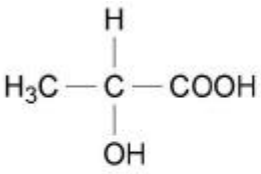
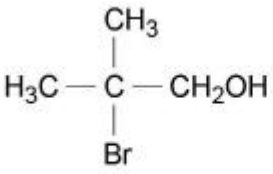
Q10.

Test-tube reactions can be used to identify the functional groups in organic molecules.

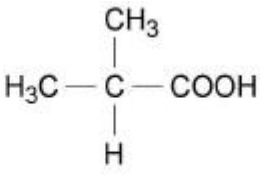
You are provided with samples of each of the four compounds.



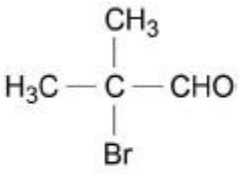
K



L



M



N

Describe how you could distinguish between all four compounds using the minimum number of tests on each compound.

You should describe what would be observed in each test.

_____

_____

_____

_____

_____

_____

_____

_____

(Total 6 marks)

Q11.

A student was given unlabelled samples of pentan-1-ol, pent-1-ene, pentanoic acid and pentanal.

(a) Name the reagent(s) that the student could use to identify the sample that was pent-1-ene. Describe the observation(s) that the student would make to confirm this.

Reagent(s) _____

_____

Observation(s) _____

(2)

(b) Name the reagent(s) that the student could use to identify the sample that was pentanoic acid.

Describe the observation(s) that the student would make to confirm this.

Reagent(s) _____

_____

Observation(s) _____

(2)

(c) Name the reagent(s) that the student could use to identify the sample that was pentanal.

Describe the observation(s) that the student would make to confirm this.

Reagent(s) _____

_____

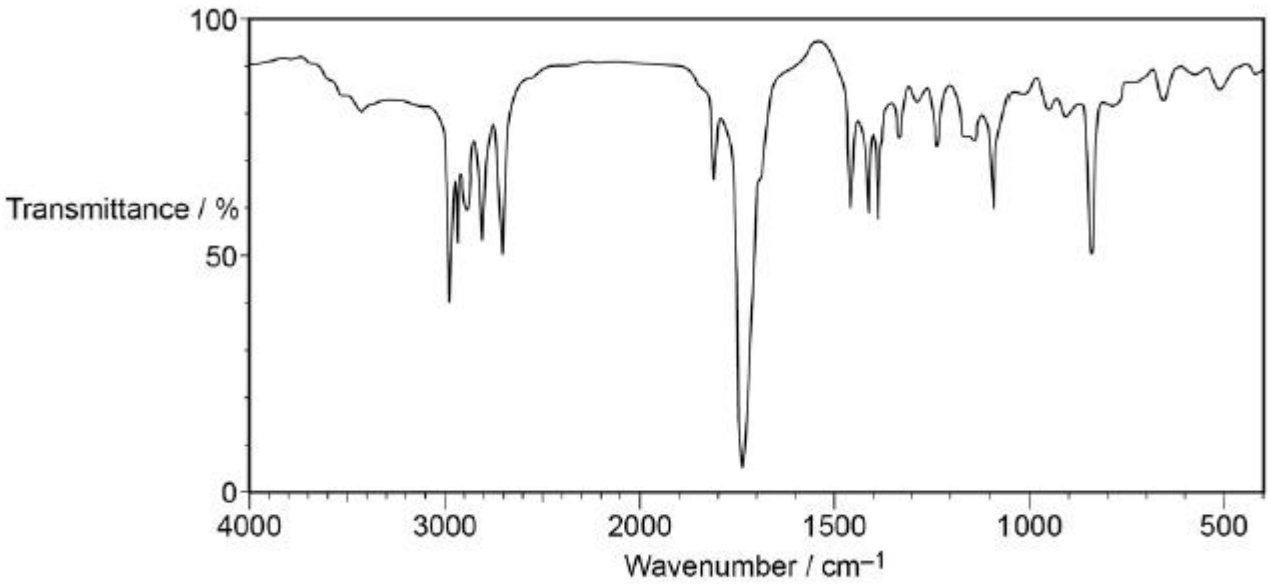
Observation(s) _____

_____

_____

(2)

(d) The student deduced that the spectrum in the image below was that of pentanal.



Justify this deduction and suggest why this spectrum **cannot** be that of pentan-1-ol, pentanoic acid or pent-1-ene.

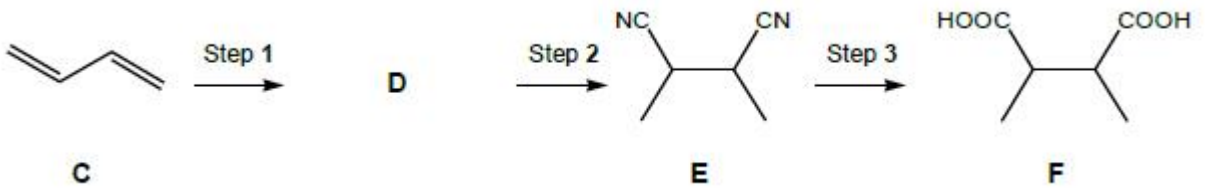
(4)

(Total 10 marks)

Q12.

Chemists design synthetic routes to convert one organic compound into another.

Buta-1,3-diene, **C**, is converted into compound **F** as shown in the diagram below.



(a) State the IUPAC name of compound **F**.

_____

(1)

(b) Deduce the structure of compound **D**.

For each of the conversions in steps **1** and **2**, suggest a reagent for the conversion and name the mechanism.

Suggest the type of reaction occurring in step **3**.

Structure of **D**

Step **1** _____

_____

_____

_____

_____

Step **2** _____

_____

_____

_____

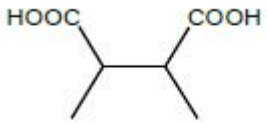
_____

Type of reaction in Step **3** _____

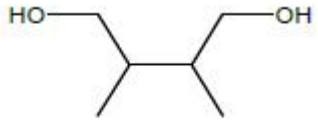
_____

(6)

(c) Compound **F** can also be made from compound **G**.



F



G

State a reagent (or combination of reagents) that can be used in a test-tube reaction to distinguish between F and G.

Describe what you would observe when the reagent is added to each compound and the test tube is shaken.

Reagent(s) _____

_____

Observation with **F** _____

_____

_____

Observation with **G** _____

_____

_____

(3)

(d) Compounds **F** and **G** react to form a polymer.

Draw the repeating unit of the polymer.

(2)

(e) In an experiment, 0.930 kg of purified **F** were obtained from 1.11 dm^3 of **G** (density 1.04 g cm^{-3}).

Calculate the percentage yield.

Give your answer to the appropriate number of significant figures.

Percentage yield _____ %

(4)

(f) One reason for a yield of less than 100% in part **(e)** is that **G** reacts to form a number of other compounds.

The other compounds are all liquids at room temperature.

Name the technique that should be used to separate and collect each of these other compounds from the reaction mixture.

Include in your answer a description of the apparatus.

Your description of the apparatus can be either a description in words or a labelled sketch.

Name of technique _____

Apparatus

(4)

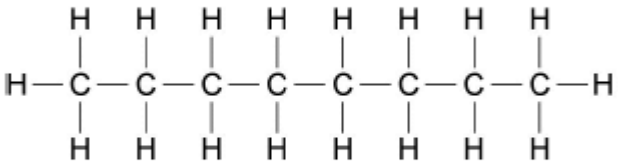
(Total 20 marks)

Q13.

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**.

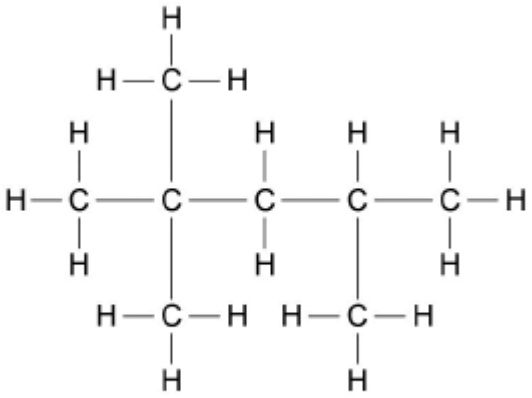
Figure 1

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.

_____

_____

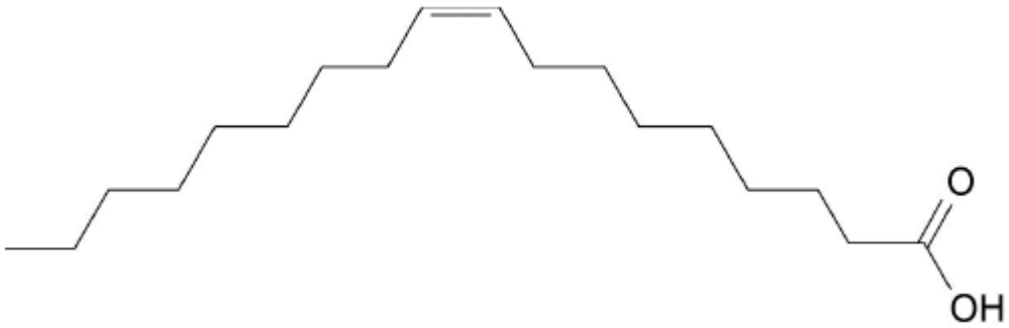
_____

_____

(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)

Q14.

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)

Q15.

Compounds **A**, **B**, **C** and **D** are isomers with the molecular formula $C_4H_{10}O$
They all have a broad absorption in their infrared spectra in the range 3230–3550 cm^{-1}.

(a) Use **Table A on the data sheet** to identify the bond and the functional group present responsible for this absorption.

_____

(1)

(b) Compounds **A** and **B** are both straight-chain compounds.
A can be oxidised to form **P**.
B can be oxidised to form **Q**.
P and **Q** are isomers with molecular formula C_4H_8O

Tollens' reagent and Fehling's solution can be used to distinguish between isomers **P** and **Q**. The results shown in the table are obtained.

Compound	Observation with Tollens' reagent	Observation with Fehling's solution
P	No visible change	No visible change
Q	Silver mirror formed	Brick-red precipitate formed

Use the information about compounds **P** and **Q** to identify compounds **A** and **B**.
Explain your answer with reference to the functional groups in **P** and **Q**.

Identity of **A** _____

Identity of **B** _____

Explanation _____

_____

_____

_____

(3)

(c) Isomer **C** is resistant to oxidation.
Isomer **C** reacts to form compound **R** that has an absorption in its infrared spectrum in the range 1620–1680 cm^{-1}.

State the bond that causes the absorption in the range 1620–1680 $^{-1}$.

Give the displayed formula of isomer **C**.

Identify the reagent and give **one** reaction condition needed to convert **C** into **R**.

Bond _____

Displayed formula of **C**

Reagent _____

Condition _____

(4)

(d) Compound **D** is a branched-chain isomer that can be oxidised to form compounds **S** and **T**.

(i) Compound **S** is obtained by distilling it off as it forms during the oxidation.
Compound **T** is formed when the oxidation takes place under reflux.

Identify the functional groups in **S** and **T**.

Explain, with reference to intermolecular forces, why it is possible to obtain compound **S** but not **T** from the reaction mixture by distilling off **S** as soon as it forms.

_____

_____

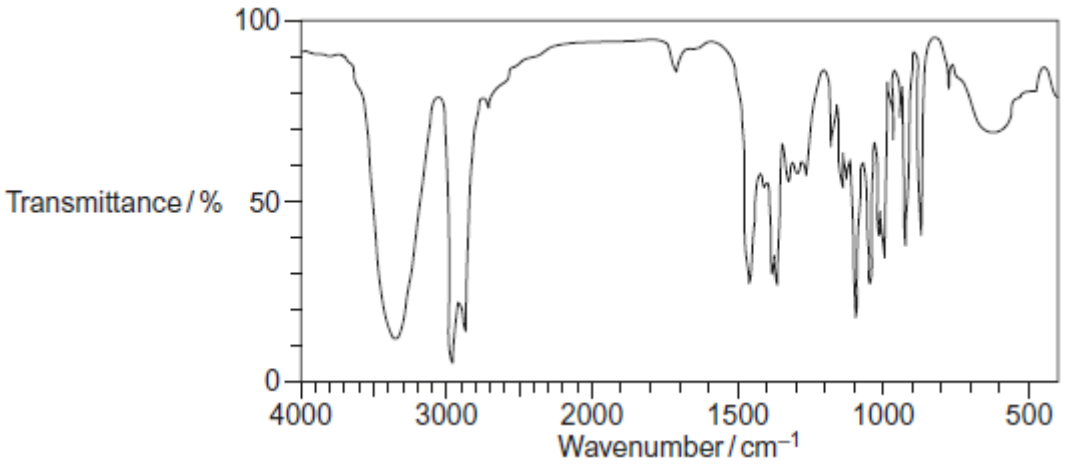
_____

_____

_____

(3)

(ii) A student claims to have oxidised compound **D**.
The infrared spectrum of the product obtained by the student is shown.



Suggest two ways in which the spectrum shows that compound **D** has **not** been oxidised.

_____

_____

_____

_____

_____

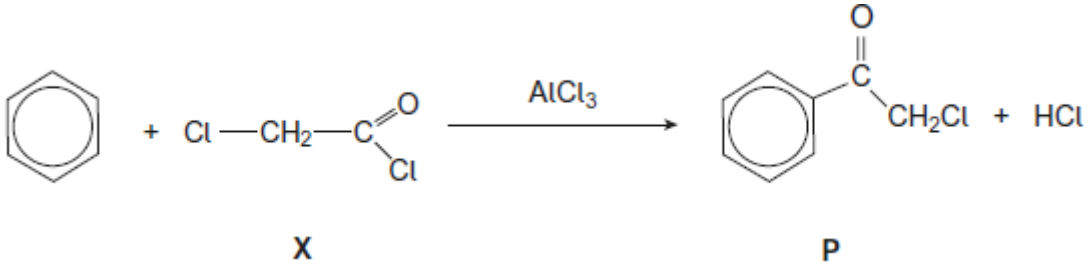
(2)

(Total 13 marks)

Q16.

Compound **X** ($ClCH_2COCl$) is used as a reagent in organic synthesis.

(a) One important reaction of **X** is in the preparation of compound **P** as shown.



X **P**

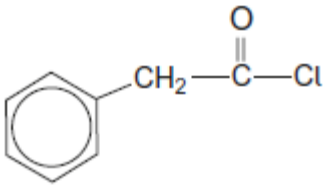
(i) Draw the structure of the electrophile formed by the reaction of **X** with $AlCl_3$.

(1)

(ii) Outline the mechanism for the reaction of the electrophile from part **(a)(i)** with benzene in the preparation of **P**.

(3)

(b) Compound **Q** is an alternative product that could be formed when **X** reacts with benzene.



Q

Describe how you could distinguish between **P** and **Q** by a test-tube reaction.
Give the reagent used and the observation with each compound.

Reagent _____

Observation with **P** _____

Observation with **Q** _____

(3)

(c) **X** is also used to make the compound $HOCH_2COOH$. This compound is polymerised to form the polymer known as PGA. PGA is used in surgical sutures (stitches).

(i) Draw the repeating unit of PGA.

(1)

(ii) Production of PGA occurs via a cyclic compound. Two $HOCH_2COOH$ molecules react together to form the cyclic compound and two molecules of water.

Draw the structure of this cyclic compound.

(1)

(d) Poly(propene) is also used in surgical sutures.

(i) Draw the repeating unit of poly(propene).

(1)

(ii) Suggest an advantage of surgical sutures made from PGA rather than from poly(propene).
Explain your answer.

_____

_____

_____

_____

(2)

(Total 12 marks)

Mark Scheme

Q10.

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

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

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

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

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

Indicative chemistry content

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

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

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

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

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

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

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

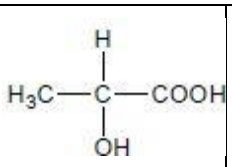
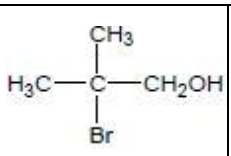
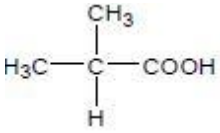
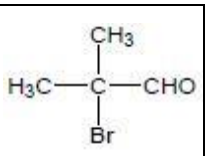
-Br
- j) Silver nitrate
- k) cream ppt

l) L and/or N but not K and/or M

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

Alternative tests

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

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

Q11.

(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 named indicator (e.g. Universal Indicator)

1

Propanoic acid will produce effervescence / bubbles

Propanoic acid would turn Universal Indicator red

1

(c) Tollen's reagent

1

(Colourless solution to) silver mirror

1

OR

Fehling's solution

(Blue solution to) brick red precipitate

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

1

No 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]

Q12.

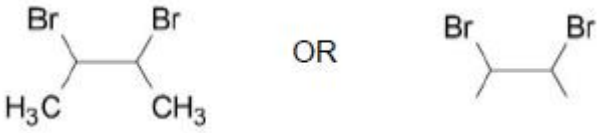
(a) 2,3-dimethylbutane(-1,4-)dioic acid

Penalise other numbers.

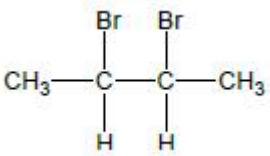
Ignore hyphens, commas, spaces.

1

(b)



Allow displayed formula



1

Step 1:

HBr

1

Electrophilic addition

1

Step 2:

KCN

Not HCN, not KCN with acid.

1

Nucleophilic substitution

1

Step 3:

Hydrolysis

1

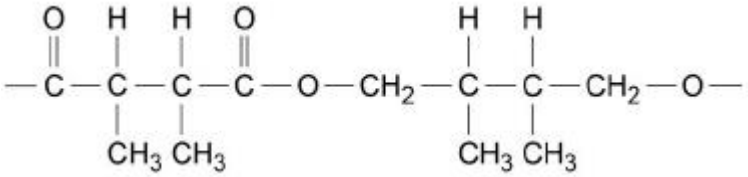
(c)

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

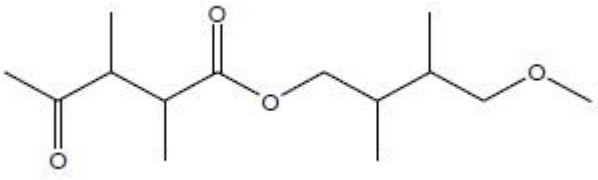
$K_2Cr_2O_7$ & H_2SO_4 (allow acidified)	**Mg**	**Na_2CO_3 or $NaHCO_3$**
F: no visible change	**F:** effervescence	**F:** effervescence
G: orange to green	**G:** no visible change	**G:** no visible change

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

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(%)

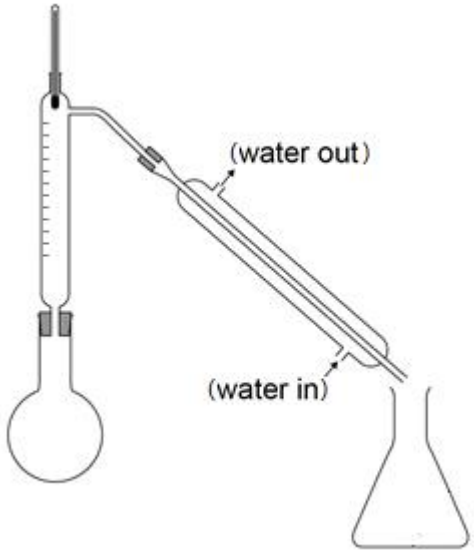
OR

% 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

Apparatus for fractional distillation must clearly work with fractionating column.

1

Fractionating column and thermometer.

1

Condenser / water jacket.

Ignore heat source.

1

[20]

Q13.

(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 <u>condenses / liquefies</u> and <u>collected</u>

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 = conc sulfuric acid, M2 = brown

M1 = iodine, M2 = colourless

[12]

Q14.

C

[1]

Q15.

(a) OH AND alcohol

***IGNORE** hydroxy(l)*

1

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

If formulae given then must be unambiguous

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

1

B = butan-1-ol / $CH_3CH_2CH_2CH_2OH$

1

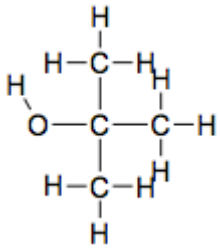
Product from **A / P** is a ketone
AND
Product from **B / Q** is an aldehyde

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 between molecules/IMFs 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

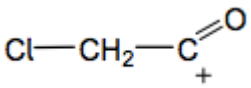
Does not contain peak at 1680−1750 cm-1 due to C=O

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

Any 2

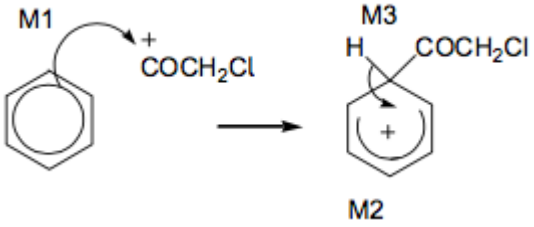
[13]

Q16.

(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
No observation

1

Q

Steamy /misty/ white fumes

White precipitate (immediately formed)

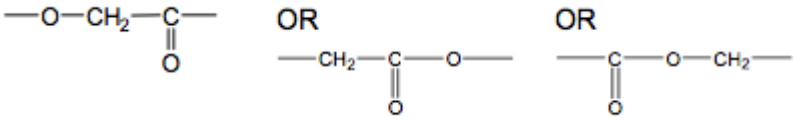
White precipitate (immediately formed)

Indicator turns to correct acid colour

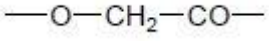
Fruity or sweet smell or misty fumes
Fizzing or effervescence (not just gas produced)
White smoke

1

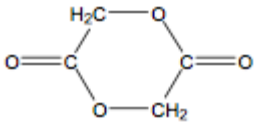
(c) (i)



One unit only
Must have trailing bonds
Ignore n and brackets

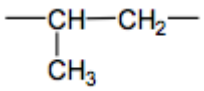
allow 

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

1

[12]