in the alcohol and the acid was stronger than dipole-dipole attractions between propanal molecules. Despite the request in the question to consider intermolecular forces, a few students still discussed the breaking of bonds in the molecules and so gained no marks, although fewer did this than is often the case in this type of question.

(b) Very few students (4%) scored both marks in this question and only 39.2% scored at least one mark, despite the question being based on one of the required practical activities.

(c) This part was answered well by nearly two-thirds of the students. The main error was to test for the aldehyde rather than the acid.

(d) This question discriminated well and there was a good spread of marks. Sadly, some students did not quote their answers to three significant figures and/or remember the negative sign for their exothermic enthalpy change of combustion.

(e) The major errors in the answers to this acid-catalysed elimination of water were where students confused this mechanism with the elimination of HX from a halogenoalkane using a base. However, just under a third of students scored full marks in a correct mechanism, either via the formation of a carbocation or by showing the simultaneous loss of water and H+ from a protonated alcohol.

(f) This part was challenging and a surprising proportion of students (8%) made no attempt. A large number scored no marks as they discussed the formation of different alkenes, rather than why pent-2-ene shows E-Z isomerism. Sadly, some of those who did gain the first mark failed to gain the second as this required two statements, not only that the C=C bond cannot rotate, but also that each carbon in the double bond has two different groups attached to it.

Q3.

(a) Most students coped with the need to convert volume to mass and gave 9.6 g of cyclohexanol at the start, but too many then assumed that this meant the maximum possible yield of cyclohexene would be 9.6 g and so divided 5.97 by this. 47.5% of students completed the calculation successfully.

(b) Most students (70.2%) were able to suggest the use of bromine water, with only very few getting the colour change the wrong way round. The most common wrong answer was the suggestion of a test for the absence of alcohol rather than a positive

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test for the presence of an alkene.

(c) This was not answered as well as expected (42% correct), with many vague references to 'removing impurities' or 'separating the layers'.

(d) The key to questions like this about understanding the method of a practical is to relate the answer to the position of the process in the overall method. The reference to periodic opening of the tap preceded the actual separation of the layers in the method, yet many answers referred to opening the tap to run off one of the layers. It was interesting that more students (57.4% correct) were able to suggest that this was to release pressure of CO_2 (due to reaction with acid) than were able to suggest, in part (c), that the carbonate had been added in order to react with acid.

(e) The low success rate in this question (28.2% correct) is explained by a lack of specificity in students' answers; the mark required a reference to a lack of reactivity with, or solubility in, **cyclohexene**.

(f) Most students chose to draw a diagram rather than write a description; the former is the recommended approach. However, clear, simple cross-sectional line diagrams of a Buchner funnel and filter paper on top of a Buchner flask (with side-arm attached to a vacuum pump) were seldom seen. Tubes were often shown as sealed, bungs and side-arms were missing and the side-arm was often drawn on the funnel rather than the flask. Only 28.7% of students gained both marks; 37.1% failed to score.

(g) This part gave numerous examples of repeating the question, with many answers seen along the lines of "the retention time is shorter because the retention time is shorter". Some students also inverted the question and tried to describe why cyclohexene had a longer retention time, while others thought incorrectly that cyclohexene is polar due to the C=C bond. An inversion of reasoning that was often seen was the incorrect idea that cyclohexanol has hydrogen bonding, which is why it is polar. 34.9% of students scored zero here.

(h) Too many students failed to remember the need always to mention both the wavenumber range **and** the bond responsible in questions of this type. Most correctly stated that a peak in the range 3230−3550 would not be visible, but many then failed to state that this peak relates to the O−H bond in an alcohol. As a result, only 43.7% of students gained the mark.

Q4.

Most students made good progress with this question, with many identifying one or more of the three compounds. However, few scored full marks as they did not explain how they deduced the structures. Many did not explain the significance of the results of the tests with bromine water. The meaning of the term stereoisomers was not well known, and often confused with structural isomers; few referred to the restricted rotation around the C=C bond leading to stereoisomers in molecules where both of the C atoms in the C=C bond have two different groups attached. Some students incorrectly suggested that alkenes that do not have stereoisomers have free rotation around the C=C bond.

Q5.

There were some very good answers to this question and nearly a fifth of the students scored full marks. The best answers followed a 'staged approach', in which a first test divided the four compounds into two groups. Subsequent tests were then made on each group.

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Students generally knew the chemistry, but didn't always show a logical approach in their answers to the problem. Some suggested testing the same reagents on all four compounds, failing to appreciate that once one compound was identified, further tests on it were unnecessary. Some suggested performing isolated tests on individual compounds.

Q8.

Alkanes in fuels

The naming of the molecule, in (a) was answered correctly by many students.

Most students realised that simple or fractional distillation could be used in (b). However, many referred to the industrial fractional distillation process where the entire mixture is vaporised and then fed into a fractional column with a temperature gradient and collection trays, rather than referring to an apparatus that would be used in the laboratory. This may suggest a lack of familiarity with carrying this out in the laboratory. Question (c) was well answered, although $8½O_2$ was seen often stemming from students not appreciating that there were two oxygen atoms in each CO_2 molecule. Many students could answer (d) by explaining, in general terms, how a catalyst works and knew the equation for the reaction of NO and CO in a catalytic converter, answering (e). Many students in (f) could explain that a thin layer of catalyst was used on a ceramic support to increase surface area, but few also explained that this reduced the amount of catalyst needed (which would be expensive). Many students in (g) knew the use of bromine (water) to show that a compound is unsaturated, but some referred to the mixture going from orange to clear rather than colourless.

Q10.

In part (b) students needed to read the question carefully and organise their thinking clearly to avoid confusing **A** with **P** and **B** with **Q** in their answers. A significant minority of students got the identities of **A** and **B** wrong way round or thought that they were carbonyls – despite having got part (a) correct in most cases.

In part (c) most students correctly identified **C** but many lost the mark for the displayed formula through not showing the O–H bond. Many students seemed to confuse the dehydration of an alcohol with the elimination reaction of a halogenoalkane and incorrectly chose ethanolic KOH as the reagent needed for the conversion of **C** into **R**.

In questions on IR spectra it is important for students to be aware that any reference to a wavenumber of an absorption must be linked to the bond responsible for that absorption.

Q11.

Apart from the occasional suggestion of $AlCl_4^-$ as the electrophile, part (a)(i) was answered well as was the mechanism in (a)(ii). Marks are still lost by some students who draw curly arrows that lack the precise start and end positions required to gain the mark. About a third of students scored full marks in part (b). The vast majority of incorrect answers involved oxidation: using Tollens or Fehling's or acidified potassium dichromate solution. Students should be reminded that when asked to give an observation, those who write the word "nothing" or "no observation" will not gain a mark.

Part (c)(i) was answered well although a few students drew more than one repeating unit. Part (c)(ii) was also answered well. About a third of students did not answer part (d)(i) correctly. Part (d)(ii) proved a good differentiator with many gaining a mark for noting that PGA is biodegradable, but only the best students were able to link this to the presence of polar bonds in PGA. Some students included the term polar but applied it to the whole molecule and not a specific bond.

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Q12.

This was a high demand question, since it requires application of chemistry from the specification and a failure to provide a suitable test reagent leads to the loss of three marks in each part. The number of possible answers to distinguish silver nitrate in part (c) was considerable and partial credit was awarded for test reagents that were unsuitable for test-tube tests, but which led to correct chemical observations. Less than one third of students scored all three marks on part (c) and part (d), whereas three quarters scored full marks on part (b).

Q13.

Part (a) was answered well. "A simple test-tube reaction" was required so students lost the marks if they suggested that two reagents were added sequentially or two different reagents were used for **P** and **S**. The most common test used was acidified potassium dichromate(VI). A few students gave the observations the wrong way round.

The answer to part (b) was usually given correctly although a number gave acidified potassium dichromate(VI) again even though this also react with **S**. Part (c) was found to be more difficult. In part (d), most students gained at least two marks out of three. Tetramethylsilane was well known but often given as a structural formula or even as a displayed formula when the molecular formula was required. A few students referred to the proton nmr spectrum rather than the ^{13}C.

There were some good, well explained answers to part (e). The spectrum in Figure 1 was usually identified as **R**, but the spectrum in Figure 2 was less well answered as **T**. The data sheet was used well, but the terms ester and ether from the table on the sheet were sometimes muddled.
Students who were unable to state correctly which isomer produced each spectrum could not access the explanation marks. Isomer **S** was the most common incorrect answer for Figure 2. Better students appreciated that the spectrum of **T** would show two C-O peaks in the region 50-90 ppm but **S** would only have one of these and then used the two peaks in this region of the spectrum to confirm their choice.

In part (f), compound **U** was often correct. There are many cyclic alcohols of $C_6H_{12}O$ which exist as optical isomers and most were seen and gained credit. Common incorrect answers were **S** itself and the optically inactive 1-methylcyclopentan-1-ol and cyclohexanol.

Q14.

Fewer than a third of students scored both marks for the definition in part (a)(i), often missing the requirement to state that stereoisomers are compounds with the same structural formula. Part (b) was generally well answered with most students scoring all 3 marks. Part (c)(ii) required appreciation of the fingerprint region or some equivalent idea and only about one-third of students scored this mark. The displayed formula in part (d) caused the usual problems and few were able to score this mark. The mechanisms in parts (e)(i) and (f) were the most discriminating questions on the paper, producing a good spread of marks. Part (e)(ii) required an explanation involving the relative stability of carbocations, with a low demand and a much higher demand mark and only the highest-scoring students scored both marks. It was a surprise to see answers that referred to the ‘Markownikoff rule’ without any explanation in terms of the stability of carbocations.

Q15.

Although many students scored well in part (a), answers were often badly expressed and very wordy. Most students gained M3 for explaining that the quartet was due to the CH_2

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group being next to a CH_3 group and this mark was allowed even if the wrong ester was given. The question instructed students to use Table B on the Data Sheet, and it was only by doing this that M2 and M4 could be accessed and earned. Parts (b) and (c) proved very straightforward, although the full name “quaternary ammonium salt” was only given by a minority of students. A significant number of students who identified the correct reagent in part (c) either had the results reversed, or discussed cyclohexane and benzene in their answer, thinking that benzene would react with bromine.

Q16.

The answers to this Question appeared familiar to most students but their ability to produce fully correct answers was variable. There were many instances where the potassium dichromate had not been acidified, was given the oxidation state of (IV), had an incomplete colour change stated and wrong / incomplete formulae for reagents. These errors were not always penalised by the marker. It should be noted that the Fehling’s or Tollens’ tests can be used but that it must be clear that an aldehyde is being distilled off correctly from the mixture first.

Q17.

This type of question demands that students have a good grasp of observational chemistry from the specification. No marks can be awarded in any of the four parts if a suitable test reagent is not known. This limited the marks for some students. No marks are awarded in the observation sections if the response is “nothing” or “no observation”. The least well answered part was part (b) with just over half of all students scoring no marks and only approximately a quarter scoring full marks, By contrast the best answered part was part (d) with only very few students scoring no marks and almost two-thirds of all students scoring full marks.

Q18.

There were many excellent answers to part (a) of this question. Common errors in what were otherwise correct answers for part (a) included incomplete reagents such as omission of the acid with potassium dichromate or simply stating “carbonate” rather than the full name or formula of a carbonate such as sodium carbonate or Na_2CO_3.

The haloalkane proved to be the most difficult to identify, with students often treating it as an acyl chloride and assuming that addition of water would give misty fumes.

A single test was required for each compound so answers which involved a preliminary step before a test did not score.

In part (b), the first two marks were often gained but few students gained both of the other two. This was often because of incorrect or missing statements about polarity in propanone or propan–2–ol or because of a lack of knowledge of what is happening in this type of chromatography. Many students thought that the substances would rise in the column while others thought that the M_r would affect retention time.

Q19.

Part (a) was a different approach to the ideas behind this concept and only 24% of students were able to explain their thinking sufficiently well to gain two marks. Part (b) was well known.

Q20.

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In this question, many candidates did not give the full observation and were content to refer to 'decolorise' alone.

Q21.

The colour change in part (a)(i) was well known but most candidates failed to score both marks for the conditions for the reaction in part (a)(ii). Many markers treated the word 'excess' as an optional extra and awarded a mark to candidates who just repeated information in the stem of the question. Most candidates were able to draw an acceptable diagram for reflux. The usual mistake was to seal the condenser and many markers failed to punish this serious error.

Part (a)(iii) was poorly answered, even by the better candidates. Distillation was often appreciated but the concept of removal of the aldehyde immediately when it is formed was rarely seen. Some centres were very generous indeed when marking this question.

The tests in part (c) were well known and better candidates scored all four marks. Some candidates lost a mark by giving an incorrect formula for a reagent. Centres are reminded that if the candidate chooses an incorrect test reagent the mark for the observation cannot be awarded.

Most candidates could make some progress in part (d), and the presence of hydrogen bonding in the acid and alcohol were known to the better candidates. Some centres were very generous when marking this question. The final mark was often given for references to stronger van der Waals forces in the carboxylic acid.

Q22.

Questions that require identification of a reagent and a subsequent observation defeat many candidates. Providing the reagent in the rubric for the question did not seem to help and correct answers to this Question were rare. Most candidates realised that one of the reactions would produce a white precipitate but often chose the wrong one. The production of a silver mirror was often given.

Overall, the scheme seems to have gone well once again. Given the pressures on centres to deliver the teaching programme, this was a very positive and encouraging outcome. Centres are once again warmly commended for their efforts.

Q23.

Recognising functional group isomerism in part (a) proved difficult for many candidates whereas testing for an aldehyde was generally done well in part (b). The free-radical substitution in part (d) produced a wide range of marks and only the best candidates scored full marks. The use of precise M_r values in part (e) was new and only 38% scored any marks.

Q24.

Correct equations were seen in parts (a) and (b), but balancing them was a problem for some. In part (a), some candidates encountered difficulty because they introduced water or oxygen on either side of the equation. The inclusion of H_2SO_4 (or H^+) on both sides of the equation in (a)(ii) was acceptable and gained full credit. Writing the formula of ethanol as C_2H_6O was penalised once only in this question. Many candidates missed the fact that the catalyst has to be *concentrated* sulphuric (or phosphoric) acid, although the alternative answer of aluminium oxide was credited. Many candidates scored full marks in part (b), with the catalyst causing most problems. In part (c)(i), while correct answers were seen,

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many candidates could not add up correctly the numbers of each type of atom or failed to include oxygen in their answers, losing both marks. In part (c)(ii), large numbers of candidates knew that unsaturated compounds contain a double bond, although some stated categorically that they do not! The test for unsaturation was less well known and caused confusion for some candidates who appeared to be relating an experiment in which the degree of unsaturation has been measured leading to an end point in which the colour of bromine is seen. Candidates need to appreciate that "clear" and "colourless" are not the same.

Q25.

Better candidates scored full marks in part (a) but others lost marks by giving incorrect colours and solubilities of the silver halides. The related silver chemistry examined in part (b) was not well known with some candidates stating incorrectly in (b)(iii) that sodium thiosulphate is used as a developer, a reduction process, rather than as a fixer in photography. Most candidates gave two correct structures in part(c) but correct observations made on the addition of aqueous silver nitrate were less common. Although, in (d)(i), the shape of the silver-containing complex ion, $[Ag(NH_3)_2]^+$, present in Tollens' reagent, was well known a surprisingly large number of candidates gave the ion a 2+ charge. Most candidates gave a correct structure for methanoic acid in (d)(ii) but few recognised that it contains an aldehyde group and is oxidised to CO_2 by Tollens' reagent. A mark was awarded in (d)(iii) for any possible carbon-containing species which could have been formed in the reaction but few scored this mark.

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