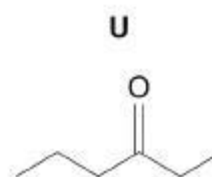
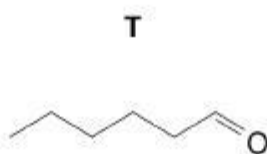
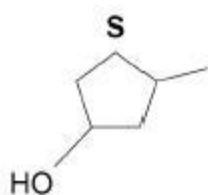
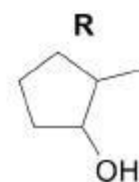
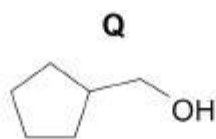
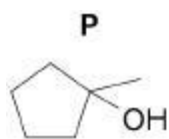


**Q1.**

This question is about the structural isomers shown.



- (a) Identify the isomer(s) that would react when warmed with acidified potassium dichromate(VI).

State the expected observation when acidified potassium dichromate(VI) reacts.

Isomer(s) _____

Expected observation _____

(2)

- (b) Identify the isomer(s) that would react with Tollens' reagent.

State the expected observation when Tollens' reagent reacts.

Isomer(s) _____

Expected observation _____

(2)



- (c) Separate samples of each isomer are warmed with ethanoic acid and a few drops of concentrated sulfuric acid. In each case the mixture is then poured into a solution of sodium hydrogencarbonate.

Identify the isomer(s) that would react with ethanoic acid.

Suggest a simple way to detect if the ethanoic acid reacts with each isomer.

Give a reason why the mixture is poured into sodium hydrogencarbonate solution.

Isomer(s) _____

Suggestion _____

Reason _____

(3)

- (d) State the type of structural isomerism shown by isomers **P**, **Q**, **R** and **S**.

(1)

- (e) Describe fully how infrared spectra can be used to distinguish between isomers **R**, **S** and **T**.

Use data from **Table A** in the Data Booklet in your answer.

(4)



- (f) State why mass spectrometry using electrospray ionisation is **not** a suitable method to distinguish between the isomers.

(1)

(Total 13 marks)

Q2.

The alkanes form an homologous series of hydrocarbons. The first four straight-chain alkanes are shown below.

methane	CH ₄
ethane	CH ₃ CH ₃
propane	CH ₃ CH ₂ CH ₃
butane	CH ₃ CH ₂ CH ₂ CH ₃

- (a) (i) State what is meant by the term *hydrocarbon*.

- (ii) Give the general formula for the alkanes.

- (iii) Give the molecular formula for hexane, the sixth member of the series.

(3)

- (b) Each homologous series has its own general formula. State **two** other characteristics of an homologous series.

(2)

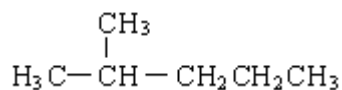
- (c) Branched-chain structural isomers are possible for alkanes which have more than three carbon atoms.

- (i) State what is meant by the term *structural isomers*.



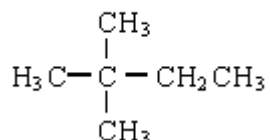
- (ii) Name the **two** isomers of hexane shown below.

Isomer 1



Name _____

Isomer 2



Name _____

- (iii) Give the structures of **two** other branched-chain isomers of hexane.

Isomer 3

Isomer 4

(6)

- (d) A hydrocarbon, **W**, contains 92.3% carbon by mass. The relative molecular mass of **W** is 78.0

- (i) Calculate the empirical formula of **W**.

- (ii) Calculate the molecular formula of **W**.

(4)

(Total 15 marks)

**Q4.**

The table below shows the structures of three isomers with the molecular formula $C_5H_{10}O$

<p>Isomer 1</p>	(<i>E</i>)-pent-3-en-2-ol
<p>Isomer 2</p>	pentanal
<p>Isomer 3</p>	

(a) Complete the table by naming Isomer 3.

(1)

(b) State the type of structural isomerism shown by these three isomers.

(1)

(c) The compound (*Z*)-pent-3-en-2-ol is a stereoisomer of (*E*)-pent-3-en-2-ol.

(i) Draw the structure of (*Z*)-pent-3-en-2-ol.

(1)

(ii) Identify the feature of the double bond in (*E*)-pent-3-en-2-ol and that in (*Z*)-pent-3-en-2-ol that causes these two compounds to be stereoisomers.

(1)



- (d) A chemical test can be used to distinguish between separate samples of Isomer **2** and Isomer **3**.
Identify a suitable reagent for the test.
State what you would observe with Isomer **2** and with Isomer **3**.

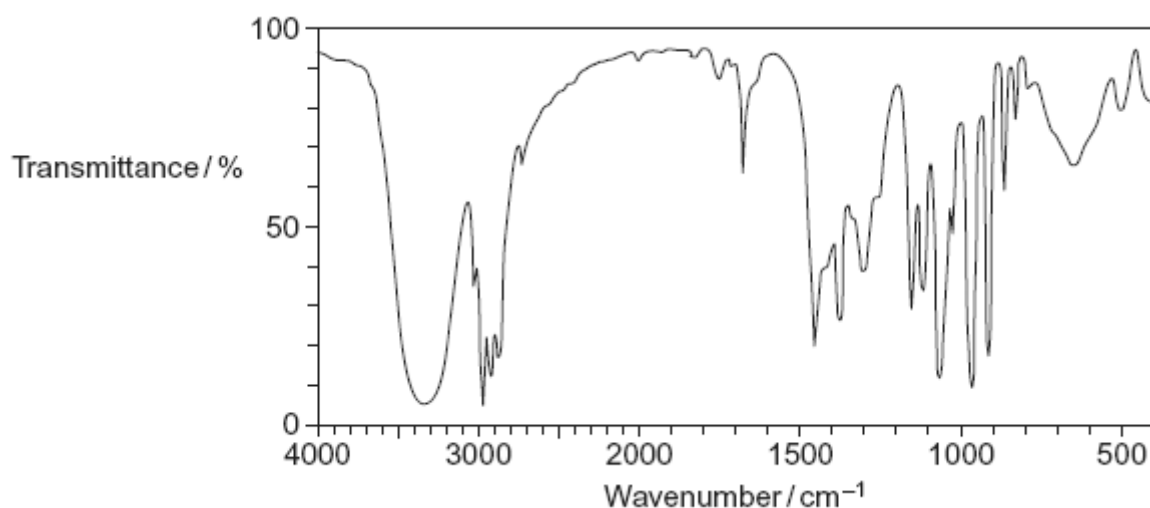
Test reagent _____

Observation with Isomer **2** _____

Observation with Isomer **3** _____

(3)

- (e) The following is the infrared spectrum of one of the isomers **1**, **2** or **3**.



- (i) Deduce which of the isomers (**1**, **2** or **3**) would give this infrared spectrum. You may find it helpful to refer to **Table 1** on the Data Sheet.

(1)



- (ii) Identify two features of the infrared spectrum that support your deduction. In each case, identify the functional group responsible.

Feature 1 and functional group _____

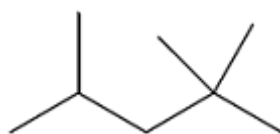
Feature 2 and functional group _____

(2)

(Total 10 marks)

Q5.

Isooctane (C_8H_{18}) is the common name for the branched-chain hydrocarbon that burns smoothly in car engines. The skeletal formula of isooctane is shown below.



- (a) Give the IUPAC name for isooctane.

(1)

- (b) Deduce the number of peaks in the ^{13}C NMR spectrum of isooctane.

5

6

7

8

(1)



- (c) Isooctane can be formed, together with propene and ethene, in a reaction in which one molecule of an alkane that contains 20 carbon atoms is cracked.

Using molecular formulas, write an equation for this reaction.

(1)

- (d) How do the products of the reaction in part (c) show that the reaction is an example of thermal cracking?

(1)

- (e) Deduce the number of monochloro isomers formed by isooctane.
Draw the structure of the monochloro isomer that exists as a pair of optical isomers.

Number of monochloro isomers

Structure

(2)

- (f) An isomer of isooctane reacts with chlorine to form only one monochloro compound.
Draw the **skeletal formula** of this monochloro compound.

(1)



- (g) A sample of a monochlorooctane is obtained from a comet. The chlorine in the monochlorooctane contains the isotopes ^{35}Cl and ^{37}Cl in the ratio 1.5 : 1.0. Calculate the M_r of this monochlorooctane.

$M_r =$ _____

(2)

- (h) Isooctane reacts with an excess of chlorine to form a mixture of chlorinated compounds. One of these compounds contains 24.6% carbon and 2.56% hydrogen by mass. Calculate the molecular formula of this compound.

Molecular formula = _____

(3)

(Total 12 marks)

Q6.

Hexane (C_6H_{14}) is a member of the homologous series of alkanes.

- (a) (i) Name the raw material from which hexane is obtained.

(1)

- (ii) Name the process used to obtain hexane from this raw material.

(1)



(b) C_6H_{14} has structural isomers.

(i) Deduce the number of structural isomers with molecular formula C_6H_{14}

Write the number in this box.

(Space for working)

(1)

(ii) State **one** type of structural isomerism shown by the isomers of C_6H_{14}

(1)

(c) One molecule of an alkane **X** can be cracked to form one molecule of hexane and two molecules of propene.

(i) Deduce the molecular formula of **X**.

(1)

(ii) State the type of cracking that produces a high percentage of alkenes. State the conditions needed for this type of cracking.

Type of cracking _____

Conditions _____

(2)

(iii) Explain the main economic reason why alkanes are cracked.

(1)



- (d) Hexane can react with chlorine under certain conditions as shown in the following equation.



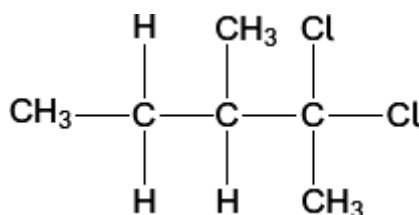
- (i) Both the products are hazardous. The organic product would be labelled 'flammable'.
Suggest the most suitable hazard warning for the other product.

(1)

- (ii) Calculate the percentage atom economy for the formation of $\text{C}_6\text{H}_{13}\text{Cl}$ ($M_r = 120.5$) in this reaction.

(1)

- (e) A different chlorinated compound is shown below. Name this compound and state its empirical formula.



Name _____

Empirical formula _____

(2)

(Total 12 marks)

Q7.

The alkene 3-methylpent-2-ene ($\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)\text{CH}_2\text{CH}_3$) reacts with hydrogen bromide to form a mixture of 3-bromo-3-methylpentane and 2-bromo-3-methylpentane.

- (a) The alkene 3-methylpent-2-ene ($\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)\text{CH}_2\text{CH}_3$) exists as *E* and *Z* stereoisomers.

Draw the structure of *Z*-3-methylpent-2-ene.

(1)



- (b) Name and outline the mechanism for the formation of 3-bromo-3-methylpentane from this reaction of 3-methylpent-2-ene with hydrogen bromide.

Explain why more 3-bromo-3-methylpentane is formed in this reaction than 2-bromo-3-methylpentane.

(7)
(Total 8 marks)



Mark schemes

Q1.

- (a) **M1** Q, R, S, T
M1 Allow the mark for candidates who correctly name or draw the isomers. 1
- M2** (Orange solution) turns green
Independent 1
- (b) **M1** T
As above 1
- M2** Silver mirror
Allow grey/black ppt 1
- (c) **M1** P, Q, R, S
As above 1
- M2** Sweet smelling (liquid) 1
- M3** To react with (remove excess) acid / neutralise
Allow easier to identify the smell 1
- (d) Position
Allow positional 1
- (e) **M1** R & S have an O-H alcohols peak at 3230-3550 cm^{-1}
Allow value within the range 1
- M2** T has C=O peak at 1680-1750 cm^{-1} 1
- M3** R & S (unique) fingerprint region or below 1500 cm^{-1} 1
- M4** Compare to a database / known spectra (and look for an exact match) 1
- (f) All have the same M_r
Allow
same (molecular) ion M/Z peak
same molecular formula 1

[13]



Q2.

- (a) (i) Molecule/compound/consists/composed/made up of hydrogen and carbon only **(1)**
- (ii) C_nH_{2n+2} **(1)**
- (iii) C_6H_{14} only **(1)**
Do not credit structures alone or in addition.

3

- (b) Chemically similar / react in same way / same chemistry
Differ by CH_2
gradation in physical properties OR specified trend e.g. b.p.
same functional group

Any 2, 2 marks 1 + 1

Not same molecular formula

2

- (c) (i) Same molecular formula **(1)**
NOT same Mr

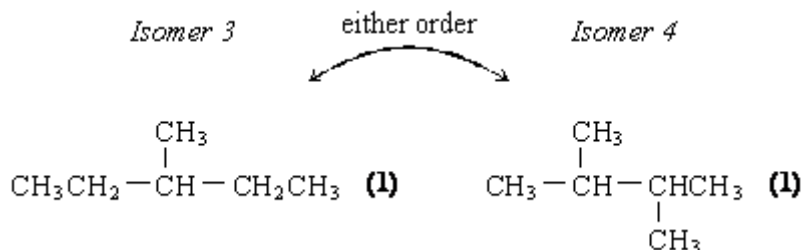
different structural formula / structures **(1)**
(or atoms arranged in different way)

NOT different spatial arrangements

Only credit M2 if M1 correct

- (ii) 2-methylpentane **(1)**
2,2-dimethylbutane **(1)**

(iii)



OR correct condensed / structural formula

Penalise "sticks" once

Penalise absence of vertical bonds once

penalise badly drawn bonds once (vertical between H atoms)

6

- (d) (i) M1 % by mass of H = 7.7(0)% **(1)**
M2 mol H = 7.70 / 1 = 7.70
mol C = 92.3 / 12 = 7.69 **(1)**

M3 (ratio 1:1 ∴) CH

Credit variations for M2 e.g. $78 \times \frac{77}{100} = 6$ and $\frac{78}{12} \times \frac{92.3}{100} = 6$



Correct answer = 3 marks

- (ii) (CH has empirical mass of 13 and $\frac{78}{13} = 6 \therefore$) C_6H_6 (1)
Correct answer 1 mark

4

[15]

Q3.

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 $82 \times 0.878 = 72$, $(72/12) = 6$ C atoms

M2 molecular formula = C_6H_{10}

M3 empirical formula = C_3H_5

M6 penalise nucleophilic addition; ignore bromination



Q4.

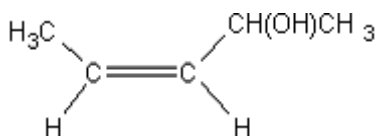
(a) Pentan-2-one*ONLY but ignore absence of hyphens*

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 CHOCH₃ 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)

<p>M1 Tollens' (reagent) (Credit ammoniacal silver nitrate OR a description of making Tollens')</p> <p>(Do not credit Ag⁺, AgNO₃ or [Ag(NH₃)₂]⁺ or "the silver mirror test" on their own, but mark M2 and M3)</p>	<p>M1 Fehling's (solution) / Benedict's (Penalise Cu²⁺(aq) or CuSO₄ but mark M2 and M3)</p>
<p>M2 <u>silver mirror</u> OR <u>black solid or black precipitate</u></p>	<p>M2 <u>Red solid/precipitate</u> (Credit <u>orange</u> or <u>brown solid</u>)</p>
<p>M3 (stays) colourless OR no (observed) change / no reaction</p>	<p>M3 (stays) blue OR no (observed) change / no reaction</p>

*If M1 is blank CE = 0, for the clip**Check the partial reagents listed and if M1 has a totally incorrect 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 any two from**

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



Q5.

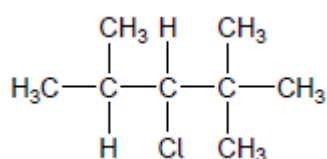
(a) 2,2,4-trimethylpentane 1

(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

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

1

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

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

$$= 1 : 1.25 : 1$$

1

$$\text{Whole number ratio } (\times 4) = 4 : 5 : 4$$

1

$$\text{MF} = C_8H_{10}Cl_8$$

1

[12]

**Q6.**

- (a) (i) Crude oil / oil / petroleum
Do not allow 'petrol' 1
- (ii) Fractional distillation / fractionation / fractionating
Not distillation alone 1
- (b) (i) 5
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'
- $(400^{\circ}\text{C} \leq T \leq 900^{\circ}\text{C})$ or $(650 \text{ K} \leq T \leq 1200 \text{ K})$
Not 'heat' alone
If no T, units must be 650 – 900
- and**
- High pressure ($\geq 10 \text{ atm}$, $\geq 1 \text{ MPa}$, $\geq 1000 \text{ kPa}$) 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

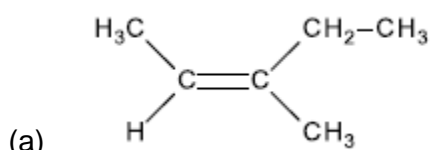
1

C₃H₆Cl

1

[12]

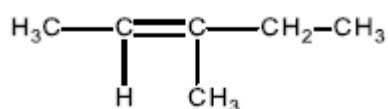
Q7.



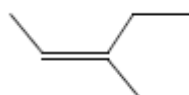
Must show all 4 groups bonded to C=C

Allow CH₃- for methyl group; allow C₂H₅ for ethyl group

Allow correct structure of the style

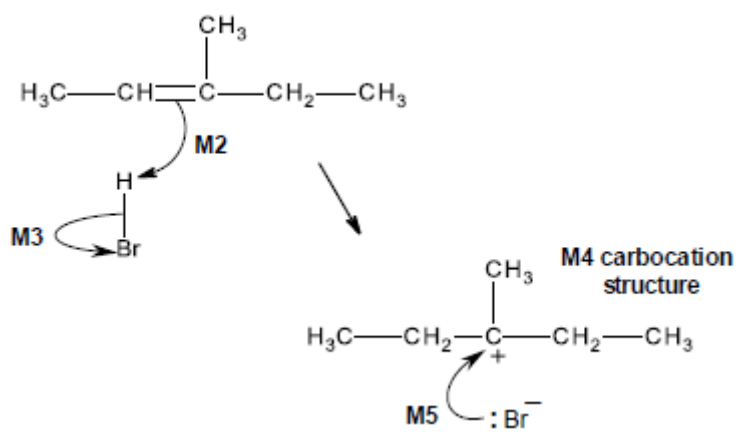


Allow correct skeletal structure



1

(b) M1 electrophilic addition



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
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 3^y carbocation</u> OR 2-bromo-3-methylpentane is <u>formed from 2^y carbocation</u>	1
M7	<u>3^y carbocation more stable than 2^y</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 charged bromide ion towards the positively charged C atom (of either a secondary or) of a tertiary carbocation*

[8]