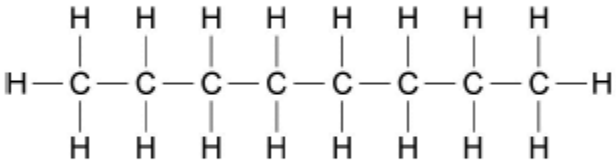
**1** Octane and isooctane are structural isomers with the molecular formula $C_8H_{18}$.
The displayed formulas and boiling points of octane and isooctane are shown in **Figure 1**.

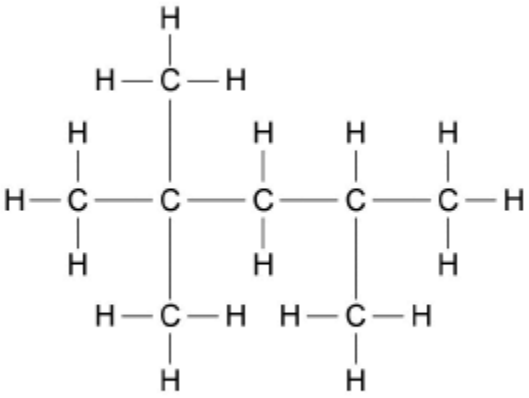
**Figure 1**

**Octane**



Boiling point: 125 °C

**Isooctane**



Boiling point: 99 °C

(a) Give the IUPAC name for isooctane.

.....

**(1)**

(b) Octane and isooctane can be separated in the laboratory.

Name a laboratory technique that could be used to separate isooctane from a mixture of octane and isooctane.

Outline how this technique separates isooctane from octane.

Name .....

Outline .....

.....

.....

.....

.....

**(3)**

(c) Isooctane is added to petrol to increase its octane rating. Some high-performance engines require fuel with a higher octane rating.

Write an equation for the complete combustion of isooctane. Use the molecular formula ($C_8H_{18}$) of isooctane in your equation.

.....

**(1)**

(d) Explain, in general terms, how a catalyst works.

.....

.....

.....

**(2)**

(e) Carbon monoxide is produced when incomplete combustion takes place in engines. Nitrogen monoxide is another pollutant produced in car engines.

Write an equation to show how these pollutants react together in a catalytic converter.

.....

**(1)**

(f) Platinum, palladium and rhodium are metals used inside catalytic converters. A very thin layer of the metals is used on a honeycomb ceramic support.

Explain why a thin layer is used in this way.

.....

.....

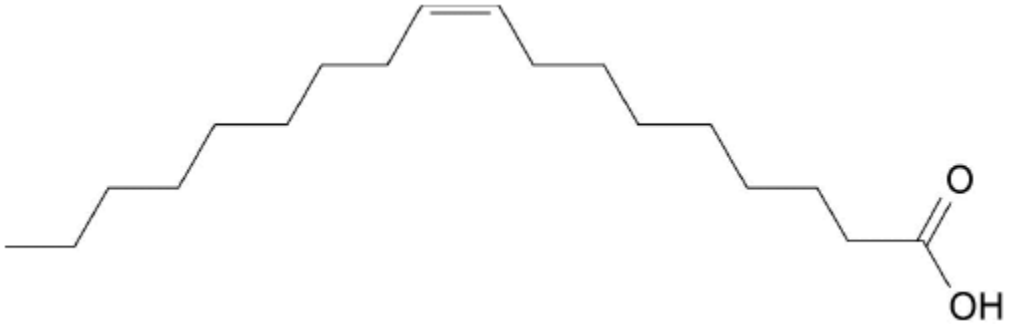
.....

.....

**(2)**

(g) Oleic acid ($C_{18}H_{34}O_2$) is a straight-chain fatty acid obtained from plant oils. Isooctane can be made from oleic acid. The skeletal formula of oleic acid is shown in **Figure 2**.

**Figure 2**




Identify a reagent that could be used in a chemical test to show that oleic acid is unsaturated.

State what would be observed in this test.

Reagent .....

Observation.....

.....

**(2)**
**(Total 12 marks)**

**2** Which of the following compounds would form an orange-red precipitate when heated with Fehling's solution?

**A** $CH_3CH_2CN$ ⬭

**B** $CH_3CH_2COOH$ ⬭

**C** $CH_3CHO$ ⬭

**D** $CH_3COCH_3$ ⬭

**(Total 1 mark)**

**3** The following pairs of compounds can be distinguished by simple test−tube reactions.

For each pair of compounds, give a reagent (or combination of reagents) that, when added separately to each compound, could be used to distinguish between them.
State what is observed in each case.

(a) Butan−2−ol and 2−methylpropan−2−ol

Reagent .....

Observation with butan−2−ol

.....

.....

Observation with 2−methylpropan−2−ol

.....

.....

**(3)**

(b) Propane and propene

Reagent .....

Observation with propane

.....

.....

Observation with propene

.....

.....

**(3)**

(c) Aqueous silver nitrate and aqueous sodium nitrate

Reagent .....

Observation with aqueous silver nitrate

.....

.....

Observation with aqueous sodium nitrate

.....

.....

**(3)**

(d) Aqueous magnesium chloride and aqueous barium chloride

Reagent .....

Observation with aqueous magnesium chloride

.....

.....

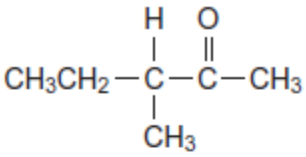
Observation with aqueous barium chloride

.....

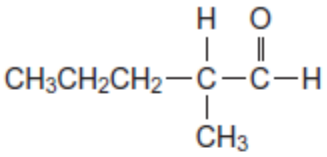
.....

**(3)**
**(Total 12 marks)**

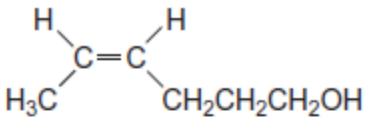
**4** The following five isomers, **P**, **Q**, **R**, **S** and **T**, were investigated using test-tube reactions and also using n.m.r. spectroscopy.



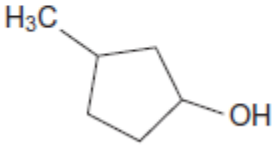

**P**



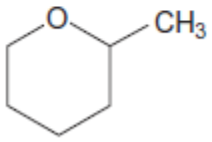

**Q**




**R**




**S**




**T**

(a) A simple test-tube reaction can be used to distinguish between isomers **P** and **S**.

Identify a reagent (or combination of reagents) you could use.
State what you would observe when both isomers are tested separately with this reagent or combination of reagents.

.....

.....

.....

.....

.....

**(3)**

(b) A simple test-tube reaction can be used to distinguish between isomer **Q** and all the other isomers.

Identify a reagent (or combination of reagents) you could use.
State what you would observe when **Q** is tested with this reagent or combination of reagents.

.....

.....

.....

.....

**(2)**

(c) State which **one** of the isomers, **P**, **Q**, **R**, **S** and **T**, has the least number of peaks in its $^{1}H$ n.m.r. spectrum.
Give the number of peaks for this isomer.

.....

.....

.....

**(2)**

(d) Write the **molecular** formula of the standard used in $^{13}C$ n.m.r. spectroscopy.
Give **two** reasons why this compound is used.

.....

.....

.....

.....

.....

**(3)**

(e) **Figure 1** and **Figure 2** show the $^{13}C$ n.m.r. spectra of two of the five isomers.

**Figure 1**

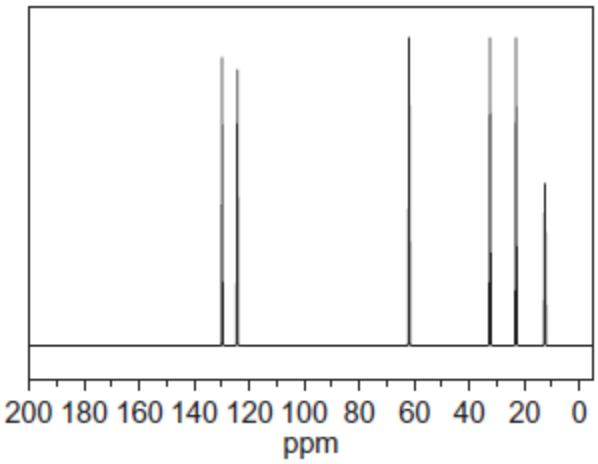
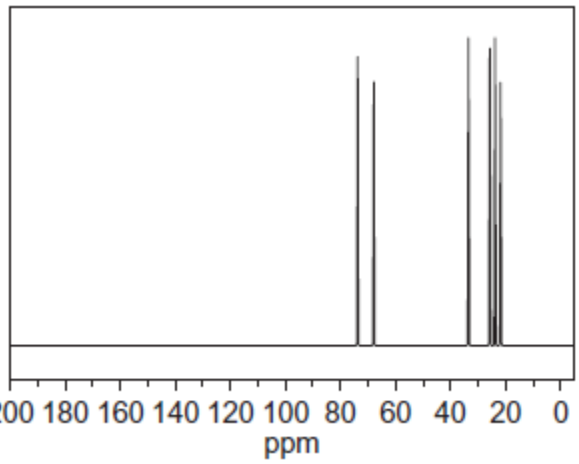
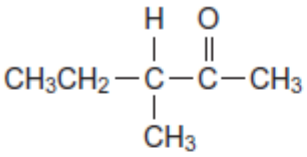


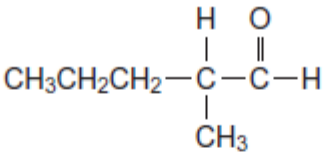

**Figure 2**



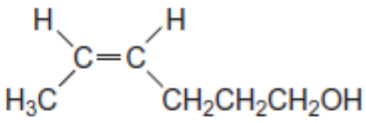

The structures of the five isomers are repeated to help you answer this question.



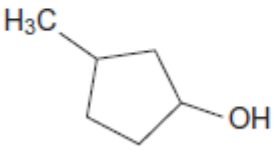
**P**



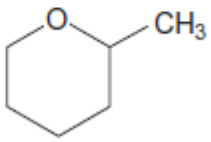
**Q**



**R**



**S**



**T**

State which isomer produces the spectrum in **Figure 1** and which isomer produces the spectrum in **Figure 2**.

Explain your answer.

You do not need to identify every peak in each spectrum.
Use **Table C** on the Data Sheet to answer the question.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

**(5)**

(f) **U** and **V** are other isomers of **P**, **Q**, **R**, **S** and **T**.
The $^{1}$H n.m.r. spectrum of **U** consists of two singlets.
**V** is a cyclic alcohol that exists as optical isomers.

Draw the structure of **U** and the structure of **V**.

**U** **V**

**(2)**
**(Total 17 marks)**

**5** The following table gives the names and structures of some structural isomers with the molecular formula $C_5H_{10}$.

| | Name of isomer | Structure |
|---|---|---|
| Isomer **1** | pent-2-ene | $CH_3CH = CHCH_2CH_3$ |
| Isomer **2** | cyclopentane |  |
| Isomer **3** | 3-methylbut-1-ene | $(CH_3)_2CHCH = CH_2$ |
| Isomer **4** | 2-methylbut-2-ene | $(CH_3)_2C = CHCH_3$ |
| Isomer **5** | 2-methylbut-1-ene | $H_2C = C(CH_3)CH_2CH_3$ |

(a) Isomer **1** exists as E and Z stereoisomers.

(i) State the meaning of the term **stereoisomers**.

.....

.....

.....

.....

.....

**(2)**

(ii) Draw the structure of the E stereoisomer of Isomer **1**.

**(1)**

(b) A chemical test can be used to distinguish between separate samples of Isomer **1** and Isomer **2**.

Identify a suitable reagent for the test.
State what you would observe with Isomer **1** and with Isomer **2**.

Reagent.....

Observation with Isomer **1**.....

.....

Observation with Isomer **2**.....

.....

**(3)**

(c) Use **Table A** on the Data Sheet when answering this question.
Isomer **3** and Isomer **4** have similar structures.

(i) State the infrared absorption range that shows that Isomer **3** and Isomer **4** contain the same functional group.

.....

.....

**(1)**

(ii) State **one** way that the infrared spectrum of Isomer 3 is different from the infrared spectrum of Isomer **4**.

.....

.....

.....

**(1)**

(d) Two alcohols are formed by the hydration of Isomer **4**.

Draw the **displayed formula** for the alcohol formed that is oxidised readily by acidified potassium dichromate(VI).

**(1)**

(e) Isomer **4** reacts with hydrogen bromide to give two structurally isomeric bromoalkanes.

(i) Name and outline a mechanism for the reaction of Isomer **4** with hydrogen bromide to give 2-bromo-2-methylbutane as the major product.

$$(CH_3)_2C = CHCH_3 + HBr \longrightarrow (CH_3)_2CBrCH_2CH_3$$

Name of mechanism.....

Mechanism

**(5)**

(ii) The minor product in this reaction mixture is 2-bromo-3-methylbutane.

Explain why this bromoalkane is formed as a minor product.

.....

.....

.....

.....

.....

**(2)**

(f) Name and outline a mechanism for the following reaction to form Isomer **5**. State the role of the hydroxide ion in this reaction.

$$(CH_3)_2CBrCH_2CH_3 + KOH \longrightarrow H_2C = C(CH_3)CH_2CH_3 + KBr + H_2O$$

Name of mechanism .....

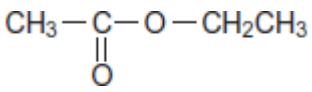
Mechanism

Role of hydroxide ion .....

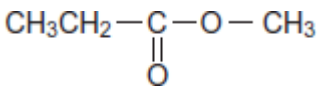
**(5)**

**(Total 21 marks)**

**6** (a) **Ester 1** and **Ester 2** were studied by $^{1}$H n.m.r. spectroscopy.

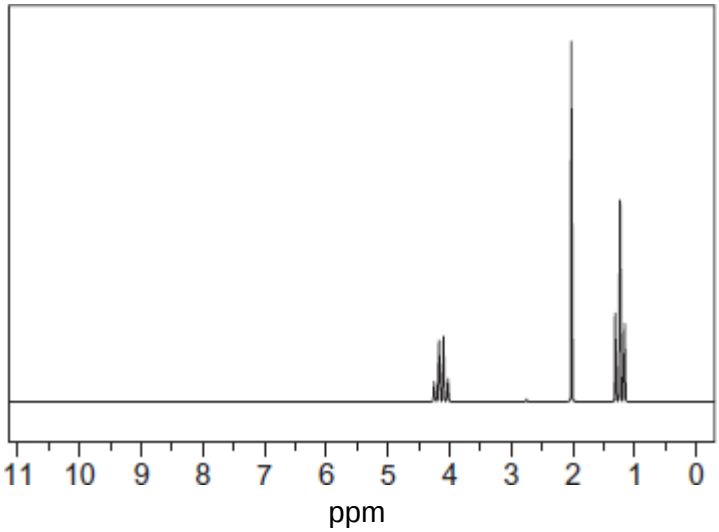


**Ester 1**



**Ester 2**

One of the two esters produced this spectrum.




Deduce which of the two esters produced the spectrum shown. In your answer, explain the position and splitting of the quartet peak at δ = 4.1 ppm in the spectrum.

Predict the δ value of the quartet peak in the spectrum of the other ester.

Use **Table B** on the Data Sheet.

.....

.....

.....

.....

.....

.....

.....

.....

**(4)**

(b) Cetrimide is used as an antiseptic.

$[CH_3(CH_2)_{15}N(CH_3)_3]^+ Br^-$

cetrimide

Name this type of compound.

Give the reagent that must be added to $CH_3(CH_2)15NH_2$ to make cetrimide and state the reaction conditions.

Name the type of mechanism involved in this reaction.

.....

.....

.....

.....

.....

.....

.....

.....

**(4)**

(c) Give a reagent that could be used in a test-tube reaction to distinguish between benzene and cyclohexene.
Describe what you would see when the reagent is added to each compound and the test tube is shaken.

.....

.....

.....

.....

.....

.....

.....

**(3)**
**(Total 11 marks)**

**7** Ethanoic acid, propyl ethanoate and propan-1-ol are all colourless liquids. Esters do **not** give a positive result with any of the usual tests for functional groups.

State how you could use chemical tests to show the presence of ethanoic acid and propan-1-ol in a mixture of the acid, the alcohol and the ester.

.....

.....

.....

.....

.....

.....

.....

.....

**(Total 4 marks)**

**8** The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair, give a suitable reagent that could be added separately to each compound to distinguish between them.
Describe what you would observe in each case.

(a) AgBr(s) and AgI(s)

Reagent .....

Observation with AgBr(s).....

.....

Observation with AgI(s) .....

.....

**(3)**

(b) HCl(aq) and $HNO_3$(aq)

Reagent .....

Observation with HCl(aq) .....

.....

Observation with $HNO_3$(aq) .....

.....

**(3)**

(c) Cyclohexane and cyclohexene

Reagent .....

Observation with cyclohexane .....

.....

Observation with cyclohexene .....

.....

**(3)**

(d) Butanal and butanone

Reagent .....

Observation with butanal .....

.....

Observation with butanone .....

.....

**(3)**
**(Total 12 marks)**

**9** (a) A chemist discovered four unlabelled bottles of liquid, each of which contained a different pure organic compound. The compounds were known to be propan-1-ol, propanal, propanoic acid and 1-chloropropane.

Describe four **different** test-tube reactions, one for each compound, that could be used to identify the four organic compounds.
Your answer should include the name of the organic compound, the reagent(s) used and the expected observation for each test.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

*(Extra space)* .....

.....

.....

.....

**(8)**

(b) A fifth bottle was discovered labelled propan-2-ol. The chemist showed, using infrared spectroscopy, that the propan-2-ol was contaminated with propanone.

The chemist separated the two compounds using column chromatography. The column contained silica gel, a polar stationary phase.

The contaminated propan-2-ol was dissolved in hexane and poured into the column. Pure hexane was added slowly to the top of the column. Samples of the eluent (the solution leaving the bottom of the column) were collected.

- Suggest the chemical process that would cause a sample of propan-2-ol to become contaminated with propanone.
- State how the infrared spectrum showed the presence of propanone.
- Suggest why propanone was present in samples of the eluent collected first (those with shorter retention times), whereas samples containing propan-2-ol were collected later.

.....

.....

.....

.....

.....

.....

.....

.....

.....

*(Extra space)* .....

.....

.....

.....

.....

.....

.....

.....

**(4)**
**(Total 12 marks)**

**10** The table shows the structures and names of three compounds with $M_r$ = 72.0

| Compound | Formula | Name |
|---|---|---|
| **1** | $CH_3CH_2CH_2CHO$ | butanal |
| **2** | $CH_3CH_2CH_2CH_2CH_3$ | pentane |
| **3** | $CH_3CH_2COCH_3$ | butanone |

(a) Explain why $M_r$ values, measured to five decimal places, cannot distinguish between compounds **1** and **3** but can distinguish between compounds **1** and **2**.

.....

.....

.....

.....

.....

**(2)**

(b) A simple chemical test, using either Fehling's solution or Tollens' reagent, can be used to distinguish between compound **1** and compound **3**.
Choose one of these two reagents and state what you would observe with each of compound **1** and compound **3**.

Chosen reagent .....

Observation with compound **1**.....

.....

Observation with compound **3**.....

.....

**(2)**
**(Total 4 marks)**

**11** A sample of an alcohol was thought to be contaminated with an alkene. Give a reagent that could be used to confirm the presence of an alkene. State what you would observe.

Reagent .....

Observation .....

**(Total 2 marks)**

**12** (a) Propanoic acid can be made from propan-1-ol by oxidation using acidified potassium dichromate(VI). Propanal is formed as an intermediate during this oxidation.

(i) State the colour of the chromium species after the potassium dichromate(VI) has reacted.

.....

**(1)**

(ii) Describe the experimental conditions and the practical method used to ensure that the acid is obtained in a high yield. Draw a diagram of the assembled apparatus you would use.

Conditions .....

.....

Apparatus

**(4)**

(iii) Describe the different experimental conditions necessary to produce propanal in high yield rather than propanoic acid.

.....

.....

**(2)**

(b) Propan-1-ol is a volatile, flammable liquid.
Give **one** safety precaution that should be used during the reaction to minimise this hazard.

.....

**(1)**

(c) A student followed the progress of the oxidation of propan-1-ol to propanoic acid by extracting the organic compounds from one sample of reaction mixture.

(i) Give a chemical reagent which would enable the student to confirm the presence of propanal in the extracted compounds.
State what you would observe when propanal reacts with this reagent.

Reagent .....

Observation .....

.....

**(2)**

(ii) Give a chemical reagent that would enable the student to confirm the presence of propanoic acid in the extracted compounds.
State what you would observe when propanoic acid reacts with this reagent.

Reagent .....

Observation .....

.....

**(2)**

(d) Predict which **one** of the compounds, propan-1-ol, propanal and propanoic acid will have the highest boiling point. Explain your answer.

Prediction .....

Explanation .....

.....

.....

.....

.....

**(3)**
**(Total 15 marks)**

**13** Samples of 1-chloropropane and ethanoyl chloride can be distinguished by the addition of an aqueous solution of silver nitrate.
State what you would observe with each sample.

Observation with 1-chloropropane

.....

.....

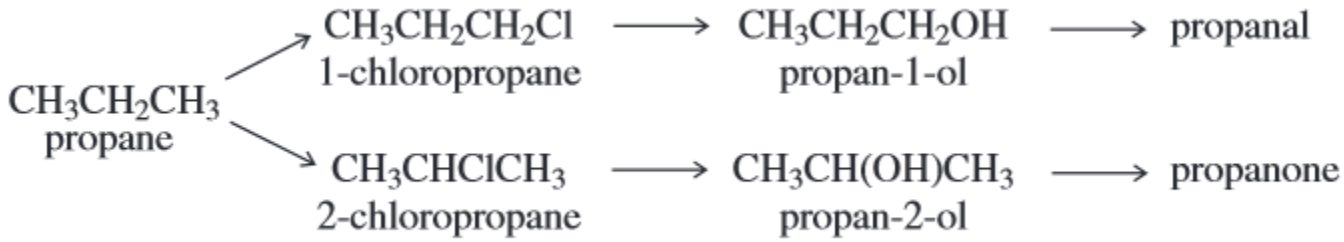
Observation with ethanoyl chloride.

.....

.....

**(Total 2 marks)**

**14** Consider the following scheme of reactions.




(a) State the type of structural isomerism shown by propanal and propanone.

.....

**(1)**

(b) A chemical test can be used to distinguish between separate samples of propanal and propanone.

Identify a suitable reagent for the test.
State what you would observe with propanal and with propanone.

Test reagent.....

Observation with propanal.....

Observation with propanone.....

**(3)**

(c) State the structural feature of propanal and propanone which can be identified from their infrared spectra by absorptions at approximately 1720 $cm^{-1}$.

.....

**(1)**

(d) The reaction of chlorine with propane is similar to the reaction of chlorine with methane.

(i) Name the type of mechanism in the reaction of chlorine with methane.

.....

**(1)**

(ii) Write an equation for each of the following steps in the mechanism for the reaction of chlorine with propane to form l-chloropropane ($CH_3CH_2CH_2Cl$).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step to form a molecule with the empirical formula $C_3H_7$

.....

**(4)**

(e) High resolution mass spectrometry of a sample of propane indicated that it was contaminated with traces of carbon dioxide.

Use the data in the table to show how precise $M_r$ values can be used to prove that thesample contains both of these gases.

| Atom | Precise relative atomic mass |
|---|---|
| $^{12}C$ | 12.00000 |
| $^{1}H$ | 1.00794 |
| $^{16}O$ | 15.99491 |

.....

.....

.....

**(2)**

**(Total 12 marks)**

**15** Many naturally-occurring organic compounds can be converted into other useful products.

(a) Glucose, $C_6H_{12}O_6$, can be fermented to make ethanol, which can then be dehydrated to make the unsaturated compound, ethane.

(i) Write an equation for the fermentation of glucose to form ethanol.

.....

(ii) Identify a catalyst for the dehydration of ethanol to form ethene. Write an equation for this reaction.

*Catalyst* .....

*Equation* .....

**(3)**

(b) Vegetable oils, which contain unsaturated compounds, are used to make margarine. Identify a catalyst and a reagent for converting a vegetable oil into margarine.

*Catalyst* .....

*Reagent* .....

**(2)**

(c) Oleic acid can be obtained from vegetable oils. Oleic acid is an example of an unsaturated compound.

$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$

oleic acid

(i) Deduce the molecular formula and the empirical formula of oleic acid.

*Molecular formula* .....

*Empirical formula* .....

(ii) State what is meant by the term *unsaturated*.

.....

(iii) Identify a reagent for a simple chemical test to show that oleic acid is unsaturated. State what you would observe when oleic acid reacts with this reagent.

*Reagent* ….....

*Observation with oleic acid* ……..

.....

**(5)**
**(Total 10 marks)**

**16** (a) (i) The addition of aqueous silver nitrate, followed by concentrated aqueous ammonia, can be used to distinguish between separate aqueous solutions of sodium bromide and sodium iodide.
Record what is observed in the table below.

| | The addition of $AgNO_3(aq)$ | followed by | the addition of concentrated $NH_3(aq)$ |
|---|---|---|---|
| Observation with NaBr(aq) | | | |
| Observation with NaI(aq) | | | |

(ii) Explain why it is not possible to distinguish between separate solutions of sodium nitrate and sodium fluoride by the addition of silver nitrate solution.

.....

**(5)**

(b) When aqueous sodium thiosulphate is added to solid silver bromide a reaction occurs and a colourless solution is formed.

(i) Identify the silver-containing species present in the colourless solution.

.....

(ii) Write an equation for this reaction.

.....

(iii) Give **one** use of this reaction.

.....

**(3)**

(c) Aqueous silver nitrate can be used to distinguish between chloroethanoic acid and ethanoyl chloride.

(i) Draw the structure of ethanoyl chloride. Predict what, if anything, you would observe when ethanoyl chloride is added to aqueous silver nitrate.

*Structure of ethanoyl chloride*

*Observation* .....

.....

(ii) Draw the structure of chloroethanoic acid. Predict what, if anything, you would observe when chloroethanoic acid is added to aqueous silver nitrate.

*Structure of chloroethanoic acid*

*Observation* .....

.....

**(4)**

(d) (i) Tollens' reagent is formed by the addition of aqueous ammonia to aqueous silver nitrate. Identify the silver-containing complex present in Tollens' reagent and state its shape.

*Silver-containing complex* .....

*Shape*…..

.....

(ii) Draw the structure of methanoic acid. By reference to this structure, suggest why a silver mirror is formed when this acid reacts with Tollens' reagent.

*Structure* .....

*Explanation*.....

.....

(iii) Deduce the identity of a carbon-containing species formed when methanoic acid reacts with Tollens' reagent.

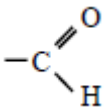
.....

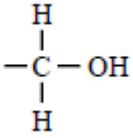
**(5)**
**(Total 17 marks)**

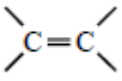
**17** Certain chemical tests were performed on the pain-relief drug ibuprofen. The results of these tests are given in the table below.

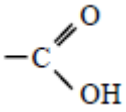
| **Test** | **Result** |
|---|---|
| Aqueous sodium carbonate | Effervescence |
| Bromine water | Remained orange |
| Acidified potassium dichromate(VI) and heat | Remained orange |
| Fehling's solution and heat | Remained blue |

Which one of the following functional groups do these results suggest that ibuprofen contains?

**A** 

**B** 

**C** 

**D** 

**(Total 1 mark)**

**1**

(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*

**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]**

**2** C

**[1]**

**3** (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"*

***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) <u>purple</u> 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** <u>concentrated</u> $H_2SO_4$

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

*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

***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"*

*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]**

**4** (a) Reagent

Acidified
$K_2Cr_2O_7$

Acidified
$KMnO_4$

$I_2$ / NaOH

Named
RCOOH with HCl or $H_2SO_4$

Named
RCOCl

*Allow names including potassium permanganate*

*Wrong or no reagent CE = 0*

**1**

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

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

**1**

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

*Allow no change or nvc but penalise <u>nothing or no observation</u>*

*If 2 reagents added sequentially or 2 different reagents used for P and S then CE = 0*

**1**

(b) Tollens'
silver mirror / solid

**1**

Fehling's / Benedicts
red ppt

**1**

(c) **G**

P

*If not P then no marks for clip*

**1**

5 OR five

**1**

(d) $C_4H_{12}Si$

*Must be molecular formula*

*Wrong substance CE = 0 for clip*

**1**

Any **two** from

- <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

M4

**1**

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

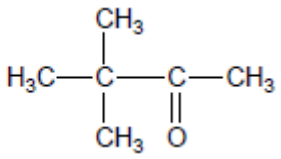
M5

**1**

(f)

**U**

$C_6H_{12}O_6$

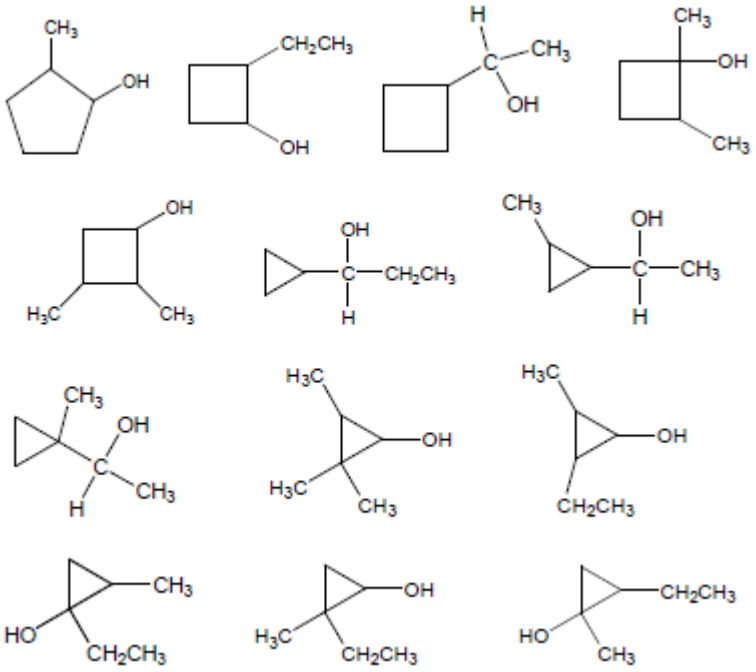


1

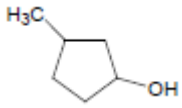
Answers include

**V**

$C_6H_{12}O_6$



*Not allow **S***



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

**[17]**

**5** (a) (i) **M1** (Compounds / molecules with) the same structural formula

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

**M2** with atoms / bonds / groups arranged differently in space

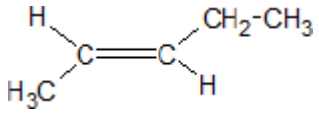
**OR** atoms / bonds / groups with different spatial arrangements / different orientation

*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) / <u>below 1500 $cm^{-1}$</u> will be different **or** its <u>fingerprinting</u> will be different

**OR**

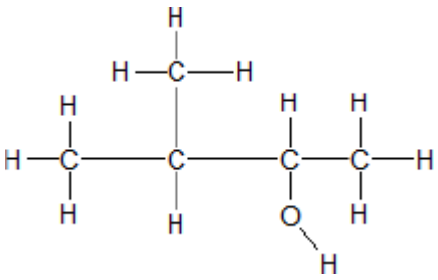
different <u>absorptions / peaks</u> are seen (in the region) below 1500 $cm^{-1}$ (or a specified region within the fingerprint range)

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

***QoL***

**1**

(d)



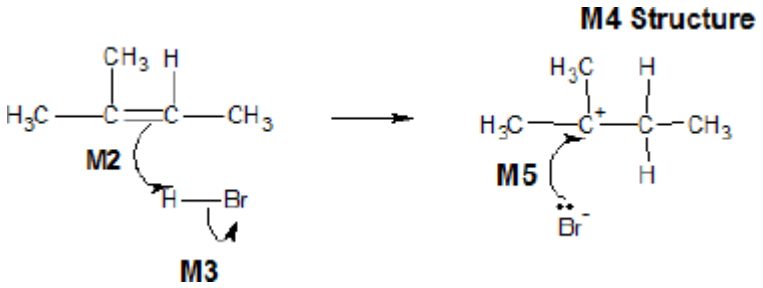
*All bonds must be drawn.*

*Ignore bond angles.*

**1**

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

***M1** both words needed.*




*Penalise one mark from <u>their</u> 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 carbocation structure but penalise **M4**.*

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

***<u>Max 2 of any 4 marks in the mechanism</u>** 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)

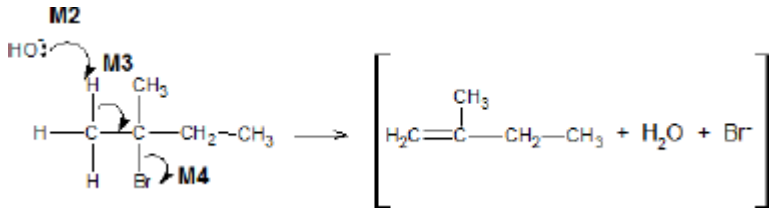
***M2** is of higher demand and requires the idea that the secondary carbocation is less stable or the tertiary carbocation is more stable. Reference to incorrect chemistry is penalised.*

*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 <u>their</u> total if half-headed arrows are used.*

**M2** must show an arrow from the <u>lone pair on oxygen</u> of a <u>negatively charged hydroxide</u> ion <u>to a correct</u> 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 <u>original molecule</u> **BUT penalise M2, M3 and M4 if nucleophilic substitution** shown

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

***<u>Max 2 of any 3 marks in the mechanism</u>** for wrong reactant <u>or</u> wrong organic product (if shown) <u>or</u> 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 <u>base</u> / <u>proton acceptor</u> / <u>electron pair donor</u> / <u>lone pair donor</u>

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

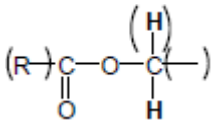
**5**

**[21]**

**6** (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 <u>adjacent / next to / attached to $CH_3$</u>

**1**

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

**1**

(b) M1 <u>Quaternary</u> (alkyl) <u>ammonium salt / bromide</u>

**1**

M2 $CH_3Br$ or bromomethane

*Penalise contradictory formula and name.*

**1**

M3 Excess ( $CH_3Br$ or bromomethane)

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

**1**

M4 Nucleophilic substitution

*Can only score M3 if reagent correct.*

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

**1**

(c)

| | Bromine<br><br>(penalise Br but mark on) | Acidified $KMnO_4$<br><br>(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]**

**7** 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]**

**8** (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 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 white precipitate or white solid / white suspension

*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".*
*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 silver mirror

***OR*** black solid / precipitate (Ignore silver precipitate)

M3 (stays) colourless 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".*

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]**

**9** (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**

(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

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]**

**10** (a) **For 2 marks at least <u>one correct reference either to *M*<sub>r</sub></u> or <u>value to 5 decimal places required</u>**

***QoL*** *(associated with the bold statement here)*

**M1** Compounds <u>1 and 3</u> (butanal and butanone) have the same $M_r$ (to 5dp) <u>because</u> **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 <u>same</u> number of atoms of the same / each element
- are <u>both</u> $C_4H_8O$
- have the <u>same molecular formula</u>

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

**M2** Compound <u>2</u> (pentane) has a different $M_r$ (to 5dp) <u>because</u> **either**

- it has <u>different</u> numbers of atoms of different elements
- is $C_5H_{12}$ / <u>only contains</u> C and H
- <u>different molecular formula</u>
- 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"*

**2**

**[4]**

**11** 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]**

**12** (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**

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]**

**13**

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]**

**14**

(a) Functional group (isomerism)

1

(b)

| | |
|---|---|
| **M1** Tollens' (reagent)<br>(*Credit ammoniacal silver nitrate* **OR** *a description of making Tollens'*)<br>(*Ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3*) | **M1** Fehling's (solution) or Benedict's solution<br>(*Ignore $Cu^{2+}(aq)$ or $CuSO_4$ on their own, but mark on to M2 and M3*) |
| **M2** silver mirror<br>**OR**<br>black solid/precipitate<br>*(NOT silver precipitate)* | **M2** Red solid/precipitate<br>(*Credit orange or brown solid*) |
| **M3** (stays) colourless<br>or no change or no reaction | **M3** (stays) blue<br>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-) radical substitution 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 the last carbon.*

**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**

(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]**

**15** (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 $CH_2{\cdot}CH_2$ 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

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]**

**16** (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**

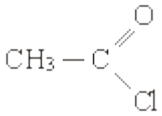
(ii) equation: $AgI + 2S_2O_3^{2-} \rightarrow [Ag(S_2O_3)_2]^{3-} + I^-$

**1**

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

**1**

(c) (i) Structure

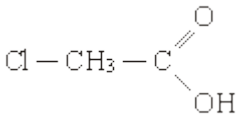


**1**

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

**1**

(ii) Structure:



**1**

Observation: No immediate precipiate or reaction

OR

white precipitate formed very slowly;

**1**

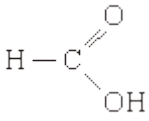
(d) (i) Silver-containing complex: $[Ag(NH_3)_2]^+$;

**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 $(NH_2)_2$ CO or $(NH_4)_2$ $CO_3$

OR

$HCOONH_4$ ;

1

**[17]**

**17** D

**[1]**