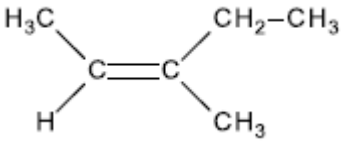
1

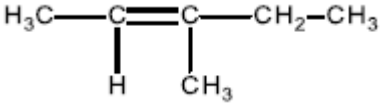
(a)



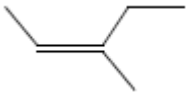
Must show all 4 groups bonded to C=C

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

Allow correct structure of the style

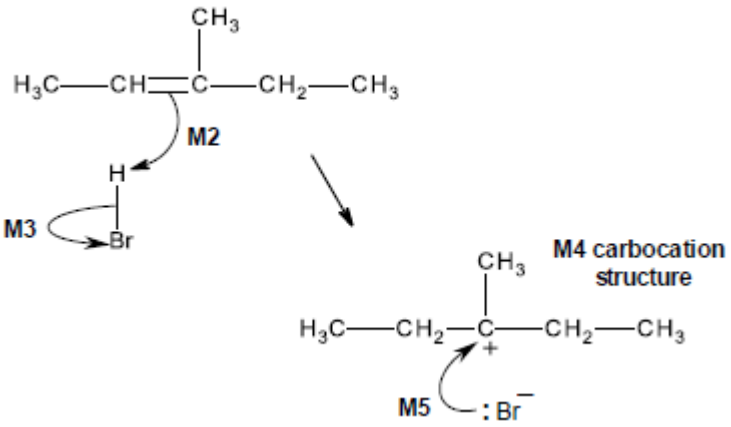


Allow correct skeletal structure



1

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



NB the arrows here are double-headed

1

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

1

M3 must show the breaking of the H-Br bond

1

M4 is for the structure of the tertiary carbocation

1

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*

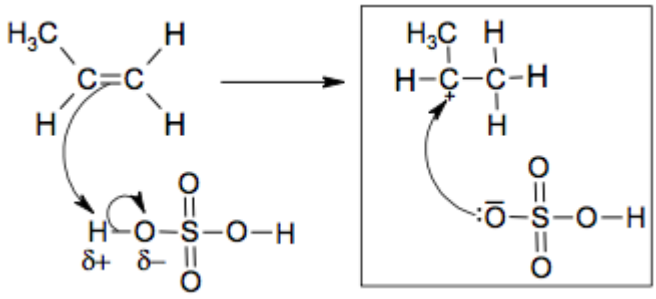
[8]

2 D

[1]

3 (a) Electrophilic addition

1



M2 = curly arrow from C=C towards H of H−O on 'their' sulfuric acid **1**

M3 = curly arrow to break H−O **1**

Penalise incorrect dipole/full charges

M4 = intermediate **1**

M5 = correct anion, lone pair on correct O and curly arrow from that lone pair to C+ on their carbocation **1**

***IGNORE** position of minus sign unless displayed structure*

***IGNORE** product*

Major product/propan-2-ol formed via most stable carbocation/carbonium ion

secondary carbocation/carbonium ion more stable (than primary) or reverse argument

M6 for idea of carbocation stability **1**

This statement gets M6 and M7

***NOT** stability of alcohols*

M7 = explanation in terms of inductive effect of alkyl groups **1**

(b) Hot/High T (and High P)

ALLOW *200-450 C/473-723 K (Quoted)*

1

(SiO_2 coated in) <u>phosphoric</u> acid (catalyst)

NOT *(aq)*

1

advantages of fermentation

- Low(er) T and P / lower energy use
- Less use of non-renewable fossil fuels/renewable /sustainable (resources)
- Low(er) equipment/plant/capital costs

IGNORE *carbon neutral*

max 2

1
1

Disadvantages of fermentation

- Slow(er) reaction
- Low atom economy
- Impure product/extra purification/distillation required
- Batch process/labour intensive/difficult to automate
- Land used for sugar crops (so not available for food crops)

IGNORE *low yield*

Max 2

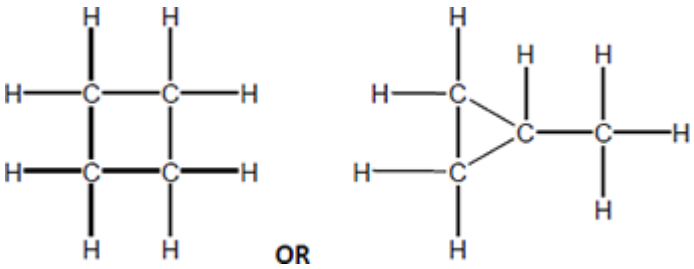
1
1

[13]

4

(a) Alkenes

1



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

1

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

Allow hexane or any other correctly named alkane with 6 carbons

1

(c) Poly(but-2-ene)

1

(d) High pressure

Allow pressure ≥ MPa

Mention of catalyst loses the mark

1

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

Level 3

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

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

5–6 marks

Level 2

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

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

3–4 marks

Level 1

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

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

1–2 marks

Level 0

Insufficient correct chemistry to gain a mark.

0 marks

Indicative chemistry content

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

(Or vice versa for lower temperature)

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

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

(Or vice versa for lower temperature)

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

Stage 3*: conclusion*

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

[11]

5 (a) Measured volume would be greater

1

Level in burette falls as tap is filled before any liquid is delivered

1

(b) Drop sizes vary

Allow percentage error for amount of oil will be large as the amount used is so small

1

(c) Use a larger single volume of oil

1

Dissolve this oil in the organic solvent

1

Transfer to a conical flask and make up to 250 cm^3 with more solvent

1

Titrate (25 cm^3) samples from the flask

1

(d) Stage 1

Mass of oil = $0.92 \times (5.0 \times 10^{-2} \times 5) = 0.23$ (g)

1

Mol of oil = 0.23 / 885 = 2.6×10^{-4}

1

Extended response calculation

To gain 4 or 5 marks, students must show a logical progression from stage 1 and stage 2 (in either order) to stage 3

Stage 2

Mol bromine = $2.0 \times 10^{-2} \times 39.4 / 1000 = 7.9 \times 10^{-4}$

1

Stage 3

Ratio oil : bromine

2.6×10^{-4} : 7.9×10^{-4}

Simplest ratio = $2.6 \times 10^{-4} / 2.6 \times 10^{-4} : 7.9 \times 10^{-4} / 2.6 \times 10^{-4}$

= 1 : 3

1

Hence, 3 C=C bonds

M5 cannot be awarded unless working for M4 is shown

1

[12]

6 C

[1]

7 B

[1]

8 C

[1]

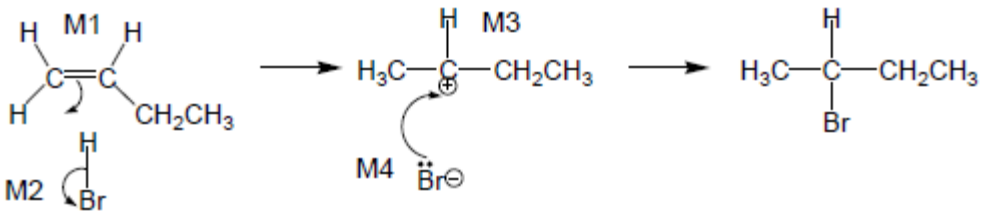
9 (a) HBr **OR** HCl **OR** H_2SO_4

Allow HI or HY

1

(b) Electrophilic addition

1



Allow consequential marking on acid in 12.1 and allow use of HY

4

(c) The major product exists as a pair of enantiomers

1

The third isomer is 1-bromobutane (minor product)

1

Because it is obtained via primary carbocation

1

[9]

10 C

[1]

11 (a) **M1** acidified potassium dichromate or $K_2Cr_2O_7$ / H_2SO_4

OR $K_2Cr_2O_7$ / H^+ ***OR*** acidified $K_2Cr_2O_7$

M2 (orange to) green solution ***OR*** goes green

M3 (solution) remains orange or no reaction or no (observed) change

*If no reagent or incorrect reagent in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

*If incomplete / inaccurate attempt at reagent e.g. "dichromate" or "dichromate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*For **M2** ignore dichromate described as "yellow" or "red"*

*For **M3** ignore "nothing (happens)" or "no observation"*

Alternative using $KMnO_4$ / H_2SO_4

M1 acidified potassium manganate(VII) / potassium permanganate or $KMnO_4$ / H_2SO_4

OR $KMnO_4$ / H^+ ***OR*** acidified $KMnO_4$

M2 colourless solution ***OR*** goes colourless

M3 (solution) remains purple or no reaction or no (observed) change

*For **M1***

*If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*Credit alkaline $KMnO_4$ for possible full marks but **M2** gives brown precipitate or solution goes green*

3

(b) **M1** (Shake with) Br_2 ***OR*** bromine (water) ***OR*** bromine (in CCl_4 / organic solvent)

M2 (stays) orange / red / yellow / brown / the same

OR no reaction ***OR*** no (observed) change

M3 decolourised / goes colourless / loses its colour / orange to colourless

*If no reagent or incorrect reagent in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

*If incomplete / inaccurate attempt at reagent (e.g. Br), **penalise M1 only and mark on***

*No credit for combustion observations; **CE = 0***

*For **M2 in every case***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear"

***OR* as alternatives**

Use $KMnO_4$ / H_2SO_4

M1 acidified potassium manganate(VII) / potassium permanganate ***OR*** $KMnO_4$ / H_2SO_4

OR $KMnO_4$ / H^+ ***OR*** acidified $KMnO_4$

M2 (stays) <u>purple</u> or no reaction or no (observed) change

M3 decolourised / goes colourless / loses its colour

Use iodine

M1 iodine or I_2 / KI or iodine solution

M2 no change

M3 decolourised / goes colourless / loses its colour

Use concentrated sulfuric acid

M1 <u>concentrated</u> H_2SO_4

M2 no change

M3 brown

***For M1**, it must be a whole reagent and / or correct formula*

For M1** penalise incorrect attempt at correct formula, but mark **M2** and **M3

With potassium manganate(VII)

*If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on***

*Credit alkaline / neutral $KMnO_4$ for possible full marks but **M3** gives <u>brown precipitate</u> or solution goes <u>green</u>*

Apply similar guidance for errors in the formula of iodine or concentrated sulfuric acid reagent as those used for other reagents.

3

(c) **M1** Any soluble chloride including hydrochloric acid (ignore concentration)

M2 white precipitate or white solid / white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 Any soluble iodide including HI

M2 yellow precipitate or yellow solid / yellow suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 Any soluble bromide including HBr

M2 cream precipitate or cream solid / cream suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

***OR* as an alternative**

M1 NaOH or KOH or any soluble carbonate

M2 brown precipitate or brown solid / brown suspension with NaOH / KOH (white precipitate / solid / suspension with carbonate)

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

*If no reagent or incorrect reagent or insoluble chloride in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

Allow chlorine water

*If incomplete reagent (e.g. chloride ions) or inaccurate attempt at formula of chosen chloride, or chlorine, **penalise M1 only and mark on***

*For **M2** require the word "white" and some reference to a solid. Ignore "cloudy solution" OR "suspension" (similarly for the alternatives)*

*For **M3***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear" on its own

Ignore "dissolves"

3

(d) **M1** Any soluble sulfate including (dilute or aqueous) sulfuric acid

M2 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

M3 white precipitate or white solid / white suspension

*If no reagent or incorrect reagent or insoluble sulfate in **M1**, **CE = 0** and no marks for **M1**, **M2** or **M3***

Accept $MgSO_4$ and $CaSO_4$ but not barium, lead or silver sulfates

*If concentrated sulfuric acid or incomplete reagent (e.g. sulfate ions) or inaccurate attempt at formula of chosen sulfate, **penalise M1 only and mark on***

*For **M3 (or M2 in the alternative)** require the word "white" and some reference to a solid.*

Ignore "cloudy solution" OR "suspension"

*For **M2 (or M3 in the alternative)***

Ignore "nothing (happens)"

Ignore "no observation"

Ignore "clear" on its own

Ignore "dissolves"

***OR* as an alternative**

M1 NaOH or KOH

M2 white precipitate or white solid / white suspension

M3 remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear

*If incomplete reagent (e.g. hydroxide ions) or inaccurate attempt at formula of chosen hydroxide, **penalise M1 only and mark on***

*If **M1** uses NH_3 (dilute or concentrated) **penalise M1 only and mark on***

3

[12]