AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.3.1 INTRODUCTION TO ORGANIC CHEMISTRY

SCORE	PERCENTAGE
/280	%

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Q1.

M1 C:H = 7.3 : 12.2 seen

*Extended response: **M1** is for working of some sort leading to the formulae.*

*If C_3H_5 and C_6H_{10} are both shown but it is not indicated which formula is which; or the formulas are stated the wrong way round, then allow 1 mark for **M2** and **M3** combined; if both correct formulas are given with only one stated correctly to be the empirical/molecular formula, then allow **M2** and **M3**.*

1

M2 (converting C:H 7.3 : 12.2 to 3:5)
to give empirical formula = C_3H_5

1

M3 molecular formula = C_6H_{10}

1

M4, 5 two possible structures of C_6H_{10} (in any structural form)
cyclic compounds with 6/5/4/3-membered C ring with one double bond, e.g.



or any dienes with 6 C atoms,

or a molecule with a triple bond

***M4** and M5 ignore names given in addition to structures*

*Credit **M4** and M5 for correct names if no structures drawn*

*Apply list principle to structures in **M4** and **M5***

2

M6 (electrophilic) addition

1

Alternative route to C_6H_{10} that could gain credit
***M1** 82/12 gives/suggests 6 C atoms*
***M2** molecular formula = C_6H_{10}*
***M3** empirical formula = C_3H_5*

Alternative route to C_6H_{10} that could gain credit
***M1** 82 × 0.878 = 72, (72/12) = 6 C atoms*
***M2** molecular formula = C_6H_{10}*
***M3** empirical formula = C_3H_5*

***M6** penalise nucleophilic addition; ignore bromination*

[6]

Q2.

C

[1]

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Q3.

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

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

Ignore Van der Waal forces

M1

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

Ignore reference to energy

M2

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

M3 only awarded following correct M1 OR M2

Allow converse for M3

M3

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

Allow temperature in range 49-96 inclusive

Allow description of cooling the vessel

M1

Cool the distillate / collecting vessel

Ignore reference to oxidising agents

Penalise lid / sealed container

M2

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

Incorrect chemical CE=0

Allow formula (mark on for incorrect formula)

Allow blue litmus or correct named indicator

M1

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

Blue litmus turns red confirms acid present or converse

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

M2

(d) (Temperature difference = 15.1 °C)

If 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

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(allow range -953 to -954)

BEWARE if they miss conversion to kJ and also miss conversion to g, they get answer = - 953 which scores 1
+953 can score M1 and M2
Allow -950 or -960 for rounding to 2sf

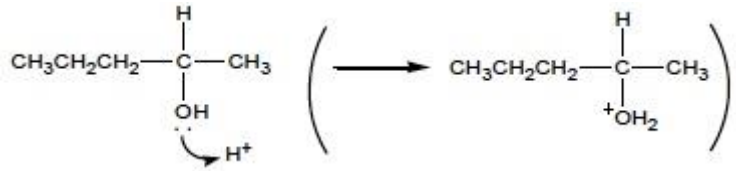
M3

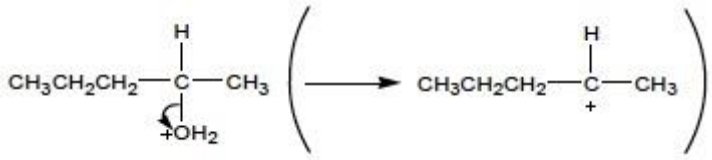
(e) Elimination

Penalise base elimination

M1

Mechanism : Either (E1)



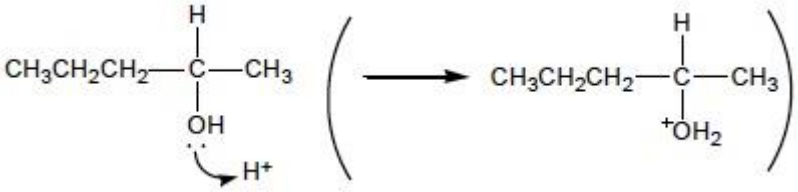




M2 for protonation of alcohol, i.e. lp plus arrow to H^+ or to H of H–O– in H_2SO_4 and from H-O bond to O
M3 for protonated alcohol plus arrow showing loss of water
M4 for arrow showing loss of H^+
From correct carbocation (E1)
wrong alcohol used / alkene formed loses M4

3

OR (E2)





M2 for protonation of alcohol, i.e. lp plus arrow to H^+ or to H of H–O– in H_2SO_4 and from H-O bond to O

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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.

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

M2

[16]

Q4.

B

[1]

Q5.

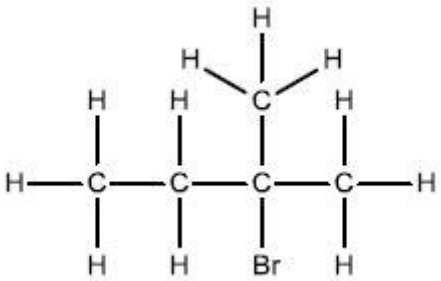
(a)



Must be a skeletal structure

1

(b)



Must be a displayed structure

1

(c) Any correct structural representation of alkene with 4 C atoms, either:

but-1-ene or
but-2-ene or
methylpropene

allow butadiene

1

[3]

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Q6.

B

[1]

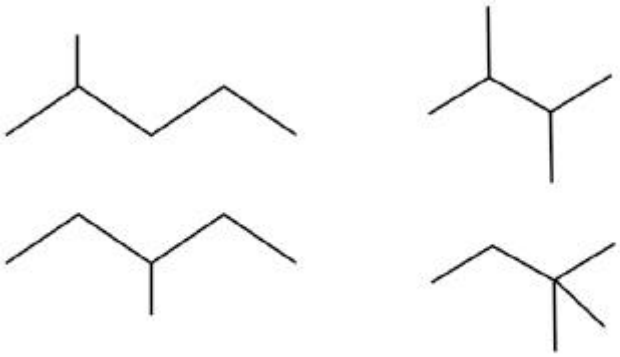
Q7.

D

[1]

Q8.

(a) Any two of these isomers



1

(b) Chain isomerism

*Mark consequential to part **(a)***

1

(c) $C_6H_{14} + 6.5O_2 \longrightarrow 6CO + 7H_2O$

M1 Product is CO or C

M2 Balanced equation

1

OR

$C_6H_{14} + 3.5O_2$ 6C + $7H_2O$

Allow equations containing CO_2 as long as either C, CO or both are also present

1

(d) Less energy given out by the fuel / engine is less powerful / less efficient / needs to burn more fuel to get the same energy / increased costs due to need to use more fuel

*Do **not** allow answers linked to CO poisoning or incomplete combustion*

1

[5]

Q9.

C

[1]

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Q10.

A

[1]

Q11.

C

[1]

Q12.

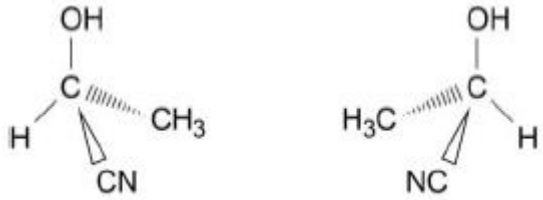
(a) 3

1

(b) Chain.

1

(c)



One 3D enantiomer.

1

Second enantiomer correctly drawn as 3D mirror image of first.

1

(d) Plane-polarised light.

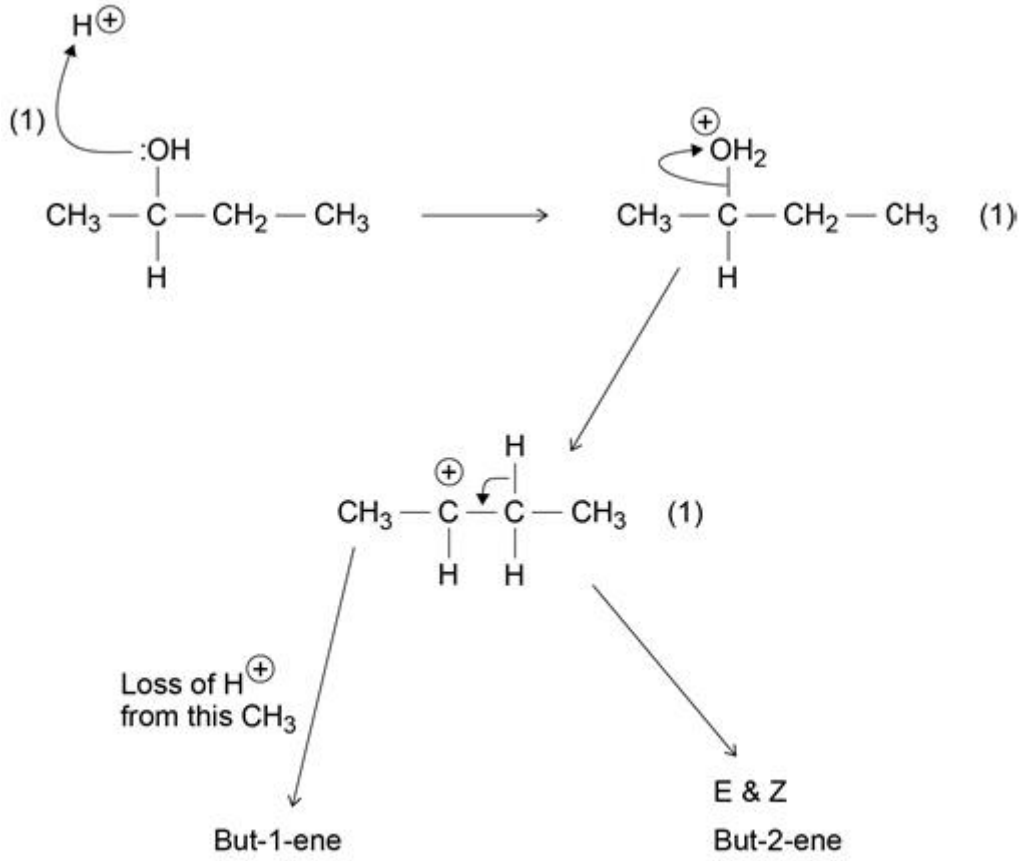
1

Rotated in opposite directions.

1

(e) Elimination

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Extended response question

M1

Mechanism (3 marks)

M2 arrow from lone pair on O to H^+

M3 1st intermediate **and** arrow from C–O^+H_2 bond to O (with loss of H_2O)

M4 2nd intermediate (carbocation) **and** arrow from C–H bond to C–C (with loss of H^+) to form C=C

M3 and M4 can be scored in one step (see alternative mechanism below).

If carbocation incorrect then answer cannot score maximum marks.

Explanation of formation of 3 alkenes

M5 loss of H^+ from C (in carbocation) adjacent to $^+$C (to which −OH was attached)

M6 From **^{1}C**–^{2}C+–^{3}C–^{4}C leads to but-1-ene

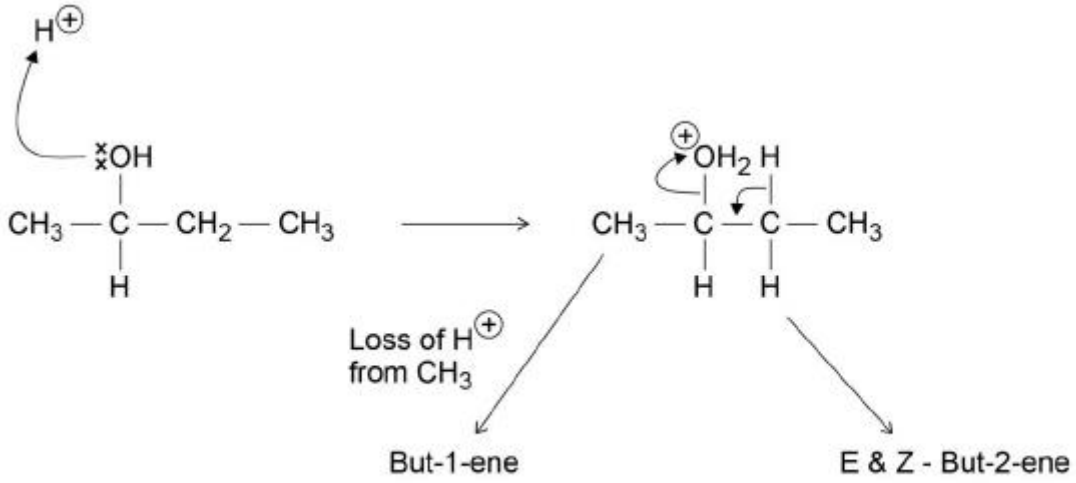
M7 From ^{1}C–^{2}C$^+$–**^{3}C**–^{4}C leads to but-2-ene

M8 But-2-ene formed as mixture of *E*-*Z* isomers

8

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Alternative mechanism



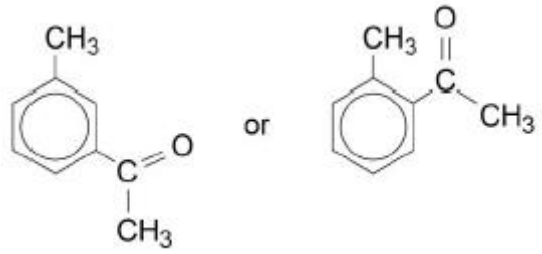
[14]

Q13.

(a) $C_9H_{10}O$

1

(b)



1

Position (isomerism).

Allow Positional.

1

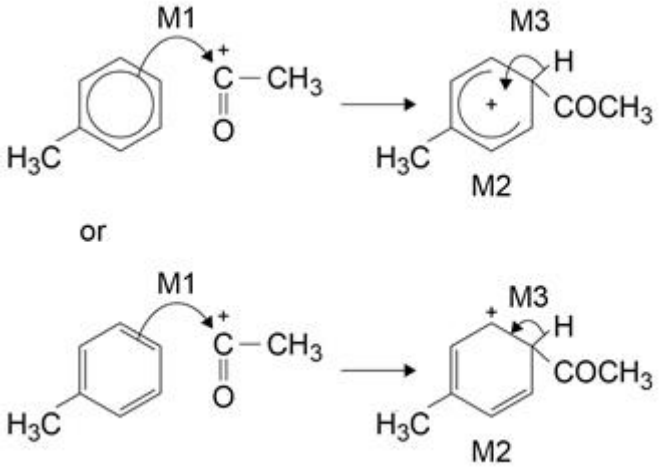
(c) Electrophilic substitution

1

$CH_3COCl + AlCl_3 \longrightarrow CH_3CO^+ + AlCl_4^-$

1

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Mechanism 3 marks:

M1 *arrow from circle or within it to C of CH_3C^+O (+ must be on C of CH_3C^+O).*

1

M2 *for Intermediate (**must** be 4-isomer)*
CH_3CO must be correctly positioned and bonded to gain M2
horseshoe must not extend beyond C2 to C6 but can be smaller
+ not too close to C1.

1

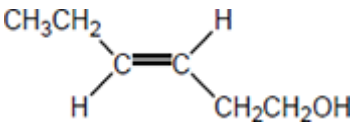
M3 *arrow into hexagon unless Kekule*
Loss of H^+ (allow from incorrect isomer)
Allow M3 arrow independent of M2 structure
Ignore base removing H in M3.
Allow Kekule structures (which must be correct).

1

[8]

Q14.

(a)



1

(b)



1

(c) **Stage 1**: consider the groups joined to right hand carbon of the C=C bond

Extended response

Maximum of 5 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

Consider the atomic number of the atoms attached

M1 can be scored in stage 1 or stage 2

1

C has a higher atomic number than H, so CH_2OH takes priority

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1

Stage 2: consider the groups joined to LH carbon of the C=C bond

Both groups contain C atoms, so consider atoms one bond further away

1

C, (H and H) from ethyl group has higher atomic number than H, (H and H) from methyl group, so ethyl takes priority

1

Stage 3: conclusion

The highest priority groups, ethyl and CH_2OH are on same side of the C=C bond so the isomer is Z

Allow M5 for correct ECF conclusion using either or both wrong priorities deduced in stages 1 and 2

1

The rest of the IUPAC name is 3-methylpent-2-en-1-ol

1

(d) Moles of maleic acid = 10.0 / 116.0 = 8.62×10^{-2}

AND mass of organic product expected = $(8.62 \times 10^{-2}) \times 98.0 = 8.45$ g

Or moles of organic product formed = 6.53 / 98.0 = 6.66×10^{-2}

1

% yield = 100 × 6.53 / 8.45

OR = $100 \times (6.66 \times 10^{-2}) / (8.62 \times 10^{-2})$

= 77.294 = 77.3%

AND statement that the student was NOT correct

1

[10]

Q15.

(a) (Compounds with the) same molecular formula but different structural / displayed / skeletal formula

1

(b) (basic) elimination

1

Mechanism points:

Correct arrow from lone pair on $:OH^-$ to H on C adjacent to C–Br

1

Correct arrow from C–H bond to C–C

1

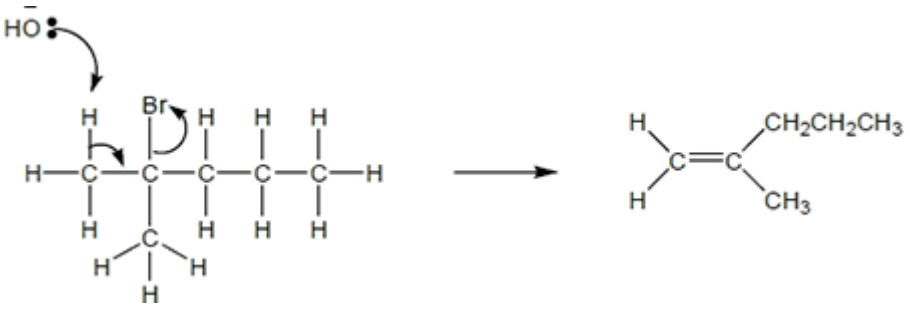
Correct arrow from C–Br bond to Br

1

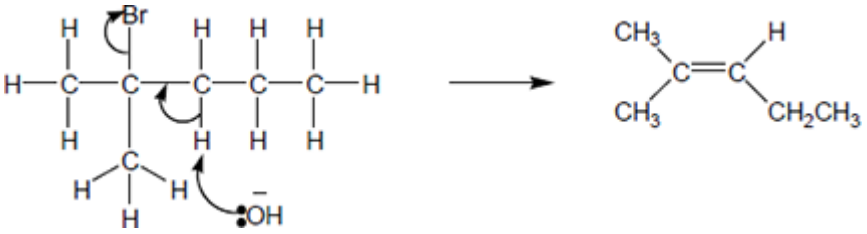
Structure of chosen product

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1



OR

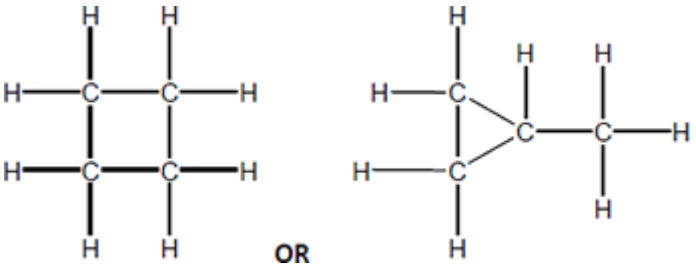


[6]

Q16.

(a) Alkenes

1



OR

Correctly drawn molecule of cyclobutane or methyl cyclopropane, need not be displayed formula

1

(b) C_6H_{14} (or correct alkane structure with 6 carbons)

Allow hexane or any other correctly named alkane with 6 carbons

1

(c) Poly(but-2-ene)

1

(d) High pressure

Allow pressure □ MPa

Mention of catalyst loses the mark

1

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

Level 3

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All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer communicates the whole process coherently and shows a logical progression from stage 1 and stage 2 (in either order) to stage 3.

5–6 marks

Level 2

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression. Some steps in each stage may be out of order and incomplete.

3–4 marks

Level 1

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

1–2 marks

Level 0

Insufficient correct chemistry to gain a mark.

0 marks

Indicative chemistry content

Stage 1*: consider effect of higher temperature on yield*

(Or vice versa for lower temperature)

- *Le Chatelier's principle predicts that equilibrium shifts to oppose any increase in temperature*
- *Exothermic reaction, so equilibrium shifts in endothermic direction / to the left*
- *So a Higher T will reduce yield*

Stage 2*: consider effect of higher temperature on rate*

(Or vice versa for lower temperature)

- *At higher temperature, more high energy molecules*
- *more collisions have E>Ea*
- *So rate of reaction increases / time to reach equilibrium decreases*

Stage 3*: conclusion*

Industrial conditions chosen to achieve (cost-effective) balance of suitable yield at reasonable rate

[11]

Q17.

(a) 2,2,4-trimethylpentane

1

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(b) 5

1

(c) $C_{20}H_{42} \longrightarrow C_8H_{18} + 2C_3H_6 + 3C_2H_4$

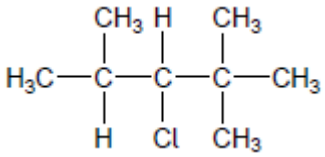
1

(d) Mainly alkenes formed

1

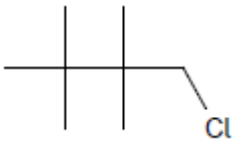
(e) 4 (monochloro isomers)

1



1

(f)



1

(g) $C_8H_{17}{}^{35}Cl = 96.0 + 17.0 + 35.0 = 148.0$
and $C_8H_{17}{}^{37}Cl = 96.0 + 17.0 + 37.0 = 150.0$
Both required

1

M_r of this $C_8H_{17}Cl$ $\frac{(1.5 \times 148.0)}{2.5} + \frac{(1.0 \times 150.0)}{2.5}$ = 148.8

1

(h) $\frac{24.6}{12} \quad \frac{2.56}{1} \quad \frac{72.8}{35.5}$ = 2.05 : 2.56 : 2.05

Simplest ratio = $\frac{2.05}{2.05} : \frac{2.56}{2.05} : \frac{2.05}{2.05}$

= 1 : 1.25 : 1

1

Whole number ratio (× 4) = 4 : 5 : 4

1

MF = $C_8H_{10}Cl_8$

1

[12]

Q18.

B

[1]

Q19.

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C

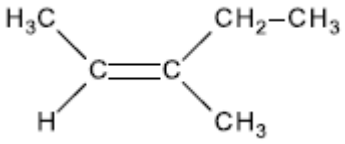
[1]

Q20.

B

[1]

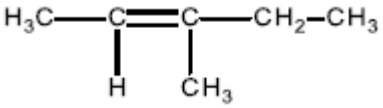
Q21.

(a) 

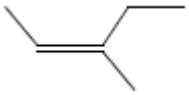
Must show all 4 groups bonded to C=C

Allow CH_3- for methyl group; allow C_2H_5 for ethyl group

Allow correct structure of the style

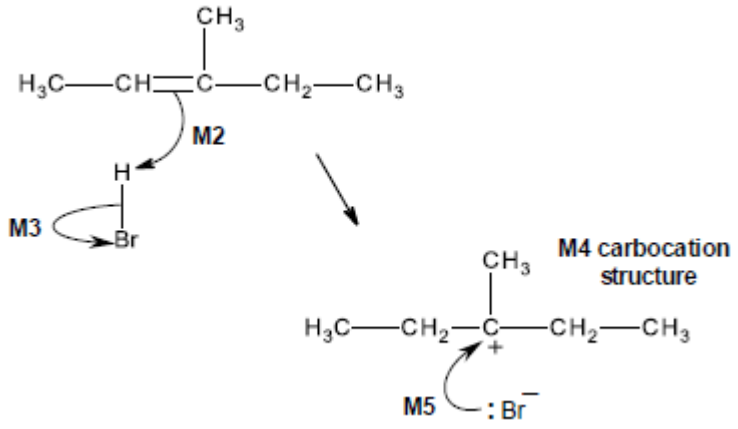


Allow correct skeletal structure



1

(b) M1 <u>electrophilic addition</u>



NB the arrows here are double-headed

1

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

1

M3 must show the breaking of the H-Br bond

1

M4 is for the structure of the tertiary carbocation

1

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

1

M6 3-bromo-3-methylpentane is <u>formed from 3y carbocation</u>
OR
2-bromo-3-methylpentane is <u>formed from 2y carbocation</u>

1

M7 <u>3y carbocation more stable than 2y</u>

1

M2-M5 *Penalise one mark from their total if half-headed arrows are used*

M2 *Ignore partial negative charge on the double bond*

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

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

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

Max 3 of any 4 marks (M2-5) *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"

For ***M5****, credit attack on a partially positively charged carbocation structure but penalise* ***M4***

M6 is high demand and must refer to product being formed from/via correct class of carbocation

M7 is high demand and must be clear answer refers to stability of carbocations (intermediates) not products

Candidate that states that products are carbocations would lose M6 and M7

M6,7 *allow carbonium ion in place of carbocation; or a description of carbocation in terms of alkyl groups/ number of carbon atoms joined to a positive C*

When asked to outline a mechanism, candidates are ***expected*** *to draw a mechanism with curly arrows (specification 3.3.1.2). On this occasion only we would allow a detailed description as shown.*

M2 *must describe the movement of a pair of electrons / curly arrow from the C=C towards the H atom of the H-Br molecule*

M3 *must describe the breaking of the H-Br bond with the bonding pair of electrons moving to the Br / curly arrow from H-Br bond to Br*

M4 *is for the structure of the tertiary carbocation (i.e. positive C bonded to one methyl and two ethyl groups)*

M5 *must describe the movement of a pair of electrons from the Br^- ion to the positive C atom of the carbocation / curly arrow from the lone pair of electrons on the negatively*

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charged bromide ion towards the positively charged C atom (of either a secondary or) of a tertiary carbocation

[8]

Q22.

B

[1]

Q23.

(a) (i) Alk**ane(s)**

Ignore C_nH_{2n+2}

1

(ii) $C_8H_{18} + 12.5O_2 \rightarrow 8CO_2 + 9H_2O$

Allow multiples

1

(iii) 2, 2, 4-trimethylpentane

1

(b) (i) But-1-ene

Ignore (E or Z)

1

(ii) $C_{14}H_{30}$

1

(iii) Thermal

If catalytic CE = 0

1

High pressure / 7000kPa / 70 atms
and
High temperature/temperature in range 400-1000°C (673–1273K)

(Allow ≥1000 kPa or ≥10 atms – no upper value)

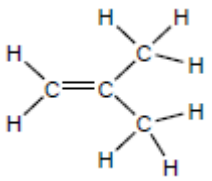
Allow high temperature and pressure or high pressure and temperature

If no units for temperature allow 673-1000

Must show unambiguous structure

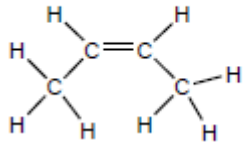
Penalise lack of displayed formula once only

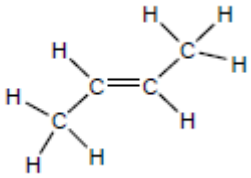
1

(iv) 

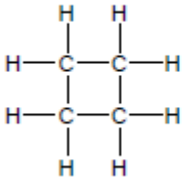
1

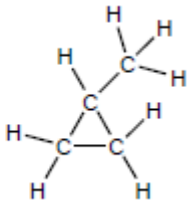
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1





1

[10]

Q24.

(a) NaOH/KOH

IGNORE *OH-*

NOT *M1 if any mention of acidified/H+ in reagents or conditions*

1

Reaction 1 = ethanolic/alcoholic **AND** *reaction 2* = aqueous

IGNORE *temp*

NOT *ethanoic*

1

rxn 1 = base/proton acceptor

1

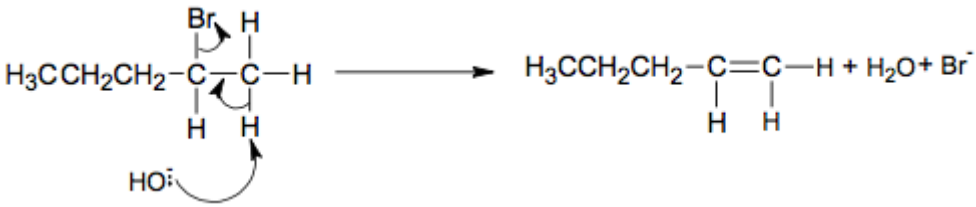
rxn 2 = nucleophile/lone pair donor/electron pair donor

1

(Base) Elimination

NOT *nucleophilic*

1



M6 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

M7 must show an arrow from a correct C–H bond on C adjacent to the C of 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 **M6**

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M8 is independent provided it is from their original molecule and shows curly arrow from C-Br to Br

ALLOW *correct E1 mechanism*

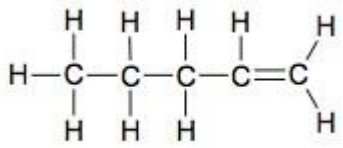
IGNORE *incorrect inorganic products*

If forming pent-2-ene can award M8 only even if arrows in mechanism correct

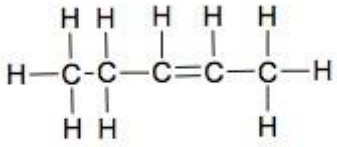
If C chain length or halogen wrong in reactant or product max 2/3

1
1
1

(b)

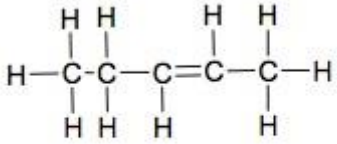


1



Z-pent-2-ene

1



E-pent-2-ene

1

If no M2 and M3 ***ALLOW*** *1 mark if both structures* ***OR*** *both names correct*

NOT *cis and trans*

No free rotation around C=C

ALLOW *no rotation of C=C*

1

2 different atoms/groups on each of the C=C Cs owtte

IGNORE *'functional'*

1

(c) Same volume/amount of $AgNO_3$(aq) added to same volume/amount/no. of drops of haloalkane (in beaker/flask) in each experiment

Both volume references needed

IGNORE *inappropriate volumes*

1

Same temp **OR** same [$AgNO_3$] each time

1

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record time to measure sensible observation about the amount of AgCl ppt

e.g. first appearance of ppt / ppt obscures mark / reading on a colorimeter

IGNORE *colour of ppt*

ALLOW *silver mirror*

NOT *reference to same time if describing method based on timing how long (for ppt to form)*

ALLOW *gravimetric method based on same time for each experiment*

1

Rate = amount/time **OR** proportional to 1/time **OR** reference to shorter time = higher rate/longer time = lower rate

ALLOW *greater mass = higher rate if gravimetric method*

1

[17]

Q25.

(a) Saturated − single bonds only / no double bonds

1

Hydrocarbon − contains carbon and hydrogen (atoms) only

1

(b) $C_{16}H_{34} + 16.5O_2 \longrightarrow 16CO + 17H_2O$

Allow multiples

1

(c) (On combustion) SO_2 produced

Allow equation to produce SO_2. Ignore sulfur oxides.

1

Which causes acid rain

If formula shown it must be correct

M2 is dependent on M1. But if M1 is sulfur oxides, allow M2.

For M2 allow consequence of acid rain or SO_2.

Ignore greenhouse effect and toxic

1

(d) (i) $C_{16}H_{34} \longrightarrow C_8H_{18} + C_2H_4 + 2C_3H_6$

Allow multiples

1

(ii) polypropene / propan(-1 or 2-)ol / propane(-1,2-)diol / isopropanol / propanone / propanal

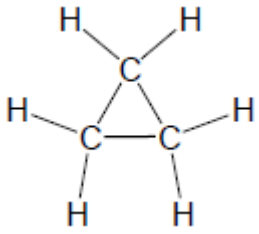
Accept alternative names

Ignore plastic and polymer

1

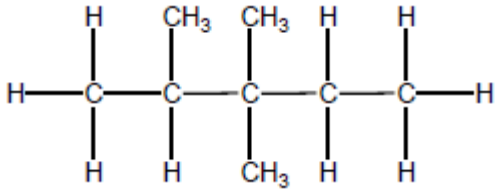
(iii)

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1

(e)



Allow any unambiguous representation

1

(f) 2,4-dichloro-2,4-dimethylhexane

Only but ignore punctuation

1

[10]

Q26.

(a) Crude oil **OR** petroleum

Not petrol.

1

Fractional distillation / fractionation

Not distillation alone.

1

(b) $C_{12}H_{26} + 12.5O_2 \longrightarrow 12CO + 13H_2O$

Allow balanced equations that produce CO_2 in addition to CO.

Accept multiples.

1

(c) (i) M1 Nitrogen and oxygen (from air) react / combine / allow a correct equation

If nitrogen from petrol / paraffin / impurities CE = 0 / 2.

1

M2 at high temperatures

Allow temperatures above 1000 °C or spark.

Not just heat or hot.

M2 dependent on M1.

But allow 1 mark for nitrogen and oxygen together at high temperatures.

1

(ii) $2NO + O_2 \longrightarrow 2NO_2$

Allow multiples.

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1

(iii) $4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$

Allow multiples.

1

(d) (i) C_nH_{2n+2}

Allow C_xH_{2x+2}

CnH2n+2

Allow CxH2x+2

1

(ii) $C_{12}H_{26} \longrightarrow C_6H_{14} + C_6H_{12}$

Only.

1

C_3H_7

Only.

1

Zeolite / aluminosilicate(s)

Ignore aluminium oxide.

1

(iii) Larger molecule / longer carbon chain / more electrons / larger surface area

1

More / stronger <u>van der Waals' forces between molecules</u>

Allow dispersion forces / London forces / temporary induced dipole-dipole forces <u>between molecules.</u>

If breaking bonds, CE = 0 / 2.

1

(e) 2,2,3,3,4,4-hexamethylhexane

Only.

Ignore punctuation.

1

Chain

Ignore branch(ed).

1

(f) Cl_2

Only.

Cl–Cl

Not CL_2 or Cl2 or CL2 or Cl^2 or CL^2.

Ignore Chlorine.

1

[16]

Q27.

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

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

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

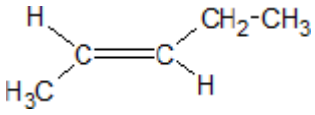
OR <u>atoms / bonds / groups</u> with <u>different spatial arrangements / different orientation</u>

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.

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3

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

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

1

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

OR

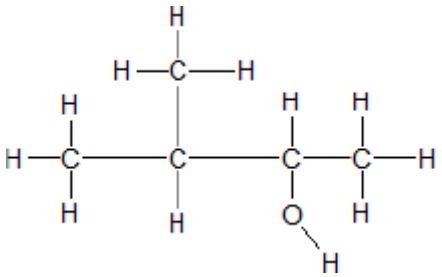
different absorptions / peaks are seen (in the region) below 1500 cm^{-1} (or a specified region within the fingerprint range)

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

QoL

1

(d)



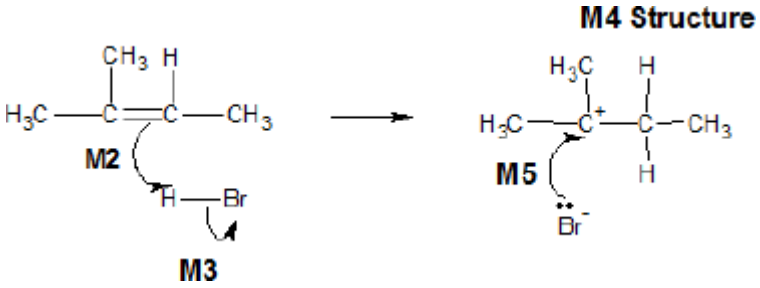
All bonds must be drawn.

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

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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**.*

***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)

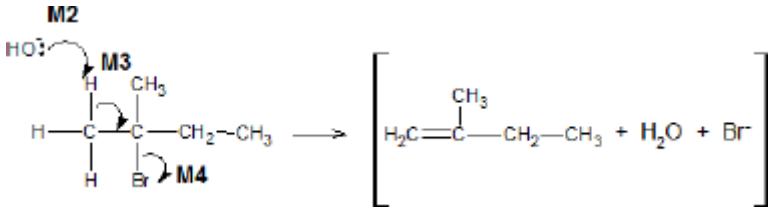
***M2** is of higher demand and requires the idea that the secondary carbocation is less stable or the tertiary carbocation is more stable. Reference to incorrect chemistry is penalised.*

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

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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]

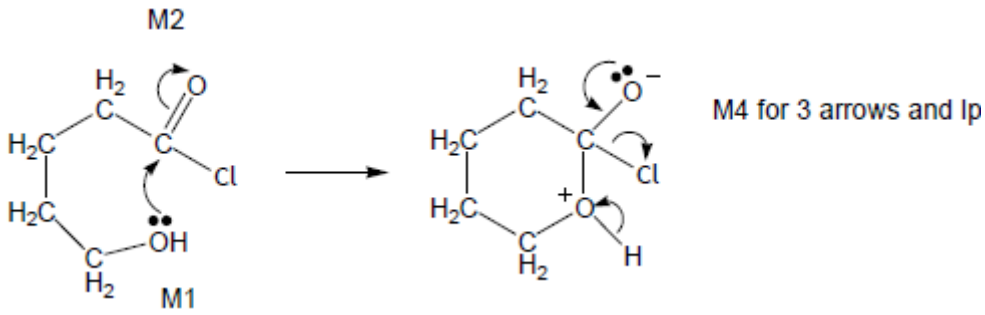
Q28.

(a) (i) (nucleophilic) <u>addition-elimination</u>

Not electrophilic addition-elimination

Ignore esterification

1



M3 for structure

- *If wrong nucleophile used or O–H broken in first step, can only score M2.*
- *M2 not allowed independent of M1, but allow M1 for correct attack on C+*
- *+ rather than δ+ on C=O loses M2.*
- *If Cl lost with C=O breaking lose M2.*
- *M3 for correct structure <u>with charges</u> but lone pair on O is part of M4.*

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- *Only allow M4 after correct / very close M3.*
- *Ignore HCl shown as a product.*

4

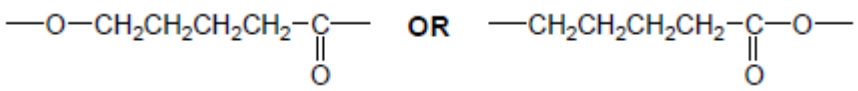
a 20-50 (ppm) or single value or range entirely within this range

If values not specified as a or b then assume first is a.

1

b 50-90 (ppm) or single value or range entirely within this range

1

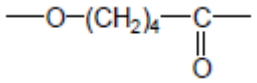
(ii)  **OR**

Must have trailing bonds, but ignore n.

1

OR $-OCH_2CH_2CH_2CH_2CO-$ **OR** $-CH_2CH_2CH_2CH_2COO-$

Allow



but not - C_4H_8-

one unit only

Condensation

1

(b)

	Tollens'	Fehling's / Benedicts	Acidified potassium dichromate

Penalise wrong formula for Tollens or missing acid with potassium dichromate but mark on.

1

J	No reaction / no (visible) change / no silver mirror	No reaction / no (visible) change / stays blue / no red ppt	No reaction / no (visible) change / stays orange / does not turn green

Ignore 'clear', 'nothing'.

Penalise wrong starting colour for dichromate.

1

K	Silver <u>mirror</u> / grey <u>ppt</u>	Red <u>ppt</u> (allow brick red or red-orange)	(orange) turns green

1

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J Two (peaks)

Allow trough, peak, spike.

1

K Four (peaks)

Ignore details of splitting.

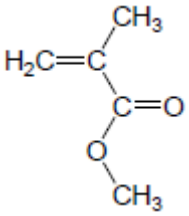
If values not specified as J or K then assume first is J.

1

(c) If all the structures are unlabelled, assume that the first drawn ester is L, the second ester is M; the first drawn acid is N, the second P. The cyclic compound should be obvious.

L

ester



OR $H_2C=C(CH_3)COOCH_3$

All $C_5H_8O_2$ L to P must have C=C.

Allow CH_3-.

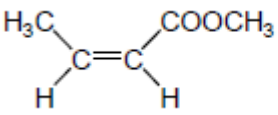
Allow $-CO_2CH_3$ etc.

Allow $CH_2C(CH_3)COOCH_3$.

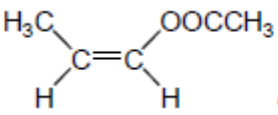
1

M

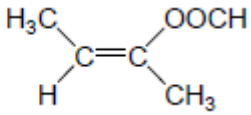
ester



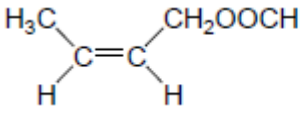
OR



OR

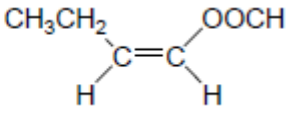


$CH_3CH=CHCOOCH_3$ $CH_3CH=CHOOCCH_3$ $CH_3CH=C(CH_3)OOCH$



OR

OR



$CH_3CH=CHCH_2OOCH$ $CH_3CH_2CH=CHOOCH$

Allow either E–Z isomer.

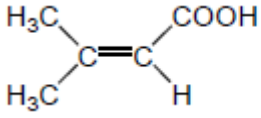
Allow CH_3- or C_2H_5- but not CH_2CH_3-.

Allow $CH_3CHCHCOOCH_3$ etc.

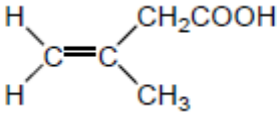
1

N

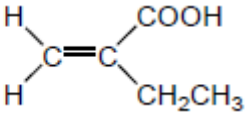
acid



OR



OR



$(CH_3)_2C=CHCOOH$ $H_2C=C(CH_3)CH_2COOH$ $H_2C=C(COOH)CH_2$

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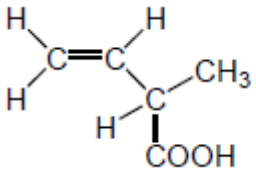
CH_3

Allow CH_3- or C_2H_5- but not CH_2CH_3-.

Allow $-CO_2H$.

Not cyclic isomers.

Not the optically active isomer.



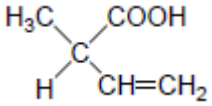
which is P anyway

Allow $(CH_3)_2CCHCOOH$ etc.

1

P

acid



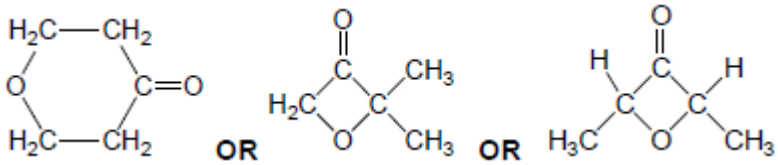
Allow $-CO_2H$.

$CH_3CH(COOH)CH=CH_2$

Allow $CH_3CH(CO_2H)CHCH_2$ or $CH_3CH(CO_2H)C_2H_3$.

1

Q



Not cyclic esters.

1

[19]

Q29.

(a) (i) (Compounds with the) same molecular formula

Allow same number and type of atom for M1

Ignore same general formula.

1

But different structural formula / different displayed formula / different structures / different skeletal formula

M2 dependent on M1

Not different positions of atoms / bonds in space.

1

(ii) But-2-ene

Allow but-2-ene.

Allow but 2 ene.

Ignore punctuation.

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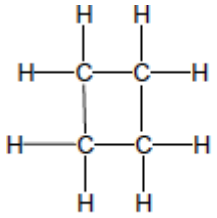
1

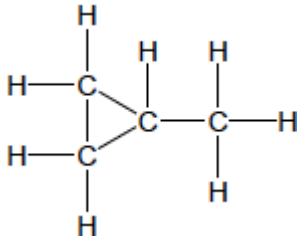
(iii) (2)-methylprop-(1)-ene

Do not allow 2-methyleprop-1-ene.

1

(iv)





Do not allow skeletal formulae.

Penalise missing H and missing C

1

(b) (i) $C_4H_8 + 2O_2 \rightarrow 4C + 4H_2O$

Accept multiples.

1

(ii) Exacerbates asthma / breathing problems / damages lungs / smog / smoke / global dimming

Ignore toxic / pollutant / soot / carcinogen.

Do not allow greenhouse effect / global warming / acid rain / ozone.

1

(c) (i) $C_{16}H_{34}$

Allow $H_{34}C_{16}$

C and H must be upper case.

1

(ii) Jet fuel / diesel / (motor) fuel / lubricant / petrochemicals / kerosene / paraffin / central heating fuel / fuel oil

Ignore oil alone.

Not petrol / bitumen / wax / LPG / camping fuel.

1

(d) (i) $C_8H_{18} + 25NO \rightarrow 8CO_2 + 12.5\ N_2 + 9H_2O$

Accept multiples.

1

(ii) Ir / iridium

OR

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Pt / platinum

OR

Pd / palladium

OR

Rh / rhodium

1

[11]

Q30.

(a) (i) C_nH_{2n} / C_xH_{2x}

1

(ii) Fractional distillation / GLC / gas liquid chromatography / fractionation

*Do **not** allow cracking / distillation*

1

(b) (i) But-1-ene / but1ene

Ignore hyphens and commas

*Do **not** allow butene-1 / but-2-ene / butane / butane /alkene / C_4H_8 / propene / straight-chain alkene*

1

(ii) A structure of cyclobutane or methyl-cyclopropane

Allow skeletal formula.

1

(c) (i) $C_{15}H_{32} \rightarrow 2C_4H_8 + C_7H_{16}$

Do not accept multiples.

1

(ii) Thermal cracking

Not catalytic cracking or cracking.

1

To produce products that are in greater demand / more valuable / more expensive / more profitable

The (unsaturated) alkene or the (unsaturated) molecule or X produced can be polymerised or can be made into plastics.

Ignore more useful products.

1

(iii) Break (C–C or C–H) bonds

Allow to overcome the activation energy.

Allow to break the carbon chain.

Penalise breaking wrong bonds.

1

(d) (i) H_2

Only.

1

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(ii) Fuel / LPG

Allow camping gas, lighter fuel, propellant, refrigerant, cordless appliances.

Do not allow petrol or motor fuel.

Ignore natural gas.

1

(iii) $C_4H_{10} + 2.5O_2 \rightarrow 4C + 5H_2O$

Accept multiples.

1

(iv) SO^2 / sulfur dioxide

If other sulfur oxides, mark on.

1

Calcium oxide / CaO / lime / quicklime

Allow $CaCO_3$ / allow $Ca(OH)_2$ or names.

Allow any solid base.

M2 dependent on M1.

Do not allow limewater.

1

(v) Neutralisation

Allow acid-base reaction.

Allow flue gas desulfurisation / FGD

1

(e) (Molecules) are similar sizes / have similar M_r / have similar number of electrons

Chemical error CE = 0/2 if breaking bonds.

Allow similar number of carbon and hydrogen atoms / similar surface area / similar chain length.

Can accept same number of carbon atoms.

Do not accept same number of H atoms / same number of bonds.

Ignore similar amount of bonds.

1

Similar van der Waals forces between molecules / similar intermolecular forces (IMF)

Not similar incorrect IMF eg dipole-dipole

1

[16]

Q31.

(a) (i) Crude oil / oil / petroleum

Do not allow 'petrol'

1

(ii) Fractional distillation / fractionation / fractionating

Not distillation alone

1

(b) (i) 5

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Allow five / V

1

(ii) Chain (isomerism)

Allow branched chain / chain branched / side chain (isomerism)

Ignore position (isomerism)

Do not allow straight chain / geometric / branched / function

1

(c) (i) $C_{12}H_{26}$ / $H_{26}C_{12}$

Only

1

(ii) Thermal cracking

If not thermal cracking, CE = 0/2

If blank mark on

1

High temperature

Allow 'high heat' for 'high temperature'

(400°C $\leq$ T $\leq$ 900°C) or (650 K $\leq$ T $\leq$ 1200 K)

Not 'heat' alone

If no T, units must be 650 – 900

and

High pressure ($\geq$ 10 atm, $\geq$ 1 MPa, $\geq$1000 kPa)

1

(iii) To produce substances which are (more) in demand / produce products with a high value / products worth more

Ignore 'to make more useful substances'

1

(d) (i) Corrosive or diagram to show this hazard symbol

Ignore irritant, acidic, toxic, harmful

1

(ii) $\left(\frac{120.5}{(86 + 71)} \times 100\right)$

=76.75(%) or 76.8(%)

Allow answers > 3 sig figs

1

(e) 2,2-dichloro-3–methylpentane

Ignore punctuation

Any order

1

C_3H_6Cl

1

[12]

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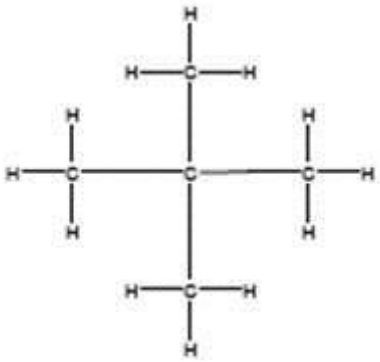
Q32.

(a) $C_n H_{2n+2}$

Allow x in place of n

1

(b)



Chain

Must show every bond

Allow branched chain

2

(c) C_9H_{20}

Only

1

To break the (C-C and/or C-H) bonds

M2=0 if break C=C

1

To make products which are in greater demand / higher value / make alkenes

Not more useful products

Allow specific answers relating to question

1

(d) $C_5H_{12} + 3O_2 \rightarrow 5C + 6H_2O$

Allow other balanced equations which give C and CO/CO_2

1

Causes global dimming / exacerbates asthma / causes breathing problems / makes visibility poor / smog

Apply list principle

Ignore causes cancer / toxic

1

(e) $\frac{106.5}{143}$ (x 100)

1

74.48%

Allow 74.5%

1

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3

Only

1

(f) 2,3-dichloro-3-methylpentane

Ignore punctuation

1

C_3H_6Cl

Only

1

[13]

Q33.

(a) Pentan-2-one

ONLY but ignore absence of hyphens

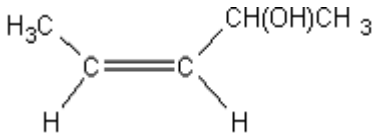
1

(b) Functional group (isomerism)

Both words needed

1

(c) (i)



Award credit provided it is obvious that the candidate is drawing the Z / cis isomer

The group needs to be $CHOHCH_3$ but do not penalise poor C–C bonds or absence of brackets around OH

Trigonal planar structure not essential

1

(ii) Restricted rotation (about the C=C)

OR

No (free) rotation (about the C=C)

1

(d)

M1 Tollens' (reagent) *(Credit ammoniacal silver nitrate OR a description of making Tollens')* *(Do not credit Ag^+, $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3)*	**M1** Fehling's (solution) / Benedict's *(Penalise $Cu^{2+}(aq)$ or $CuSO_4$ but mark M2 and M3)*
M2 silver mirror	**M2** Red solid/precipitate

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OR <u>black solid or black precipitate</u>	*(Credit <u>orange</u> or <u>brown solid</u>)*
M3 (stays) colourless OR no (observed) change / no reaction	**M3** (stays) blue OR no (observed) change / no reaction

*If **M1** is blank CE = 0, for the clip*

Check the partial reagents listed and if M1 has a <u>totally incorrect</u> reagent, CE = 0 for the clip

Allow the following alternatives

***M1** (acidified) potassium dichromate(VI) (solution); mark on from incomplete formulae or incorrect oxidation state*

***M2** (turns) green*

M3 (stays) orange / no (observed) change / no reaction

OR

***M1** (acidified) potassium manganate(VII) (solution);*

mark on from incomplete formulae or incorrect oxidation state

***M2** (turns) colourless*

***M3** (stays) purple / no (observed) change / no reaction*

*In all cases for **M3***

Ignore ''nothing (happens)''

Ignore ''no observation''

3

(e) (i) **Spectrum is for Isomer 1**

or named or correctly identified

The explanation marks in (e)(ii) depend on correctly identifying Isomer 1.

The identification should be unambiguous but candidates should not be penalised for an imperfect or incomplete name. They may say ''the alcohol'' or the ''alkene'' or the ''E isomer''

1

(ii) **If Isomer 1 is correctly identified, award <u>any two</u> from**

- (Strong / broad) absorption / peak in the range **<u>3230 to 3550</u>** cm^{-1} or specified value <u>in this range</u> or **<u>marked correctly</u>** on spectrum **<u>and</u>** (characteristic absorption / peak for) <u>OH</u> group /**<u>alcohol</u>** group
- No absorption / peak in range **<u>1680 to 1750</u>** cm^{-1} or absence <u>marked correctly</u> on spectrum **<u>and</u>** (No absorption / peak for a) **<u>C=O</u>** group / **<u>carbonyl</u>** group / **<u>carbon-oxygen double bond</u>**
- Absorption / peak in the range **<u>1620 to 1680</u>** cm^{-1}

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or specified value <u>in this range or marked correctly</u>
on spectrum
and

(characteristic absorption / peak for) **C=C** group
/ **alkene** / **carbon-carbon double bond**

If 6(e)(i) is incorrect or blank, CE=0

Allow the words "dip" OR "spike" OR "trough" OR "low transmittance" as alternatives for absorption.

Ignore reference to other absorptions e.g. C-H, C-O

2

[10]

Q34.

(a) (Different) boiling points

Ignore mp's, references to imf, different volatilities

1

(b) (i) Compound which have the same <u>molecular</u> formula

Accept same no and type of atom for M1
But If same (chemical) formula M1 = 0 but allow M2
If empirical formula CE = 0/2

1

but different structures/different structural formulae/different displayed formulae

M2 dependent on M1

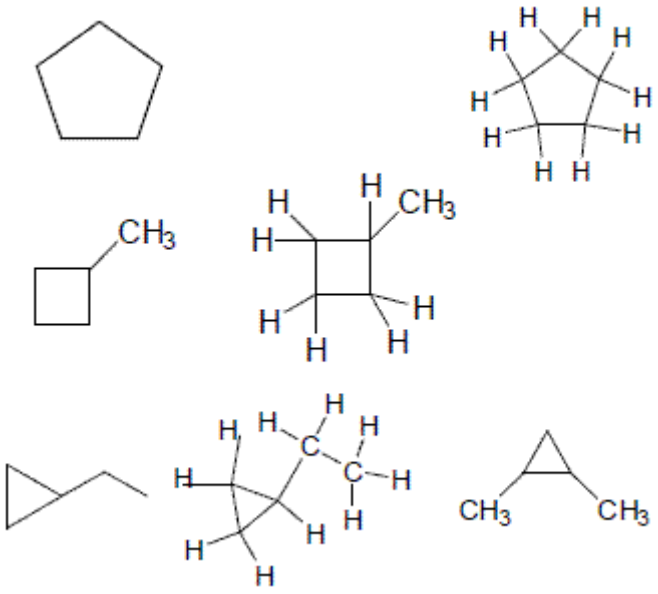
1

(ii) 3-methylbut-1-ene

only
ignore commas and hyphens

1

(iii)

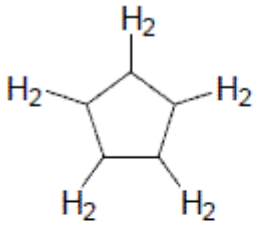


Allow any correct structure with a cyclic alkane

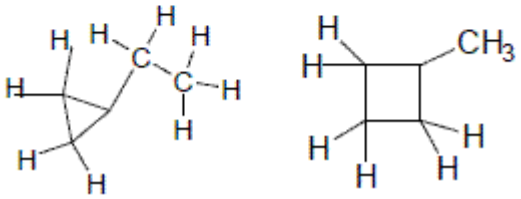
1

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Do not allow



or



i.e with an H missing on one C

(c) $C_{13}H_{28}$

only

1

Making plastics/used to make polymers or polythene/used to make antifreeze/make ethanol/ripening fruit/any named additional polymer

*not used **as** a plastic/polymer/antifreeze*
not just 'polymers' – we need to see that they are being made

1

[6]

Q35.

(a)
- (Same) General formula/allow a named homologous series with its general formula
- Chemically similar/same (chemical) reactions
- Same functional group
- Trend in physical properties/eg inc bp as M_r increases
- (Molecules) increase by $CH_2/M_r = 14$

Any two points

2

(b) Fractional distillation/fractionation/chromatography

Allow GLC

1

(c) (Molecules/compounds/substances) with the same molecular formula/same number and type of atoms

Allow alkanes with same molecular formula
Allow same chemical formula in M1 = 0 but can allow M2

1

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but different structural formula/different displayed formula/different arrangement of atoms/different structures

Not different positions in space

1

2,4-dimethylhexane

M2 dependent on M1

1

C_4H_9

Ignore the absence of dash and/or commas

1

(d) less surface contact/less surface area/less polarisable molecule

1

so fewer/weaker/less Van der Waals'/vdw forces

Allow more spherical or fewer points of contact

Not smaller molecule/not more compact molecule/not shorter chain

Allow converse arguments

Must be comparative answer ie not just few VDW forces

QoL

Assume 'it' refers to the branched isomer

1

[9]

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Q1.

Some students could not convert the ratio 7.3 : 13.2 to a whole number ratio, but the question was answered well on the whole and discriminated well.

Q2.

Few students (28.7%) got this correct, with most believing there are fewer isomers than there actually are.

Q3.

(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.

Q4.

A was the commonest incorrect response to this question which had a 47% success rate. This suggests there were many students who recognised that the answer is an aldehyde, but who then missed a possible isomer. Drawing out possible structures in a logical sequence is the key here. Students are advised to start with a 5C chain, then 4C and find possible positions for the fifth C (carbon 2 or carbon 3), and finally a 3C chain and find positions for the remaining two carbons (both on carbon 2).

Q5.

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(a) This straightforward question was not answered well. Many students drew 2-methylbutanal rather than 3-methylbutanal, not appreciating that the C atom in the aldehyde group is carbon-1.

(b) Many students drew the displayed structure of the correct product, thereby demonstrating their understanding of the identity of the major product of this addition reaction of hydrogen bromide to the alkene.

(c) Most students realised that thermal cracking produced an alkene.

Q6.

A minority of students (31.9%) scored this mark, with many incorrectly thinking there were one more or one fewer isomers than there actually were. Students are encouraged to take a systematic approach to deducing all possible structures.

Q21.

Electrophilic addition

Many students could draw the correct structure of the Z isomer in (a).

Many students did well on (b), but a significant number attempted to describe the curly arrow mechanism in words rather than drawing it. The phrase “outline the mechanism” has been used for many years and is explained in the specification to mean drawing a curly arrow diagram. On this occasion, it was decided that credit could stem from an accurate description in words but it was very hard for students to match the level of precision in words that is demanded in the drawing, and so most students who described the curly arrow diagrams did not score well at all. The final two marks were awarded for an explanation of why more of one product was formed than another. The explanation should refer to the relative stability of the two possible carbocation intermediates. Many students were confused and thought that the products were the carbocations. To score these marks, students had to be clear that carbocations are intermediates from which the products are formed and not the products themselves.

Q23.

Most students answered part (a) extremely well. They recognised that octane is an alkane and then correctly balanced an equation for its complete combustion. A number stated $8.5O_2$ in the equation having not taken into account that CO_2 contains two oxygen atoms. Most students could give the correct IUPAC names in (a)(iii) and (b)(i). The molecular formula of the alkane produced in (b)(ii) was deduced well and the type of cracking and conditions were mostly stated correctly. A number of students then gave zeolite catalyst as a condition. The displayed formulae in part (b)(iv) were drawn accurately with many students scoring full marks. For those who did not score full marks there was a good attempt at the question with marks two and three being accessed by the majority of students. A number of students did not always show the displayed formula or did not deduce the chain isomer.

Q24.

The lack of structure in part (a) caused problems for some students and they needed to be clearer in some cases whether they were referring to reaction 1 or reaction 2. The mechanism was generally done well although showing attack by OH- at the wrong C-H lost some marks. In part (b) very few students appreciated the need for two different groups on each C of the C=C in addition to the lack of free rotation.

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In part (c) it was expected that an experiment based on a ‘disappearing cross’ approach would be familiar to most students as would the general idea of a ‘fair test’. There were, however, many elaborate and often unworkable methods suggested. There was also too much emphasis on things such as ‘the same person observing’ or ‘the same stopwatch being used’ instead of making suggestions to ensure that the only variable was the identity of the chloroalkane and that other conditions should be kept constant such as temperature, volumes of solutions and concentration of silver nitrate solution.

Q25.

Most students gave correct answers for part (a) although there were still some who did not state that *only* carbon and hydrogen are present in a hydrocarbon. The equation in part (b) was generally correct although some did have carbon dioxide as one of the two products. In part (c) the majority of students scored the first mark but some just stated that sulfur dioxide was toxic and failed to mention acid rain. A few students suggested that the sulfur compounds themselves escaped into the atmosphere without any mention of combustion. The equation in part (d)(i) was well done; the most common error was having the correct products but then failing to balance the equation. Answers to part (d)(ii) were poor with relatively few stating a correct substance made. Part (d)(iii) was answered by a majority of students; the most common error was to draw propene rather than the functional group isomer. The structure in part (c) was also well done by the majority of students, although some students left out a hydrogen atom from the chain and could not score the mark.

Q26.

Part (a) was very well answered but many students could not give a correct balanced equation in part (b); some gave carbon as a gaseous product. Answers to part (c) were mixed. Some were excellent and gave the correct answer and condition but far too many thought that the nitrogen was from a nitrogen-containing impurity in the paraffin. Equations given in part (c)(ii) were generally good but many students found writing the equation in part (c)(iii) more difficult.

The general formula of the alkanes was well known in part (d)(i). Answers to part (d)(ii) suggested that many students did not read the question carefully and so did not write equations giving two molecules with equal numbers of carbon atoms. Due to this error, the empirical formula was often incorrect. A range of catalysts was seen but many did know the correct one. In part (d)(iii), far too many students thought that covalent bonds were broken during melting. When students realise that the van der Waals forces are broken they must state that these forces are between the molecules. In a few answers, students referred to van der Waals bonds breaking and this is unclear. The IUPAC name in part (e) proved difficult for many students, especially the numbers of the substituent groups. The type of isomerism in part (e) was well known by most students; the most common incorrect answer was positional isomerism.

Q27.

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

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to the 'Markownikoff rule' without any explanation in terms of the stability of carbocations.

Q28.

The nucleophilic addition-elimination mechanism in part (a)(i) presented a real challenge to many students, who were confused by the cyclic nature of the product, failed to identify the correct nucleophile and suggested either separate nucleophiles such as H_2O, CH_3OH and OH^- or alternatively loss of the proton from the OH group before nucleophilic attack. Most students gave the correct range for the carbon atom labelled **b**, but often the range for the carbon atom labelled **a** was given as 160–185 as for a carbonyl carbon. In part (a)(ii), the repeating unit for the polyester was answered well although some students gave twice the repeating unit.

The distinguishing test in part (b) was well done, although a significant number of students thought that substance **K** was an acid and wrongly suggested $NaHCO_3$ or Na_2CO_3 to distinguish between the compounds. It was common for students to fail to see the symmetry of **J** and so to predict, incorrectly, three peaks in its proton n.m.r. spectrum. Five peaks was a common incorrect answer for **K**, suggesting that students had misread the question and given the ^{13}C n.m.r. result.

Part (c) of this question proved to be very challenging and fewer than 10% of students scored full marks. Isomer **Q** was found particularly difficult where many students omitted one of the O atoms from their suggested structure. Other common errors included missing the double bond in **L**, giving the structure of **P** as the structure of **N** (which suggests a failure to recognise that optical isomerism is a form of stereoisomerism) or writing an unbranched carbon chain for the acid **N**. Answers to part (c) were often very badly presented, with a great deal of crossing out, duplication of answers and poor labelling of structures.

Q29.

Most students answered part (a) well although there were a few who omitted the key word 'molecular' in molecular formula. Most students could give the correct IUPAC name in part (a)(ii) but the name in part (a)(iii) was more problematic. Part (a)(iv) was reasonably well done although some students showed a cyclobutane structure without showing the displayed formula as asked for in the question. The solid product in part (b)(i) was often given as CO or CO_2 and hence the mark for the hazard could not be scored in part (b)(ii). Many those who correctly gave C as the product, simply stated that it was a pollutant without further qualification. Part (c)(i) was answered well as was part (c)(ii). Common incorrect answers to part (c)(ii) were bitumen and plastics. The equation in part (d)(i) was generally answered well although again there were a lot of students who gave the formula of nitrogen gas as N. The catalyst in part (d)(ii) was usually correct with the most common answer being platinum.

Q30.

Part (a) was done well but part (b) proved more difficult for some students. Many simply named the isomer given in part (b)(i) and few knew of the existence of cyclic alkanes in part (b)(ii). Part (c) produced many careless responses; students should know that all equations should be balanced. The type of cracking was not always specified in part (c)(ii) and many students referred to the usefulness of the products rather than to their value. It should be noted that cracking does not produce plastics; it produces alkenes that can be polymerised. Answers to part (c)(iii) showed that some students think that intermolecular forces are the only bonds broken in cracking. There were a vast number of incorrect reagents stated in part (d)(i) and many gave names rather than formulae as asked for in the question. The equation in part (d)(iii) was often not balanced and many students showed carbon monoxide as the solid product. There were many students who did not

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know the identity of the toxic gas in (d)(iv) and therefore did not know a chemical that could remove it.

The answers to (d)(v) were very varied. Only the students that knew the answer to part (d)(iv) could get this right. Answers to part (e) showed that many students thought that boiling involved the breaking of covalent bonds.

Q31.

The majority of students knew the answers to parts (a)(i) and (a)(ii) although a common wrong answer to part (a)(ii) was cracking. Deducing the number of structural isomers in part (b)(i) caused problems for many students and several students showed a lot of working but then did not write a number in the box as instructed in the question. The type of structural isomerism in part (b)(ii) was well known but many wrong answers for the molecular formula were seen in part (c)(i). Many students lost marks in part (c)(ii) by identifying the wrong type of cracking. Even when thermal cracking was identified correctly, some students lost a mark by not stating the full conditions.

Most students scored the mark in part (c)(iii) although a few still gave answers in terms of usefulness rather than demand. Most students realised that the product in part (d)(i) was corrosive although ‘acidic’ was often seen. The atom economy was well answered in part (d)(ii) although weaker students did not give the correct number for the denominator or forgot to multiply by 100. The name in part (e) proved difficult for students with many omitting the numbers or giving the wrong numbers and many putting the chloro and methyl in the wrong order. The empirical formula was generally answered better although a lot of students just gave the molecular formula.

Q32.

The general formula of alkanes was well known although some candidates did not write clearly and the subscripts were often very difficult to read. The displayed formula in part (b) was generally well done although there are still many candidates who do not understand what a displayed formula is. The type of structural isomerism was generally well known.

The molecular formula in part (c) was generally well answered but many candidates could not give a clear answer as to why cracking reactions occur. Many simply stated that ‘the chain was broken’ with no reference to bonds breaking. There are still a considerable number of candidates who do not understand the concept of ‘supply and demand’ as applied to the fractions obtained from crude oil. In part (d) equations were often given with no solid product and consequently these candidates could not state the environmental problem. The percentage atom economy in part (e) was generally well attempted although many candidates truncated their answers rather than rounding up. Candidates gave a wide range of answers for the number of isomers. The expected answer of three was often seen since there are three straight chain structural isomers of C5H11Cl. However, there is also an optical isomer of one of the straight chain isomers and candidates repeating this unit with knowledge of CHEM4 may have answered four and so this was also allowed. In part (f) the naming of the organic compound discriminated well but there are quite a number of candidates who did not know the difference between empirical and molecular formula.

Q33.

This was a relatively high-scoring question, although the correct name was only given by 33% of the candidates in part (a). Infrared spectroscopy is an area which candidates are finding very accessible and although 90% identified the correct isomer in part (e), only 51% were able to obtain both marks in part (e)(ii).

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Q34.

The idea of boiling point was generally well known although a few stated melting point as being the property in part (a). The definition in (b)(i) was well done with only a few missing the idea of isomers having the same molecular formula. The name in (b)(ii) proved difficult for a large number of candidates and the idea of cyclic alkanes in (b)(iii) was only achieved by the most able candidates. Part (c) was answered reasonably well although many candidates thought that the ethene itself was used as a plastic rather than being used to make plastics.

Q35.

The answers to part (a) were generally quite good although there were some candidates who quoted ‘similar properties’ without reference to chemical or physical properties. Less able candidates thought that members of the series had the same molecular or empirical formulae. The most common incorrect answer in part (b) was cracking. Part (c) was not well answered. A surprisingly high number of candidates did not know the correct definition and many candidates could not give the name of the structure. Some candidates did not seem to understand how to deduce the empirical formula and often quoted the molecular formula instead. Very few candidates scored full marks in part (d). Many candidates realised that there would be fewer van der Waals forces in the branched chain isomer but found difficulty with the idea of less surface contact. A disappointing number of answers referred to breaking the covalent bonds in the molecules.

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