

OCR A-LEVEL CHEMISTRY A • H432

CHEMISTRY



EXAM QUESTION PACK

4.1.1 BASIC CONCEPTS OF ORGANIC CHEMISTRY

SCORE

/174

PERCENTAGE

%

STEMUP

These questions belong to OCR, not to us.

The examination questions, mark schemes and examiner comments in this pack were written and published by OCR. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with OCR and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. OCR has not endorsed, approved or been involved in the production of it. OCR and the qualification titles used here belong to their respective owners and appear for identification only.

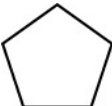
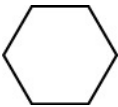
Where to find the originals

OCR publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at ocr.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

1(a) This question is about cyclic organic compounds.

The table shows some information about cycloalkanes.

Cycloalkane	Skeletal formula	Boiling point / °C
Cyclopropane		-33
Cyclopentane		49
Cyclohexane		81

These cycloalkanes are members of the same homologous series and have the same general formula.

(i) What is meant by the term *homologous series*?

[2]

(ii) State the general formula for these cycloalkanes.

[1]

(iii) Explain the increase in boiling points of the cycloalkanes shown in the table.

[2]

(b) **Cyclobutane** is another cycloalkane.

There are several **unsaturated** isomers of cyclobutane that are alkenes.

Two of these isomers are stereoisomers.

(i) Explain what is meant by the term *stereoisomers*.

----- [1]

(ii) Draw these **two** stereoisomers.

[2]

(c) In the presence of ultraviolet radiation, **cyclohexane** reacts with bromine.

A mixture of cyclic organic compounds is formed, including $\text{C}_6\text{H}_{11}\text{Br}$.

(i) Complete the table below to show the mechanism of the reaction between bromine and cyclohexane to form $\text{C}_6\text{H}_{11}\text{Br}$.

Include all possible termination steps in your answer.

Step	Equation
Initiation	-----
Propagation	----- -----
Termination	----- ----- -----

[5]

(ii) The initiation step involves homolytic fission.

Explain why the initiation step is an example of *homolytic fission*.

[1]

(d) The reaction between cyclohexane and bromine in (f) also forms $C_6H_{10}Br_2$.

- (i) Write an equation, using molecular formulae, for the reaction of cyclohexane and bromine in the presence of ultraviolet radiation to form $C_6H_{10}Br_2$.

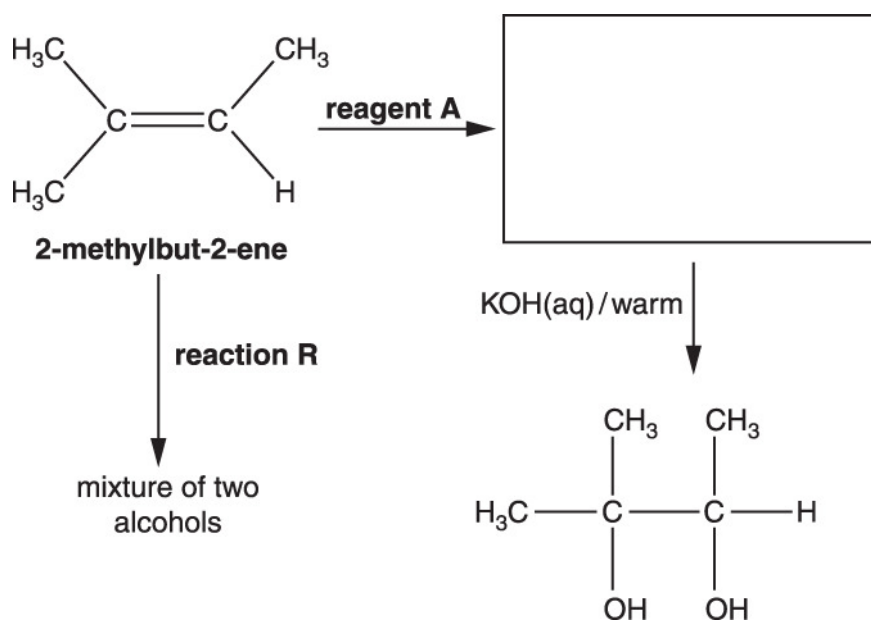
-----[1]

- (ii) Name **one** of the structural isomers of $C_6H_{10}Br_2$ formed in the reaction between cyclohexane and bromine.

-----[1]

2(a) The flowchart shows how 2-methylbut-2-ene can be converted into a number of organic products.

Complete the flowchart by drawing an organic structure in the box below.



(b) Identify reagent A.

[1]

-----[1]

(c) In the flowchart, **reaction R** forms a mixture of two alcohols that are structural isomers of $C_5H_{12}O$.

(i) State the reagents and conditions needed for **reaction R**.

-----[1]

(ii) What is meant by the term *structural isomers*?

-----[1]

(iii) Draw the two structural isomers of $C_5H_{12}O$ formed in **reaction R**.

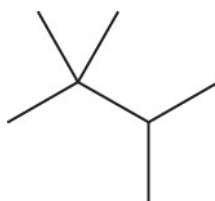
[2]

(iv) Suggest why 2-methylbut-2-ene is less soluble in water than either of the structural isomers formed.

-----[2]

3(a) This question is about different alkanes present in crude oil.

Compound A, shown below, is one of the structural isomers of C_7H_{16} .



Compound A

(i) What is meant by the term *structural isomers*?

----- [1]

(ii) Name compound A.

----- [1]

(b) The structural isomers of C_5H_{12} have different boiling points.

Draw the **skeletal formula** of the structural isomer of C_5H_{12} with the highest boiling point.

[1]

4(a) Allyl bromide, $\text{CH}_2=\text{CHCH}_2\text{Br}$, is used in the production of polymers.

Allyl bromide is a member of a homologous series. Compounds in this series have the same general formula.

(i) What is meant by the term *homologous series*?

----- [2]

(ii) What is the general formula of the homologous series that has allyl bromide as a member?

----- [1]

(iii) Give the systematic name for allyl bromide.

----- [1]

(b) Reaction mechanisms use curly arrows and can involve electrophiles and nucleophiles.

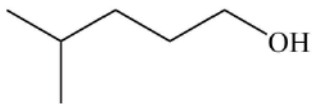
(i) What does a *curly arrow* represent in mechanisms?

----- [1]

(ii) What is meant by the term *nucleophile*?

----- [1]

5 What is the systematic name for the molecule shown below?

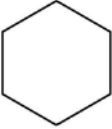
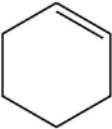
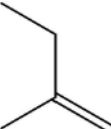
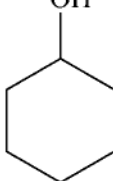


- A hexan-1-ol
- B 2-methylpentan-5-ol
- C 4-methylpentan-1-ol
- D 4-methylpentanol

Your answer

[1]

6(a) The organic compounds in the table below can be termed, aliphatic, alicyclic or aromatic.

E 	F 	G 
H 	I 	J 

Identify, using letters E, F, G, H, I, J, the compound(s) which are the following types.

Each response may contain more than one letter.

aliphatic _____

alicyclic _____

aromatic _____

[3]

(b) Compound I has one alkyl group.

What is the general formula of alkyl groups?

_____ [1]

(c) Compound H can be prepared in an elimination reaction by heating compound J with an acid catalyst.

A student carries out this preparation using 7.65 g of compound J.

The student obtains 2.05 g of compound H.

(i) Write an equation for this reaction, using molecular formulae.

Calculate the percentage yield of compound H.

Give your answer to **one** decimal place.

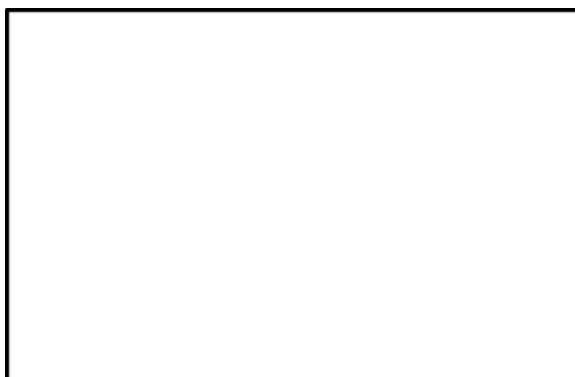
percentage yield = _____ % [4]

- (ii) Describe a simple test that the student could carry out to confirm the presence of the functional group in compound H.

Draw the structure of the organic product from the test.

test: _____

organic product =



[2]

7

Ethane reacts with chlorine by radical substitution.

Describe fully, with equations, the mechanism for this reaction.

[5]

8 Iodine monobromide, I-Br, is a polar molecule.

Heterolytic fission of the I-Br bond forms an electrophile.

State the meaning of the term *electrophile* and suggest the formula of the electrophile formed from IBr.

----- [2]

9 * Alcohols can be converted into alkenes in an elimination reaction.

The elimination of H₂O from pentan-2-ol forms a mixture of organic products.

Give the names and structures of all the organic products in the mixture.

Your answer should explain how the reaction leads to the different isomers.

----- [6]

- 10 An alcohol **A** contains carbon, hydrogen and oxygen only. The alcohol is a liquid at room temperature and pressure but can easily be vaporised.

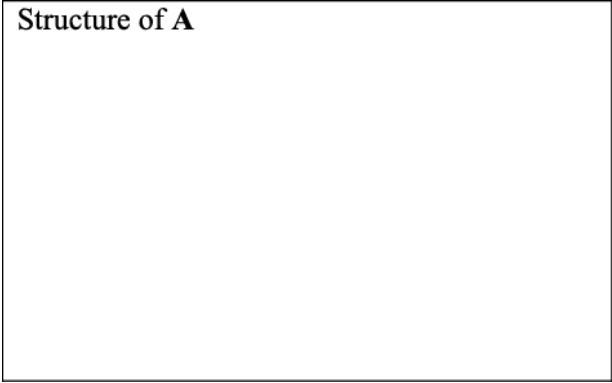
1.15 g of **A** produces 761 cm^3 of gas when vaporised, measured at 100 kPa and 366 K.

Determine the molar mass of compound **A** and draw a possible structure for **A**.

Show all your working.

molar mass = _____ g mol^{-1}

Structure of **A**



[5]

11 A student carries out a titration to determine the molar mass of an unknown acid, **A**.

- The student dissolves 2.24 g of acid **A** in distilled water and makes the solution up to 250.0 cm³.
- The student titrates a 25.0 cm³ portion of this solution with 0.120 mol dm⁻³ NaOH.
- 25.25 cm³ of 0.120 mol dm⁻³ NaOH are required to reach the end point.

The acid reacts with NaOH in a 1 : 1 molar ratio.

Calculate the molar mass of acid **A**.

molar mass of acid **A** = _____ g mol⁻¹ [3]

12 Propene reacts with bromine, Br₂. In this reaction, bromine acts as an electrophile.

(i) Outline the mechanism of this reaction.

Include curly arrows, relevant dipoles and the structures of the intermediate and final product(s).

[4]

(ii) What does a curly arrow represent in a reaction mechanism?

----- [1]

13 * You are provided with three alcohols that are structural isomers: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$, $\text{CH}_3\text{CH}_2\text{CHOHCH}_3$ and $(\text{CH}_3)_3\text{COH}$. You do not know which is which.

You have access to normal laboratory apparatus and chemicals, Quickfit apparatus, and an infrared spectrometer.

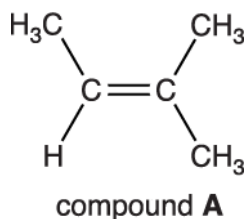
Describe a plan that would allow you to identify the three alcohols using the same experimental set up and method.

You should provide

- equations using structural formulae for any reactions
- a description of how you will identify the three alcohols from any observations and results.

[6]

14(a) Compound A is an alkene.



The C=C bond in a molecule of compound A has restricted rotation because it comprises a σ bond and a π bond.

- (i) Describe **one** difference between the σ bond and the π bond.

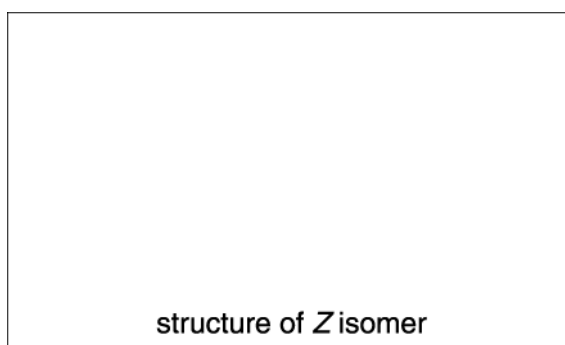
[1]

- (ii) Explain why compound A does **not** have *E/Z* isomers.

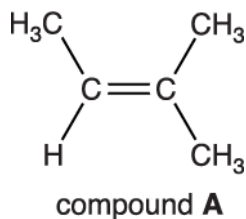
[1]

- (iii) A structural isomer of compound A has *E/Z* isomers.

Draw the structure of the *Z* isomer and then name this isomer.



- (b) *Compound **A** reacts with hydrogen bromide to form a mixture of two different organic products.



Give the structures of the **two** possible organic products of the reaction.

Outline the mechanism, using the 'curly arrow' model, for the formation of one of the organic products from compound **A**.

Explain which of the two organic products is more likely to be formed.

----- [6]

15 Nitrogen forms several different oxides.

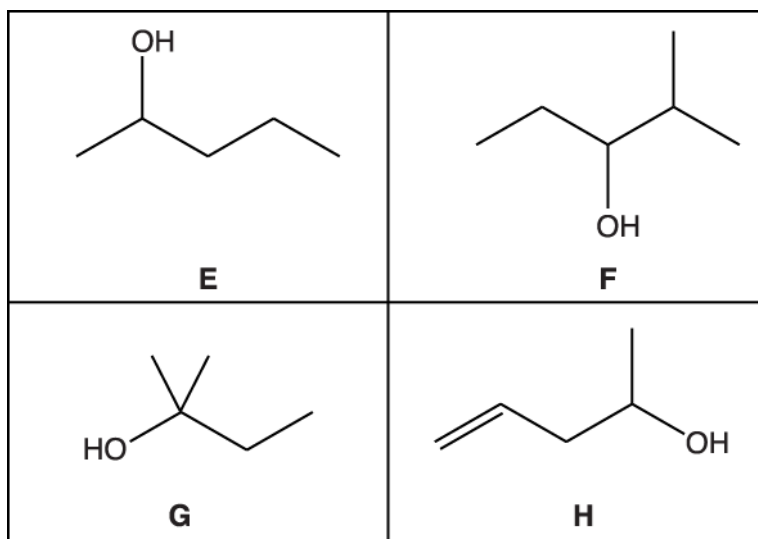
N_2O is a useful anaesthetic and NO has been linked to the depletion of ozone in the stratosphere.

NO radicals catalyse the breakdown of ozone in the stratosphere.

Write **two** equations to show how NO radicals catalyse this breakdown.

----- [2]

16 The skeletal formulae of four alcohols, E, F, G and H, are shown below.



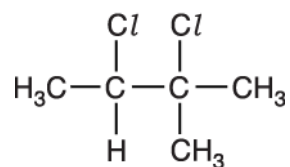
Which pair of alcohols are structural isomers of each other?

- A E and F
- B E and G
- C E and H
- D F and G

Your answer

[1]

17 What is the name of the following compound?



- A 1,2-dichloro-1,2-dimethylpropane
- B 2,3-dichloro-2,3-dimethylpropane
- C 2,3-dichloro-2-methylbutane
- D 2,3-dichloro-3-methylbutane

Your answer

[1]

18 Chlorine reacts with 1-chloropropane in the presence of ultraviolet radiation via a radical substitution mechanism.

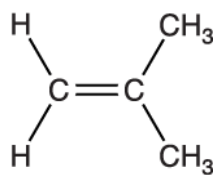
Which equation shows a propagation step in the mechanism for this reaction?

- | | | | |
|---|---|---------------|---|
| A | Cl_2 | $\rightarrow$ | $\cdot\text{Cl} + \cdot\text{Cl}$ |
| B | $\cdot\text{Cl} + \cdot\text{C}_3\text{H}_6\text{Cl}$ | $\rightarrow$ | $\text{C}_3\text{H}_6\text{Cl}_2$ |
| C | $\text{C}_3\text{H}_7\text{Cl} + \cdot\text{Cl}$ | $\rightarrow$ | $\text{C}_3\text{H}_6\text{Cl}_2 + \cdot\text{H}$ |
| D | $\cdot\text{Cl} + \text{C}_3\text{H}_7\text{Cl}$ | $\rightarrow$ | $\cdot\text{C}_3\text{H}_6\text{Cl} + \text{HCl}$ |

Your answer

[1]

19(a) Compound **B**, shown below, can be used to synthesise organic compounds with different functional groups.



Compound B

- (i) Compound **B** is a member of a homologous series.

Name the homologous series and state its general formula.

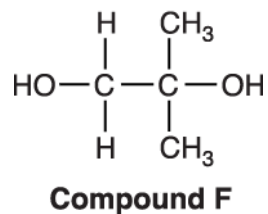
Homologous series

General formula

- (ii) What reagents and conditions are needed to convert compound **B** into a saturated hydrocarbon?

..... **[1]**

(b) The structure of compound F is shown below.



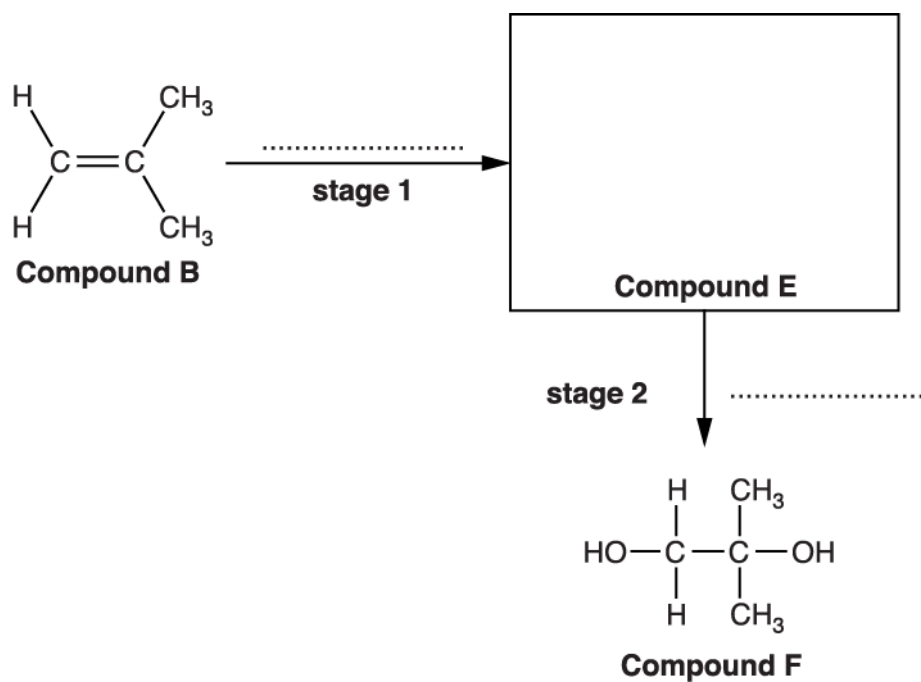
(i) What is the empirical formula of compound F?

-----[2]

(ii) A student plans a two-stage synthesis for preparing compound F from compound B.

The synthesis first prepares compound E, as shown in the flowchart.

Draw the structure of compound E in the box and state the reagents for each stage on the dotted lines.



[3]

20 This question is about the homologous series of alcohols.

What is meant by the term *homologous series*?

[2]

21(a) The hydrocarbons present in crude oil are processed to obtain useful materials, including many fuels.

Alkanes with 6–10 carbon atoms are used in petrol.

What is the general formula of an alkane?

[1]

(b) Oil companies process alkanes into branched and cyclic hydrocarbons to promote efficient combustion in petrol.

- Draw the structure of one branched and one cyclic saturated hydrocarbon that contains 8 carbon atoms.
- Name each hydrocarbon.

Branched	Cyclic
<i>name:</i> -----	<i>name:</i> -----

[3]

22(a) A student was provided with a mixture of two structural isomers. Each isomer has the percentage composition by mass C, 29.29%; H, 5.70%; Br, 65.01%. The relative molecular mass of each isomer is less than 150.

Determine the structures of the two structural isomers.

Show your working.

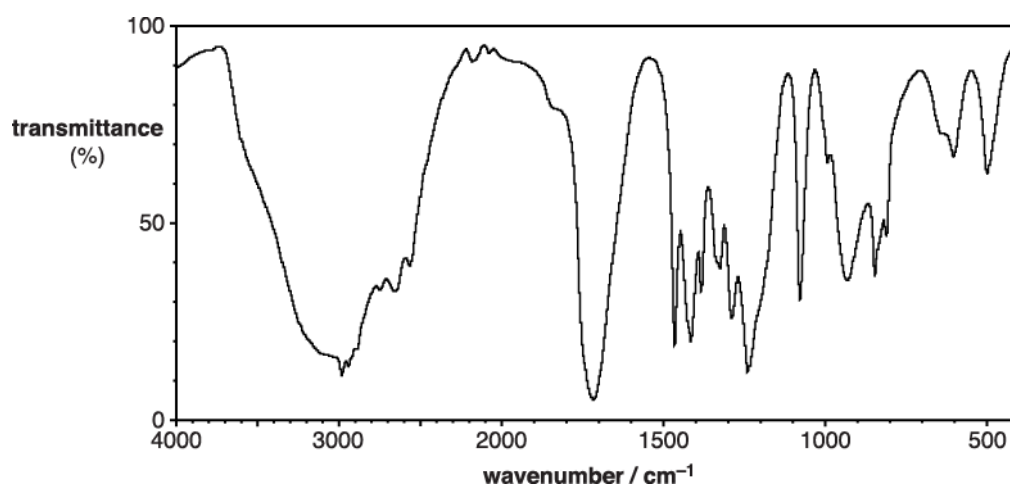


In your answer you should link the evidence with your explanation.

[5]

- (b) The student heats the mixture of the two structural isomers from (a) under reflux with aqueous sodium hydroxide to form two compounds, E and F. The student separates the two compounds.

Compound E is heated under reflux with acidified potassium dichromate(VI) to form compound G, which gives the infrared spectrum below.



- (i) Analyse the information and spectrum to determine the structures of E, F and G.

Include an equation for the formation of G from E.

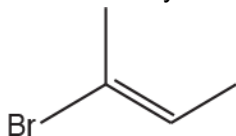


In your answer you should link the evidence with your explanation.

[6]

- Draw the structure of the organic compound H.

23 What is the systematic name of the compound below?

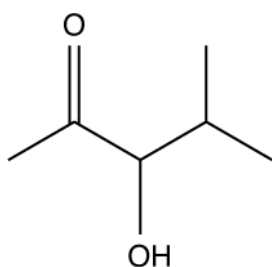


- A *E*-2-bromobut-2-ene
- B *Z*-2-bromobut-2-ene
- C *E*-1,2-dimethyl-1-bromoethene
- D *Z*-1,2-dimethyl-1-bromoethene

Your answer

[1]

24 The skeletal formula of an organic compound is shown below.



What is the molecular formula of the organic compound?

- A $\text{C}_6\text{H}_{10}\text{O}_2$
- B $\text{C}_6\text{H}_{11}\text{O}_2$
- C $\text{C}_6\text{H}_{12}\text{O}_2$
- D $\text{C}_6\text{H}_{13}\text{O}_2$

Your answer

[1]

25 How many structural isomers have the molecular formula C_5H_{12} ?

- A 2
- B 3
- C 4
- D 5

Your answer

[1]

26(a) Propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$, is a member of the homologous series of carboxylic acids.

Suggest the general formula for a carboxylic acid.

-----[1]

- (b) 2-Chloropropanoic acid, $\text{CH}_3\text{CHClCOOH}$, can be made by reacting propanoic acid with chlorine in a radical substitution reaction.

- (i) State the conditions for the reaction.

-----[1]

- (ii) Write the overall equation for the reaction.

-----[1]

- (iii) The first step in the reaction mechanism involves homolytic fission of a chlorine molecule to form two chlorine radicals.

Why is this step an example of *homolytic fission*?

-----[1]

- (iv) Write **two** equations to show the propagation steps in the mechanism for this reaction.

Use dots, •, to show the unpaired electrons on radicals.

-----[2]

- (v) Draw the displayed formula of the radical formed in the first propagation step.

Use a dot, •, to show the position of the unpaired electron.

[1]

(vi) Further substitution forms a mixture of organic products.

Draw the structure of an organic product formed from 2-chloropropanoic acid by further substitution.

[1]

27 An alkene **D** is a liquid at room temperature and pressure but can easily be vaporised.

When vaporised, 0.1881 g of **D** produces 82.5 cm³ of gas at 101 kPa and 373 K.

Determine the molar mass and molecular formula of alkene **D**.

Show all your working.

molar mass = _____ g mol⁻¹

molecular formula = _____ [5]

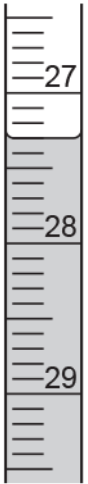
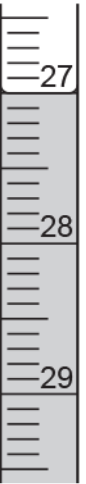
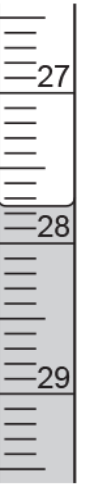
28(a) A student carries out a titration to determine the molar mass and structure of a weak acid **A**.

The student follows the method below.

- Dissolve a weighed mass of **A** in 100 cm³ of distilled water and make the solution up to 250 cm³ in a beaker.
- Add the solution of **A** to a burette.
- Titrate the solution of **A** with a standard solution of sodium hydroxide, NaOH.

The student carries out a trial, followed by three further titrations.
The diagram shows the initial and final burette readings for the three **further** titrations.

The student measures all burette readings to the nearest 0.05 cm³.

Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading
					

(i) Record the student's readings and the titres in the table below.

Calculate the mean titre, to the nearest 0.05 cm³, that the student should use for analysing the results.

	Titration 1	Titration 2	Titration 3
Final reading/cm ³			
Initial reading/cm ³			
Titre/cm ³			

mean titre = ----- cm^3 [4]

- (ii) The uncertainty in each burette reading is $\pm 0.05 \text{ cm}^3$.

Calculate the percentage uncertainty for the titre in **Titration 1**.

percentage uncertainty = ----- % [1]

- (iii) The student realised that the solution of **A** had not been prepared correctly.

How should the student have made up the solution?

----- [1]

(b) A student repeats the titration to determine the molar mass and structure of **A**.

- The student prepares a 250.0 cm³ solution from 1.513 g of **A**.
- The solution of **A** is added to the burette and titrated with 25.0 cm³ volumes of 0.112 mol dm⁻³ NaOH(aq).
- 1 mol of **A** reacts with 2 mol of NaOH.
- The student obtains a mean titre of 27.30 cm³.

(i) Calculate the molar mass of **A** from these results.

Give your answer to the nearest whole number.

Show your working.

molar mass of **A** = ----- g mol⁻¹ [4]

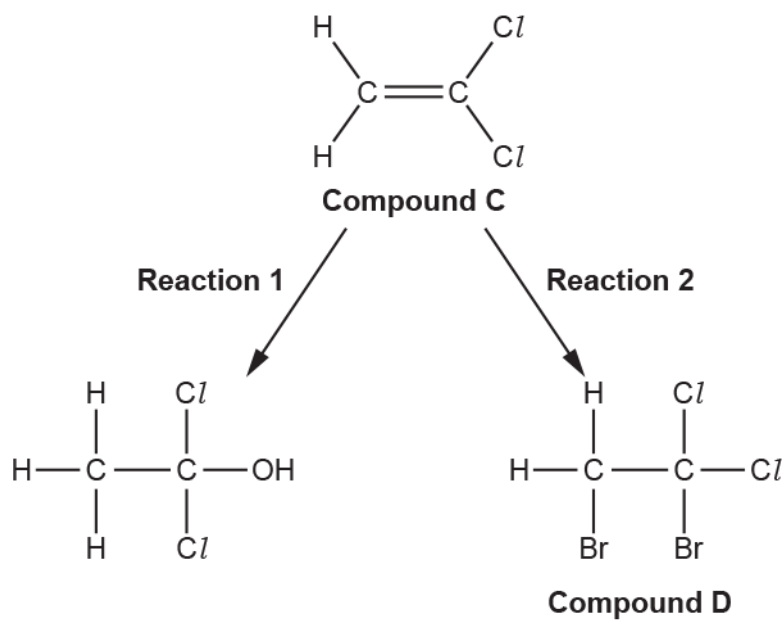
(ii) **A** is an organic acid, containing C, H and O only.

One molecule of **A** contains two COOH groups.

Suggest the structure of **A**.

[1]

29(a) Two reactions of compound **C** are shown in the flowchart below.



State the reagents and conditions for **reaction 1**.

.....

..... **[1]**

(b) In **reaction 2**, compound **C** reacts with bromine to form compound **D**.

(i) Give the systematic name of compound **D**.

-----[1]

(ii) Outline the mechanism for **reaction 2**.

Include curly arrows, charges and relevant dipoles.

[3]

(c) Compound **C** forms an addition polymer **E**.

(i) Write a balanced equation for this reaction.

Show displayed formulae.

[2]

(ii) State **one** advantage and **one** disadvantage of using combustion as a method for the disposal of waste polymer **E**.

Advantage -----

Disadvantage -----

----- [2]

30 How many structural isomers of $C_6H_{14}O$ are tertiary alcohols?

A 1

B 2

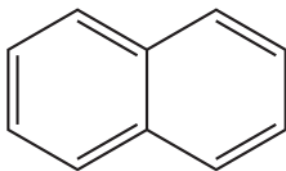
C 3

D 4

Your answer

[1]

31 The structure of naphthalene is shown below.



What is the molecular formula of naphthalene?

A $C_{10}H_8$

B $C_{10}H_{10}$

C $C_{12}H_{10}$

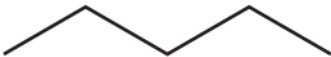
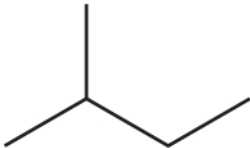
D $C_{12}H_{12}$

Your answer

[1]

Compounds **A**, **B** and **C** are saturated hydrocarbons.

The structures and boiling points of **A**, **B** and **C** are shown below.

	Isomer	Boiling point / °C
A		36
B		28
C		9

- Use the structures to explain what is meant by the term structural isomer.
- Explain the trend in boiling points shown by **A**, **B** and **C** in the table.

[5]

(b) Compounds **A**, **B** and **C** all react with chlorine in the presence of ultraviolet radiation to form organic compounds with the formula $C_5H_{11}Cl$.

(i) Name the mechanism for this reaction.

----- [1]

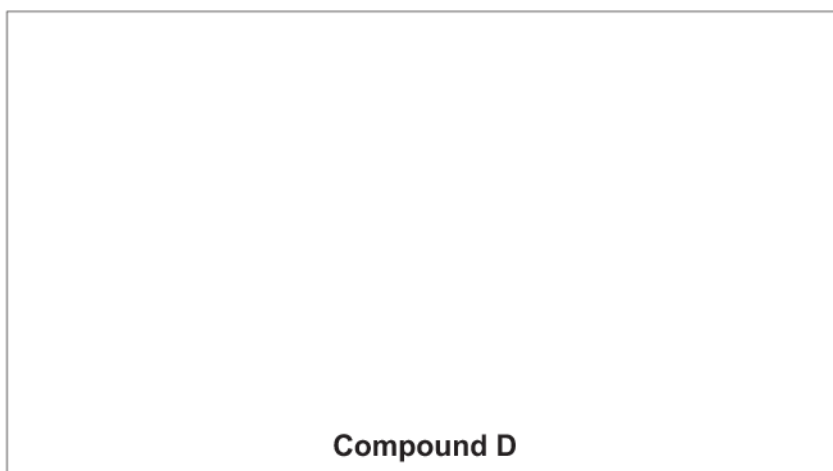
(ii) Complete the table to show the number of structural isomers of $C_5H_{11}Cl$ that could be formed from the reaction of chlorine with **A** and **B**.

	A	B
Number of structural isomers		

[2]

(iii) The reaction of compound **A** with excess chlorine forms a compound **D**, which has a molar mass of 175.5 g mol^{-1} .

Draw a possible structure for compound **D** and write the equation for its formation from compound **A**. Use molecular formulae in the equation.



Equation ----- [2]

33(a) This question is about reactions involving alcohols.

Three reactions of an alcohol **E** are shown in Fig. 25.1.

(i) Complete Fig. 25.1 to show the structures of the organic products formed in the reactions.

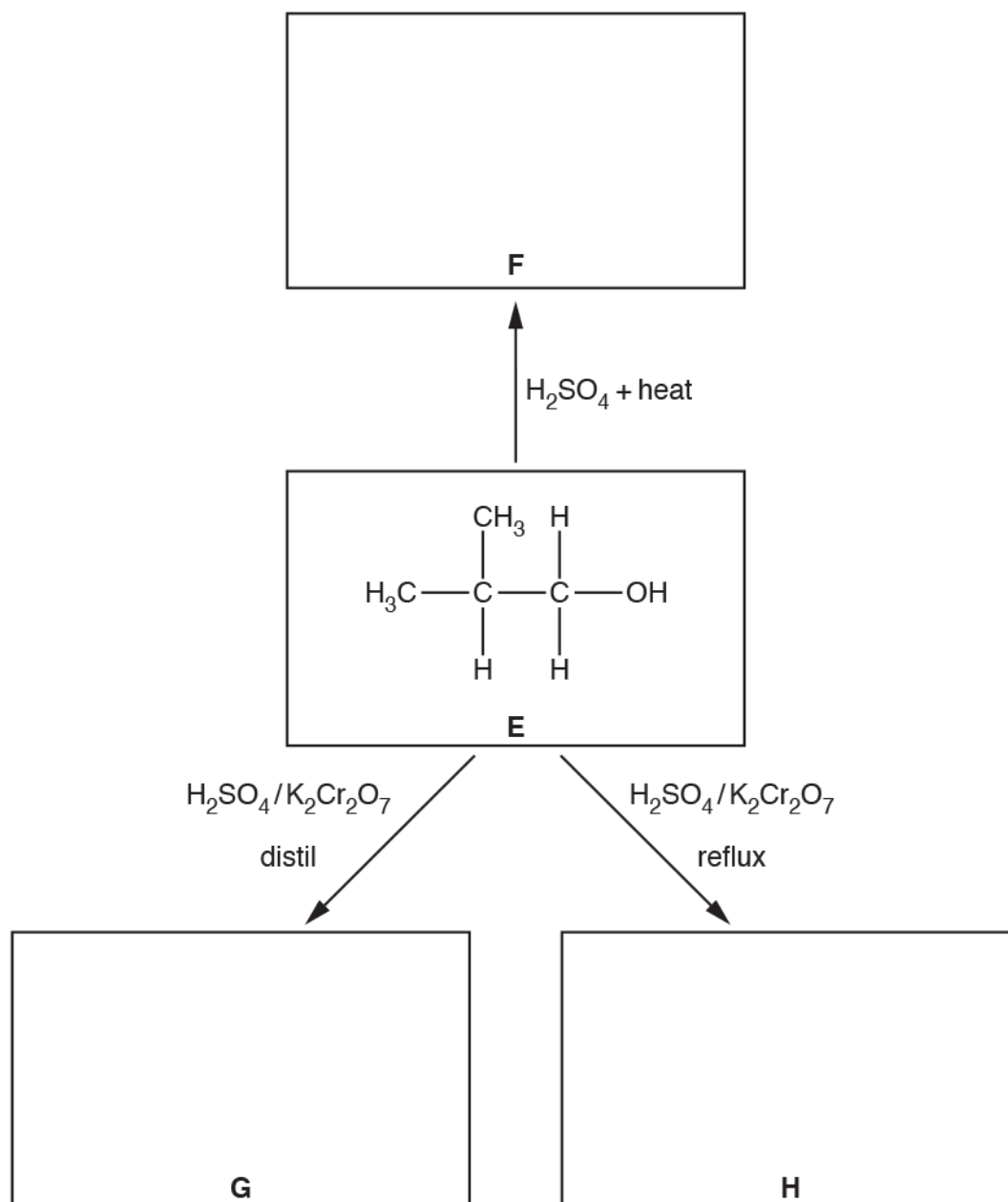


Fig. 25.1

[3]

(ii) What is the systematic name of alcohol E?

-----[1]

(b) An alcohol can be prepared by hydrolysing the haloalkane $\text{C}_2\text{H}_5\text{CHBrCH}_3$ with aqueous sodium hydroxide.

(i) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles.

[3]

(ii) The infrared (IR) spectrum for $\text{C}_2\text{H}_5\text{CHBrCH}_3$ is shown in Fig. 25.2.

The C–Br bond absorption is labelled.

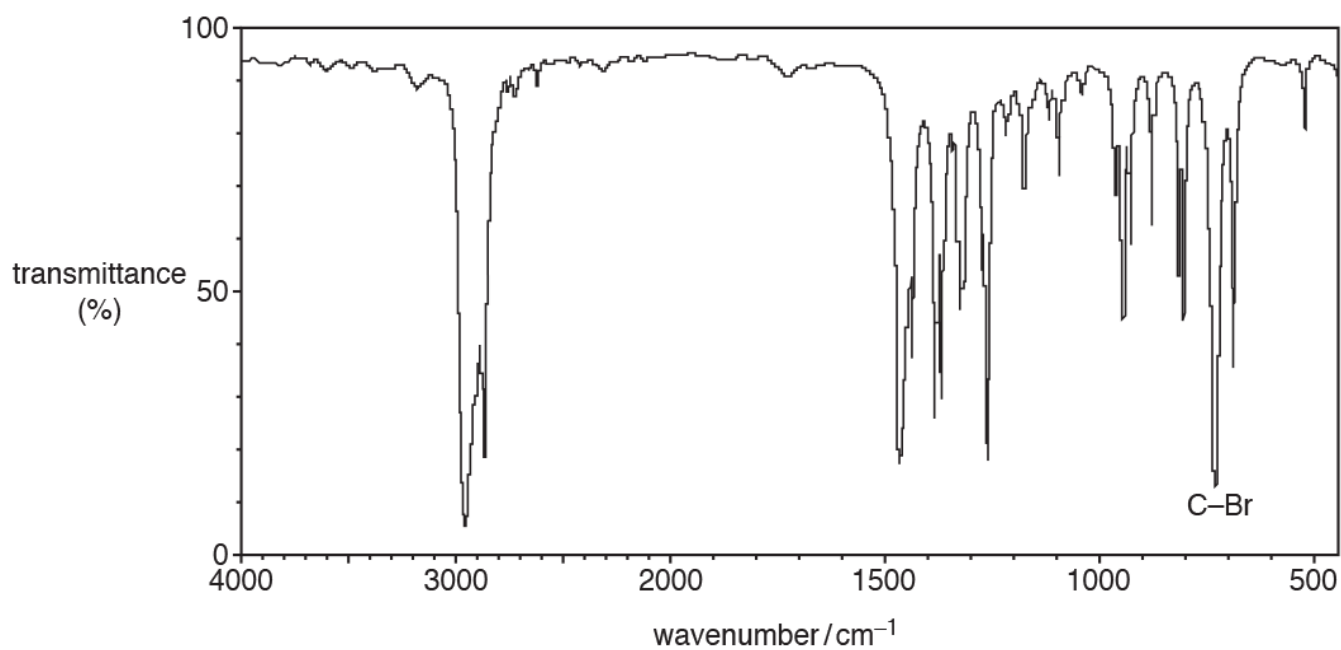
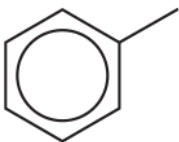
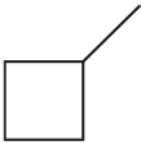
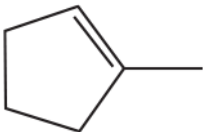
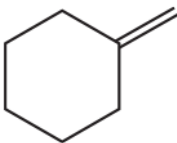


Fig. 25.2

Outline how IR spectroscopy could be used to show that the bromoalkane functional group has reacted and that the alcohol functional group has formed.

----- [2]

34 Which compound is unsaturated, alicyclic and contains an alkyl group?

A	
B	
C	
D	

Your answer

[1]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a	i	(series of compounds with the) same functional group OR same / similar chemical properties OR same / similar chemical reactions ✓ each successive/subsequent member differing by CH₂ ✓	2	IGNORE references to physical properties IGNORE has same general formula (in question) DO NOT ALLOW have the same empirical formula OR have the same molecular formula Examiner's Comments Many candidates were able to score both marks by specifying the same functional group and that each successive member varies by a CH₂ group. Some responses were imprecise and referred to just members differing by CH₂ group.
		ii	C _n H _{2n} ✓	1	Examiner's Comments Most candidates were able to state the general formula for the cycloalkanes.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	More carbons (in ring) OR more (surface area of) contact AND more van der Waals forces OR stronger van der Waals forces ✓ More energy needed to break the intermolecular forces ✓	2	Both answers need to be comparisons ALLOW ORA throughout ALLOW has more electrons OR larger (carbon) ring OR higher molecular mass IGNORE bigger molecule IGNORE chain instead of ring DO NOT ALLOW 'more contact between atoms' ALLOW 'VDW' for van der Waals 'More intermolecular forces' is not sufficient ALLOW it is harder to overcome the intermolecular forces ALLOW intermolecular bonds / van der Waals bonds ALLOW more energy is needed to separate molecules IGNORE more energy is needed to break bonds Examiner's Comments This was a well answered question and many candidates could relate the difference in boiling point to the increase in points of contact and stronger van der Waals' forces. A significant number of candidates referred to the breaking of bonds rather than intermolecular forces.
	b	i	(Compounds with the) same structural formula but a different arrangement (of atoms) in space ✓	1	ALLOW different spatial arrangement of atoms. DO NOT ALLOW different displayed formula. Examiner's Comments Although many candidates were able to provide the correct definition, some responses did not state that stereoisomers have the same structural formula.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance							
		ii	H H₃C C = C CH₃ H ✓ H H₃C C = C H CH₃ ✓	2	ALLOW displayed OR skeletal formula OR mixture of the above. ALLOW structures in either order IGNORE molecular formula IGNORE structural formula IGNORE names IGNORE E/Z and cis / trans labels ALLOW 1 mark for a pair of E/Z isomers of an incorrect hydrocarbon structure with four C atoms e.g. C, or CH or CH₂ instead of CH₃ groups. Examiner's Comments This question required candidates to identify isomers of cyclobutane that would exhibit stereoisomerism and proved challenging for some. The more able candidates were able to provide two correct structures. A significant number of candidates suggested cyclic alkenes, which were not isomers of cyclobutane.							
c	i	<table><tr><th>Step</th><th>Equation</th></tr><tr><td>Initiation (1 mark)</td><td>Br₂ → 2Br• ✓</td></tr><tr><td>Propagation (2 marks)</td><td>C₆H₁₂ + Br• → C₆H₁₁• + HBr ✓ C₆H₁₁• + Br₂ → C₆H₁₁Br + Br• ✓</td></tr><tr><td>Termination (2 marks)</td><td>C₆H₁₁• + Br• → C₆H₁₁Br C₆H₁₁• + C₆H₁₁• → C₁₂H₂₂ Br• + Br• → Br₂ Two correct ✓ All three correct ✓✓</td></tr></table>	Step	Equation	Initiation (1 mark)	Br ₂ → 2Br• ✓	Propagation (2 marks)	C ₆ H ₁₂ + Br• → C ₆ H ₁₁ • + HBr ✓ C ₆ H ₁₁ • + Br ₂ → C ₆ H ₁₁ Br + Br• ✓	Termination (2 marks)	C ₆ H ₁₁ • + Br• → C ₆ H ₁₁ Br C ₆ H ₁₁ • + C ₆ H ₁₁ • → C ₁₂ H ₂₂ Br• + Br• → Br ₂ Two correct ✓ All three correct ✓✓	5	IGNORE state symbols IGNORE dots If an incorrect hydrocarbon with six C atoms is used: DO NOT ALLOW any marks for the propagation steps but ALLOW ECF for termination steps (<i>i.e.</i> 3 <i>max</i>) Examiner's Comments This question required candidates to apply their knowledge of the radical substitution mechanism and those who had prepared well scored full marks. A common misconception was to have hydrogen radicals being formed and reacted in propagation and termination steps.
Step	Equation											
Initiation (1 mark)	Br ₂ → 2Br• ✓											
Propagation (2 marks)	C ₆ H ₁₂ + Br• → C ₆ H ₁₁ • + HBr ✓ C ₆ H ₁₁ • + Br ₂ → C ₆ H ₁₁ Br + Br• ✓											
Termination (2 marks)	C ₆ H ₁₁ • + Br• → C ₆ H ₁₁ Br C ₆ H ₁₁ • + C ₆ H ₁₁ • → C ₁₂ H ₂₂ Br• + Br• → Br ₂ Two correct ✓ All three correct ✓✓											

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	The breaking of a (Br-Br) bond AND forms (two) radicals OR the breaking of a (Br-Br) bond AND one electron (from the bond pair) goes to each atom / bromine ✓	1	ALLOW 'the breaking of a covalent bond' ALLOW the splitting of the bond in bromine ALLOW the breaking of a covalent bond where each atom keeps one of the bonding electrons IGNORE particle for atom ALLOW one electron goes to each product / species DO NOT ALLOW molecule or compound for atom IGNORE homolytic fission equations Examiner's Comments This question was better attempted than in previous sessions. Although many candidates were able to identify that radicals were formed, a significant number did not refer to the breaking of the covalent bond in Br₂.
	d	i	$\text{C}_6\text{H}_{12} + 2\text{Br}_2 \rightarrow \text{C}_6\text{H}_{10}\text{Br}_2 + 2\text{HBr} \quad \checkmark$	1	ALLOW molecular formula only. Examiner's Comments This question proved quite difficult for the vast majority of candidates who failed to apply their knowledge of radical substitution to an unfamiliar example. The most common incorrect answer was $\text{C}_6\text{H}_{12} + \text{Br}_2 \rightarrow \text{C}_6\text{H}_{10}\text{Br}_2 + \text{H}_2$.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	1,1-dibromocyclohexane OR 1,2-dibromocyclohexane OR 1,3-dibromocyclohexane OR 1,4-dibromocyclohexane ✓	1	Locant numbers MUST lowest possible e.g. DO NOT ALLOW 2,4-dibromocyclohexane etc. IGNORE structures Examiner's Comments Candidates were required to name one of the dibromocyclohexane compounds that could be formed from cyclohexane and the more able candidates were able to apply their understanding of nomenclature successfully. Common incorrect responses included straight chain dibromo compounds e.g. 1,2—dibromohexane and incorrect use of locant numbers e.g. 2,3—dibromocyclohexane.
			Total	16	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
2	a		$ \begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{Br} \quad \text{Br} \quad \checkmark \end{array} $	1	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above DO NOT ALLOW molecular formula ALLOW dichloro or diiodo compound instead of the dibromo compound as the only alternatives. Examiner's Comments This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		Reagent A: correct halogen✓ e.g. Br ₂ / bromine	1	ALLOW C_l₂ if dichloro compound drawn ALLOW I₂ if diiodo compound drawn IGNORE state symbols Answer must match box from (a) to score Examiner's Comments This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).

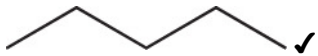
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	Steam AND acid catalyst ✓	1	ALLOW H^+ / named acid / H_2SO_4 / H_3PO_4 ALLOW $H_2O(g)$ ALLOW water only if a temperature of 100 °C or above is quoted. IGNORE any temperature given with steam IGNORE pressure Examiner's Comments One would expect the majority of candidates to do well in a question which required them to state the reagents and conditions required for the hydration of alkenes; however this was not the case. The most able candidates provided accurate responses which referred to both steam and the acid catalyst, which was often shown to be H_3PO_4. Other candidates stated only one of the two required responses and it was common to see the acid catalyst stated alongside a temperature and pressure but with no reference to steam. Some candidates stated the reagent as H_2O instead of steam and this was allowed if accompanied by a temperature of over 100 °C. Candidates should be encouraged to learn reagents and conditions required for organic reactions.
		ii	(compounds or molecules) having the same molecular formula but different structural formulae ✓	1	ALLOW different structure OR different displayed formula OR different skeletal formula for structure Same formula is not sufficient Different arrangement of atoms is not sufficient Examiner's Comments The majority of candidates were able to explain the term structural isomers.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$ \begin{array}{c} \text{CH}_3 \text{ CH}_3 \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{OH} \text{ H} \quad \checkmark \end{array} \qquad \begin{array}{c} \text{CH}_3 \text{ CH}_3 \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{OH} \quad \checkmark \end{array} $	2	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above ALLOW any vertical bond to OH DO NOT ALLOW OH⁻ Examiner's Comments Many candidates found this question difficult and a large number of candidates showed structures of alcohols with the molecular formula C₅H₁₂O, but that could not be formed from 2-methylbut-2-ene. Examples of these incorrect responses included 2-methylbutan-1-ol, pentan-1-ol, pentan-2-ol and pentan-3-ol. Only the most able could show the structures of both alcohols produced by the hydration of 2-methylbut-2-ene. Candidates should be reminded to check that any structures they suggest are consistent with the context of the question.
		iv	Does not contain OH group(s) OR does not contain hydroxyl group(s) OR is not an alcohol ✓ Does not form hydrogen bonds with water ✓	2	ALLOW ORA throughout DO NOT ALLOW OH⁻ (ions) / hydroxide (ions) 'Does not form hydrogen bonds' is not sufficient Examiner's Comments The majority of candidates were able to recognise that the key to the solubility of the isomers in water is that they contain the OH group whereas 2-methylbut-2-ene does not. Most candidates scored the second mark by accurately explaining that the OH group could form hydrogen bonds with water.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3	a	i	(compounds or molecules having the) same molecular formula but different structural formulae ✓	1	ALLOW different structure OR different displayed formula OR different skeletal formula for structure DO NOT ALLOW any reference to spatial / space Same formula is not sufficient (<i>no reference to molecular</i>) Different arrangement of atoms is not sufficient (<i>no reference to structure / structural</i>) Examiner's Comments Most candidates were able to define structural isomers. Some responses were imprecise with candidates stating that isomers had 'different arrangements of atoms' rather than referring to different structural formulae.
		ii	2, 2, 3-trimethylbutane ✓	1	ALLOW trimethylbutane as the ONLY alternative response Examiner's Comments Many candidates found this question difficult and it was common to see incorrect names for compound A. These included incorrect use of locant numbers e.g. 2,3,3-trimethylbutane and inappropriate nomenclature e.g. 2,2-dimethyl-3-methylbutane. A small proportion of candidates named compound A as heptane.
	b		 ✓	1	DO NOT ALLOW molecular formulae OR structural formula OR displayed formula OR mixture of the above Examiner's Comments The majority of candidates were able to provide the skeletal formula of pentane.
			Total	3	

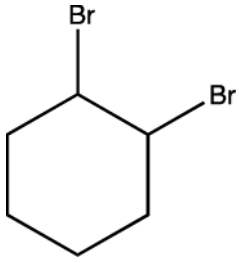
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a	i	(series of compounds with the) same functional group OR same / similar chemical properties OR same / similar chemical reactions ✓ each successive / subsequent member differing by CH₂ ✓	2	IGNORE reference to physical properties IGNORE same general formula (<i>in question</i>) Differs by CH₂ is not sufficient (<i>no successive</i>) DO NOT ALLOW same empirical OR have the same molecular formula Examiner's Comments Many candidates were able to score both marks by specifying the same functional group and that each successive member varies by a CH₂ group. Some responses were imprecise and referred to just members differing by a CH₂ group.
		ii	C _n H _{2n-1} Br ✓	1	ALLOW C_nH_{2n-1}X ONLY if X is specified as Br (<i>question asks for bromide</i>) Examiner's Comments The most able candidates were able to determine the general formula required. Many candidates came close and stated C_nH_{2n-1}X, but failed to specify that X was Br.
		iii	3-bromoprop(-1-)ene ✓	1	ALLOW 1-bromoprop-2-ene Examiner's Comments Candidates were asked to give the systematic name for allyl bromide. Although a fair proportion stated 3-bromopropene, 1-bromoprop-2-ene was also a common response. Either of these was allowed by the mark scheme. A common incorrect response was 1-bromoprop-3-ene. Candidates should be aware that the lowest possible locant numbers should be used when naming compounds.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	Movement of an electron pair ✓	1	ALLOW movement of a lone pair OR movement of a bond Examiner's Comments Although the definition of a curly arrow was well known, many imprecise responses were seen. The most common was that a curly arrow represents the movement of electrons. Candidates should be aware that it is important to refer to an electron pair, when describing the meaning of a curly arrow.
		ii	Electron pair donor ✓	1	ALLOW can donate a lone pair Examiner's Comments Most candidates could state the correct definition. However, as with part (i) a significant number of candidates failed to specify 'electron pair' and stated that a nucleophile is an electron donor.
			Total	6	
5			C	1	
			Total	1	

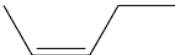
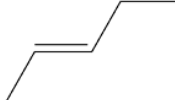
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6	a		Aliphatic = E, H, I, J (1) Alicyclic = E, H, J (1) Aromatic = F, G (1)	3	
	b		C_nH_{2n+1}	1	do not allow C_nH_{2n+1}
	c	i	<i>Equation:</i> $C_6H_{12}O \rightarrow C_6H_{10} + H_2O$ (1) <i>Calculation:</i> FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 32.7 (%) award 3 marks theoretical yield = $7.65 / 100 = 0.0765$ (mol) (1) actual yield = $2.05 / 82 = 0.025$ (mol) (1) % yield = $(0.025 / 0.0765) \times 100\% = 32.7(\%)$ (1)	4	ignore state symbols allow $C_6H_{11}OH$ for $C_6H_{12}O$ If there is an alternative answer, check to see if there is any ECF credit possible using working below % yield must be to 1 dp allow theoretical and actual yield calculated in mass theoretical yield = $0.0765 \times 82 = 6.273$ g % yield = $(2.05 / 6.273) = 32.7(\%)$ allow ecf from calculated actual and theoretical yields
		ii	bromine water is decolourised (1)  (1)	2	allow bromine water turns colourless ignore 'goes clear' allow correct structural OR displayed OR skeletal formula OR mixture of the above
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
7			Initiation $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$ (1) Propagation $\text{C}_2\text{H}_6 + \text{Cl}\cdot \rightarrow \text{C}_2\text{H}_5\cdot + \text{HCl}$ (1) $\text{C}_2\text{H}_5\cdot + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_5\text{Cl} + \text{Cl}\cdot$ (1) Termination $\text{Cl}\cdot + \text{Cl}\cdot \rightarrow \text{Cl}_2$ OR $\text{C}_2\text{H}_5\cdot + \text{Cl}\cdot \rightarrow \text{C}_2\text{H}_5\text{Cl}$ OR $\text{C}_2\text{H}_5\cdot + \text{C}_2\text{H}_5\cdot \rightarrow \text{C}_4\text{H}_{10}$ (1) Initiation, propagation, termination used in correct context (1)	5	If the structure of the ethyl radical is drawn, the lone electron must be attached to a C atom
			Total	5	
8			Electron pair acceptor (1) I^+ (1)	2	
			Total	2	

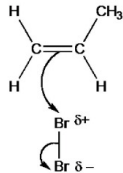
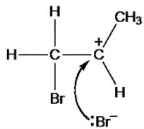
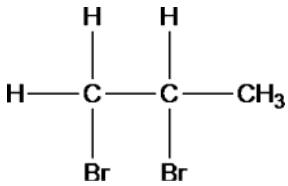
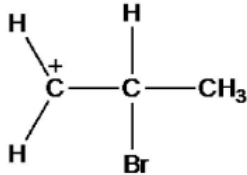
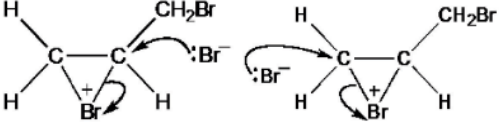
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
9	<i>* Please refer to the marking instruction point 10 for guidance on how to mark this question.</i> (Level 3) Applies knowledge of elimination reactions to provide the correct names and structures of all three alkenes. AND Full, detailed explanation of formation of both types of isomers linked to the reaction, with clear understanding of both types of isomerism. <i>The explanations show a well-developed line of reasoning which is clear and logically structured. The information presented is relevant to the compounds drawn / named.</i> (5–6 marks) (Level 2) Applies knowledge of elimination reactions to provide the correct name and structure for pent-1-ene. AND Correct structures of stereoisomers of pent-2-ene but full names missing or incorrect. AND Explanation of formation of at least one type of isomers in some detail. <i>The explanations show a line of reasoning presented with some structure. The information presented is in the most-part relevant to the compounds drawn / named.</i> (3–4 marks) (Level 1) Applies knowledge of elimination reactions to name and draw the structures of organic products. Either name OR structure should be correct for two compounds. AND Attempts to explain formation of one type of isomer.	6	Indicative scientific points may include: - the elimination can produce a double bond in either the 1- or the 2- position (through combination of the hydroxyl group with a hydrogen from either the 1st or the 3rd carbon) - this leads to the formation of structural isomers (pent-1-ene and pent-2-ene) - pent-2-ene exhibits stereoisomerism / <i>E/Z</i> isomerism / <i>cis-trans</i> isomerism because it has two different groups attached to each carbon atom - there are two possible isomers of pent-2-ene and three in total. Names and structures of alkenes  pent-1-ene  Z or <i>cis</i>-pent-2-ene  E or <i>trans</i>-pent-2-ene

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>The information about isomerism is basic and communicated in an unstructured way. The relationship to the compounds drawn / named may not be clear.</i> (1–2 marks) (0 marks) No response or no response worthy of credit.		
			Total	6	
10			FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 46.0 (g mol⁻¹) award 4 marks for calculation <i>Rearranging ideal gas equation to make n subject</i> $n = \frac{pV}{RT} \quad (1)$ <i>Substituting all values taking into account conversion to Pa and m³</i> $n = \frac{(100 \times 10^3) \times (761 \times 10^{-6})}{8.314 \times 366} \quad (1)$ $n = 0.0250 \text{ mol} \quad (1)$ <i>Calculation of M</i> $M = \frac{m}{n} = \frac{1.15}{0.0250} = 46.0 \text{ (g mol}^{-1}\text{)} \quad (1)$ <i>Identification of A (1)</i> $\begin{array}{c} \text{H} \qquad \text{H} \\ \qquad \\ \text{H} - \text{C} - \text{C} - \text{OH} \\ \qquad \\ \text{H} \qquad \text{H} \end{array}$	5	If there is an alternative answer, check to see if there is any ECF credit possible using working below. 1st mark may be implicit in direct substitution of correct values into rearranged equation. allow any unambiguous structure allow C₂H₅OH do not allow C₂H₆O
			Total	5	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
11	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 73.9 or 73.93 (g mol⁻¹) award 3 marks for calculation $n(\text{NaOH}) = (25.25/1000) \times 0.120 = 3.03 \times 10^{-3}$ (mol) (1) $n(\text{acid in } 250 \text{ cm}^3 \text{ flask}) = 3.03 \times 10^{-3} \times 10 = 3.03 \times 10^{-2}$ (mol) (1) molar mass of unknown acid = $2.24/3.03 \times 10^{-2} = 73.9$ (g mol⁻¹) (1)	3	If there is an alternative answer, check to see if there is any ECF credit possible using working below
	Total	3	
12	i Curly arrow from double bond to Br of Br-Br (1) Correct dipole shown on Br-Br AND curly arrow showing breaking of Br-Br bond (1)  Correct carbocation with + charge on C with 3 bonds AND curly arrow from Br⁻ to C⁺ of carbocation (1)  Correct product: (1) 	4	Curly arrow must start from bond and go to correct atom do not allow partial charges on C=C bond allow carbocation on terminal CH₂  do not allow δ+ on C of carbocation Curly arrow must come from a lone pair on Br⁻ OR from the negative sign of Br⁻ ion (then lone pair on Br⁻ ion does not need to be shown) allow formation of bromonium intermediate and curly arrows, i.e.: 
	ii Movement of a pair of electrons	1	allow movement of a lone pair
	Total	5	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
13	<i>* Please refer to the marking instruction point 10 for guidance on how to mark this question.</i> (Level 3) Candidate provides a method for identifying the alcohols AND provides all supporting evidence from IR spectrum AND gives details of reagents and conditions and correct equations. <i>The explanation is detailed and well structured. The information is clearly supported by details of reactions and evidence of oxidation product.</i> (5–6 marks) (Level 2) Candidate provides a basic method AND provides some supporting evidence from IR spectrum AND gives details of reagents and conditions with some attempt at equations. <i>The explanation has some structure. The information is supported by some details of reactions and evidence from IR spectrum.</i> (3–4 marks) (Level 1) Candidate attempts to describe a basic method AND gives some supporting evidence from IR spectrum OR details of reagents and conditions with some attempt at equations. <i>The explanation is basic and lacks structure. The information is supported by limited evidence from the reactions and oxidation products and would not lead to identification.</i> (1–2 marks)	6	Indicative scientific points may include Identification of alcohols Based on recognition of alcohols as primary, secondary and tertiary (stated or implied by method). Basic procedure involves reflux followed by use of IR to identify different oxidation products. Reactions - stated reagents ($\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$ and conditions (reflux)) - equations using [O] including structural formulae $\text{CH}_3\text{CH}_2\text{CHOHCH}_3 + [\text{o}] \rightarrow \text{CH}_3\text{CH}_2\text{COCH}_3 + \text{H}_2\text{O}$ $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 2[\text{o}] \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + \text{H}_2\text{O}$ Identification of oxidation product - IR: carboxylic acid from broad OH absorption and C=O - IR: carbonyl / ketone from C=O and no OH - tertiary alcohol from lack of C=O and OH peak in IR OR no colour change in reflux.

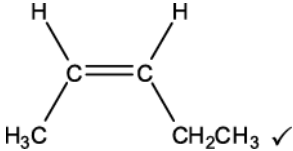
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			No response or no response worthy of credit. (0 marks)		
			Total	6	

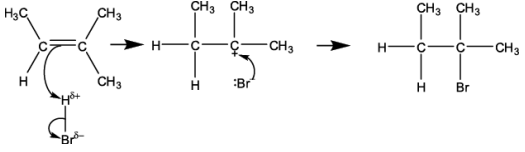
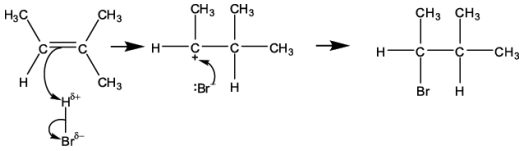
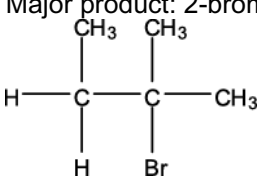
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14	a	i	Any one from: • σ bond is between bonding atoms/nuclei AND π bond is above and below the bonding atoms / nuclei • σ bond has direct/head-on overlap of orbitals AND π bond has sideways overlap • π bond has a lower bond enthalpy / is weaker than a σ bond • σ bond has electron density between bonding atoms AND π bond has electron density above and below bonding atoms ✓	1	IGNORE the length of the σ bond and π bond IGNORE the type of orbital for σ bond Examiner's Comments The vast majority of candidates were unable to describe the difference between a σ and a π bond. The simplest answer was that the π bond was the weaker bond or the σ bond was the stronger. Many candidates attempted to describe how the two different bonds were formed. It was clear that candidates understood the concept of the sideways overlap of the p orbitals to form the π bond but were unable to describe the formation of the σ bond. A common misconception was that the σ bond could only be formed by the overlapping of the s orbitals. The best candidates were able to articulate that the σ bond results from the head on overlap of orbitals resulting in the bond forming directly between two atoms whereas the π bond results in the electron density being located above and below the plane of the bonding atoms.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	One carbon atom (in double bond) is attached to two groups which are identical / the same ✓	1	ALLOW - One carbon atom in (double bond) is not attached to (two) different groups/groups of atoms - Right-hand carbon is attached to two groups that are the same/two methyl groups. - Two groups are the same on right-hand side - Three groups are the same (on the double bond) DO NOT ALLOW - Two groups on the same side of the double bond <i>Must be right-hand side; Same side could be top or bottom</i> - Functional groups OR molecules for groups Examiner's Comments This question required candidates to apply their knowledge of <i>E/Z</i> isomerism to suggest why compound A did not have <i>E/Z</i> isomers. Whilst it was clear that many candidates understood the concept of <i>E/Z</i> isomerism many found it difficult to apply this concept and articulate an explanation.
		iii	 ✓	1	Mark Independently ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW C₂H₅ for CH₂CH₃ IGNORE connectivity of alkyl groups BUT DO NOT ALLOW –CH₃CH₂
		iii	(Z-)pent-2-ene ✓	1	DO NOT ALLOW trans-pent-2-ene Examiner's Comments Most candidates were able to draw the structural isomer of compound A and provide a suitable name.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b	<i>Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) A comprehensive description with all three scientific points explained thoroughly. <i>There is a well-developed and detailed description of the mechanism, including correct structures, accurately drawn curly arrows and using charges and dipoles consistently. Candidates compare tertiary and secondary carbocation stability to justify major product.</i> Level 2 (3–4 marks) Attempts to describe all three scientific points but explanations may be incomplete. OR Explains two scientific points thoroughly with no omissions. <i>The description has some structures with reasonably accurate curly arrows and some charges and dipoles identified.</i> Level 1 (1–2 marks) A simple description based on at least two of the main scientific points OR Explains one scientific point thoroughly with few omissions. <i>The description is communicated in an unstructured way, including some use of curly arrows, charges or dipoles.</i> 0 marks No response worthy of credit.	6	Throughout: ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above if unambiguous Indicative scientific points 1. Two possible products of reaction $\text{CH}_3\text{C}(\text{CH}_3)\text{BrCH}_2\text{CH}_3$ $\text{CH}_3\text{CHBrCH}(\text{CH}_3)\text{CH}_3$ IGNORE names where correct structures are present 2. Mechanism for formation of either product. Curly arrow from $\text{C}=\text{C}$ to attack the H atom of the HBr Correct dipole on $\text{H}-\text{Br}$ Curly arrow from $\text{H}-\text{Br}$ bond to Br Carbocation with full positive charge on carbon atom Curly arrow from negative charge on Br^- or lone pair on Br^- to carbon atom with positive charge  or  3. Major organic product Major product: 2-bromo-2-methylbutane 

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Major product is formed from the most stable carbocation intermediate OR –Br is attached to carbon atom with the least hydrogens attached OR the carbon with the most –CH₃ groups attached OR the –H is attached to the carbon atom with most hydrogens attached Examiner's Comments The first of the six mark level of response questions required candidates to draw the mechanism of electrophilic addition, outline the two possible products and explain which one of these products would be the most likely to be formed. The most common mark for this question was five marks mainly due to candidates not being able to explain the formation of the major product in terms of the formation of the more stable tertiary carbocation in the intermediate stage of the mechanism. Candidate scoring five marks frequently quoted Markownikoff's rule as an explanation. Varying degrees of competence was displayed in the production of the mechanism. The correct positioning of curly arrows was a skill that the most candidates had clearly mastered with many accurate mechanisms being submitted. Weaker candidates clearly need more time to develop these skills.
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15			Propagation step 1 $\text{NO}\cdot + \text{O}_3 \rightarrow \text{NO}_2\cdot + \text{O}_2 \checkmark$	1	ALLOW one mark for both correct symbol equations with (any or all) dots missing or extra dots
			Propagation step 2 $\text{NO}_2\cdot + \text{O} \rightarrow \text{NO}\cdot + \text{O}_2 \checkmark$	1	e.g. $\text{NO} + \text{O}_3 \rightarrow \text{NO}_2\cdot + \text{O}_2$ $\text{NO}_2 + \text{O} \rightarrow \text{NO} + \text{O}_2\cdot$ Examiner's Comments Many incorrect equations or correct symbol equations containing incorrect radicals were observed. A large proportion of candidates scored no marks on this question although the most able often provided both equations to gain two marks.
			Total	2	
16			B	1	Examiner's Comments Generally scored well.
			Total	1	
17			C	1	Examiner's Comments Generally scored well.
			Total	1	
18			D	1	Examiner's Comments Generally scored well.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19	a	i	Alkene AND C_nH_{2n} ✓	1	IGNORE branched before alkene <u>Examiner's Comments</u> This part was answered very well. Most candidates identified Compound B as a member of the alkenes and showed the correct general formula of C_nH_{2n}.
		ii	Hydrogen/ H_2 AND Ni (catalyst) ✓	1	ALLOW Pt OR Pd OR Rh ALLOW hydrogenation for hydrogen IGNORE any temperature and pressure stated <u>Examiner's Comments</u> A surprisingly large number of candidates answered this part poorly. Many candidates identified either hydrogen or nickel, but not both. Other common errors included steam and H_3PO_4. This was an easy question and the incorrect answers reflected that many candidates had not learnt organic reagents and conditions for the reactions in the specification.
	b	i	C_2H_5O ✓	1	ALLOW elements in any order DO NOT ALLOW any other answer <u>Examiner's Comments</u> This part was answered well by most candidates. Some candidates however wrote the molecular rather than the empirical formula, or attempted to show the empirical formula as C_2H_4OH instead of C_2H_5O.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Compound E: <pre> H CH₃ Br — C — C — Br H CH₃ ✓ </pre> Stage 1: Compound E: Bromine/Br₂ ✓ Stage 2: NaOH/KOH OR OH⁻ ✓ <i>Only award if intermediate contains at least one halogen atom</i>	3	For structures: ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above ALLOW dichloro/diiodo compound IGNORE connectivity of bonds to CH₃ ALLOW chlorine/Cl₂ OR iodine/I₂ IGNORE conditions, e.g. u.v. DO NOT ALLOW H₂O IGNORE conditions NOTE: Max of 2 marks available for monobrominated intermediate 1 mark Reagent: HBr AND Intermediate: CH₃C(CH₃)₂Br OR BrCH₂CH(CH₃)₂ 1 mark Intermediate: CH₃C(CH₃)₂Br OR BrCH₂CH(CH₃)₂ AND Reagent: NaOH <u>Examiner's Comments</u> This demanding part was answered poorly by weaker candidates and was good for differentiating higher ability candidates. The mark scheme allowed some credit for using a hydrogen halide to obtain a monosubstituted haloalkane for compound E. Surprisingly, reaction mechanism names were often given instead of reagents. Many candidates seemed to guess, sometimes showing the same reagents for both stages in the hope of getting a mark. Many showed an intermediate containing no halogen atom.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20			(series of compounds with the) same functional group OR same / similar chemical properties / reactions ✓ each successive / subsequent member differs by CH₂ ✓	2	IGNORE reference to physical properties IGNORE same general formula Differs by CH₂ is not sufficient (<i>no successive</i>) DO NOT ALLOW same empirical OR molecular formula Examiner's Comments Many candidates were able to score both marks by specifying that compounds from a homologous series possess the same functional group and that each successive member varies by a CH₂ group. Some responses were imprecise and referred to just members differing by a CH₂ group, but this was less common compared to previous sessions.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
21	a		C_nH_{2n+2} ✓	1	Examiner's Comments Almost all candidates were able to state the general formula of an alkane correctly.
	b		structure of a branched saturated hydrocarbon with 8 C atoms ✓ structure of a cyclic saturated hydrocarbon with 8 C atoms ✓ Correct name for BOTH structures given ✓	3	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above DO NOT ALLOW names for hydrocarbons that do not have 8 C atoms Examiner's Comments The majority of candidates were able to provide appropriate structures to represent a branched and cyclic alkane. Perhaps unsurprisingly, the most common responses were 2- or 3-methylheptane and cyclooctane. However, a wide range of responses was seen. In general candidates demonstrated a clear understanding of organic nomenclature and provided appropriate names for their chosen compounds. In some cases incorrect locant numbers were used. For example 2,3-dimethylcyclohexane rather than 1,2-dimethylcyclohexane.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
22	a		Empirical / molecular formula 3 marks Mole ratio C : H : Br is 2.44 : 5.70 : 0.814 ✓ (Empirical formula) = C₃H₇Br ✓ QWC (Molecular formula) = C₃H₇Br AND relative mass linked to 150 evidence ✓ Structural isomers 2 marks CH₃CH₂CH₂Br ✓ CH₃CHBrCH₃ ✓	5	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW $\frac{29.29}{12.0} : \frac{5.70}{1.0} : \frac{65.01}{79.9}$ Evidence could include a calculation of the relative mass of C₃H₇Br as 122.9 linking to M_r being less than 150 ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) DO NOT ALLOW missing H atom(s) in a displayed formula for one structure but ALLOW missing H atoms in subsequent structure Note: structures from an incorrect molecular formula will be credited on their merits. Please consult TL for advice on how to mark the subsequent parts of this question Examiner's Comments Calculation of empirical formula has always been a strength of candidates at this level. Consequently the vast majority were able to deduce the structures of the two isomers correctly. A significant number of candidates failed to secure full marks as they did not link the M_r of the empirical formula with the information about the M_r of the isomers being less than 150. Some candidates tried to use the value of 150 to determine the formula of C and D, ultimately ending up with an incorrect answer. However, error carried forward marks were allowed through subsequent parts of this question where appropriate.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	<i>Infrared for G 2 marks</i> 1700 cm⁻¹ AND C=O/carbonyl group ✓ (broad) 2300–3600 cm⁻¹ AND O–H in carboxylic acid ✓ <i>Structures 3 marks</i> CH₃CH₂CH₂OH ✓ CH₃CHOHCH₃ ✓ CH₃CH₂COOH ✓	6	ANNOTATE ANSWER WITH TICKS AND CROSSES LOOK ON THE SPECTRUM for labelled peaks which can be given credit ALLOW ranges from <i>Data Sheet</i>: C=O within range 1640–1750 cm⁻¹; (broad) O–H within range 2500–3300 cm⁻¹ ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) ALLOW CH₃CH₂CO₂H for carboxylic acid IGNORE names IGNORE labels DO NOT ALLOW missing H atom(s) in a displayed formula for one structure but ALLOW missing H atoms in subsequent structures

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		i	<i>Equation for formation of G 1 mark</i> $\text{C}_3\text{H}_8\text{O} + 2[\text{O}] \rightarrow \text{C}_3\text{H}_6\text{O}_2 + \text{H}_2\text{O} \checkmark$		ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above in equation Examiner's Comments Candidates were well prepared for a structural determination question and examiners were encouraged by the number of high quality of responses to this question. Most candidates were able to interpret the key peaks in the IR spectrum and identified the O-H bond of a carboxylic acid and C=O bond accurately. Most candidates identified all three structures correctly. Only the strongest responses included a correct equation for the formation of G by oxidation of E. Many responses failed to include this and others often had H_2 as the inorganic product. Candidates are advised to revise oxidation reactions of alcohols thoroughly as it is often the case that incorrect equations are frequently seen in responses to exam questions.
		ii	2 marks for correct ester. $\text{CH}_3\text{CH}_2\text{COOCH}(\text{CH}_3)_2 \checkmark\checkmark$ Award 1 mark for: $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3$ OR Ambiguous ester: $\text{CH}_3\text{CH}_2\text{COOC}_3\text{H}_7 \checkmark$	2	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) ALLOW $\text{C}_2\text{H}_5\text{CO}_2\text{CH}(\text{CH}_3)_2$ IF there is one bond and its H missing from the correct ester award 1 mark Examiner's Comments Most candidates were able to show the structure of the ester formed from propanoic acid (G) and propan-2-ol (F) correctly. Some candidates used the incorrect alcohol, propan-1-ol (E) and such responses received only one of the two marks available.

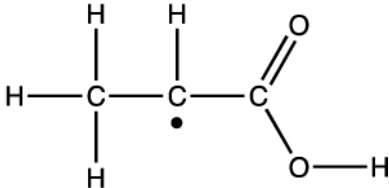
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	13	
23			A	1	Examiner's Comments Able candidates who approached this question correctly (based on priority) obtained the correct answer. Some candidates seemed to look for the same group (CH ₃) on the same side (<i>cis</i>), and incorrectly identified the compound as answer option B, the Z isomer.
			Total	1	
24			C	1	Examiner's Comments Most successful candidates showed rough working at the side with the formula displayed.
			Total	1	
25			B	1	Examiner's Comments Most candidates correctly identified the correct number of isomers. However, about a third of candidates gave the incorrect answer C, perhaps trying to use an ethyl branch.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
26	a		$C_nH_{2n}O_2$ OR $C_nH_{2n+1}COOH$ ✓	1	Examiner's Comment: The correct response; $C_nH_{2n}O_2$ or $C_nH_{2n+1}COOH$, was presented by a good proportion of candidates but many incorrect alternatives were seen.
	b	i	Ultraviolet (radiation)/UV ✓	1	ALLOW sunlight IGNORE temperature Examiner's Comments Most candidates scored this mark.
		ii	$CH_3CH_2COOH + Cl_2 \rightarrow CH_3CHClCOOH + HCl$ ✓	1	ALLOW $C_2H_5COOH + Cl_2 \rightarrow C_2H_4ClCOOH + HCl$ ALLOW $C_3H_6O_2 + Cl_2 \rightarrow C_3H_5ClO_2 + HCl$ Examiner's Comments Many candidates could write the overall equation but there was some confusion with propagation steps and some equations contained radicals or missed out HCl as a product.
		iii	one electron from the bond (pair) goes to each atom / chlorine/radical ✓	1	ALLOW the breaking of a covalent bond where each atom keeps one of the bonding electrons IGNORE particle for atom ALLOW one electron from the bond goes to each product / species DO NOT ALLOW molecule or compound for atom IGNORE homolytic fission equations Examiner's Comments Homolytic fission is described in the specification in terms of each bonding atom receiving one electron from the bonded pair forming two radicals. A large proportion of candidates failed to match the essential points in this definition.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	<i>Propagation step 1</i> $\text{Cl}\cdot + \text{CH}_3\text{CH}_2\text{COOH} \rightarrow \text{CH}_3\text{CHCOOH}\cdot + \text{HCl}$ ✓ <i>Propagation step 2</i> $\text{CH}_3\text{CHCOOH}\cdot + \text{Cl}_2 \rightarrow \text{CH}_3\text{CHClCOOH} + \text{Cl}\cdot$ ✓	2	ALLOW 1. $\text{Cl}\cdot + \text{C}_3\text{H}_6\text{O}_2 \rightarrow \text{C}_3\text{H}_5\text{O}_2\cdot + \text{HCl}$ 2. $\text{C}_3\text{H}_5\text{O}_2\cdot + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_5\text{ClO}_2 + \text{Cl}\cdot$ ALLOW dot at any position on the radical ALLOW 1 mark if both equations correct but any dots omitted from radicals Examiner's Comments Generally well answered. Candidates took note of the instruction in the question and it was very rare to see radicals without their unpaired electron.
		v	✓ 	1	Dot shown in correct position ALLOW –OH Examiner's Comments Unfortunately, candidates who were not able to attempt equations for the propagation steps in part (iv) were then unable to suggest the structure of the radical formed in the first step. Many candidates did not present a fully displayed formula. However, formulae showing –OH were given credit in this question.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		vi	Any structure with two or more Cl atoms on alkyl chain (provided that one Cl is at C-2) e.g. ✓	1	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above DO NOT ALLOW C₃H₄Cl₂O₂ ALLOW further substitution into any or all of the 4 positions occupied by H atoms in the alkyl group, provided that at least one Cl is at C-2 Examiner's Comment: Generally well answered but it was clear from some of the structures drawn that some candidates did not understand what is meant by further substitution.
			Total	8	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
27	FIRST check the molar mass on answer line MUST be derived from $pV = nRT$, Award 4 marks for calculation for: - answer = 70 - OR answer that rounds to 69.9 OR 70.0 Rearranging ideal gas equation to make n subject $n = \frac{pV}{RT} \checkmark$ Substituting all values including conversion to Pa and m^3 $n = \frac{(101 \times 10^3) \times (82.5 \times 10^{-6})}{8.314 \times 373} \checkmark$ $n = 2.68693073 \times 10^{-3} \rightarrow 2.69 \times 10^{-3} \text{ (mol)} \checkmark$ unrounded rounded to 3 SF Calculation of molar mass, M $M = \frac{m}{n} = \frac{0.1881}{2.68693073 \times 10^{-3}} = 70(.0) \text{ (g mol}^{-1}\text{)}$ $\rightarrow \frac{0.1881}{2.69 \times 10^{-3}} = 69.9 \text{ (g mol}^{-1}\text{)} \checkmark$ Molecular formula of D $C_5H_{10} \checkmark$ IF candidate has failed to derive suitable value of n, ALLOW value of M from 0.1881 AND 24000 with alkene closest to calculated value for last 2 marks See Guidance column.	5	FULL ANNOTATIONS MUST BE USED If there is an alternative answer, check to see if there is any ECF credit possible using working below 1st mark may be implicit by direct substitution of correct values below into rearranged equation. ONLY award this mark if n has been derived from correct rearranged ideal gas equation ALLOW 3 SF up to calculator value, correctly rounded NOTE: ALLOW 69.9 $\rightarrow$ 70.0 AND 70 (2 SF) Calculator from unrounded: 70.00552634 ALLOW any unambiguous structure ALLOW ECF provided that formula given is an alkene and matches M calculated from 0.1881 AND $pV = nRT$ $M = \frac{0.1881}{82.5/24000} \text{ OR } \frac{0.1881}{3.4375 \times 10^{-3}}$ $= 54.72 \text{ OR } 54.7 \text{ OR } 55 \checkmark$ ALLOW 54.68 from use of 3.44×10^{-3} From 54.72, ONLY ALLOW = $C_4H_8 \checkmark$ Examiner's Comments Most candidates realised the need to use the ideal gas equation. The equation was usually rearranged correctly, with substituted values for p, V, R and T being added. Pressure and volume were not always converted correctly into Pa and m^3, creating problems for subsequent parts. Many candidates attempted to convert

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					from cm^3 to m^3 by multiplying by 10^{-3} rather than 10^{-6}. Candidates usually obtained a value for n, although those who had struggled with unit conversion obtained values that differed by powers of 10. Finally, candidates needed to derive the molar mass using their value of n and the mass of the alkene. Some candidates over-rounded their value of n, introducing an error in calculating the molar mass. Surprisingly, an appreciable number of candidates wrote their value of n on the answer line rather than the molar mass indicated by the answer prompt. This suggested that some candidates do not understand the term molar mass. Candidates who had obtained a molar mass of 70.0 usually determined that the alkene had the formula C_5H_{10}. Answer: 70.0 g mol^{-1}
			Total	5	

Mark Scheme

Question			Answer/Indicative content				Marks	Guidance									
28	a	i	<table><tr><td>Final reading/ cm³</td><td>27.30</td><td>27.00</td><td>27.75</td></tr><tr><td>Initial reading/ cm³</td><td>0.45</td><td>0.60</td><td>1.25</td></tr><tr><td>Titre/cm³</td><td>26.85</td><td>26.40</td><td>26.50</td></tr></table> <i>Initial and final readings</i> All burette readings (×6) correct ✓ <i>Titres</i> recorded to two decimal places with the last figure either 0 or 5 Correct subtractions to obtain final titre values ✓ <i>Mean titre calculated from concordant results</i> Correct mean titre = 26.45 (cm³) ✓ Mean titre recorded to accuracy of burette Final answer recorded to two decimal places with the last figure either 0 or 5 ✓	Final reading/ cm ³	27.30	27.00	27.75	Initial reading/ cm ³	0.45	0.60	1.25	Titre/cm ³	26.85	26.40	26.50	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC ALLOW missing zeroes for burette readings i.e. 0.6 for 0.60 27 OR 27.0 for 27.00 ALLOW ECF from incorrect burette readings IF MEAN IS CALCULATED FROM ECF, IT MUST BE FROM CLOSEST TITRES ALLOW ecf from incorrect mean DO NOT ALLOW 26.5 cm³ <i>Question asks for nearest 0.05 cm³</i> <u>Examiner's Comments</u> Most candidates were able to accurately record the burette readings and made the correct subtractions. Despite the examination question requesting the mean titre to be recorded to the accuracy of the burette, many candidates did not do this. A common error was taking a mean of all three readings instead of only the concordant results; this led the candidates to give an answer of 26.58 which lost them 2 marks.
Final reading/ cm ³	27.30	27.00	27.75														
Initial reading/ cm ³	0.45	0.60	1.25														
Titre/cm ³	26.85	26.40	26.50														
		ii	$\frac{2 \times 0.05}{26.85} \times 100 = 0.37(2) (\%) \checkmark$	1	ALLOW 0.4 up to full calculation display of 0.372439478 ALLOW ECF FOR CORRECT CALCULATION FROM 1 (c) (i) OR USE OF ANY TITRE <u>Examiner's Comments</u> A good attempt by many candidates but some did not know how to calculate this or did not multiply by 2.												

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Use a (250 cm ³) volumetric flask (instead of a beaker)✓	1	IGNORE graduated flask <u>Examiner's Comments</u> Although there were some excellent descriptions of the correct processes, such as inverting the apparatus to ensure mixing and then making the solution up to the mark, many candidates could not name a volumetric flask.
	b	i	FIRST CHECK ANSWER ON ANSWER LINE If answer = 118 (g mol⁻¹) award 4 marks If answer = 108 (g mol⁻¹) award 3 marks $n(\text{NaOH})$ $= 0.112 \times \frac{25.0}{1000} = 0.00280 \text{ (mol)} \checkmark$ $n(\text{A})$ in 25.0 cm³ $= \frac{0.00280}{2} = 0.00140 \text{ (mol)} \checkmark$ $n(\text{A})$ in 250 cm³ $= 0.00140 \times \frac{250.0}{27.30} = 0.0128 \text{ (mol)} \checkmark$ Molar mass, $M(\text{A})$ to nearest whole number. $= \frac{1.513}{0.0128} = 118 \text{ (g mol}^{-1}\text{)} \checkmark$	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC Throughout: IGNORE trailing zeroes in intermediate working, e.g. For $n(\text{NaOH})$ ALLOW 0.0028 for 0.00280 ALLOW ECF from incorrect $n(\text{NaOH})$ ALLOW ECF from incorrect $n(\text{A})$ OR $n(\text{NaOH})$ ALLOW 3 sig fig up to full calculator display correctly rounded (0.012820512) ALLOW ECF from incorrect $n(\text{NaOH})$ Possible ECFs for 3 marks $1.513 \div (0.00140 \times 250/25) = 108$ $1.513 \div 0.00140 = 1081$ No $\div 2$ for $n(\text{A})$ - Molar mass A = 59 (g mol⁻¹) Using mean titre of 26.45 cm³ from 1c(i) - Molar mass A = 114 (g mol⁻¹) Using 27.3×0.112 in M1 and then 25.0 in M3 - Molar mass A = 99 (g mol⁻¹) <u>Examiner's Comments</u> Although there were some excellent descriptions of the correct processes, such as inverting the apparatus to ensure mixing and then making the solution up to the mark, many candidates could not name a volumetric flask.

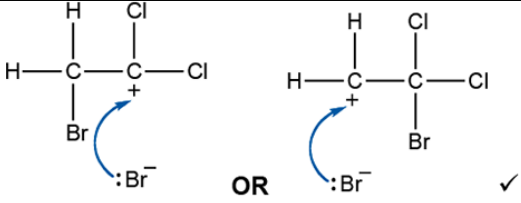
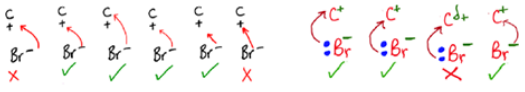
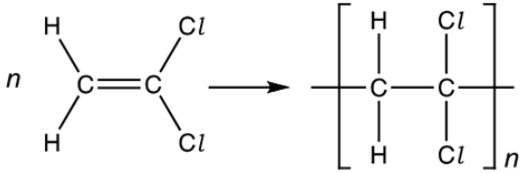
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Structure of dicarboxylic acid $\text{HOOCCH}_2\text{CH}_2\text{COOH}$ OR $\text{HOOCCH}(\text{CH}_3)\text{COOH}$ ✓ STRUCTURE MUST MATCH M_r from answer to 1 d) i) (within 10 AMU)	1	ALLOW correct structural OR skeletal OR displayed formulae OR a combination ALLOW incorrect connectivity e.g. -HO ALLOW ECF from incorrect molar mass in (d)(i) but only if $2 \times \text{COOH}$ possible and M_r is a close match to (d) (i) within 10 AMU <u>Examiner's Comments</u> Most candidates that obtained a sensible value for the previous question managed to draw a creditable structure. Allowing error carried forward meant that feasibly derived structures could be credited a mark.
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
29	a		steam AND Acid/H ⁺ (catalyst) ✓	1	Examiner's Comments Many candidates knew the answer to this question but forgot that water must be in the gaseous state. There were numerous responses stating nickel as the catalyst, but most knew that an acid catalyst was required.
	b	i	1,2-dibromo-1,1-dichloroethane✓	1	Examiner's Comments This question was generally well answered, although some candidates made careless mistakes such as not writing -di or writing 1,2-dibromo-1-dichloroethane
		ii	1st curly arrow (from ANY alkene) Curly arrow from double bond to Br of Br-Br ✓ DO NOT ALLOW partial charge on C=C 2nd curly arrow Correct dipole on Br Br AND curly arrow for breaking of Br-Br bond ✓ 3rd curly arrow Correct carbocation with + charge on C with 3 bonds AND curly arrow from Br⁻ to C⁺ of carbocation ✓ DO NOT ALLOW δ^+ on C of carbocation	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples): 1st curly arrow must • go to a Br atom of Br-Br • AND • start from, OR be traced back to any point across width of C=C 2nd curly arrow must • start from, OR be traced back to, any part of $\delta^+ \text{Br} - \delta^-$ bond • AND go to δ^- 3rd curly arrow must • go to the C⁺ of carbocation • AND • start from, OR be traced back to any point across width of lone pair on :Br⁻

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	 <i>i.e. ALLOW carbonium + on either C atom</i> DO NOT ALLOW half headed or double headed arrows but allow ECF if seen more than once		OR start from – charge on Br[–] ion  (Lone pair NOT needed if curly arrow shown from – charge on Br[–]) <u>Examiner's Comments</u> Many candidates gained all three marks on this question and the diagrams were clear and easy to read. Lower ability candidates had incorrect dipoles or curly arrows that could not be traced back to the correct origin. Candidates should be encouraged to consider what the arrows mean rather than memorising mechanisms with no understanding.
c i	 Correct polymer with side links and brackets ✓ Equation balanced with <i>n</i> ✓ TAKE CARE of '<i>n</i>' position on both sides of equation.	2	For repeat unit, - displayed formula required 'side bonds' required on either side of repeat unit from C atoms ALLOW section containing more than one repeat unit DO NOT ALLOW ECF from incorrect repeat unit <i>n</i> on LHS at any height to the left of the formula <i>n</i> on RHS must be subscript <u>Examiner's Comments</u> Most candidates correctly drew the repeat unit and were credited with one mark, but many placed the <i>n</i> position in the wrong place on the left-hand side of the equation or forgot to write it in at all.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Advantage (1 mark) Energy production / (energy) used to produce electricity ✓ Disadvantage (1 mark) Formation of HCl/products of combustion cause acid rain OR Formation of CO₂/gases that cause global warming / greenhouse gases OR Formation of CO ✓	2	ALLOW reduced use of fossil fuels ALLOW less landfill / less harm to wildlife ALLOW chlorine/Cl OR Cl₂ ALLOW toxic/poisonous waste products <u>Examiner's Comments</u> With all the media interest in plastic pollution this question was answered well, although many gave the answer 'quick and efficient' as an advantage which was not credited. Candidates should beware of vague statements such as these. Many wrote 'harmful' instead of toxic, or 'bad for the environment' instead of being specific about the environmental issue.
			Total	9	
30			C	1	ALLOW 3 <u>Examiner's Comments</u> The responses showed a reasonably even split across all options with relatively few correct responses of C. A good route to success here is to draw out the possibilities.
			Total	1	
31			A	1	<u>Examiner's Comments</u> Many candidates added H atoms to the structure to aid their choice. Most candidates selected the correct response of A, with a sizeable number selecting B (by adding two H atoms where the two rings join).
			Total	1	

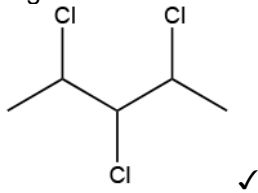
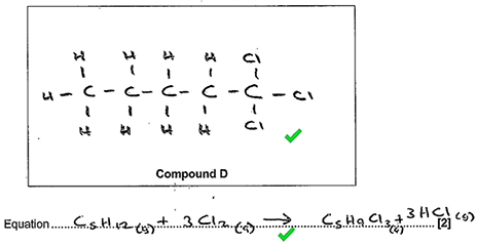
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
32	a	Structural isomers: 1 mark Different structural formulae AND same molecular formula ✓ Common molecular formula: 1 mark C_5H_{12} for all 3 hydrocarbons ✓ Boiling point and branching: 1 mark Boiling point decreases with more branching OR more methyl/alkyl groups/side chains OR shorter carbon chain ✓ Branching and London forces: 1 mark <i>Could be seen anywhere within response</i> More branching gives less (surface) contact AND fewer/weaker London forces ✓ Energy and intermolecular forces: 1 mark Less energy to break London forces/intermolecular forces/intermolecular bonds/ ✓	5	For 'structural': ALLOW different structure OR different displayed/ skeletal formula DO NOT ALLOW any reference to spatial/space/3D Same formula is not sufficient (no 'molecular') Different arrangement of atoms is not sufficient (no 'structure'/'structural') ALLOW 5 carbons and 12 hydrogens ALLOW for 2 marks: Different structural formulae AND same molecular formula ✓ of C_5H_{12} ✓ Comparisons needed throughout ORA throughout ALLOW comparison between any alcohols, e.g. A is least branched and has highest b pt C is most branched and has lowest b pt ALLOW induced dipole(–dipole) interactions IGNORE van der Waals'/vdw forces ALLOW SA for surface area ALLOW 'harder to overcome' intermolecular forces ALLOW more energy to separate the molecules IGNORE just 'bonds' <i>intermolecular/London forces required</i> Examiner's Comments This question discriminated well and resulted in a full range of marks. Most candidates were aware that structural isomers have different structural formulae

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance				
					but the same molecular formulae. It was common though for candidates to refer to different arrangements of atoms in space, clearly confusing with stereoisomerism. The best candidates used the structures (as in the question) to show that the common molecular formula was C5H12. Candidates were expected to link the amount of surface contact between molecules with induced dipole–dipole forces or London forces. ‘Contact’ or the name of the intermolecular forces was often omitted. Finally, candidates were expected to link the amount of branching to the strength of the intermolecular forces and the energy needed to change state. Lower ability candidates often let themselves down by being unable to construct a well-reasoned response. There was often a gulf between the clear responses of able candidates and those of lower ability candidates.				
	b	i	Radical substitution ✓	1	ALLOW Free radical substitution <u>Examiner’s Comments</u> Most candidates identified this reaction as radical substitution.				
		ii	<table><tr><td>A</td><td>B</td></tr><tr><td>3 ✓</td><td>2 ✓</td></tr></table>	A	B	3 ✓	2 ✓	2	<u>Examiner’s Comments</u> Most candidates achieved at least one mark, particularly for isomer A. Successful candidates often drew structures of the isomers alongside the table to help with their response.
A	B								
3 ✓	2 ✓								

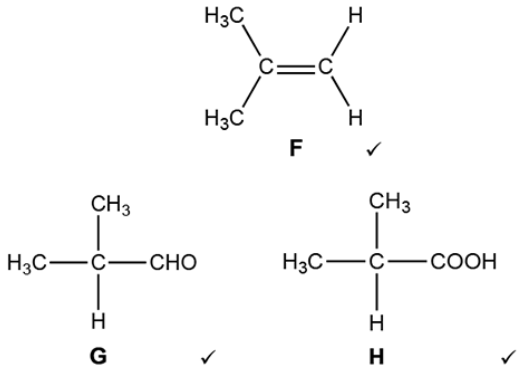
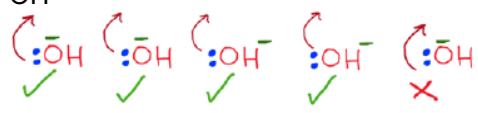
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
iii	Structure of D Structure of a trichloro isomer of A, e.g.  ALLOW any trichloro isomer of A CHECK carefully Equation $C_5H_{12} + 3Cl_2 \rightarrow C_5H_9Cl_3 + 3HCl$ ✓ Molecular formulae required NO ECF from incorrect structure of D	2	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) IGNORE molecular formula ALLOW multiples, e.g. $2C_5H_{12} + 6Cl_2 \rightarrow 2C_5H_9Cl_3 + 6HCl$ Examiner's Comments Many candidates correctly drew the structure of compound D but comparatively few were able to construct a correct equation. For this equation, candidates needed to apply their knowledge and understanding of monosubstitution of alkanes to substitution of three H atoms by three Cl atoms. This task proved to be one of the most difficult questions on this paper. The exemplar shows an excellent response. The candidate has drawn a trisubstituted structure that fits the molar mass of 175.5 g mol^{-1} and a correct equation for its formation. Many attempts at this equation showed H_2 as the second product rather than HCl. Exemplar 6 (iii) The reaction of compound A with excess chlorine forms a compound D, which has a molar mass of 175.5 g mol^{-1}. Draw a possible structure for compound D and write the equation for its formation from compound A. Use molecular formulae in the equation. 

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	10	

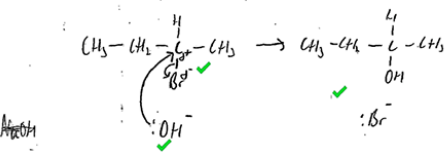
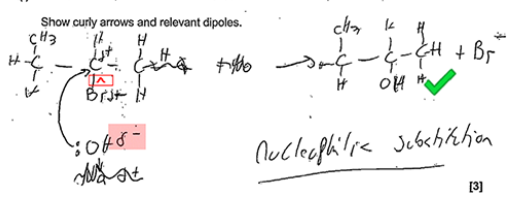
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33	a	i	 F ✓ G ✓ H ✓	3	ALLOW correct structural OR displayed OR skeletal formulae OR mixture of the above (as long as unambiguous) IGNORE molecular formula ALLOW CH₃– ALLOW 1 mark for G AND H combined if structures are correct but in wrong boxes <u>Examiner's Comments</u> Part (i) discriminated extremely well and rewarded the well-prepared candidate. Compound F proved to be the most difficult option, with a large variety of responses, many appearing to be guesses. Candidates were much more successful with compounds G and H, although these were sometimes shown in reverse order. A significant number of candidates drew structures containing C=C or C=O bonds in which the carbon atom had five bonds. Candidates should check drawing of organic structures carefully to ensure that all carbon atoms have four bonds. There were some good responses for part (ii), with many clearly shown and correct systematic names.
		ii	2-methylpropan-1-ol ✓ <i>Both numbers required</i>	1	IGNORE absence of hyphen or use of dots or commas as separators DO NOT ALLOW 2-methylprop-1-ol OR 2-methpropan-1-ol OR 2-methypropan-1-ol
	b	i	ANNOTATE ANSWER WITH TICKS AND CROSSES ----- Curly arrows 2 marks curly arrow from OH[–] to C atom of C–Br bond ✓ dipole shown on C–Br bond, C^{δ+} and Br^{δ–}, AND curly arrow from C–Br bond to Br atom	3	1st curly arrow must - go to the C of C–Br AND - start from, OR be traced back to any point across width of lone pair on O of OH[–] 

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	IGNORE incorrect R groups for curly arrow marks IGNORE presence of Na⁺/Na but OH⁻ needed i.e. Na⁺OH⁻; NaOH⁻ can be allowed with correct use of curly arrow Products 1 mark correct organic product AND Br⁻ ✓ IGNORE presence of Na⁺ but Br⁻ needed i.e. Na⁺Br⁻/NaBr⁻ can be allowed BUT NaBr does NOT show Br⁻ NOTE: curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows		OR start from – charge on O of OH⁻ ion (Lone pair NOT needed if curly arrow shown from O⁻) 2nd curly arrow must start from, OR be traced back to, any part of C–Br bond and go to Br ALLOW S_N1 mechanism for 2 curly arrow marks First mark Dipole shown on C–Br bond, C^{δ+} and Br^{δ-}, AND curly arrow from C–Br bond to Br atom Second mark Curly arrow from OH⁻ AND to correct carbocation Use curly arrow criteria in guidance above Examiner's Comments As with 25(a)(i), this question rewarded the well-prepared candidate. The large number of proposed mechanisms showed little resemblance to the accepted mechanism for nucleophilic substitution. Mechanisms were often seen showing curly arrows going in the wrong direction and between the wrong bonds and atoms, charges and dipoles were often incorrect, and partial charges used where full charges were required. Two exemplars are shown. The first

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			exemplar shows clear curly arrows, the role of the lone pair and all charges correct. The second exemplar shows a typical muddled response. Although the curly arrow from the hydroxide ion has been accurately drawn, the hydroxide ion has a partial charge rather than a - charge. There is also no curly arrow showing breaking of the C–Br bond. The only mark available is for the correct organic product and a Br⁻ ion. Some mechanisms were so poor that it was impossible to credit many candidates with any marks. Writing mechanisms is an important skill in organic chemistry and it is recommended that candidates learn and practice their writing. Exemplar 7 (b) An alcohol can be prepared by hydrolysing the haloalkane C₂H₅CHBrCH₃ with aqueous sodium hydroxide. (i) Outline the mechanism for this reaction. Show curly arrows and relevant dipoles.  [3] Exemplar 8 (b) An alcohol can be prepared by hydrolysing the haloalkane C₂H₅CHBrCH₃ with aqueous sodium hydroxide. (i) Outline the mechanism for this reaction. Show curly arrows and relevant dipoles.  [3]

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Disappearance of peak at 500-800 cm^{-1} OR C–Br peak ✓ Appearance of peak at 3200-3600 cm^{-1} OR alcohol O–H peak	2	ALLOW value within range 500–800 cm^{-1} ALLOW value within range 3200–3600 cm^{-1} DO NOT ALLOW responses that only describe the spectrum shown <u>Examiner's Comments</u> This part discriminated very well with able candidates identifying that the absorption for the C–Br bond would disappear, with a new peak appearing for the alcohol O–H bond. A significant number of candidates did not seem to understand what was required, with many interpreting the spectrum as that of the alcohol, rather than predicting how the spectrum would change during the reaction. A common error was to interpret the absorption for a C–H bond at $\sim 3000 \text{ cm}^{-1}$ as that of an O–H bond.
			Total	9	
34			C	1 (AO1.2)	<u>Examiner's Comments</u> Unsaturated, alicyclic and alkyl are all terms that are introduced in AS Chemistry and about two-thirds of candidates recognised that option C met the three criteria. From the annotations on scripts, most candidates ruled out the saturated option B. A sizeable number of candidates selected either the aromatic option A, or structure D which does not possess an alkyl group. It is important that candidates learn the terms introduced in the specification Section 4.1.1, Basic concepts in organic chemistry.
			Total	1	