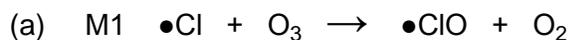
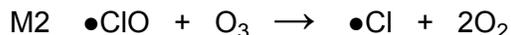


## Mark schemes

1



1



1

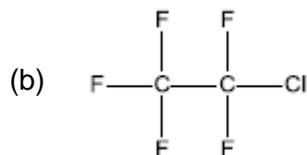
*M1 and M2 could be in either order*

*Credit the dot anywhere on the radical*

*Penalise absence of dot once only*

*Individual multiples acceptable but both need to be doubled if two marks are to be awarded*

*Ignore state symbols*



*Must be displayed formula*

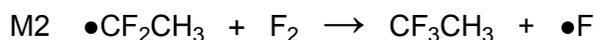
1

- (c) Does not contain Cl or does not release Cl (atoms/radicals)  
or no C-Cl bonds  
or C-F bond(s) strong / does not break / no F (atom/radicals) released

1



1

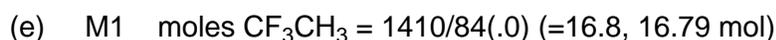


1

*M1 and M2 could be in either order*

*Credit the dot anywhere on the radical*

*Penalise absence of dot once only*



1



1

*Correct answer scores both marks*

*Allow M2 for  $M1 \times \text{Avogadro}$  with answer to 3 sf (but must have attempted to calculate moles for M1)*

*Ignore incorrect units*

- (f) (bonds) vibrate/stretch/bend OR (as bonds) are polar

*NOT polar molecules; 'they' = bonds*

1

[9]

2	D		[1]
3	B		[1]
4	(a)	(i) $\text{CH}_3\text{Cl} + 2\text{Cl}_2 \rightarrow \text{CHCl}_3 + 2\text{HCl}$ <b>IGNORE</b> state symbols <b>ALLOW</b> multiples	1
		(ii) (Free-)radical substitution <i>This answer only</i>	1
		(iii) Initiation: $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$ <i>Penalise absence of dot once only</i>	1
		1st Propagation step $\text{Cl}\cdot + \text{CH}_2\text{Cl}_2 \rightarrow \cdot\text{CHCl}_2 + \text{HCl}$ <i>Penalise + and/or – charges every time</i>	1
		2nd Propagation step $\cdot\text{CHCl}_2 + \text{Cl}_2 \rightarrow \text{CHCl}_3 + \text{Cl}\cdot$ <b>ALLOW</b> $\cdot$ anywhere on $\cdot\text{CHCl}_2$ but, if drawn out as a structure, then $\cdot$ must be on C	1
		Termination $2 \cdot\text{CHCl}_2 \rightarrow \text{C}_2\text{H}_2\text{Cl}_4$ <i>Mark independently</i> <b>ALLOW</b> $\cdot\text{CH}_2\text{Cl} + \cdot\text{CCl}_3 \rightarrow \text{C}_2\text{H}_2\text{Cl}_4$ <b>IGNORE</b> state symbols throughout	1
	(b)	(i) $\text{CClF}_3 \rightarrow \cdot\text{CF}_3 + \text{Cl}\cdot$ <b>ALLOW</b> $\cdot$ anywhere on $\cdot\text{CF}_3$ unless displayed	1
		(ii) $\text{Cl}\cdot + \text{O}_3 \rightarrow \text{ClO}\cdot + \text{O}_2$ <i>Equations can be in either order</i> <i>Penalise absence of <math>\cdot</math> once only</i>	1
		$\text{ClO}\cdot + \text{O}_3 \rightarrow 2\text{O}_2 + \text{Cl}\cdot$ <b>ALLOW</b> $\cdot$ anywhere on $\cdot\text{ClO}$ <b>NOT</b> $\cdot\text{O}_3$	1

[9]

**5**

(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

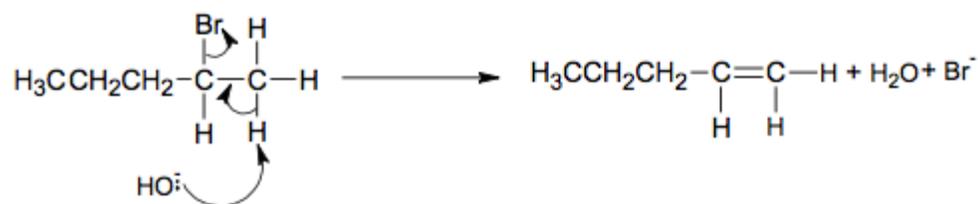
rxn 2 = nucleophile/lone pair donor/electron pair donor

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

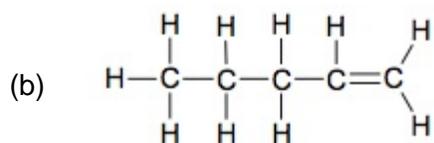
If forming pent-2-ene can award M8 only even if arrows in mechanism correct

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

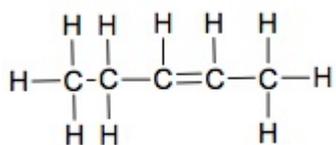
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1

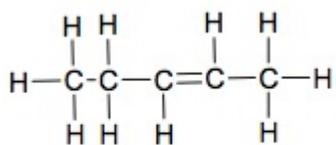


1



Z-pent-2-ene

1



E-pent-2-ene

1

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

**NOT** cis and trans

No free rotation around C=C

**ALLOW** no rotation of C=C

1

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

**IGNORE** 'functional'

1

- (c) Same volume/amount of  $\text{AgNO}_3(\text{aq})$  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  $[\text{AgNO}_3]$  each time

1

record time to measure sensible observation about the amount of  $\text{AgCl}$  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]

- 6** (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  $:\text{OH}^-$  to H on C adjacent to C-Br

1

Correct arrow from C-H bond to C-C

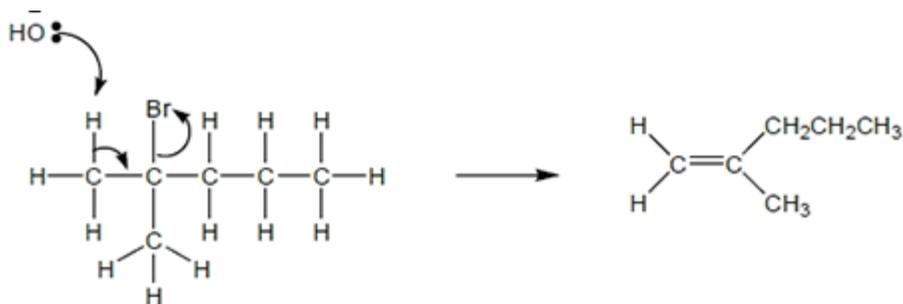
1

Correct arrow from C-Br bond to Br

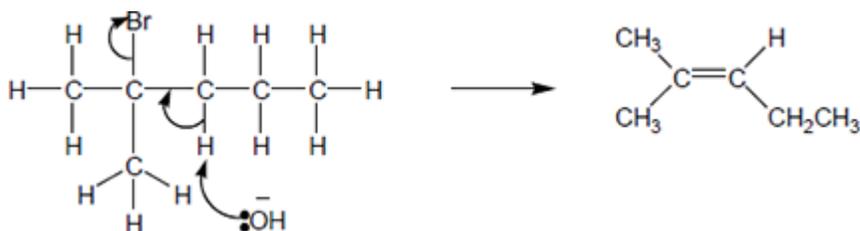
1

Structure of chosen product

1

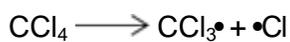


OR



[6]

7 (a) UV light



(b)  $\text{Cl}\cdot + \text{O}_3 \longrightarrow \text{ClO}\cdot + \text{O}_2$



(c)  $M_r$  of  $\text{CF}_3\text{Cl} = 104.5$

$$\text{Moles freon} = 1.78 \times 10^{-4} \times 10^3 / 104.5 = 1.70 \times 10^{-3}$$

$$\text{Number of molecules} = 1.70 \times 10^{-3} \times 6.02 \times 10^{23} = 1.02 \times 10^{21}$$

$$\text{Molecules in } 500 \text{ cm}^3 = (1.02 \times 10^{21} \times 500 \times 10^{-6}) / 100 = 5.10 \times 10^{15}$$

Allow answer in the range  $5.10$ – $5.13 \times 10^{15}$

Answer must be given to this precision

1 [7]

8 D

[1]

9 C

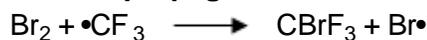
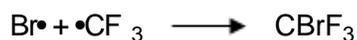
[1]

10 D

[1]

11

(a) (i)

**Initiation****First propagation****Second propagation****Termination****OR****OR**

*Penalise absence of dot once only*

*Credit the dot anywhere on the radical*

4

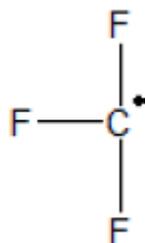
(ii) Ultra-violet / uv / sunlight

**OR**

T > 100°C OR high temperature

1

(b) (i)



*Displayed formula required with the radical dot on carbon*

1

(ii) (The) C–Br (bond) breaks more readily / is weaker than (the) C–Cl (bond) (or converse)**OR**

The C–Br bond enthalpy / bond strength is less than that for C–Cl (or converse)

*Requires a comparison between the two bonds*

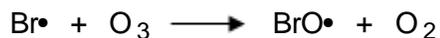
*Give credit for an answer that suggests that the UV frequency / energy may favour C–Br bond breakage rather than C–Cl bond breakage*

*Ignore correct references either to size, polarity or electronegativity*

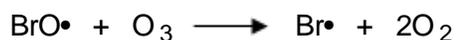
*Credit correct answers that refer to, for example “the bond between carbon and bromine requires less energy to break than the bond between carbon and chlorine”*

1

(iii) **M1**



**M2**



*M1 and M2 could be in either order*

*Credit the dot anywhere on the radical*

*Penalise absence of dot once only*

*Penalise the use of multiples once only*

**M3 One of the following**

They / it / the bromine (atom)

- does not appear in the overall equation
- is regenerated
- is unchanged at the end
- has not been used up
- provides an alternative route / mechanism

3

[10]

12

(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

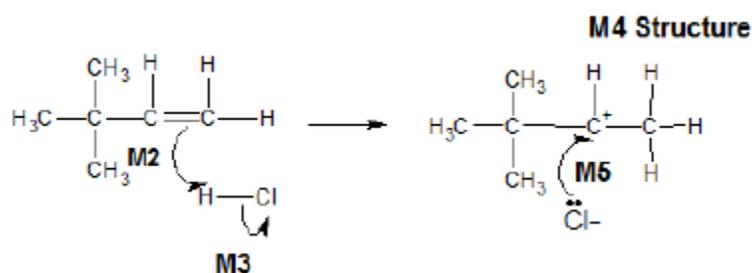
**OR**

accept 2-chloro-3,3-dimethylbutane

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

2

(b) **M1** Electrophilic addition



**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 their 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.*

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

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

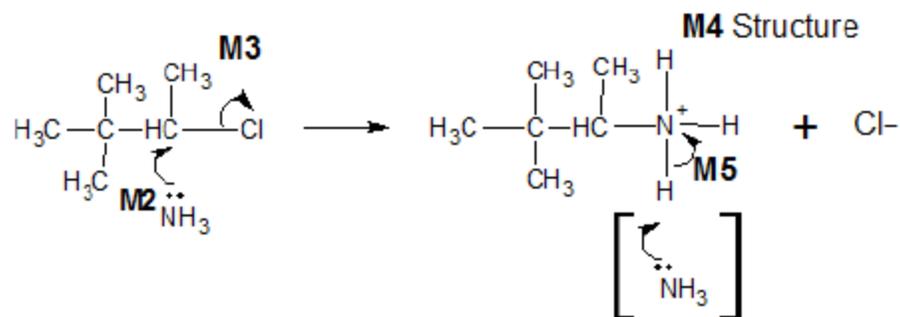
*Credit the correct use of "sticks"*

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

(c) **M1 Nucleophilic substitution**

For **M1**, both words required.

Accept phonetic spelling



**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 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

**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

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

Accept the correct use of “sticks”

(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

- high temperature **OR** hot **OR** heat / boil under reflux
- concentrated
- alcohol / ethanol (as a solvent) / (ethanolic conditions)

**M3** not “reflux” alone

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

Ignore “pressure”

3

(e) **M1**



**M1** Credit correct ionic species in the equation

**M2 and M3**

SO<sub>2</sub> **and** Br<sub>2</sub> identified

**M4**

Concentrated sulfuric acid

- is an oxidising agent
- oxidises the bromide (ion) or Br<sup>-</sup> 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<sub>2</sub> and Br<sub>2</sub>*

- *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]