

1. This question is about the chemistry of compounds containing phosphorus.

When phosphorus(V) chloride, PCl_5 , and ammonium chloride are heated together, the compound $P_3N_3Cl_6$ is formed, together with HCl gas.

$P_3N_3Cl_6$ has a cyclic structure, like the Kekulé structure of benzene.

- i. Write an equation for the reaction of PCl_5 and ammonium chloride to form $P_3N_3Cl_6$.

[1]

- ii. Calculate the percentage by mass of P in $P_3N_3Cl_6$.

Give your answer to **2** decimal places.

percentage by mass of P = % [2]

- iii. Suggest **one** example of evidence that could show that $P_3N_3Cl_6$ has a Kekulé structure rather than a delocalised structure.

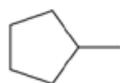
[1]

- iv. In a molecule of $P_3N_3Cl_6$ all the N and Cl atoms are bonded to P atoms. Suggest a possible structure for a molecule of $P_3N_3Cl_6$.

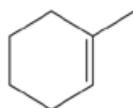
[2]

2. This question is about hydrocarbons.

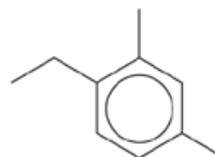
The structures of hydrocarbons **A–E** are shown below.



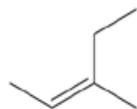
A



B



C



D



E

What is the systematic name of hydrocarbon **C**?

[1]

- ii. Ester **F** can be prepared from a carboxylic acid in two steps.

Step 1 The carboxylic acid is converted into an acyl chloride.

Step 2 The acyl chloride is converted into ester **F**.

Write equations for **Step 1** and **Step 2**.

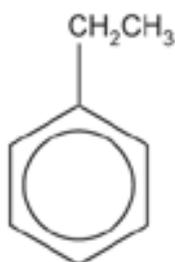
Show organic compounds as structures.

Step 1

Step 2

[4]

5. Ethylbenzene, $C_6H_5CH_2CH_3$, can be prepared by reacting benzene with chloroethane, CH_3CH_2Cl , in the presence of $AlCl_3$. The $AlCl_3$ acts as a halogen carrier.



Ethylbenzene

Ethylbenzene

In the mechanism, chloroethane reacts with the halogen carrier to form a carbocation, which acts as the electrophile.

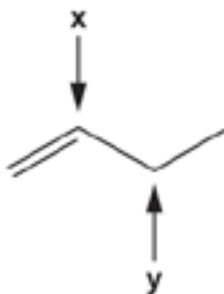
- i. What is meant by the term **electrophile**?

[1]

- ii. Outline the mechanism for this reaction, including the role of $AlCl_3$ as a halogen carrier.

[5]

6. The structure of but-1-ene is shown below.



Which row has the correct **shape** around carbon atoms labelled **x** and **y**?

	x	y
A	Tetrahedral	Pyramidal
B	Trigonal planar	Tetrahedral
C	Trigonal planar	Pyramidal
D	Pyramidal	Tetrahedral

Your answer

[1]

7. The CFC CCl_2F_2 can cause the breakdown of ozone in the upper atmosphere.

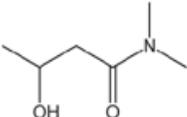
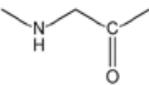
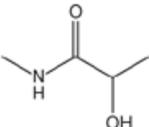
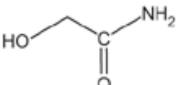
Which initiation step could occur with ultraviolet radiation to catalyse this breakdown?

- A** $\text{CCl}_2\text{F}_2 \rightarrow \cdot\text{C} + \cdot\text{CCl}_2\text{F}_2$
- B** $\text{CCl}_2\text{F}_2 \rightarrow \cdot\text{F} + \cdot\text{CCl}_2\text{F}$
- C** $\text{CCl}_2\text{F}_2 \rightarrow \cdot\text{Cl} + \cdot\text{CClF}_2$
- D** $\text{CCl}_2\text{F}_2 \rightarrow \cdot\text{Cl}_2 + \cdot\text{CF}_2$

Your answer

[1]

8. Which compound is a secondary amide?

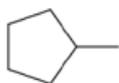
A	
B	
C	
D	

Your answer

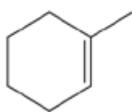
[1]

9(a). This question is about hydrocarbons.

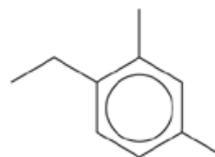
The structures of hydrocarbons **A–E** are shown below.



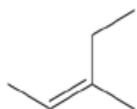
A



B



C



D



E

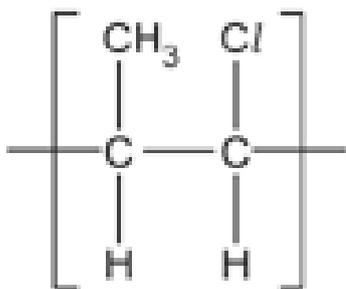
Which hydrocarbons are unsaturated?

..... [1]

(b). Which hydrocarbons are alicyclic?

..... [1]

10. The repeat unit of an addition polymer is shown below.



Which statement about this addition polymer is correct?

- A Combustion produces toxic alkaline fumes.
- B The addition polymer is biodegradable.
- C The monomer is $\text{H}_3\text{CCH}=\text{CHCl}$.
- D The repeat unit above is shown as a displayed formula.

Your answer

[1]

11(a). This question is about hydrocarbons.

The hydrocarbon C_2H_6 reacts with bromine, Br_2 , to form $\text{C}_2\text{H}_5\text{Br}$ under suitable conditions.

Complete the table below to show the mechanism for the three stages of the reaction of C_2H_6 with Br_2 to form $\text{C}_2\text{H}_5\text{Br}$.

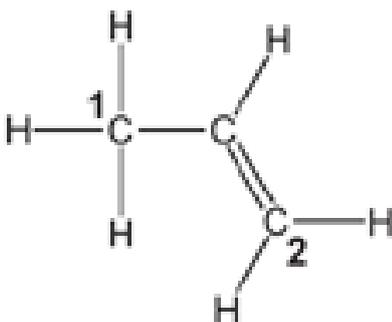
The equation for one of the possible reactions for termination has been completed.

In your equations, use molecular formulae and 'dots' (\cdot) with any radicals.

Initiation	Conditions
	Equation \rightarrow
Propagation	1 \rightarrow
	2 \rightarrow
Termination	1 $\text{Br}\cdot + \text{Br}\cdot \rightarrow \text{Br}_2$
	2 \rightarrow
	3 \rightarrow

[5]

(b). Propene, C_3H_6 , has different bond angles and shapes around the carbon atoms. The displayed formula of a propene molecule is shown below.



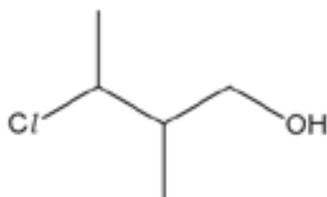
Predict the bond angles and the names of the shapes around the C atoms **1** and **2** above, and explain why the bond angles and shapes are different.

Carbon atom	Bond angle	Name of shape
1		
2		

Explanation:

[5]

12. What is the name of the compound below?



- A 1-chloro-1,2-dimethylpropan-3-ol
- B 2-chloro-3-methylbutan-4-ol
- C 3-chloro-2-methylbutan-1-ol
- D 3-chloro-2,3-dimethylpropan-1-ol

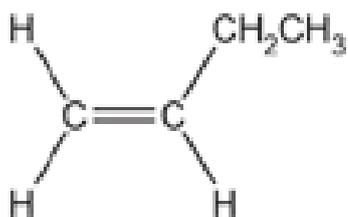
Your answer

[1]

13. HBr reacts readily with alkenes.

- i. Outline the mechanism for the reaction of but-1-ene with HBr to form **2-bromobutane**.

Include curly arrows, relevant dipoles and the structure of the product.



[4]

- ii. During this reaction, a small amount of **1-bromobutane** is also produced.

Explain why **2-bromobutane** is the major product.

[2]

14. The benzenediazonium ion, shown below, is stable at temperatures below 10 °C.



Above 10 °C, the benzenediazonium ion reacts with water to form phenol.

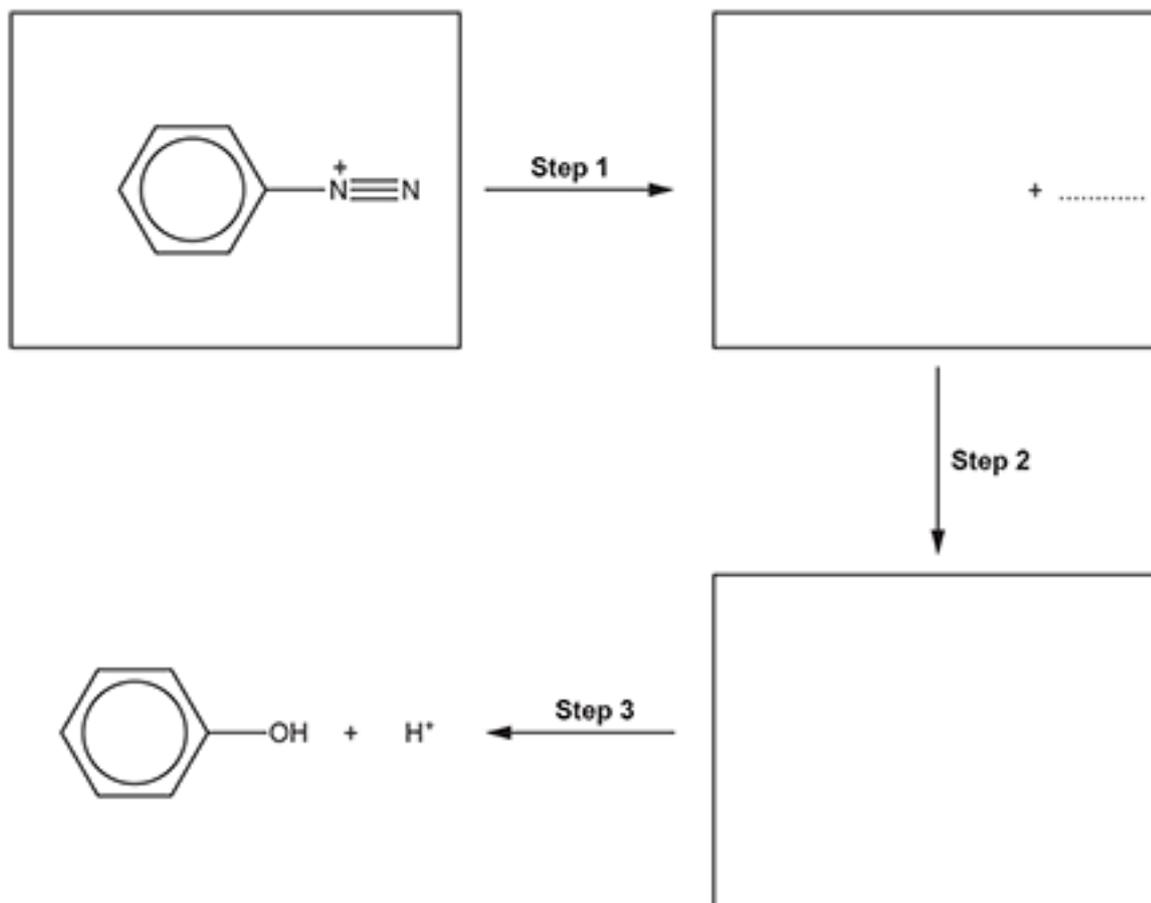
The reaction proceeds in a three-step mechanism.

Step 1 Elimination of nitrogen gas to form a carbocation.

Step 2 Nucleophilic attack by water.

Step 3 Proton loss to form the organic product.

Complete the boxes below with intermediates and curly arrows to show the mechanism for this reaction.



On your diagram:

- Label the enthalpy change of reaction, ΔH .
- Include the formulae of the reactants and products.
- Label the activation energy, E_a .



Fig. 23.1

[2]

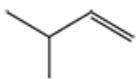
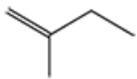
- iii. CO and NO are removed by use of a catalyst.

Explain the role of the catalyst.

Refer to your enthalpy profile diagram in **Fig. 23.1** in your answer.

[2]

18. Which formula does **not** represent 3-methylbut-1-ene?

A	$\text{CH}_3\text{CHCH}_3\text{CH}_2$
B	$\text{CH}_2\text{CHCH}(\text{CH}_3)_2$
C	
D	

Your answer

[1]

19. How many structural isomers have the molecular formula $\text{C}_4\text{H}_9\text{Cl}$?

- A** 2
B 3
C 4
D 5

Your answer

[1]

20. This question is about α -amino acids.

The α -amino acid valine has the R group of $-\text{CH}(\text{CH}_3)_2$.

- i. What is the systematic name of valine?

----- [1]

- ii. Draw diagrams to show 3D structures of the optical isomers of valine.

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[2]

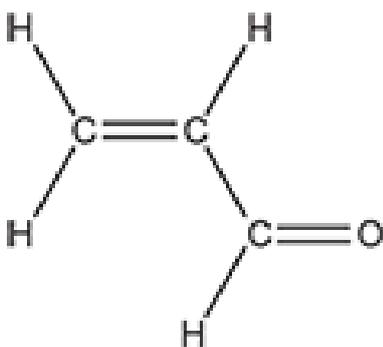
21. This question is about reactions of acrolein, $\text{H}_2\text{C}=\text{CHCHO}$.

Acrolein reacts with sodium cyanide in acidic conditions, $\text{NaCN}(\text{aq}) / \text{H}^+(\text{aq})$.

- i. Outline the reaction mechanism for this reaction, showing the intermediate and the organic product.

The structure of acrolein has been provided.

Include curly arrows and relevant dipoles.



[4]

- ii. Name this type of mechanism.

----- [1]

22. 2-methylpentane reacts with bromine by radical substitution.



2-methylpentane

A mixture of organic products is formed, including 3-bromo-2-methylpentane, and compounds **A** and **B**.

- i. Complete the table below to show the mechanism for the formation of 3-bromo-2-methylpentane and **three** possible equations for termination.

In your equations, use **structural or skeletal formulae** and 'dots' (•) for the position of radicals.

Initiation	Equation: Conditions:
Propagation	→ →
Termination	→ → →

[6]

- ii. Organic compound **A** is formed by the substitution of **all** 14 H atoms in 2-methylpentane by Br atoms.
Write the equation, using **molecular formulae**, for the formation of compound **A** from 2-methylpentane.

[2]

- iii. Organic compound **B** is formed by the substitution of **some** of the 14 H atoms in 2-methylpentane by Br atoms.

0.8649 g of compound **B** is heated until it is vaporised.

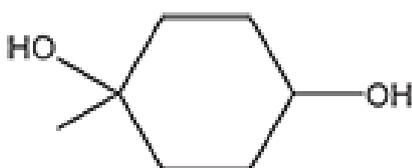
Under the conditions used:

- compound **B** has a volume of 72.0 cm³
- the molar gas volume is 40.0 dm³ mol⁻¹.

Determine a possible molecular formula of compound **B**.

molecular formula = [3]

23. Compound **D**, shown below, is refluxed with H_2SO_4 , as an acid catalyst, to form a mixture of three isomers with the molecular formula C_7H_{10} .



Compound D

i. Draw the structures of the **three** isomers of C_7H_{10} formed from compound **D**.

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[3]

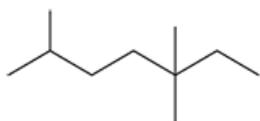
ii. A student converts compound **D** into a diiodoalkane.

Suggest suitable reagents for this reaction.

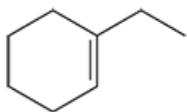
[1]

24. Which compound(s) is/are aliphatic?

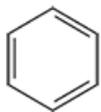
1



2



3



- A 1, 2 and 3
 B Only 1 and 2
 C Only 2 and 3
 D Only 1

Your answer

[1]

25. Propyne, $\text{CH}_3\text{C}\equiv\text{CH}$, is a member of the alkynes homologous series with the $\text{C}\equiv\text{C}$ functional group.

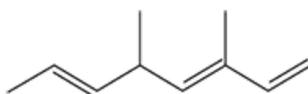
What is the general formula of the alkynes?

- A $\text{C}_n\text{H}_{2n-4}$
 B $\text{C}_n\text{H}_{2n-2}$
 C C_nH_{2n}
 D $\text{C}_n\text{H}_{2n+2}$

Your answer

[1]

26. What is the systematic name for the compound below?



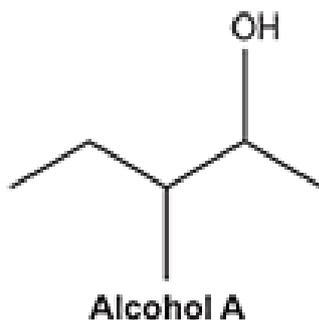
- A 3,5-dimethylocta-1,3,6-triene
 B 3,5-dimethylocta-2,5,7-triene
 C 4,6-dimethylocta-1,3,6-triene
 D 4,6-dimethylocta-2,5,7-triene

Your answer

[1]

27. This question is about alkenes.

A mixture of alkenes is produced when water is eliminated from alcohol **A**.



i. What is the systematic name of alcohol **A**?

[1]

ii. Alcohol **A** is refluxed with an acid catalyst.

- A mixture of alkene isomers **B**, **C** and **D** is formed.
- Alkenes **B** and **C** show *E/Z* isomerism but alkene **D** does not.

Construct the equation for the formation of alkene **D** from alcohol **A**.
Show the structure of the organic product.

[2]

iii. The skeletal formulae of alkenes **B** and **C** are shown below.

	Alkene B	Alkene C
Skeletal formula		
Isomer	<i>Z</i>	<i>E</i>

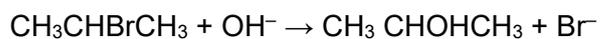
Use the Cahn-Ingold-Prelog priority rules to explain why alkene **B** is the *Z* isomer.

[2]

28. This question is about halogens and halogen compounds.

A student is studying the hydrolysis of haloalkanes.

The equation for the alkaline hydrolysis of 2-bromopropane, $\text{CH}_3\text{CHBrCH}_3$, is shown below.



Use the curly arrow model to outline the mechanism for the alkaline hydrolysis of 2-bromopropane.

Show relevant dipoles and lone pairs, and name the mechanism.

name of mechanism **[3]**

29. Butan-1-ol reacts with sodium bromide and sulfuric acid to form 1-bromobutane by nucleophilic substitution.

The mechanism for this reaction takes place by two steps.

Step 1 The oxygen atom of the alcohol group accepts a proton to form a positively-charged intermediate.

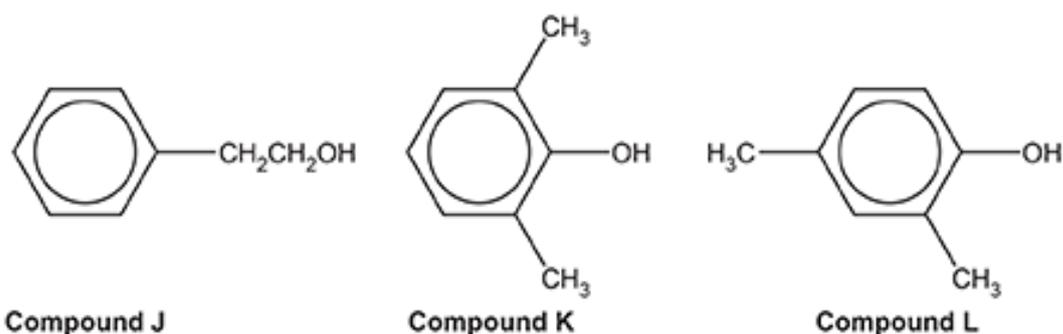
Step 2 Bromide ions react with the intermediate from **Step 1** by nucleophilic substitution to form 1-bromobutane.

Show both steps in this mechanism.

[4]

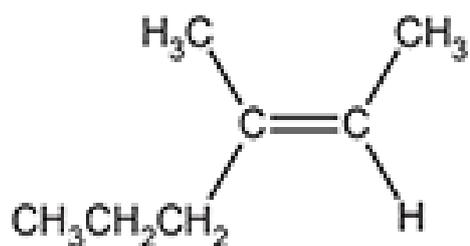
30. This question is about the chemistry of aromatic compounds.

Compounds **J**, **K** and **L**, shown below, are structural isomers.



31(a). This question is about unsaturated hydrocarbons.

The unsaturated hydrocarbon **A**, shown below, is reacted with bromine.



Hydrocarbon A

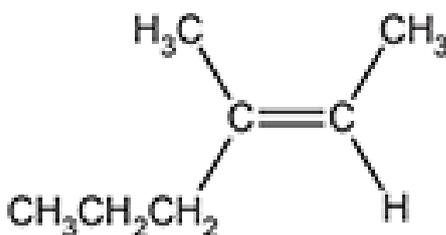
- i. What is the systematic name of hydrocarbon **A**?

[1]

- ii. Outline the mechanism for the reaction of hydrocarbon **A** with bromine.

The structure of hydrocarbon **A** has been provided.

Include curly arrows and relevant dipoles.



[3]

(b). Compounds **B** and **C** are **branched** hydrocarbons that are structural isomers of C_6H_{12} .

Compounds **B** and **C** both have stereoisomers.

- Compound **B** has *cis* and *trans* isomers but does **not** have optical isomers.
- Compound **C** has optical isomers but does **not** have *cis* and *trans* isomers.

i. What is meant by the term **structural isomers**?

[1]

ii. What is meant by the term **stereoisomers**?

[1]

iii. Draw structures for the *cis* and *trans* isomers of the branched hydrocarbon **B**.

<i>cis</i> isomer	<i>trans</i> isomer

[2]

iv. Draw 3D structures for the optical isomers of compound **C**.

Optical isomers	

[2]

- v. Compounds **D** and **E** are two more structural isomers of C_6H_{12} .

Compounds **D** and **E** do **not** show stereoisomerism.

Table 16.1 shows NMR and infrared (IR) spectral data for **D** and **E**.

	Number of peaks in 1H NMR spectrum	Number of peaks in ^{13}C NMR spectrum	IR peak at $1620-1680\text{ cm}^{-1}$
D	1	1	No
E	1	2	Yes

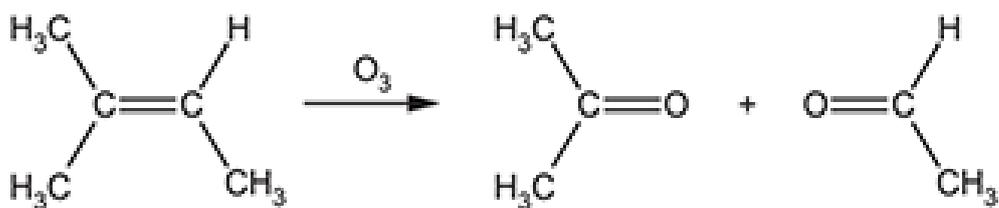
Table 16.1

Draw the structures of **D** and **E** and explain how the spectral data in **Table 16.1** provides evidence for the structures.

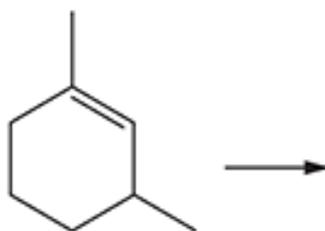
D	E

(c). 'Ozonolysis' is used in organic synthesis. Ozone breaks C=C bonds to form carbonyl compounds.

For example, the complete ozonolysis of methylbut-2-ene is shown below.



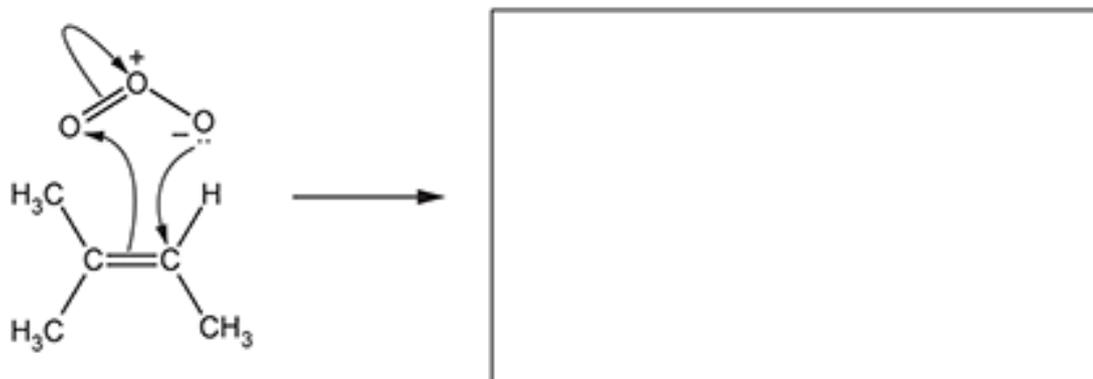
i. Draw the structures of the products you would expect from the ozonolysis of the **two** compounds below.



- ii. The mechanism for ozonolysis takes place in several steps.

The curly arrows in the first step in the ozonolysis of methylbut-2-ene are shown below.

In the box, draw the structure(s) for the product(s) of this step.



[1]

32. This question is about an analysis of an unknown organic **Compound X**.

Some properties of **Compound X** are shown in the table.

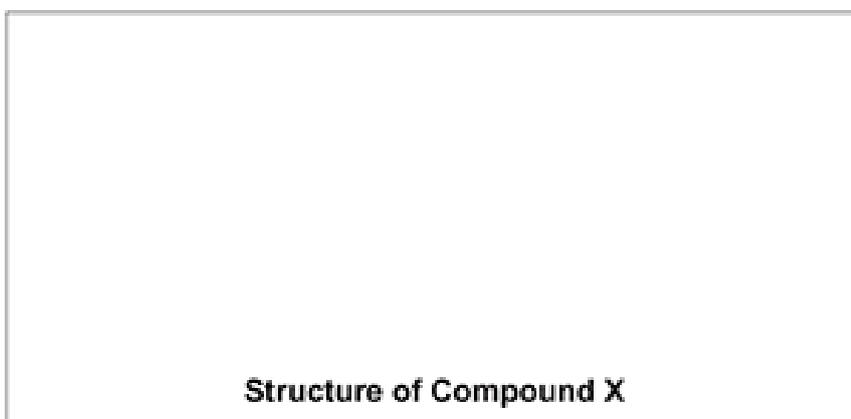
Molecular formula	Functional groups	Chirality
$C_xH_yF_6O$	$\begin{array}{c} C-F \\ C-O-C \end{array}$	1 chiral carbon

At a pressure of 1.07×10^5 Pa at 30°C , 1.327 g of **Compound X** is a gas with a volume of 186 cm^3 .

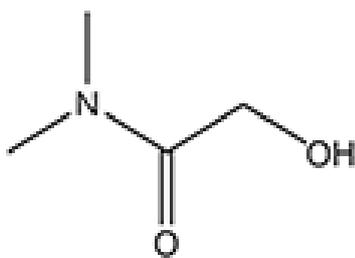
Determine the molar mass of **Compound X** and its molecular formula.

Draw a possible structure for a molecule of **Compound X**.

molar mass g mol^{-1}
molecular formula



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



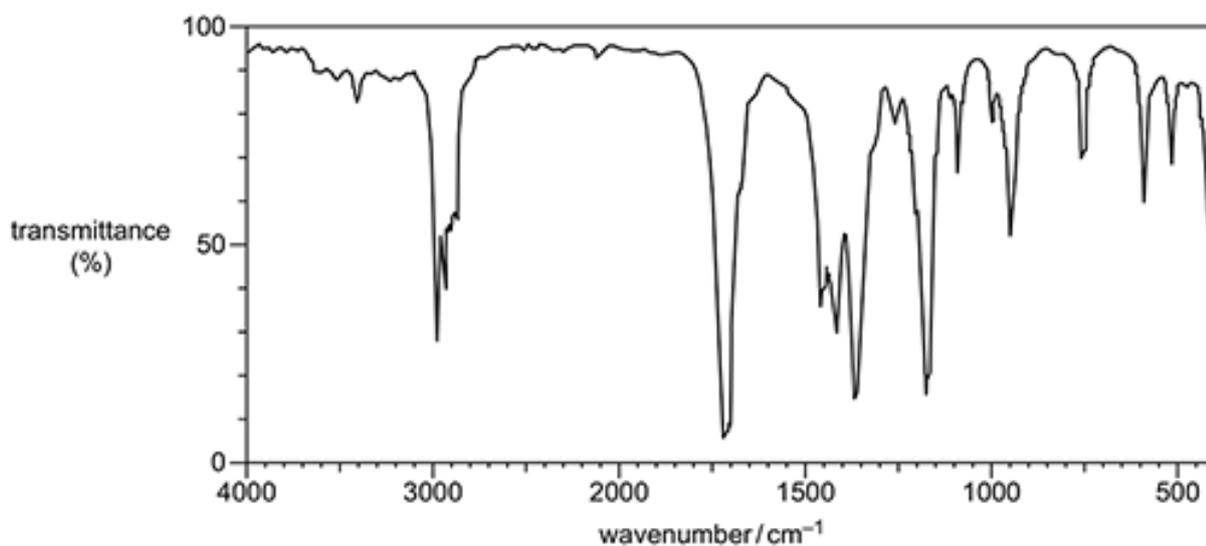
Which functional groups are present?

- A amide and alcohol
- B amide and carboxylic acid
- C amine and carboxylic acid
- D amine, ketone and alcohol

Your answer

[1]

34. Which organic compound could have produced the infrared spectrum below?



- A $\text{CH}_3\text{COCH}_2\text{CH}_3$
- B $\text{CH}_3\text{CH}_2\text{CHOHCH}_3$
- C $\text{CH}_3\text{COCH}_2\text{CH}_2\text{OH}$
- D $\text{CH}_3\text{CH}_2\text{COOH}$

Your answer

[1]

35. The alkene, $(\text{CH}_3)_3\text{CCH}=\text{CH}_2$, is used to make some perfumes.

- i. What is the systematic name for $(\text{CH}_3)_3\text{CCH}=\text{CH}_2$?

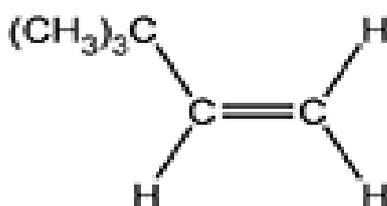
[1]

$(\text{CH}_3)_3\text{CCH}=\text{CH}_2$ decolourises bromine.

Outline the reaction mechanism for the reaction of $(\text{CH}_3)_3\text{CCH}=\text{CH}_2$ and bromine.

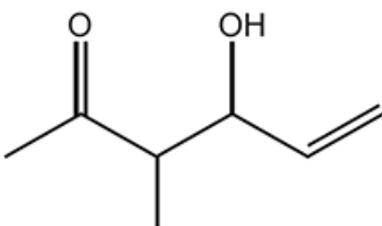
The structure of $(\text{CH}_3)_3\text{CCH}=\text{CH}_2$ has been provided.

Include curly arrows and relevant dipoles, the structure of the product and the name of the mechanism.



name of mechanism..... [5]

36. What is the number of hydrogen atoms in **one** molecule of the compound below?



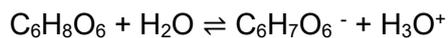
- A 8
 B 10
 C 12
 D 14

Your answer

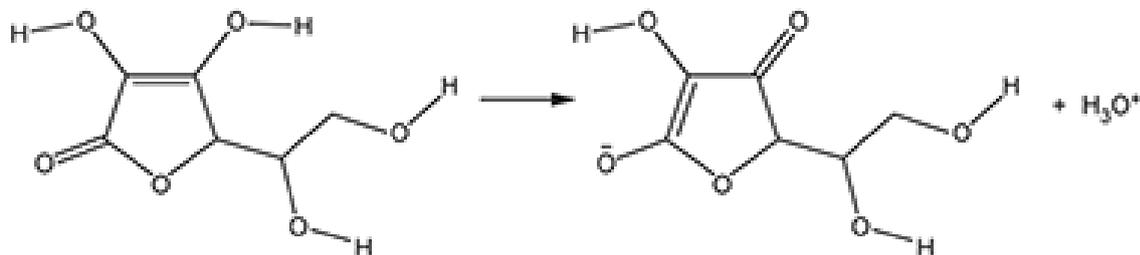
[1]

37. Vitamin C, $C_6H_8O_6$, is a weak acid ($K_a = 7.94 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}$), which is often referred to as ascorbic acid.

- i. In aqueous solution, vitamin C donates a proton to water:



Add curly arrows to the diagram to suggest the mechanism for this process.



[2]

- ii. The student dissolves 0.150 mol of vitamin C in water and makes the solution up to 250 cm³ in a volumetric flask.

Calculate the pH of this solution of vitamin C.

Give your answer to **2** decimal places.

pH = [3]

END OF QUESTION PAPER