AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.3.3 HALOGENOALKANES

SCORE	PERCENTAGE
/296	%

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Q1.

(a) 3-chloro-2,4-dimethylpentane

This answer only apart from slips with commas and dashes

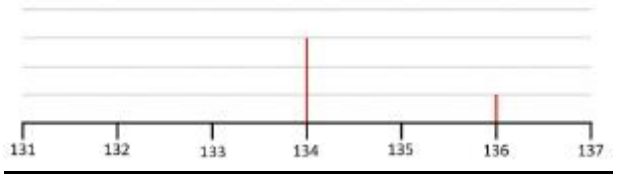
1

(b) **M1** lines at 134 and 136

***M1** is for drawing the correct two lines (if other lines are drawn, penalise **M1** (but ignore any additional very small lines at 135 or 137)*

1

M2 line at 134 to be three times higher than line at 136

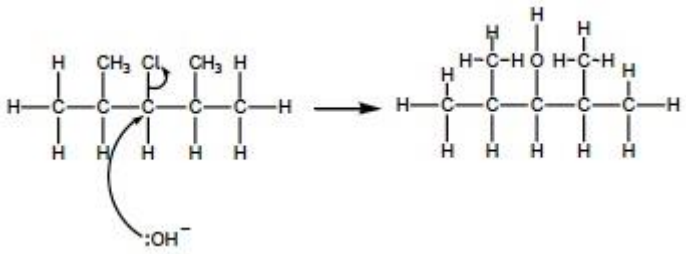


***M2** is for the line at 134 being three times as big as the one at 136 (ignore other lines)*

Accept cross to represent top of lines; if bars drawn – they should be narrow (less than 10% of division) and clear which value they refer to.

1

(c) **M1** nucleophilic substitution



1

M2 curly arrow from lone pair on O of OH^- to C of C–Cl

*For SN2: penalise **M2** for any additional arrow(s) on NaOH, or for covalent NaOH; penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else*

*If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3***

1

M3 curly arrow from C–Cl bond to the Cl

*Penalise **M3** for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C– Cl; ignore other partial charges on uncharged atoms*

*For SN2: penalise **M2** for any additional arrow(s) on NaOH, or for covalent NaOH; penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else*

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*If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3***

If SN1 mechanism given (loss of Cl first followed by attack by OH^-) then:
***M2** curly arrow from C–Cl bond to the Cl*
***M3** curly arrow from lone pair on O of OH^- to positive C atom of correct carbocation*
*penalise **M2** for any additional arrow(s) to/from the Cl to/from anything else*
*penalise **M3** for any additional arrow(s) on NaOH*

1

M4 correct structure of alcohol (in any form)

***M4** is independent*

***M4** ignore presence of non-organic products*

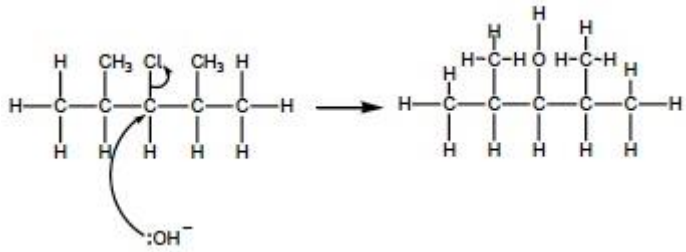
1

(d) **M1** elimination

***M1** allow base elimination (but nothing else)*

1

M2 base



***M2** allow proton acceptor*

1

M3 curly arrow from lone pair on O of OH^- to H on one of the C atoms adjacent to the C–Cl

*If curly arrows represent an attempt at a substitution mechanism, cannot score **M3** or **M4***

1

M4 curly arrow from a correct C-H bond adjacent to the C–Cl 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 **M3**

*If curly arrows represent an attempt at a substitution mechanism, cannot score **M3** or **M4***

1

M5 curly arrow from C–Cl bond to the Cl (mark is independent

Penalise M5 for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C–Cl; ignore other partial charges on uncharged atoms

1

M6 correct structure of alkene (in any form)

***M6** is independent*

***M6** ignore presence of non-organic products*

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If E1 mechanism given (loss of Cl first followed by attack by OH^-) then:
M3 *curly arrow from C–Cl bond to the Cl*
M4 *curly arrow from lone pair of OH^- to a correct H on the correct C adjacent to C^+ on the carbocation*
M5 *curly arrow from a correct C-H bond to a correct C-C bond*
*penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else*
*penalise **M4** for any additional arrow(s) on KOH*

1

(e) C as C=C 1620-1680 cm^{-1} OR no O-H 3230-3550 cm^{-1}

need the correct compound and an explanation

full wavenumber range or value(s) within the range

on this occasion candidates do not need to refer to the O-H bond being O-H alcohol as opposed to O-H acid – just reference to O-H with wavenumbers is required

1

(f) C–Br is weaker than C–Cl or

C–Br has lower bond enthalpy than C–Cl or

C–Br breaks more easily C–Cl

Must compare the C–Br and C–Cl bonds specifically

Ignore references to bond length, size of atoms, shielding, electronegativity and polarity

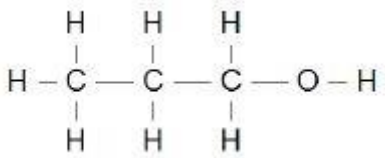
Penalise idea that bromine is more reactive than chlorine

1

[15]

Q2.

(a)



Must be displayed

1

(b) Nucleophilic substitution

1

Excess NH_3

Ignore aqueous, alcoholic, conc, dil, temp, heat, pressure

1

(c) Amount of $CH_3CH_2CH_2Br$ 25.2/122.9 (=0.205) (mol)

M1

Amount of $CH_3CH_2CH_2NH_2$ M1 × 0.75 (= 0.154) (mol)

M2

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Mass $CH_3CH_2CH_2NH_2$ M2 × 59.0 = 9.07g Must be 3sf

M3

If either Mr incorrect or used incorrectly then only award 1 mark for 75% yield calculation

(ignore rounding to 123 for $CH_3CH_2CH_2Br$)

OR

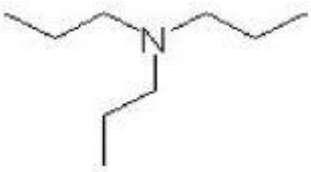
Max mass amine = M1 × 59.0 (= 12.1) (g)

Actual mass = M2 × 0.75 = 9.07g Must be 3sf

Allow 9.09 but if 9.08 check for AE

18.9 scores 1 for 75%

(d)



Must be skeletal

Ignore lone pair

1

tertiary amine or 3° amine (only award if a tertiary amine shown)

1

(e) NaOH/ ethanol or KOH / ethanol (both required)

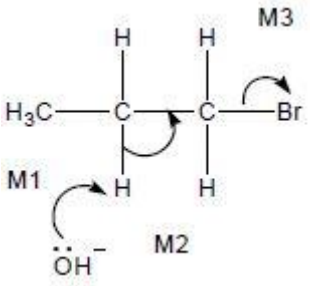
***NOT** aqueous*

Ignore heat, temp, conc., dil,

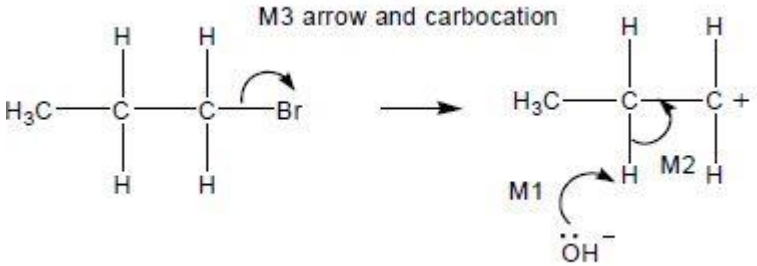
Accept alcoholic for ethanol

1

(f) (Basic) Elimination



Also credit E1 mechanism



1

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M1 arrow from lone pair on O of hydroxide to correct H (or to space mid way between hydroxide O and H)

M2 arrow from C-H bond to C-C bond following attack by OH^- on the correct H

M3 arrow from C-Br bond to Br

If nucleophilic substitution shown then allow M3 only in mechanism

If wrong haloalkane used then Max 2 for mechanism

M3 curly arrow for loss of Br^- & structure of carbocation

M1 arrow from lone pair on O of hydroxide to H (or to space mid way between hydroxide O and H) (same as E2)

M2 arrow from C-H bond to C-C bond (same as E2)

3

[13]

Q3.

A

[1]

Q4.

(a) $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$

Allow dot in free-radical on either O or Cl.

1

$ClO\bullet + O_3 \longrightarrow 2O_2 + Cl\bullet$

1

(b) (KOH acts as a) base

1

(propan-1-ol acts as a) solvent.

Allow product of reaction between KOH and propan-1-ol / $CH_3CH_2CH_2O^-$ acts as base.

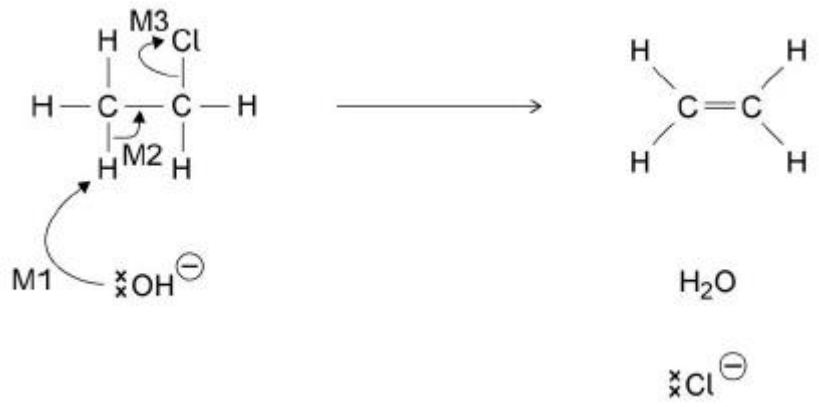
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(c) (Name of mechanism) Elimination

1

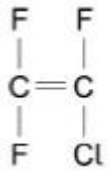
mechanism: 3 arrows (1 mark each).

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3

(d)



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

All stages are covered & the explanation of each stage is generally correct and virtually complete. Stages 1 and 2 are supported by correct data. Answer communicates the whole process coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

Steps in stage 3 are in logical order and working is shown. If there is no working for ratio or statement of ratio then full marks cannot be awarded.

If the formulae of the three molecular ions are not correct (2d) then the student can't access Level 3 (any incorrect chemistry drops the student to the bottom mark within the level they have achieved).

5-6 marks

Level 2

Stage 2 is attempted (**2a-2c** do not need to be explicitly stated) but the calculation may contain inaccuracies **OR** the explanation may be incomplete **OR** first two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows a progression through the first two stages. Some steps in each stage may be incomplete.

If percentage of carbon is missing or incorrect (1a) then student can't access Level 2.

3-4 marks

Level 1

Stage 1 needs to be attempted but may contain inaccuracies.

OR

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Stage 3 attempted but may contain inaccuracies / molecular formula not determined.

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

1-2 marks

Level 0

Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1 (determines empirical formula)

1a *16.3% carbon*

1b *Divide by* A_r

1c *Divide by smallest (0.904)*

1d *Convert ratio in simplest integer (x 2)*

C	Cl	F
$\frac{16.3}{12.0} = 1.358$	$\frac{32.1}{35.5} = 0.904$	$\frac{51.6}{19.0} = 2.716$
$\frac{1.358}{0.904}$	$\frac{0.904}{0.904}$	$\frac{2.716}{0.904}$
3	2	6

Stage 2 (determines formulae of three molecular ions)

2a *For E.F.* M_r *(corresponds to the molecule) = 221*

2b *since* M_r *= 221 lies within molecular ion range 220–224*

2c *Thus empirical formula = molecular formula*

2d *Three correct formulae*

2e *Correct* M_r *for each of three molecules*

$C_3{}^{35}Cl_2F_6^+$	$C_3{}^{35}Cl^{37}ClF_6^+$	$C_3{}^{37}Cl_2F_6^+$
220	222	224

Stage 3 (explains the ratio of 3 molecular ion peaks)

3a *Working*

2b *Correct (simplified) ratio* ***9:6:1***

Note: 9:3:1 will be a common incorrect answer (max 5).

Working:

$C_3{}^{35}Cl_2F_6^+$	$C_3{}^{35}Cl^{37}ClF_6^+$	$C_3{}^{37}Cl_2F_6^+$
220	222	224

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$^{35}Cl_2 = \left(\frac{3}{4}\right)^2 = \frac{9}{16}$	$^{35}Cl^{37}Cl$ and $^{37}Cl^{35} = 2 \times \frac{1}{4} \times \frac{3}{4} = \frac{6}{16}$	$^{37}Cl_2 = \left(\frac{1}{4}\right)^2 = \frac{1}{16}$

[15]

Q5.

(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

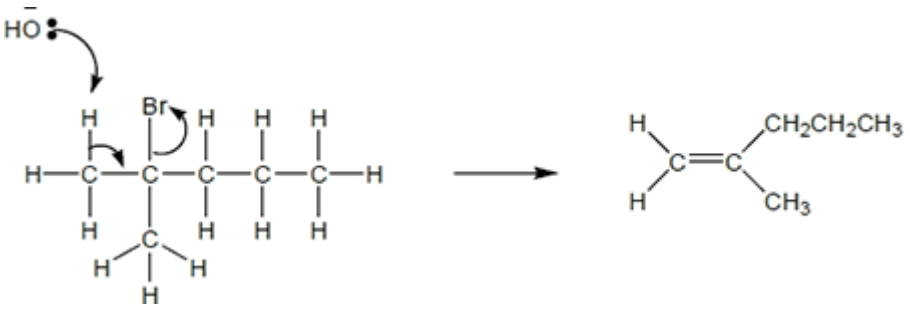
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Correct arrow from C–Br bond to Br

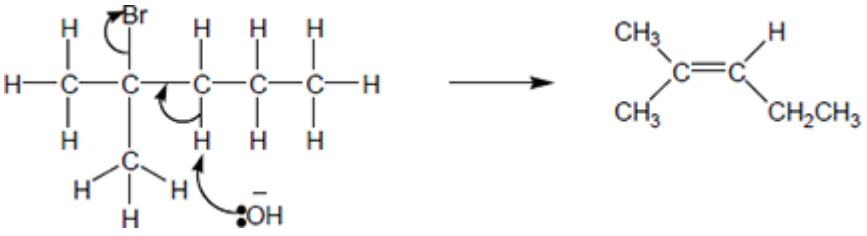
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Structure of chosen product

1



OR



[6]

Q6.

B

[1]

Q7.

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(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

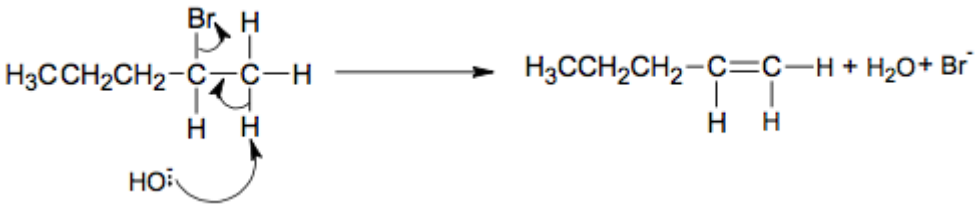
rxn 2 = nucleophile/lone pair donor/electron pair donor

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**

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

ALLOW *correct E1 mechanism*

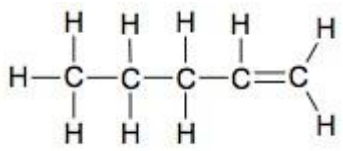
IGNORE *incorrect inorganic products*

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

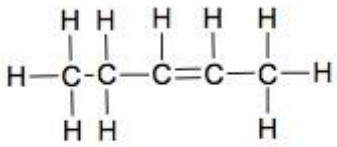
1
1
1

(b)



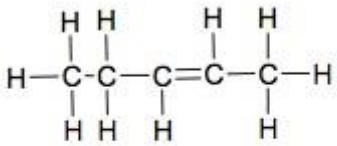
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Z-pent-2-ene

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

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]

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Q8.

(a) **P** 3,3−dimethylbut−1−ene

OR

accept 3,3−dimethylbutene

Ignore absence of commas, hyphens and gaps

Require correct spelling

Q 3−chloro−2,2−dimethylbutane

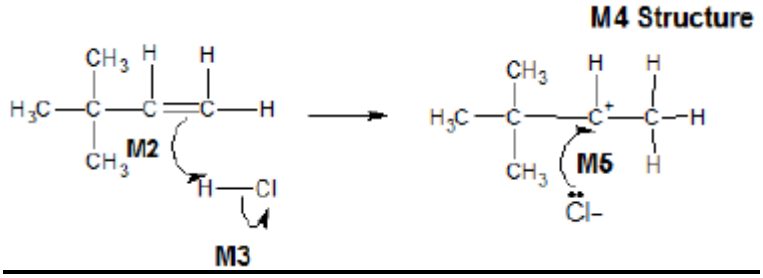
OR

accept 2−chloro−3,3−dimethylbutane

In Q, "chloro" must come before "dimethyl"

2

(b) **M1 <u>Electrophilic addition</u>**



M2 must show an arrow from the double bond towards the H atom of HCl
M3 must show the breaking of the H−Cl bond
M4 is for the structure of the carbocation
M5 must show an arrow from the lone pair of electrons on the negatively charged chloride ion towards the positively charged carbon atom on <u>their</u> carbocation.

NB The arrows here are double−headed

M1 *both words required*

For the mechanism

M3 *Penalise incorrect partial charge on H−Cl bond and penalise formal charges*

Ignore partial negative charge on the double bond.

<u>Maximum 3 of 4 marks for a correct mechanism</u> *<u>using HBr or the wrong organic reactant or wrong organic product (if shown) or a primary carbocation</u>*

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

Credit the correct use of "sticks"

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

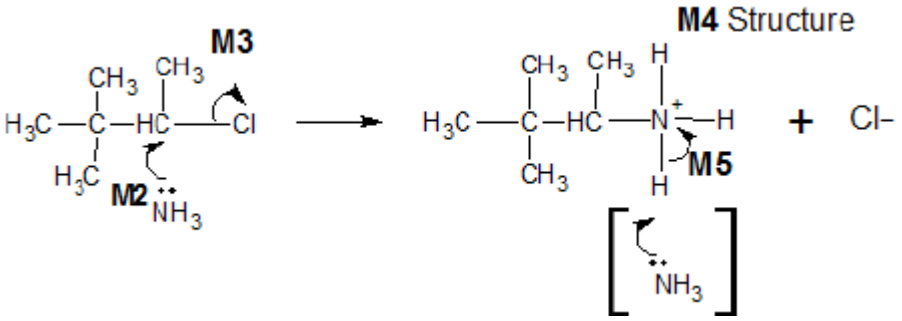
5

(c) **M1 <u>Nucleophilic substitution</u>**

*For **M1**, both words required.*

Accept phonetic spelling

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M2 must show an arrow from the lone pair of electrons **on the nitrogen atom** of an ammonia molecule to the correct C atom
M3 must show the movement of a pair of electrons from the C− Cl bond to the Cl atom. Mark **M3** independently provided it is from <u>their original molecule</u>
M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge **must** be shown on, or close to, the N atom.
M5 is for an arrow from the N−H bond to the N atom
Award full marks for an S_N1 mechanism in which **M2** is the attack of the ammonia on the intermediate carbocation

NB These are double-headed arrows

For the mechanism

*Penalise **M2** if NH_3 is negatively charged.*

*Penalise **M3** for formal charge on C of the C−Cl or incorrect partial charges on C−Cl*

*Penalise **M3** for an additional arrow from the Cl to something else*

*The second mole of ammonia is not essential for **M5**; therefore ignore any species here*

Penalise once only for a line and two dots to show a bond

***<u>Maximum 3 of 4 marks for the mechanism</u>** for wrong organic reactant OR wrong organic product if shown*

Accept the correct use of "sticks"

5

(d) **M1** (base) elimination

***M1** Dehydrohalogenation*

M2 KOH **OR** NaOH
M3 Must be consequential on a correct reagent in **M2**, but if incomplete or inaccurate attempt at reagent (e.g. hydroxide ion), **penalise M2 only and mark on**

Any **one** from
- <u>high</u> temperature OR <u>hot</u> OR <u>heat / boil under reflux</u>
- <u>concentrated</u>
- <u>alcohol / ethanol (as a solvent) / (ethanolic conditions)</u>

***M3** not "reflux" alone*

***M3** if a temperature is stated it must be in the range 78C to 200 °C*

Ignore "pressure"

3

(e) **M1**

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$3NaBr + H_3PO_4 \longrightarrow 3HBr + Na_3PO_4$

M1 *Credit correct ionic species in the equation*

M2 and M3
SO_2 **and** Br_2 identified
M4
Concentrated sulfuric acid
- is an oxidising agent
- oxidises the bromide (ion) or Br^- or NaBr or HBr
- is an electron acceptor

*In **M2** and **M3** the two gases need to be identified. If equations are used using sulfuric acid and the toxic gases are not identified clearly, allow one mark for the formulas of SO_2 and Br_2*

- *apply the list principle as appropriate but ignore any reference to HBr*
- *the marks are for identifying the two gases either by name or formula*

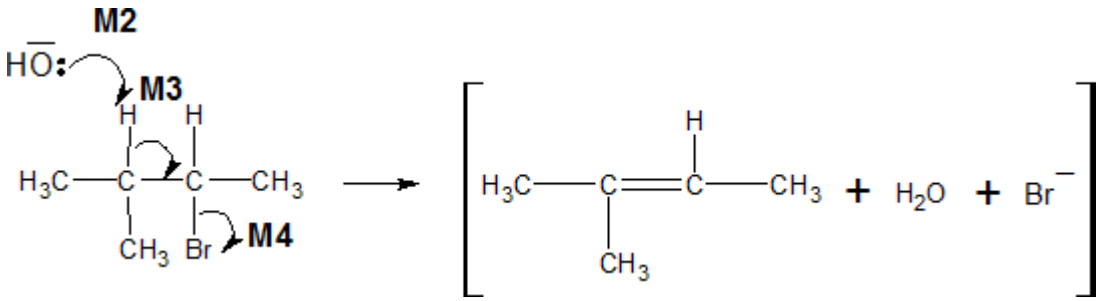
4

[19]

Q9.

(a) (i) M1 **Elimination**

M1 *Credit "base elimination" but no other prefix.*



*Penalise **M2** if covalent KOH*

*Penalise **M4** for formal charge on C or Br of C−Br or incorrect partial charges on C−Br*

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

Ignore other partial charges

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

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

M4 is independent provided it is from their original molecule, **BUT CE=0 for the mechanism (penalise M2, M3 and M4 only) if nucleophilic substitution mechanism is shown**

Maximum any 2 of 3 marks for the mechanism *for wrong organic reactant or wrong organic product (if shown).*

Credit the correct use of "sticks" for the molecule except for

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the C−H being attacked

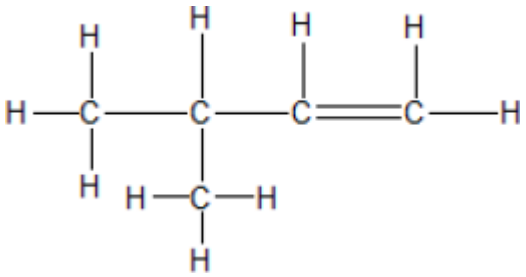
Award full marks for an E1 mechanism in which **M4** is on the correct carbocation

*Penalise **M4**, if an additional arrow is drawn from Br eg to K^+*

NB These are double-headed arrows

4

(ii) Displayed formula for 3-methylbut-1-ene



All bonds and atoms must be drawn out, but ignore bond angles

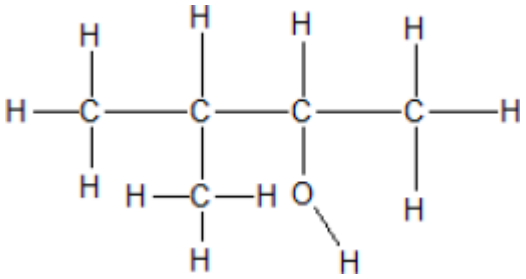
1

(iii) Position(al) (isomerism or isomer)

Penalise any other words that are written in addition to these.

1

(b) (i) Displayed formula for 3-methylbutan-2-ol



All bonds and atoms must be drawn out, but ignore bond angles.

1

(ii) Any **one** from

- Lower / decreased temperature **OR** cold
- Less concentrated (comparative) ***OR*** dilute KOH
- Water (as a solvent) / (aqueous conditions)

Ignore "pressure".

1

(iii) Nucleophilic substitution

Both words needed - credit phonetic spelling.

1

(iv) (Strong / broad) absorption / peak in the range **3230 to 3550** cm^{-1} or

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

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

1

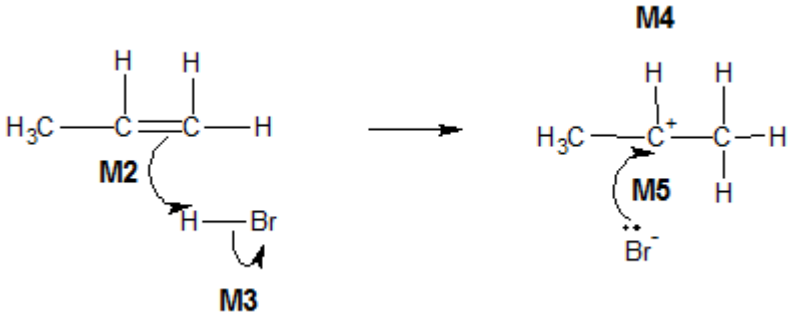
[10]

Q10.

(a) **M1 <u>electrophilic addition</u>**

*For **M1**, both words required*

Accept phonetic spelling



For the mechanism

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

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

***M3** Penalise partial charges on H–Br bond if wrong way and penalise formal charges*

M3 must show the breaking of the H–Br bond

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

M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the correct (positively charged) carbon atom

<u>Maximum any 3 of 4 marks for the mechanism</u> for wrong (organic) reactant OR wrong organic product (if shown) OR primary carbocation

Accept the correct use of sticks

NB These are double-headed arrows

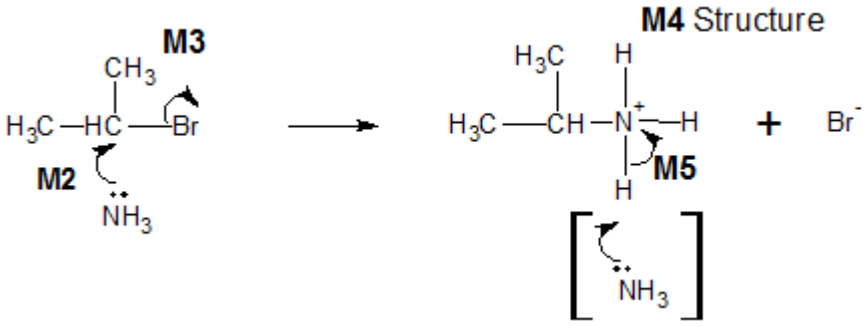
5

(b) **M1 <u>Nucleophilic substitution</u>**

*For **M1**, both words required*

Accept phonetic spelling

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For the mechanism

*Penalise **M2** if NH_3 is negatively charged*

M2 must show an arrow from the lone pair of electrons **on the nitrogen atom** of an ammonia molecule to the correct C atom

*Penalise **M3** for formal charge on C of the C−Br or incorrect partial charges on C−Br*

*Penalise **M3** for an additional arrow from the Br to something else*

M3 must show the movement of a pair of electrons from the C–Br bond to the Br atom. Mark **M3** independently provided it is from <u>their original molecule</u>

*The second mole of ammonia is not essential for **M5**; therefore ignore any species here*

M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge **must** be shown on / or close to, the N atom

Penalise once only for a line and two dots to show a bond

M5 is for an arrow from the N–H bond to the N atom

***<u>Maximum any 3 of 4 marks for the mechanism</u>** for wrong organic reactant **OR** wrong organic product if shown*

Award full marks for an S_N1 mechanism in which **M2** is the attack of the ammonia on the intermediate carbocation

Accept the correct use of "sticks"

NB These are double-headed arrows

5

(c) M1 (addition) polymerisation OR poly-addition

Ignore "additional"

Credit polyprop-1-ene and polypropylene

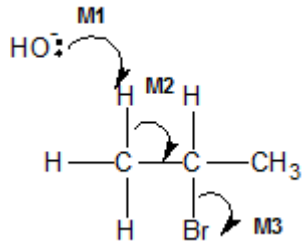
M2 poly(propene) / polypropene

Penalise "condensation polymerisation"

2

(d)

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*Penalise **M1** if covalent KOH*

M1 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom

*Penalise **M3** for formal charge on C of C–Br or incorrect partial charges on C−Br.*

M2 must show an arrow from a correct C–H bond adjacent to the C–Br bond to the appropriate C–C bond. Only award if an arrow is shown attacking the H atom of a correct C−H bond in **M1**

Ignore other partial charges

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

M3 is independent provided it is from their original molecule, but **CE=0 if nucleophilic substitution**

***Maximum any 2 of 3 marks** for wrong organic reactant*

Award full marks for an E1 mechanism in which **M3** is on the correct carbocation.

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

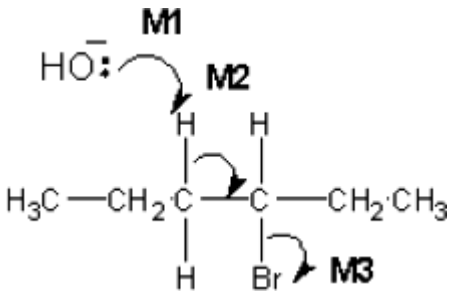
NB These are double-headed arrows

3

[15]

Q11.

(a) (i)



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

*Penalise **M3** for formal charge on C of the C-Br or incorrect partial charges on C-Br*

Ignore other partial charges

M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom

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

M2 must show an arrow from the correct C–H bond to the correct C–C bond. Only award if an arrow is shown attacking the H atom of the correct C–H bond in **M1**

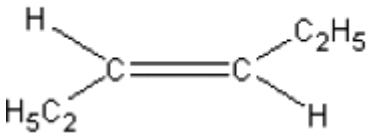
M3 is independent but **CE=0 if nucleophilic substitution**

N.B these are double-headed arrows

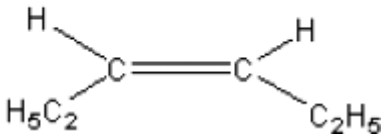
3

(ii)

M1 E isomer



M2 Z isomer



Award 1 mark if both correct stereoisomers but in the wrong places

Accept no other alkenes.

Be reasonably lenient on the bonds to ethyl (or to CH_2CH_3) since the question is about E and Z positions but penalise once only if connection is clearly to the CH_3 of CH_2CH_3

Accept linear structures

2

(iii) **M1** (Compounds / molecules with) the same structural formula

*Penalise **M1** if "same structure"*

M2 with atoms/bonds/groups arranged differently in space

Ignore references to "same molecular formula" or "same empirical formula" or any reference to "displayed formula"

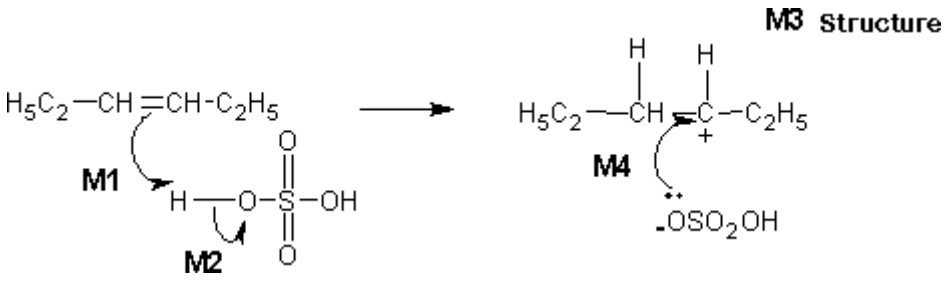
OR

atoms/bonds/groups that have different spatial arrangements / different orientation.

Mark independently

2

(b)



M1must show an arrow from the double bond towards the H atom of the H – O bond OR HO on a compound with molecular formula for H_2SO_4

M1 could be to an H+ ion and M2 an independent O – H bond break on a compound with molecular formula for H_2SO_4

***M1** Ignore partial negative charge on the double bond.*

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M2 must show the breaking of the O – H bond.

***M2** Penalise partial charges on O – H bond if wrong way and penalise formal charges*

In M2 do not penalise incorrect structures for H_2SO_4

M3 is for the structure of the carbocation.

M4 must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards a correct (positively charged) carbon atom.

***M4** NOT HSO_4^-*

*For **M4**, credit <u>as shown</u> or <u>$^-OSO_3H$</u> ONLY with the negative charge anywhere on this ion*

OR <u>correctly</u> drawn out with the negative charge placed correctly on oxygen

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

NB The arrows here are double-headed

<u>Max 3 of any 4 marks</u> for wrong organic reactant or wrong organic product (if shown)

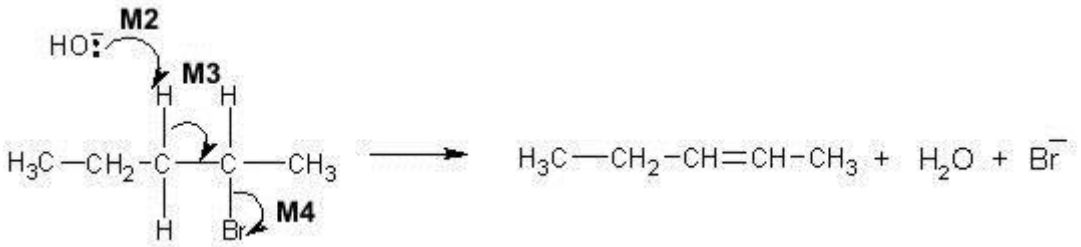
Accept the correct use of "sticks"

4

[11]

Q12.

(a) (i) **M1** <u>Elimination</u>



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

M3 must show an arrow from a C-H bond adjacent to the C-Br bond towards the appropriate C-C bond.
Only award if a reasonable attempt has been made at the attack on the H atom of the appropriate adjacent C-H

M4 is independent provided it is from their <u>original molecule</u>

Award full marks for an E1 mechanism in which **M3** is on the correct carbocation.

N.B. These are double-headed arrows

For M1, accept ''Base elimination'' but <u>no other prefix</u>.

*Penalise **M2** if covalent KOH*

*Penalise **M4** for formal charge on C of C-Br or incorrect*

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partial charges on C-Br

Ignore other partial charges

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

Max any 2 of 3 marks ***for the mechanism*** *for wrong reactant (or wrong product if shown).*

Accept the correct use of ''sticks'' for the molecule except for the C-H being attacked

4

(ii) **Structure for pent-1-ene**

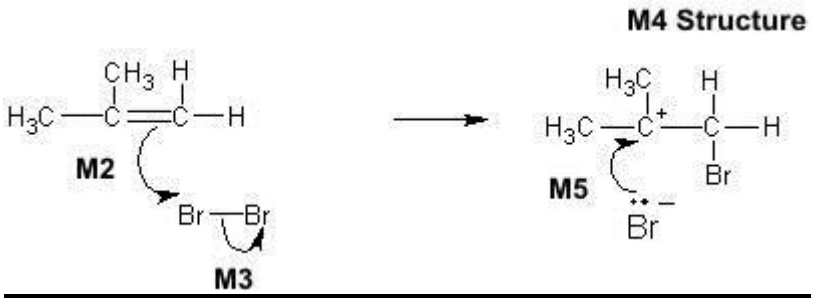
$CH_3CH_2CH_2CH=CH_2$

Penalise C_3H_7

Accept correct ''sticks''

1

(b) **M1 Electrophilic addition**



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

M3 must show the breaking of the Br-Br bond.

M4 is for the structure of the tertiary carbocation with Br on the correct carbon atom.

M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged carbon atom.

N.B. These are double-headed arrows

For M1, both words required.

For the mechanism

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

M3 *Penalise partial charges on Br-Br bond if wrong way and penalise formal charges*

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

Max any 3 of 4 marks ***for the mechanism*** *for*

wrong organic reactant or wrong organic product (if shown) or primary carbocation.

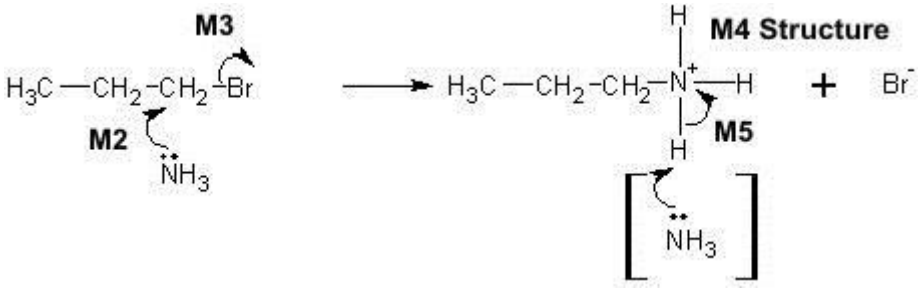
If HBr is used, max 2 marks ***for their mechanism***

Accept the correct use of ''sticks''

5

(c) **M1 Nucleophilic substitution**

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M2 must show an arrow from the lone pair of electrons on the nitrogen atom of an ammonia molecule to the C atom.

M3 must show the movement of a pair of electrons from the C-Br bond to the Br atom. **M3** is independent provided it is from their original molecule

M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge must be shown on/or close to, the N atom.

M5 is for an arrow from the N-H bond to the N atom.

Award full marks for an S_N1 mechanism in which M2 is the attack of the ammonia on the intermediate carbocation.

N.B. These are double-headed arrows

*For **M1**, both words required.*

*Penalise **M2** if NH_3 is negatively charged.*

*Penalise **M3** for formal charge on C or incorrect partial charges*

The second mole of ammonia is not essential for M5; therefore ignore any species here.

Penalise once only for a line and two dots to show a bond.

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

Accept the correct use of ''sticks''

5

[15]

Q13.

(a) (i) Electron pair donor

OR

Species which uses a pair of electrons to form a co-ordinate/covalent bond.

Credit "lone pair" as alternative wording

Credit "electron pair donator"

1

(ii) Replacement of the halogen (atom) (by the nucleophile)

OR

The carbon-halogen bond/C-X breaks and a bond forms

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with the nucleophile or between the carbon and the nucleophile

They must describe the idea of substitution in a haloalkane.

Accept the idea that a nucleophile replaces the halogen which becomes a halide ion

Penalise reference to "halogen molecule" and penalise the idea that the haloalkane contains a halide

1

(iii) Splitting molecules using/by water

OR

breaking/splitting/dissociating (C¡VX) bond(s)/using/by water

NOT simply the reaction with water or simply the addition of water.

Ignore "compound"

1

(iv) (Heat) energy/enthalpy required/needed/absorbed (at constant pressure) to break/split it/the (carbon-halogen) bond

OR

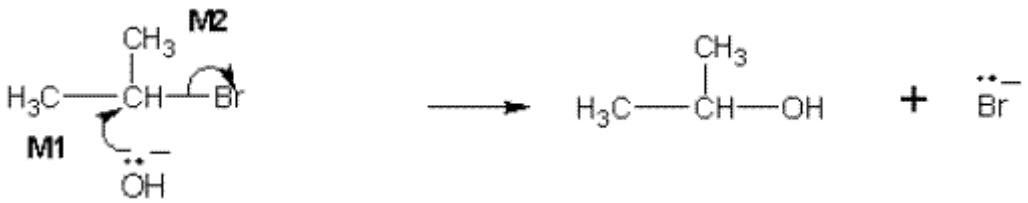
(Heat) energy/enthalpy required/needed/absorbed (at constant pressure) for homolysis of the (C–X/the carbon-halogen) bond

Ignore bond formation

Ignore "average"

1

(b)



M1 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom.

M2 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.

Penalise M1 if covalent KOH is used

Penalise M2 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

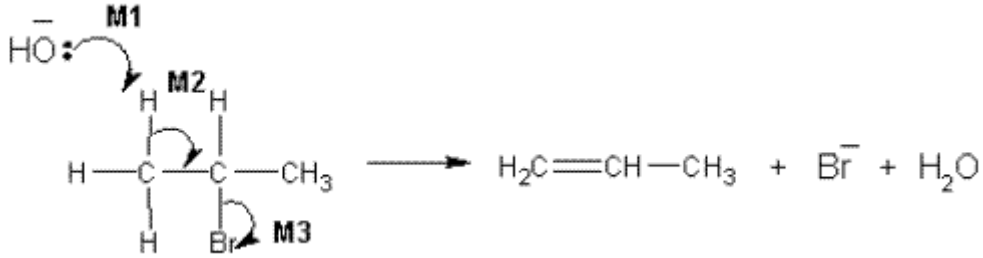
Max 1 mark for the wrong reactant

Accept the correct use of "sticks"

2

(c) (i)

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M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion <u>to the correct</u> H atom

M2 must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1

M3 is independent provided it is from the <u>original molecule</u>

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

Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

Max 2 marks for wrong reactant

Accept the correct use of "sticks" for the molecule except for the C-H being attacked

3

(ii) **M1** <u>Stated</u> that the spectrum has an <u>absorption/absorbance/ peak in the range 1620 cm^{-1} to 1680</u> (cm^{-1}) or specified <u>correctly in this range</u> from the spectrum

M2 **depends on correct <u>range or wavenumber being specified</u>**

M2 (Infrared absorption) <u>due to C=C OR carbon-carbon double bond</u>

QoL for correct M1 statement which includes both the word absorption (or alternative) <u>and</u> the correct range or wavenumber

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

For M2 it is not sufficient simply to state that an alkene has C=C

M2 could be on the spectrum

Ignore reference to other absorptions

2

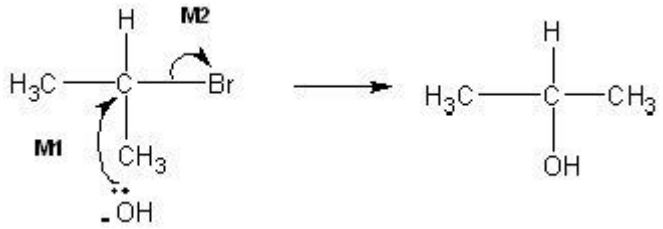
[11]

Q14.

(a) (i) <u>Nucleophilic substitution</u>

1

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2

M1 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom.
M2 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Penalise M1 if covalent KOH is used

Penalise M2 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

*Max 1 mark **for the mechanism** for the wrong reactant and/or "sticks"*

Ignore product

Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.

(ii) 2-bromopropane ONLY

1

(iii) Polar C–Br ***OR*** polar carbon–bromine bond ***OR*** dipole on C–Br ***OR*** δ+ (δ–)
C atom of carbon–bromine bond is δ+/electron deficient ***OR*** C—Br

(Credit carbon–halogen bond as an alternative to carbon–bromine bond)

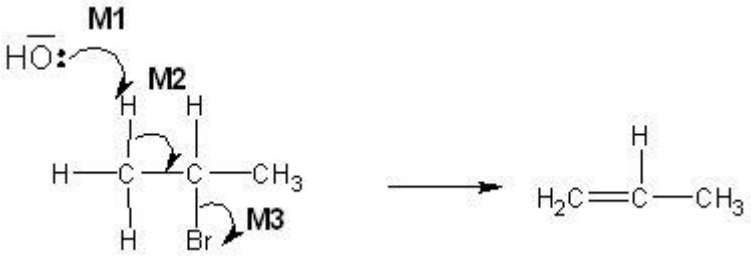
It must be clear that the discussion is about the carbon atom of the C–Br bond. NOT just reference to a polar molecule. Ignore X for halogen

1

(b) Elimination

Credit "base elimination" but NOT "nucleophilic elimination" No other prefix.

1



3

M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom
M2 must show an arrow from the correct C-H bond to the C-C bond

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and should only be awarded if an attempt has been made at M1
M3 is independent.

Mechanism
Penalise M1 if covalent KOH
Penalise M3 for formal charge on C or incorrect partial charges
Penalise once only for a line and two dots to show a bond.
*Max 2 marks **for the mechanism** for wrong reactant and/or "sticks"*
Ignore product

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

(c) *Any one condition from this list to favour elimination*;
Apply the list principle

- alcohol(ic)/ethanol(ic) (solvent)
- high concentration of KOH/alkali/hydroxide ***OR*** concentrated KOH/hydroxide
  Ignore "aqueous"
- high temperature or hot or heat under reflux or T = 78 to 100°C
  Ignore "excess"

1

(d) (i) Addition (polymerisation) ONLY
Penalise "additional"

1

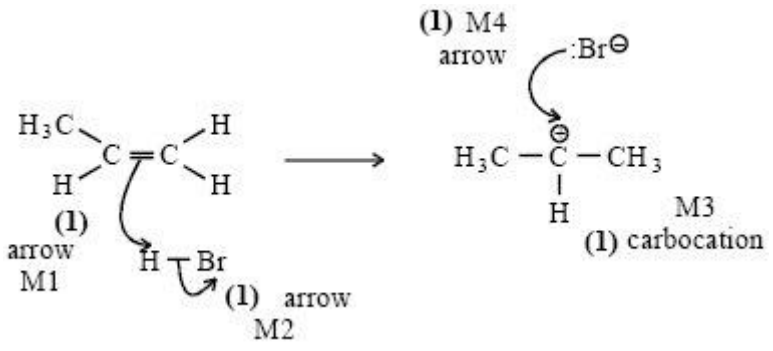
(ii) But-2-ene ONLY (hyphens not essential)
Ignore references to cis and trans or E/Z
Ignore butane

1

[12]

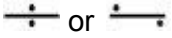
Q15.

(a) (i)



If wrong carbocation, lose structure mark
If wrong alkene, lose structure mark

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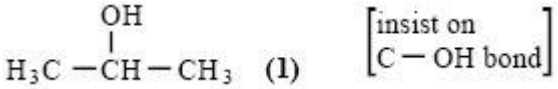
Can still score ¾ i.e. penalise M3
Penalise M2 if polarity included incorrectly
no bond between H and Br
bond is shown as  or

4

(ii) 
$CH_3CH_2CH_2$
credit secondary carbocation here if primary carbocation has been used in (i)

Ignore attack on this carbocation by 

1

(b) (i) *Structure*: 

1

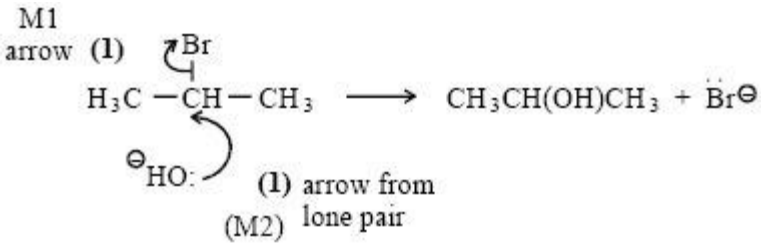
Name: propan-2-ol
Not 2-hydroxypropane

1

(ii) *Name of mechanism*: nucleophilic substitution **(both words)**
(NOT S_N1 or S_N2)

1

Mechanism:



penalise incorrect polarity on C-Br (M1)
Credit the arrows even if incorrect haloalkane
If S_N1, both marks possible

2

(c) (i) elimination

1

(ii) base
OR proton acceptor
NOT nucleophile

1

[12]

Q16.

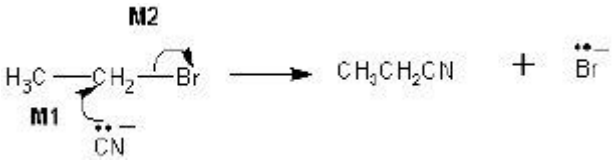
(a) Electron pair donor
OR
Species which uses a pair of electrons
to form a co-ordinate / covalent bond.
QoL

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Credit "lone pair" as alternative wording

1

(b)



M1 Must show an arrow from the lone pair of electrons on the carbon atom of the negatively charged cyanide ion to the central C atom.

M2 Must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Award full marks for an S_N1 mechanism in which M1 is the attack of the cyanide ion on the intermediate carbocation.

Penalise M1 if covalent KCN is used

Penalise M2 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

Max 1 mark for the wrong reactant or "sticks"

2

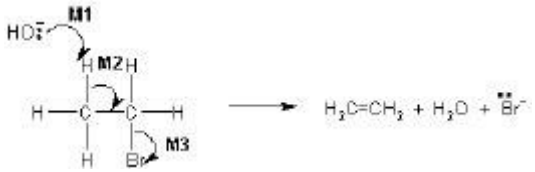
(c) Ethylamine / $CH_3CH_2NH_2$ is a nucleophile
OR
Ethylamine could react further
OR
Ethylamine could make secondary / tertiary amines
OR
To make reaction with ammonia more likely
OR
To minimise further substitution
OR
The idea of releasing free amine from the salt
OR
The idea of removing a proton from the intermediate alkylammonium ion
OR
The idea that ammonia acts <u>both</u> initially as a nucleophile and then as a base

Do not credit a simple reference to the equation or the mechanism requiring two moles of ammonia.

1

(d) **Elimination**

Credit "base elimination" but NOT "nucleophilic elimination"
No other prefix.



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1

M1 Must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom

M2 Must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1

M3 Is independent.

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

Mechanism
Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

*Max 2 marks **for the mechanism** for wrong reactant or "sticks"*

3

[8]

Q17.

A

[1]

Q18.

(a) (base) elimination

(penalise other words before 'elimination' e.g. nucleophilic)

1

M1: curly arrow from lone pair of electrons on oxygen of hydroxide ion

(insist on a lone pair of electrons on the oxygen atom and a negative charge, but only credit this mark if the attack is to a correct H atom)

1

M2: curly arrow from the middle of the C-H bond to the middle of the C–C bond

1

(only credit this mark if the arrow originates from the correct C–H bond and if an attempt has been made at M1)

M3: curly arrow from the middle of the C–Br bond towards/alongside the Br atom

(credit M3 independently unless the bond breaking is contradicted by an additional arrow)

(penalise curly arrow if the C–Br has a formal positive charge)

(credit full marks for an E1 mechanism, with M2 awarded for a correct curly arrow on the correct carbocation)

(award a maximum of two marks for either an incorrect

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haloalkane or an incorrect organic product)

(maximum 2 marks for use of 'sticks' for the haloalkane, unless RE from 2(b), when credit can be given)

(b) (i) **M1**: compounds with the same structural formula

1

M2: but the bonds/groups/atoms have different spatial arrangements or orientation or configuration/are arranged differently in space/3D

(ignore reference to the same molecular formula for M1)

1

(ii) **M1**: correct structural representation for cis-but-2-ene and its name or its identification as the cis isomer

1

M2: correct structural representation for trans-but-2-ene and its name or its identification as the trans isomer

(accept representations which are 90° to linear)

(award one mark for two correct structures but either wrong/no names)

(maximum 1 mark for an incorrect alkene)

1

(iii) geometric(al) or cis-trans

1

(c) nucleophile or electron pair donor

(penalise 'base')

1

(d) $CH_3CH_2CH_2CH_2Br + 2NH_3 \rightarrow CH_3CH_2CH_2CH_2NH_2 + NH_4Br$

(M1 correct product)

(M2 balanced equation using $2NH_3$ and leading to NH_4Br)

(penalise M1 for use of $C_4H_9NH_2$ or for incorrect haloalkane, but allow consequent correct balancing of equation with 2 moles of ammonia)

2

(1–)butylamine

(credit 1–aminobutane and butyl–1–amine)

(award QoL mark for correct spelling)

1

[13]

Q19.

(a) 2-bromobutane;

1

(b) Elimination;

(penalise "nucleophilic" OR "electrophilic" before the word "elimination")

1

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M1: curly arrow from lone pair on oxygen of hydroxide ion to H atom on correct C-H adjacent to C-Br;

(penalise M1 if KOH shown as covalent with an arrow breaking the bond)

1

M2: curly arrow from single bond of adjacent C-H to adjacent single bond C-C;

(only credit M2 if M1 is being attempted to correct H atom)

1

M3: curly arrow from C-Br bond to side of Br atom;

(credit M3 independently unless arrows contradict)
(Credit possible repeat error from 2(c)(iii) for M3)
(If the wrong haloalkane is used OR but-1-ene is produced, award MAX. 2 marks for the mechanism)
(If E1 mechanism is used, give full credit in which M1 and M2 are for correct curly arrows on the correct carbocation)

(c) (i) (structural) isomers/hydrocarbons/compounds/they have the same molecular formula, but different structural formulas/different structures; 1

(penalise statements which are not expressed in good English and which do not refer clearly to structural isomers i.e. plural)
(penalise statements which refer to "different (spatial) arrangements")
(credit" different displayed formulas")
(Q of L mark)

(ii) Correct structure for but-1-ene;

1

[7]

Q20.

(a) M1 curly arrow from lone pair on oxygen of hydroxide ion to H atom on C-H adjacent to C-Br

1

M2 curly arrow from single bond of adjacent C-H to adjacent single bond C-C

(only credit M2 if M1 is being attempted to correct H atom)

1

M3 curly arrow from C-Br bond to side of Br atom

(credit M3 independently)

1

(b) Ml credit a correct structure for either geometrical E-Z isomer and its designation as either *cis* or *trans.*
OR credit two correct geometrical E-Z isomer structures (ignore the names)
OR credit two correct names for *cis* pent-2-ene and *trans* pent-2-ene (ignore the structures)

1

M2 credit a second mark if all four parts of the required structures and

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names are correct.

(credit "linear" structures)
(insist on the alkyl groups being attached clearly by C-C bonds)

1

(c) (i) MI curly arrow from middle of C = C bond to H atom on H-Br

(penalise M1 if partial negative charge or formal positive charge on H)
(penalise MI if pent-2-ene is used)

1

M2 curly arrow from H-Br bond to side of Br atom

1

M3 correct structure for correct secondary carbocation

1

M4 curly arrow from lone pair on bromide ion to the positive carbon of carbocation, ensuring that bromide ion has a negative charge.

(with the exception of pent-2-ene, if the wrong alkene is used, only penalise the structure M3)
(penalise the use of two dots in addition to a covalent bond, once only)

1

(ii) 1-bromopentane

1

(iii) MI 2-bromopentane is formed *via* the secondary (or 2°) carbocation

1

OR 1-bromopentane is formed *via* the primary (or 1°) carbocation
M2 a secondary carbocation is more stable than a primary carbocation -
award this mark only if the quality of language justifies the award.

(the argument must involve clear statements about carbocations)

1

[12]

Q21.

A

[1]

Q22.

B

[1]

Q23.

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(a) Reaction 2: NaOH OR KOH **(1)** M1 alcohol (ic) OR ethanol (ic)**(1)** M2

ignore heat

Condition mark linked to correct reagent but award M2 if OH^- or base or alkali mentioned

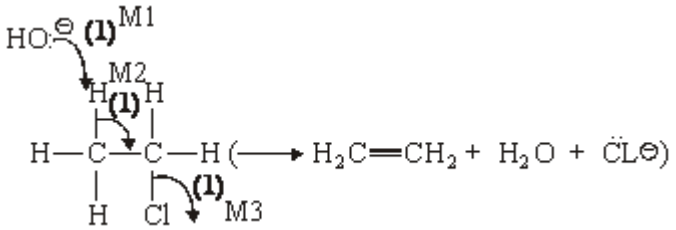
Reaction 3: concentrated H_2SO_4 OR H_3PO_4 M1 **(1)** heat **(1)** M2
OR 150°C - 200°C

Condition mark linked to correct reagent but award M2 if H_2SO_4 or H_3PO_4, but not concentrated

Penalise reagent and condition if dilute H_2SO_4 / H_3PO_4

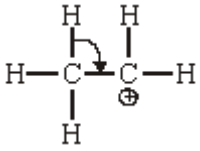
4

(b) Mechanism:



Award M3 *independently*

M1 and M2 must be to / from correct places



E1 mechanism possible in which M2

Name: of mechanism = elimination **(1)**

NOT dehydrohalogenation

Ignore "base" OR "nucleophilic" before elimination

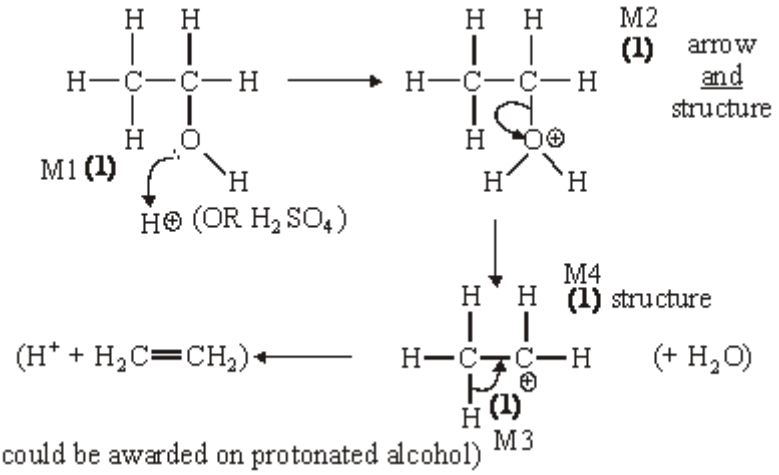
Reason: Reaction 2 has (very) low yield **(1)**

5

QoL OR chloroethane has to be made (from ethane)
OR chloroethane is expensive
OR chloroethane is not redily available

(c) Mechanism:

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Name of mechanism = elimination **(1)**

NOT dehydration alone

Reason: Ethanol could come from (fermentation of) renewable

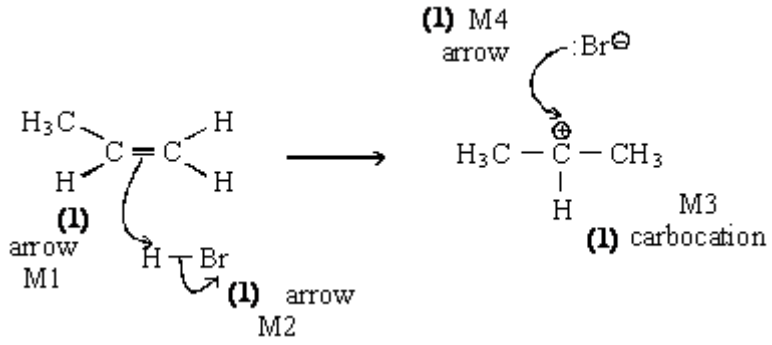
*QoL sugars / glucose / carbohydrates / sources **(1)***

6

[15]

Q24.

(a) (i)



If wrong carbocation, lose structure mark
If wrong alkene, lose structure mark
Can still score ¾ i.e. penalise M3
Penalise M2 if polarity included incorrectly
no bond between H and Br
bond is shown as ÷ *or* ·÷·

(ii) $CH_3CH_2\overset{\oplus}{C}H_2$ **(1)**

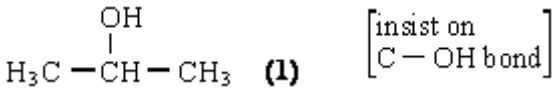
credit secondary carbocation here if primary carbocation has been used in (i)

Ignore attack on this carbocation by $\ddot{Br}^{\ominus}$

5

(b) (i) *Structure*:

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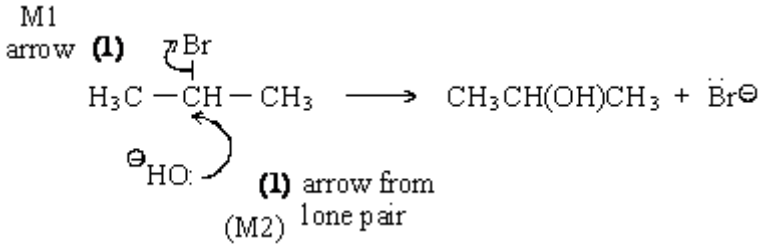


No credit for propan-1-ol even when named correctly
Credit propane-2-ol

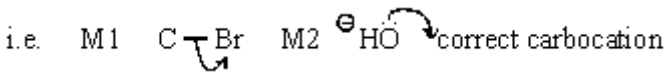
Name: propan-2-ol **(1)**
Not 2-hydroxypropane

(ii) *Name of mechanism*: nucleophilic substitution **(1) (both words)**
(NOT S_N1 orS_N2)

Mechanism:



penalise incorrect polarity on C-Br (M1)
Credit <u>the arrows</u> even if incorrect haloalkane
If S_N1, <u>both marks</u> possible



5

(c) (i) elimination **(1)**
Ignore nucleophylic elimination
Penalise electrophilic elimination

(ii) base **(1)**
OR proton acceptor
NOT nucleophile (base)

2

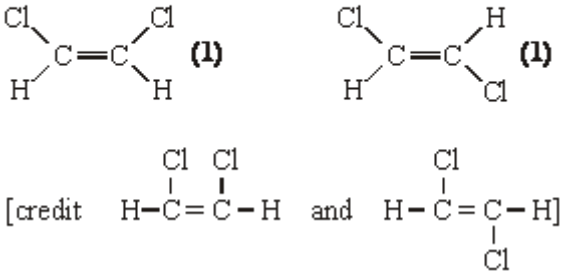
[12]

Q25.

(a) (i)

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Isomer 1 either order *Isomer 2*

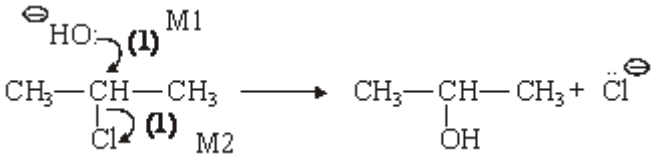


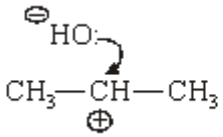
[credit and]

(ii) restricted <u>rotation</u> OR no <u>rotation</u> OR cannot <u>rotate</u> **(1)**

3

(b) (i) *Mechanism*:



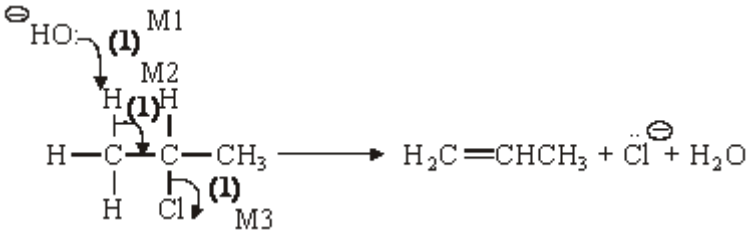
[Credit M1 for ]

M1 and M2 independent
Curly arrows <u>must</u> be from a bond or a lone pair
Do not penalise sticks
Penalise M1 if  *precedes (penalise this once)*
Penalise incorrect δ+ δ– for M2
Penalise + on C atom for M2
Only allow M1 for incorrect haloalkane

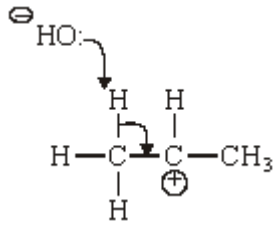
Role of the hydroxide ion: nucleophile **(1)**
electron pair donor
lone pair donor

NOT nucleophilic substitution

(ii) *Mechanism*:



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Only allow M1 and M2 for incorrect haloalkane unless RE on (i)

+ charge on H on molecule, penalise M1

M3 independent
M2 must be to correct C–C

M1 must be correct H atom

Credit M1 and M2 via carbocation mechanism

No marks after any attack of C ⊕ *by* OH^-

Role of the hydroxide ion: base **(1)**
proton acceptor
accepts H^+

7

[10]

Q26.

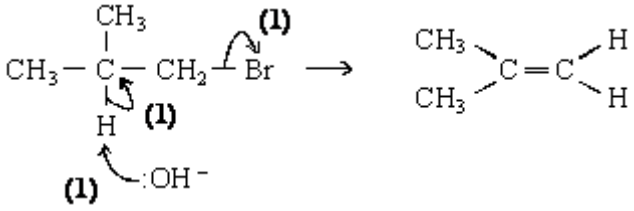
(a) Identity of **X**; 2-methylpropene **(1)**
Absorption at 1650 cm^{-1} indicates an alkene present **(1)**
OR a chemical answer e.g. Br_2 (aq) brown to colourless

2

(b) Reagents
Step 1 KOH (allow NaOH) **(1)** alcoholic **(1)** warm **(1)**
Only allow solvent and warm if reagent correct

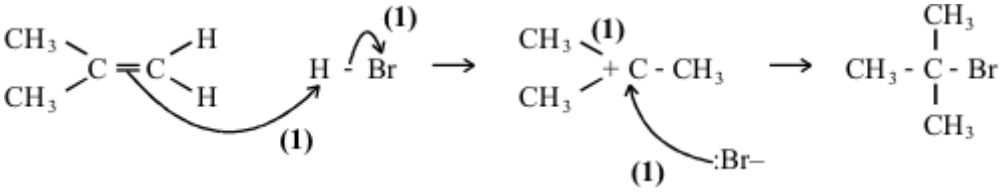
Step 2 HBr **(1)**

Mechanism: A → **X**



Or a carbocation mechanism

Mechanism **X** → B



11

(c) A gives three peaks **(1)**

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B gives one peak **(1)**

Allow one for "A has more peaks than B" when no number of peaks is given

2

[15]

Q27.

C

[1]

Q28.

(a) Alcohol: Reaction = Substitution (/ hydrolysis) **(1)**

Ignore reference to nucleophilic, but electrophilic give zero

Alcohol: Role = nucleophile (/ lone pair donor) **(1)**

Alkene: reaction = elimination **(1)**

Ignore ref to nucleophilic or electrophilic

Alkene: base (/ proton acceptor) **(1)**

If no indication of order in (a) assume as in question.
If order is wrong can still score 'role' mark.

4

(b) Alcohol: Role = butan-2-ol **(1)**

Not 2-hydroxybutane or but-2-ol

Appropriate structure for $CH_3CH(OH)\ CH_2CH_3$ **(1)**

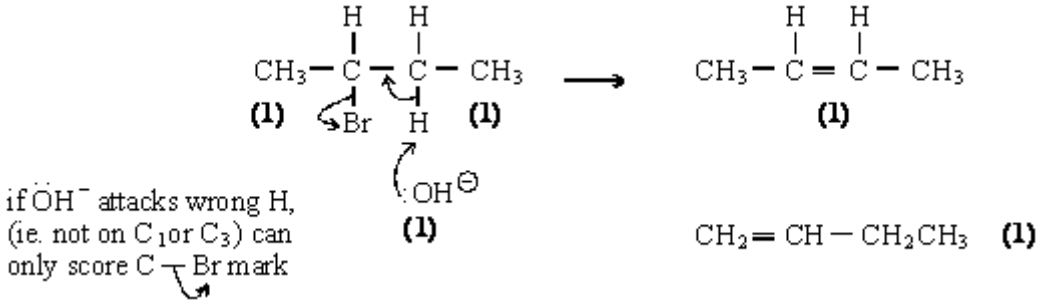
Brackets not essential

S_N2 version	S_N1 version
$\overset{\delta+}{C}-\overset{\delta-}{Br}$ bond is polar	C–Br bond is polar **(1)**
Lone pair of OH^-	C–Br bond breaks **(1)**
Attacks the $C^{\delta+}$	forming carbocation / carbonium ion **(1)**

M1 can be scored from a diagram, M2 and M3 from written explanation only

5

(c)



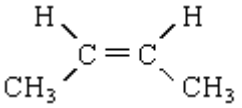
If but-2-ene not given here it may be obtained from cis / trans

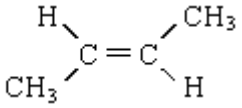
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isomer

H lost from different carbon atoms (1)
H removes from C^1 and C^3 to give two isomers (1)
Draws clear Cis and trans isomers for but-2-ene

Can score these marks from a diagram



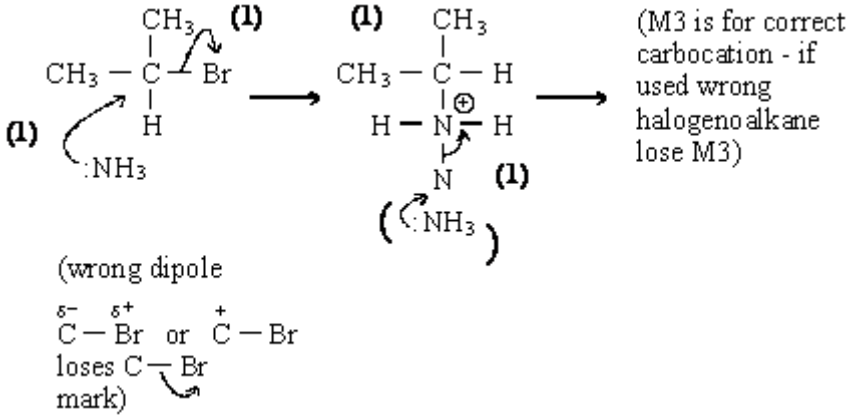


8

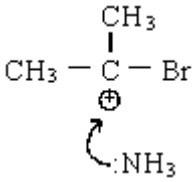
[17]

Q29.

(a) *Name of mechanism*: nucleophilic substitution **(1)**
Mechanism:



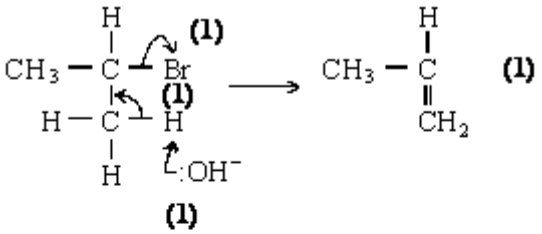
Marks S_N1 using same points
∴ M2 requires



5

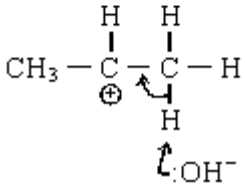
(b) *Role of potassium hydroxide*: Base **(1)**
Mechanism:

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Mark E1 using same points

∴ M2/M3



5

[10]

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Q1.

(a) Most students (56.1%) could name compound **A** correctly.

(b) This question proved to be demanding. The calculation of the M_r of individual molecules containing different isotopes was a challenge for many students. 61.8% of students either failed to score or made no attempt; 33.4% did, however, score both marks.

(c) The nucleophilic substitution mechanism was well-answered; 45.6% of students scored full marks here.

(d) The elimination mechanism was more challenging, and many students did not know the role of the hydroxide ion. This question discriminated particularly well.

(e) Just under half of students could determine that the IR spectrum was of an alkene rather than an alcohol and explain this by reference to the absorption for a bond and its wavenumber range.

(f) Students struggled to explain the relative rates of reaction of the halogenoalkanes. The most common answer incorrectly referred to the reactivity of the elements bromine and chlorine, rather than looking at the C-Br and C-Cl bond strengths. Only 28.6% of students gained this mark.

Q2.

(a) Although most students identified compound **J** as propan-1-ol, a surprising number failed to show the O−H bond as is necessary in a displayed formula.

(b) Most students could name the mechanism, but the condition proved more difficult.

(c) This calculation was done well and 56% of students scored full marks. The main errors were in working out or using the correct M_r values.

(d) Only 30% of students scored both marks here. Others drew a primary amine or a non-skeletal structure.

(e) Both the reagent (which must be a complete compound) and a condition were needed to score the mark; several omitted the condition.

(f) This was a high scoring question for many. For others, the main errors were missing the negative sign or the lone pair on the hydroxide ion, or showing attack on the wrong hydrogen atom.

Q7.

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.

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,

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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.

Q8.

Part (a) was answered quite well. The naming of P and Q was a challenge for some with a demand both for correct spelling and correct use of the alphabet for functional groups and this led to only 48% scoring both marks. This question included two curly arrow mechanisms and these questions always result in the best discrimination of student performance. Part (b) and part (c) provided an excellent distribution across the full range of marks with the usual errors seen, such as an incorrect carbocation in part (b), a negative charge on ammonia in part (c) and, in both parts, a failure to use either a lone pair of electrons or a bond as the origin of a pair of electrons. It was essential in part (d) to identify a reagent, in order to be able to access the reaction condition mark and some excellent responses were seen. It is worth reminding students that as a general guide, a reagent is something that you get out of a bottle; for example, sodium hydroxide and not hydroxide ion. Part (e) also discriminated well with most students able to write the equation and then to identify sulfur dioxide as one of the toxic gases.

Q9.

Mechanisms continue to discriminate well and over two-thirds of all students scored at least two marks in part (a)(i). Two displayed formulas were required in this question in parts (a)(ii) and (b)(i) and 37% and 25%, respectively, scored the mark in each part. Part (b)(ii) was relatively demanding, whereas the remainder of part (b) was very high-scoring.

Q10.

Organic reaction mechanisms discriminate well. Schools and colleges still need to heed the advice that full marks will only be awarded in a mechanism such as that in part (b) if the positive charge on the intermediate alkylammonium ion is placed on the N atom and not on or adjacent to a hydrogen atom. Over 80% scored at least 3 marks on both parts (a) and (b). A surprising number of students were unable to name substance X correctly in part (c).

Q11.

Providing the students with the basic information for the elimination reaction in part (a)(i) enabled most students to score at least one mark and more than half scored full marks. Structures of *E* and *Z* isomers were generally well understood and many students could score at least one mark in their answers to the meaning of the term *stereoisomers*.

The mechanism in part (b) is demanding and discriminated very well

Q12.

Putting three mechanisms together proved to be very discriminating. Weaker candidates were able to score some marks and the best candidates scored all 15. There is always a concern that in these longer Section B questions, candidates might forget to record the name of a mechanism and there was some evidence of that happening here. Partial credit was given in part (a)(i) for a mechanism that used an incorrect starting or finishing compound with much of the focus concentrated on the curly arrows. This guiding principle was applied to good effect in parts (b) and (c). In part (c), centres need to appreciate that

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full marks will only be awarded in a mechanism of this type if the positive charge on the intermediate is placed on the N atom and not on or adjacent to a hydrogen atom.

Q13.

It was surprising to see that the term “nucleophile” was still not well known when all that was required was “an electron pair donor”. Part (a)(ii) was well answered but part (a)(iii) was answered surprisingly poorly given that a similar question was included on the paper in June 2010. The remainder of this question was well answered by most candidates.

Q14.

Candidates are able to tackle organic reaction mechanisms with confidence and this question was well answered. The most demanding part was part (a)(iii) in which they had to indicate that the carbon-bromine bond was polar.

Q16.

While some very good answers were seen for all parts of this question, the general impression was that some candidates found this question demanding. Relatively few candidates were able to state correctly the meaning of the term *nucleophile*, but almost 70% could gain at least half of the marks in the nucleophilic substitution mechanism in part (b). Part (c) was recognised by examiners to be a difficult question and only a minority of candidates were successful. Part (d) discriminated very well with the full range of marks seen and more than half the candidates were able to score at least half of the marks.

Q18.

The name of the mechanism in part (a) was usually known, although some candidates lost the mark by writing words such as “nucleophilic” or “electrophilic” in front of the correct name, elimination. Most candidates gained at least one mark from the mechanism and a great many well-presented correct answers were seen. Candidates who chose an incorrect haloalkane were still able to score two out of the three marks. In part (b), correct definitions of stereoisomers were seen, but the idea of these isomers having the same structural formula, but different spatial arrangements of atoms or groups was not well understood by many candidates. Drawing and naming the two geometric isomers of but-2-ene caused few problems for the majority of candidates and the role of hydroxide ions in part (c) was well known. In part (d), to gain full credit it was necessary to draw and name butylamine correctly and to balance the equation with two moles of ammonia leading to the formation of ammonium bromide.

Q19.

This question was often relatively high scoring despite having a mechanism which has caused problems on previous papers. Part (a) was usually well answered, although it was a surprise to see "bromine" as an answer on several scripts. The name of the mechanism in part (b) was often well known, although some candidates incorrectly prefaced the word "elimination" with electrophilic or nucleophilic. The mechanism itself usually yielded at least one mark from C-Br bond breakage and some complete and very well presented answers were seen. In part (c), many candidates struggled to state that *structural isomers* have the same molecular formula, but different structural formulae and the mark was often lost from one or the other part of this statement. Problems arose, because candidates appeared to confuse the idea with stereoisomers and referred to different (spatial) arrangements of atoms or groups. This latter point was compounded by some candidates drawing *cis* and/or *trans* isomers of but-2-ene in part (c)(ii), while others chose to draw

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methylpropene. Even those who knew that the answer was but-1-ene, too often failed to complete their structure correctly.

Q20.

Part (a) of this question took a familiar mechanism but presented it in a format different from previous papers. Candidates have had problems in the past with this mechanism, usually to do with drawing the organic compound or failing to use a lone pair of electrons on the hydroxide ion. It was decided to try to help candidates by drawing the organic structure and presenting the hydroxide ion in a position appropriate for a reaction to occur. There is no doubt that a larger proportion of the entry than hitherto were able to have a go at this mechanism as a consequence of this strategy. Regrettably, there was some evidence that a small minority of candidates appear to have missed this part of the question completely and left it blank.

In part (b), rather too many poor responses were seen and there was evidence to suggest that the idea of geometrical isomerism was not as well known as had been expected. Part (c)(i) was generally well answered with clear structures and mechanisms. Few candidates had problems with part (c)(ii) and the answers to part (c)(iii) were often well expressed. Candidates should be discouraged from using arguments which involve the Markownikoff rule and in their discussion of carbocations, they should be encouraged to make a clear link between the product formed and each of the possible intermediates.

Q23.

Overall, this question discriminated well and allowed the more able candidates to show what they knew and understood and answers with full marks to one, two or all three parts of the question were seen. The weakest candidates had difficulty scoring more than a few marks. In part (a) there was confusion by some candidates between Reaction 2 and Reaction 3 and even when these candidates were able to discriminate between these two elimination reactions, the reagent given was rarely correct. For Reaction 2, reference simply to hydroxide ions would not gain any credit and candidates need to be advised to identify a whole substance, such as potassium or sodium hydroxide, in this case, when asked for a reagent. Similarly in Reaction 3 it is necessary to use concentrated sulphuric acid for the reaction to work. In part (b), most candidates had a go at the mechanism and among those producing reasonable attempts, the main errors included a missing charge on the hydroxide ion or the failure either to include or to use a lone pair of electrons on oxygen. Many candidates thought that the reason for not using chloroethane was due either to the “toxicity of chlorine” or “the release of toxic hydrogen chloride into the atmosphere”. Some candidates correctly recognised either that chloroethane would have to be manufactured first or that the yield of Reaction 2 would be very low. In part (c) the mechanism is described in the specification as an elimination and the word “dehydration” alone is an insufficient response. Many candidates gained some marks from the mechanism producing at least one correct intermediate, which was often the carbocation. The synchronous loss of a proton and water from the protonated alcohol resulted in the loss of one mark out of four for this mechanism. The relatively straightforward final mark in this question was not always scored because candidates failed to indicate that ethanol could be made from renewable sources, such as the fermentation of sugars.

Q24.

The poor use of curly arrows and the failure to use a lone pair of electrons on the bromide ion were common problems in the mechanism in part (a). The use of both a line and two dots to indicate a single covalent bond was penalised. Candidates who had the two carbocations the wrong way around were given credit in part (a)(ii), although this was seen less often than the candidates who failed to answer the question correctly and gave a structure for 1-bromopropane as the answer to (a)(ii), rather than a carbocation. Part (b)

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was generally well answered, marks tending to be lost from a poorly presented structure with badly positioned bonds and from mechanisms with incorrect curly arrows or the absence of either a lone pair or the negative charge on the hydroxide ion or the inclusion of a formal positive charge on the carbon atom of the C-Br bond. A good deal of guesswork characterised some of the responses to part (c) with (c)(ii) causing the greater difficulty.

Q25.

Part (a) proved straightforward for most candidates, although some of the weakest did have problems in knowing which compounds they were trying to draw. While the most able found part (b) of this question relatively trivial and scored full marks, it is clear that mechanisms continue to be a challenge for the less able candidates. Almost all of the candidates attempted the questions and a large majority were able to score at least 3 of the 7 marks available in part (b). The usual difficulties associated with the position and direction of curly arrows and either incomplete hydroxide ions or attempts to use an apparently covalent sodium hydroxide resulted in the loss of marks. The mechanism in (b)(ii) is one of the more demanding parts of the specification and the weakest candidates struggled to score any marks here.

Q26.

Many candidates identified compound **X** correctly as 2-methylpropene and used the infra-red data to deduce the presence of the carbon-carbon double bond. Identifying the reagents and essential conditions for the conversion of **A** into **X** proved much more difficult. Some of the candidates who did give the correct reagent then failed to give the correct mechanism for the reaction. The conversion of **X** into **B** was rather better answered and most candidates gave the correct reagent, HBr, and a correct mechanism for this reaction. Part (c) was generally well answered. No statement of peak splitting was required and candidates who made errors when describing splitting patterns were not penalised.

Q28.

This question was often, but not universally, well done. The reaction types in part (a) were quite well known, although it was quite common for the first type to be described as ‘nucleophilic substitution’. Some candidates having quoted this as the type then went on to give the role of potassium hydroxide as, for example, ‘oxidising agent’. ‘Nucleophilic substitution’ earned the mark for the type of reaction but did not earn the mark for the role of potassium hydroxide. This mark was earned only by a specific reference to the role being that of a nucleophile. Many candidates recognised the formation of an alkene as being an elimination reaction but the role of potassium hydroxide as a base was less well known. Most candidates correctly deduced the name and structure of the product in part (b). Some candidates wasted time here by drawing the mechanism for the substitution reaction. The polarity of the C-Br bond was frequently shown or described but the attraction of the partial positive charge on the carbon atom for the hydroxide ion was less often seen. Better candidates described the attack of a lone pair from the hydroxide ion on the ä+ carbon. Part (c) was well done by many candidates and high scores were common. The mechanism was generally well known and clear explanations for the formation of two structurally isomeric products were quite common. Successful candidates either tackled the explanation by showing an alternative mechanism or by identifying the possibility of proton removal at C^1 or at C^3. Appropriate structures showing the cis/trans isomers of but-2-ene were very common. Errors in the position and direction of curly arrows were quite common and in some instances, the charge was omitted from the hydroxide ion. Some candidates, mainly those who outlined an E1 mechanism, incorrectly explained the formation of structural isomers in terms of the formation of different carbocations. Also, it

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was not unusual to see a mechanism in which butan-2-ol was formed which then underwent dehydration.

Q29.

Overall, this question was quite well answered, with many candidates producing clear and accurately drawn mechanisms. There were, however, some quite common errors. In part (a), a fair number of candidates showed the NH_3 molecule carrying a negative charge. Also, the central carbon in 2-bromopropane was sometimes shown carrying a full positive charge or the positive charge on the intermediate was omitted. In part (b), it was not unusual to see the hydroxide ion removing the wrong hydrogen atom, or for an incorrect E1 mechanism to be offered. Again, poorly drawn curly arrows, which did not start at a bond/lone pair, or which did not end at a bond/atom, were quite common. The name of the mechanism was generally well known but a variety of incorrect names were seen. The role of potassium hydroxide, in part (b), was less well known, with ‘nucleophile’ being suggested by some candidates, while others attempted to describe the mode of action of the reagent.

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