1. The table below lists the boiling points of some alkanes.

alkane	number of carbon atoms	molecular formula	boiling point /°C
butane	4	C_4H_{10}	0
pentane	5	C_5H_{12}	36
hexane	6	C_6H_{14}	69
heptane	7	C_7H_{16}	99
octane	8	C_8H_{18}	
nonane	9	C_9H_{20}	152
decane	10	$C_{10}H_{22}$	175

(i) Predict the boiling point of octane.

.....

[1]

(ii) State and explain the trend in the boiling points of these alkanes.

.....

.....

.....

[2]

[Total 3 marks]

2. Predict the molecular formula of an alkane with 13 carbon atoms.

.....

[Total 1 mark]

3. Long chain alkanes, such as nonane, are cracked into shorter chain alkanes and alkenes.

Write a balanced equation for the cracking of nonane into heptane and ethene.

.....

[Total 1 mark]

4. Straight chain alkanes such as heptane, C_7H_{16}, are processed into branched-chain alkanes and cyclic compounds. These products are required to make petrol burn better in car engines than when using unbranched alkanes.

(i) Draw the skeletal formula of a branched structural isomer of heptane and state its name.

skeletal formula:

name: .....

[2]

(ii) Write a balanced equation to show the formation of the cyclic compound methylcyclohexane from heptane.

[2]

[Total 4 marks]

5. Butane, C_4H_{10}, reacts with chlorine to produce a chloroalkane with molecular formula C_4H_9Cl.

The reaction is initiated by the formation of chlorine radicals from chlorine.

(i) What is meant by the term *radical*?

.....

[1]

(ii) State the conditions necessary to bring about the formation of the chlorine free radicals from Cl_2.

.....

[1]

(iii) State the type of bond fission involved in the formation of the chlorine radicals.

.....

[1]

(iv) The chlorine radicals react with butane in several steps to produce C_4H_9Cl.

Write equations for the two propagation steps.

.....

.....

[2]

[Total 5 marks]

6. Bromobutane, $CH_3CH_2CH_2CH_2Br$, can be reacted with hot aqueous sodium hydroxide to prepare butan-1-ol.

$$CH_3CH_2CH_2CH_2Br + OH^- \rightarrow CH_3CH_2CH_2CH_2OH + Br^-$$

A student reacted 8.72 g of bromobutane with an excess of OH^-. The student produced 4.28 g of butan-1-ol.

(i) Calculate the amount, in mol, of $CH_3CH_2CH_2CH_2Br$ reacted.

$CH_3CH_2CH_2CH_2Br$, *M*r = 136.9

..... mol

[1]

(ii) Calculate the amount, in mol, of $CH_3CH_2CH_2CH_2OH$ produced.

..... mol

[2]

(iii) Calculate the percentage yield.

Quote your answer to **three** significant figures.

..... %

[1]

[Total 4 marks]

7. Ethanol, C_2H_5OH, is manufactured on a large scale for a wide range of uses such as alcoholic drinks, as an industrial solvent and as a raw material for the synthesis of many organic compounds.

Ethanol, C_2H_5OH, is manufactured on a large scale by two methods:

- Fermentation, using yeast, of sugars, such as glucose, $C_6H_{12}O_6$.

  $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

  The ethanol is then distilled off.

- Hydration of ethene, C_2H_4, with steam in the presence of an acid catalyst.

  $C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(g)$

Compare the sustainability of these methods of manufacturing ethanol in terms of:

- availability of starting materials and energy requirements;
- atom economy.

In your answer, you should make clear how the atom economy of the processes links with chemical theory.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[Total 7 marks]

8. Two workers decide to car-share on a 25 mile journey to work and back. On this journey, each of their cars uses petrol equivalent to 2.0 kg of heptane.

Assuming such car-sharing, use your equation from (a)(i) to:

(i) calculate the amount, in mol, of heptane, C_7H_{16}, saved;

[2]

(ii) calculate the energy saved ($\Delta H_c^{\ominus}$ [C_7H_{16}] = – 4817 kJ mol^{-1});

[1]

(iii) calculate the decrease in volume of CO_2(g) emitted into the atmosphere.

Assume that the conditions are the same as room temperature and pressure.

[2]

[Total 5 marks]

9. But-1-ene is just one isomer with the molecular formula C_4H_8.

Using C_4H_8 as your example, describe and explain what is meant by structural isomerism and *cis-trans* isomerism.

Include diagrams in your answer.

In your answer you should make clear how each type of isomerism is related to structural features.

(Allow one lined page).

[Total 7 marks]

10. But-1-ene is just one isomer with the molecular formula C_4H_8.

The chemical properties of but-1-ene are similar to those of ethene.

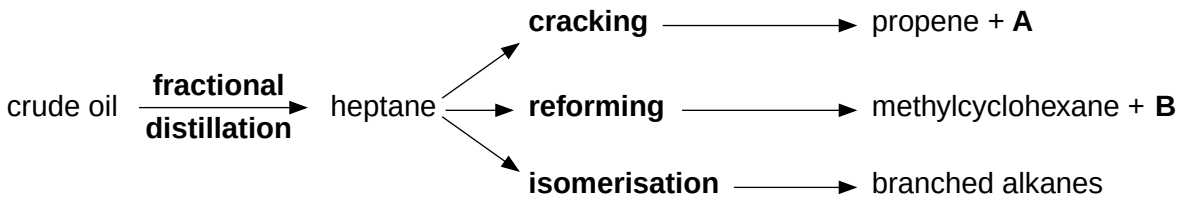
- Using this information, predict the organic products in, and the equations for, the reactions of but-1-ene with bromine, hydrogen bromide and steam.
- Draw a section of the polymer formed from but-2-ene by showing two repeat units.
- Discuss **two** ways in which chemists are trying to minimise the damage to the environment caused by the disposal of polymers.

(Allow one lined page).

[Total 10 marks]

11. Crude oil is first separated by fractional distillation. The fractions can then be refined further by cracking, reforming and isomerisation.

The reaction sequence below shows the production of heptane, C_7H_{16}, from fractional distillation of crude oil, followed by cracking, reforming and isomerisation.



(a) What is meant by the term *fractional distillation?*

.....

.....

[1]

(b) The cracking of heptane produces propene and **A**.

Write a balanced equation for this cracking of heptane.

.....

[1]

(c) The reforming of heptane produces methylcyclohexane and **B**.

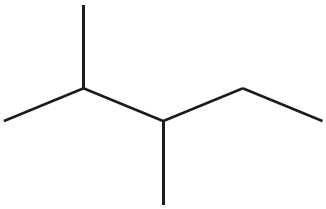
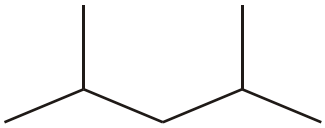
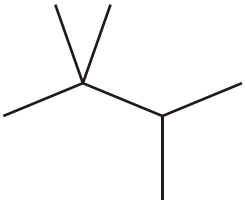
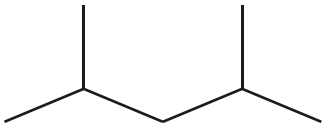
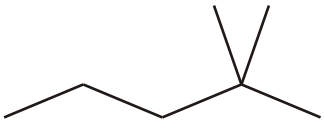
(i) Show the structural formula of methylcyclohexane.

[1]

(ii) Write a balanced equation for this reforming.

[1]

(d) The isomerisation of heptane produces **seven** branched alkanes, five of which are shown below.

2,3-dimethylpentane 	2,4-dimethylpentane 
2,2,3-trimethylbutane 	2,4-dimethylpentane 
compound **C** 	

(i) Name compound **C**.

.....

[1]

(ii) In the boxes above, draw skeletal formulae for the other **two** branched alkanes formed by isomerisation of heptane.

[2]

(iii) Predict which of 2-methylhexane, 2,3-dimethylpentane and 2,2,3-trimethylbutane has the lowest boiling point.

.....

[1]

(iv) Explain why 2-methylhexane, 2,3-dimethylpentane and 2,2,3-trimethylbutane have different boiling points.

.....

.....

.....

[2]

[Total 10 marks]

12. (a) Propan-2-ol can be formed by the hydration of an alkene in the presence of a catalyst.

(i) Suggest a suitable catalyst for this reaction.

.....

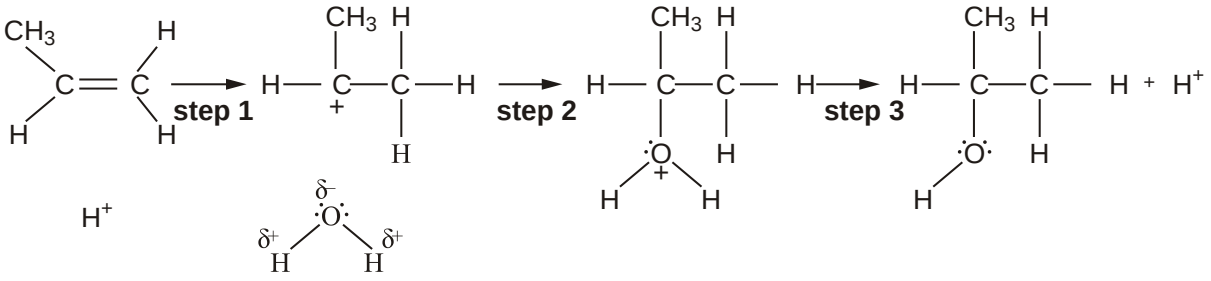
[1]

(ii) This is an electrophilic addition reaction. What is meant by the term *electrophile*?

.....

[1]

(b) A mechanism for the reaction in (a) is shown below.



(i) Add 'curly arrows' to the mechanism to show the movement of electron pairs in steps **1**, **2** and **3**.

[3]

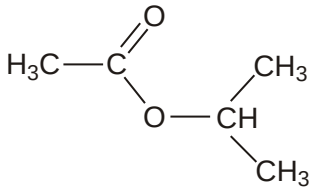
(ii) Suggest, with a reason, the role of the H^+.

.....

[1]

[Total 6 marks]

13. Methyl allyl chloride, MAC, is an important industrial chemical. It is used as an intermediate in the production of synthetic fibres, pharmaceuticals and epoxy resins. The structural formula of MAC is shown below.



compound **D**

(a) Give the **systematic** chemical name of MAC.

.....

[1]

(b) MAC contains the alkene group and can undergo polymerisation. Draw a section of the polymer, poly(MAC), showing **two** repeat units.

[2]

[Total 3 marks]

14. Butane, C_4H_{10}, under certain conditions, reacts with Cl_2 to form a mixture of chlorinated products. One possible product is C_4H_9Cl.

$$C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$$

(a) (i) State the conditions.

.....

[1]

(ii) Write equations to show the mechanism of this reaction.

initiation .....

propagation .....

.....

[3]

(iii) Write **one** equation for a reaction that would terminate this mechanism.

.....

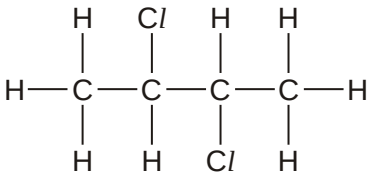
[1]

(iv) State the type of bond fission involved in the initiation step. .....

[1]

(b) One other possible product of the reaction between butane and chlorine is compound **J**, $C_4H_8Cl_2$, shown below.

compound **J**



(i) Name compound **J**.

.....

[1]

(ii) Draw the skeletal formula of compound **J**.

[1]

(iii) In addition to compound **J**, suggest **one** other possible structural isomer of $C_4H_8Cl_2$ that could have been formed in this reaction.

[1]

[Total 9 marks]

15. In this question, one mark is available for the quality of use and organisation of scientific terms.

- Describe, with the aid of a suitable diagram, the formation of the π-bond in propene.
- State the shape, and an approximate value for the bond angles, around each carbon atom in propene.
- Describe, with the aid of a suitable example, why some alkenes show *cis-trans* isomerism.

(Allow one lined page).

[9]

Quality of Written Communication [1]

[Total 10 marks]

16. Hexane reacts with Br_2 in the presence of ultraviolet light.

$$C_6H_{14} + Br_2 \rightarrow C_6H_{13}Br + HBr$$

(i) State the type of reaction.

.....

[1]

(ii) Identify the three possible structural isomers of the product, $C_6H_{13}Br$, that could be formed from this reaction with hexane.

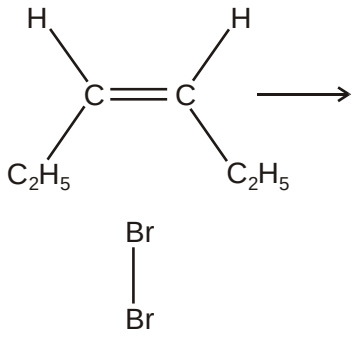
[3]

[Total 4 marks]

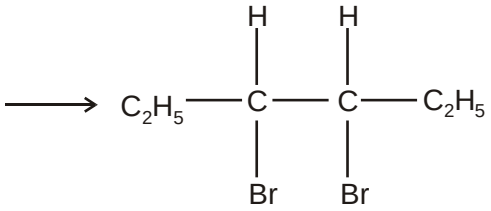
17. (a) Hex-3-ene reacts with Br_2 to produce 3,4-dibromohexane.

Describe, with the aid of curly arrows, the movement of the electrons in the mechanism.

Show the intermediate, any relevant dipoles and lone pairs of electrons.



intermediate



3,4-dibromohexane

[4]

(b) The mechanism in (a) shows *cis*-hex-3-ene reacting with Br_2. *Trans*-hex-3-ene also reacts with Br_2 to produce 3,4-dibromohexane.

(i) How does the structure of *trans*-hex-3-ene differ from that of *cis*-hex-3-ene?

.....

.....

[1]

(ii) Explain why both *cis* and *trans* hex-3-ene react with Br_2 to produce the same structural isomer.

.....

.....

.....

[1]

[Total 6 marks]

18. In this question, one mark is available for the quality of spelling, punctuation and grammar.

The fractions from crude oil can be processed by cracking, reforming and isomerisation.

- Outline these processes with the aid of suitable equations.
- State clearly the industrial importance of the products formed in each process.

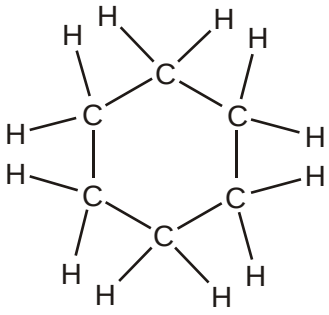
(Allow one lined page).

[8]

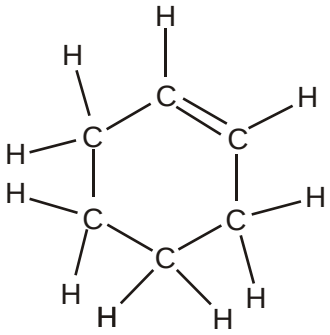
Quality of Written Communication [1]

[Total 9 marks]

19. Cylcohexane and cyclohexene are both cyclic hydrocarbons.



cyclohexane



cyclohexene

(i) What is the molecular formula of cyclohexene? .....

[1]

(ii) What is the empirical formula of cyclohexene? .....

[1]

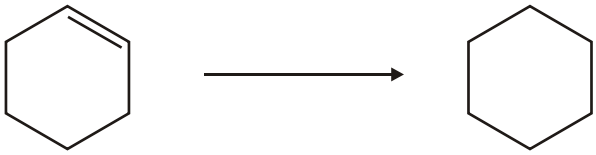
(iii) Calculate the percentage, by mass, of carbon in cyclohexene. Give your answer to **two** significant figures.

answer .....

[2]

[Total 4 marks]

20. Cyclohexene can be converted into cyclohexane.



cyclohexene **cyclohexane**

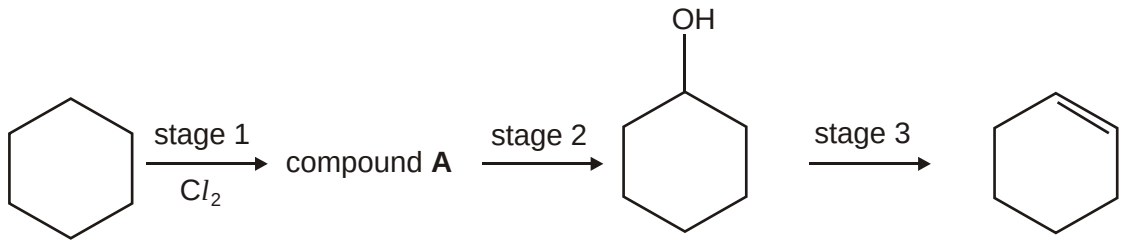
Suggest suitable reagents and conditions for this reaction.

reagents .....

conditions .....

[Total 2 marks]

21. (a) Cyclohexane can be converted into cyclohexene via a three-stage synthesis.



cyclohexane **cyclohexanol** **cyclohexene**

(i) In stage 1, cyclohexane reacts with chlorine to form the organic product, compound **A**.

Show the structure of compound **A**.

[1]

(ii) Stage 3 involves the dehydration of an alcohol.

State a suitable reagent for dehydrating an alcohol.

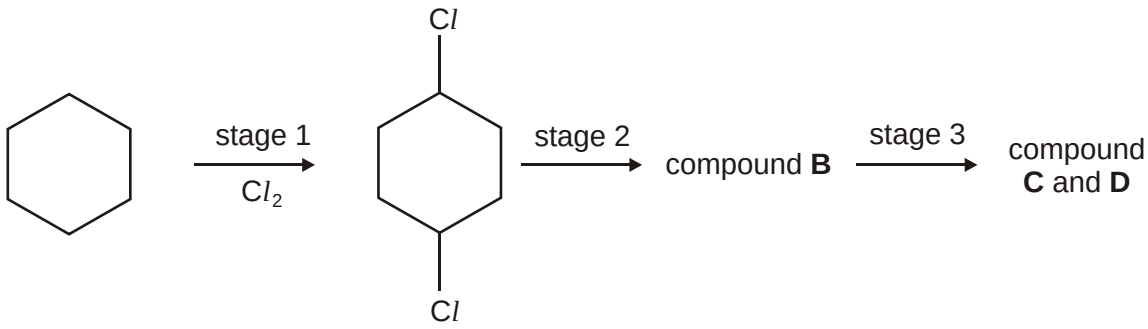
.....

[1]

(iii) Write a balanced equation for the dehydration of cyclohexanol, $C_6H_{11}OH$.

[1]

(b) The reaction in stage 1 is difficult to control. One other possible chlorinated product is 1,4-dichlorocyclohexane.This is shown below.



cyclohexane **1,4-dichlorocyclohexane**

1,4-Dichlorocyclohexane reacts in the same way as compound **A** in stages 2 and 3.

(i) Suggest the structure of compound **B**.

[1]

(ii) Two cyclic alkenes, **C** and **D** are formed in stage 3. **C** and **D** are structural isomers. Suggest the structures of **C** and **D**.

[2]

[Total 6 marks]

22. Crude oil is a complex mixture of hydrocarbons. Initial separation is achieved by fractional distillation. The separate fractions are then further refined to produce hydrocarbons such as decane.

(a) (i) State what is meant by the term *hydrocarbon.*

.....

.....

[1]

(ii) A molecule of decane contains ten carbon atoms. State the molecular formula of decane.

.....

[1]

(iii) Deduce the empirical formula of decane. .....

[1]

(b) Dodecane, $C_{12}H_{26}$, is a straight chain alkane that reacts with chlorine to produce a compound with molecular formula $C_{12}H_{25}Cl$.

$$C_{12}H_{26} + Cl_2 \rightarrow C_{12}H_{25}Cl + HCl$$

The reaction is initiated by the formation of chlorine free radicals from chlorine.

(i) What is meant by the term *free radical*?

.....

[1]

(ii) State the conditions necessary to bring about the formation of the chlorine free radicals from Cl_2.

.....

[1]

(iii) State the type of bond fission involved in the formation of the chlorine free radicals.

.....

[1]

(iv) The chlorine free radicals react with dodecane to produce $C_{12}H_{25}Cl$. Write equations for the **two** propagation steps involved.

.....

.....

[2]

(v) How many different structural isomers can be formed when chlorine reacts with dodecane to form $C_{12}H_{25}Cl$?

answer .....

[1]

(c) Dodecane, $C_{12}H_{26}$, can be cracked into ethene and a straight chain alkane such that the molar ratio ethene: straight chain alkane is 2 : 1.

(i) Write a balanced equation for this reaction.

.....

[2]

(ii) Name the straight chain alkane formed.

.....

[1]

(d) Straight chain alkanes such as heptane, C_7H_{16}, can be isomerised into branched chain alkanes and reformed into cyclic compounds.

(i) Using **skeletal** formulae, write an equation to show the isomerisation of heptane into 2,2,3-trimethylbutane.

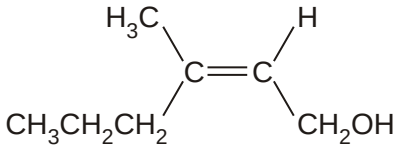
[2]

(ii) Write a balanced equation to show the reforming of heptane into methylcyclohexane.

[2]

[Total 16 marks]

23. Body odour often begins with secretions from glands called apocrine glands, which are most numerous in the armpits. Bacteria, which live in the armpits, use these secretions to produce energy and many different waste products. Scientists have isolated one of these waste products, compound **E**, which is shown below.



compound **E**

Compound **E** contains two functional groups, one of which is a primary alcohol.

(i) **Name** the other functional group and state how you could test for it.

name of the other functional group .....

test .....

observation .....

[3]

(ii) Name compound **E** .....

[1]

[Total 4 marks]

24. In this question, one mark is available for the quality of use and organisation of scientific terms.

Alkenes are used in the industrial production of many organic compounds.

Outline how alkenes are used in the manufacture of

- margarine,
- polymers such as poly(propene).

State any essential conditions.

Write a balanced equation for the manufacture of poly(propene) and draw a section of the polymer to show two repeat units.

State **two** difficulties in the disposal of polymers like poly(propene).

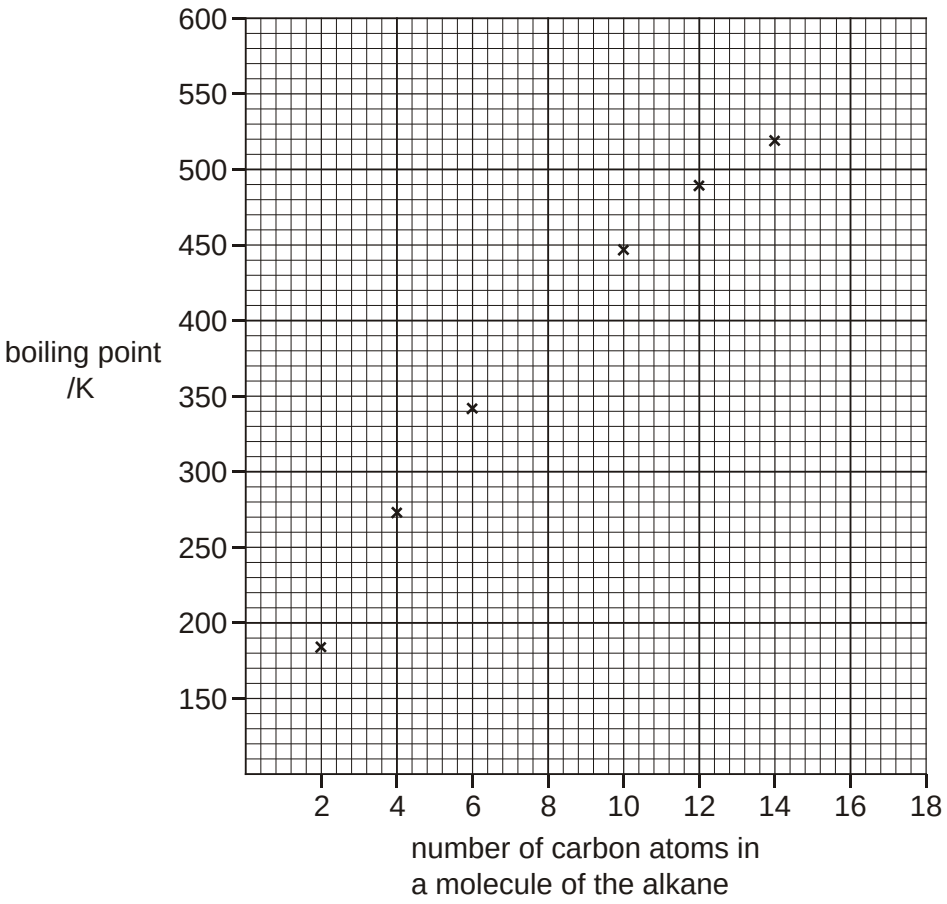
Suggest **two** ways in which waste polymers may be treated in the future.

[9]

Quality of Written Communication [1]

[Total 10 marks]

25. The graph below shows the boiling points of some alkanes.



(a) Draw a smooth curve through the points on the graph and estimate the boiling points of

octane C_8H_{18}, …… hexadecane, $C_{16}H_{34}$ ……

[2]

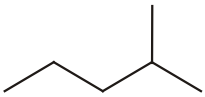
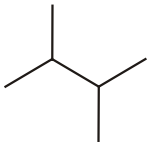
(b) State how decane, $C_{10}H_{22}$, can be separated from a mixture of the alkanes.

.....

[1]

(c) Isomerisation of hexane, C_6H_{14}, produces a mixture of structural isomers, three of which are shown in the boxes below.

(i) Draw, using skeletal formulae, **two** other structural isomers of hexane.

				
isomer **A**	isomer **B**	isomer **C**		

[2]

(ii) Name isomer **B**. .....

[1]

(iii) Isomers **A**, **B** and **C** have different boiling points. In the boxes below, list the isomers **A**, **B** and **C** in order of their boiling points.

lowest boiling point | | | | highest boiling point

[1]

(iv) Explain the order given in **(c) (iii)**.

.....

.....

.....

[2]

(d) Hexane can be reformed to produce cyclohexane as one of the products.

(i) Draw the structural formula of cyclohexane.

[1]

(ii) Write a balanced equation for the reforming of hexane into cyclohexane.

[1]

(iii) Suggest **one** reason why oil companies reform alkanes such as hexane.

.....

.....

[1]

(e) Oxygen-containing compounds can be added to improve the efficiency and performance of fuels.

In Formula One racing cars, it is common practice to add oxygen-containing compounds, such as 2-methylpropan-2-ol, $(CH_3)_3COH$. The amount of oxygen-containing compounds added is strictly controlled by the Federation Internationale de l'Automobile, FIA.

(i) Calculate the percentage by mass of oxygen in $(CH_3)_3COH$. Give your answer to three significant figures.

answer …….

[2]

(ii) Write a balanced equation for the complete combustion of $(CH_3)_3COH$.

[2]

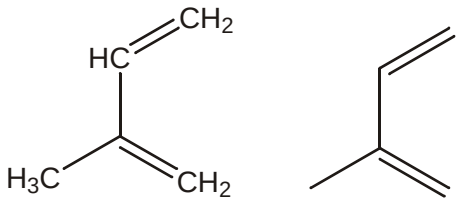
[Total 16 marks]

26. Isoprene is an alkene that can be tapped from some trees. It is the monomer in natural rubber.

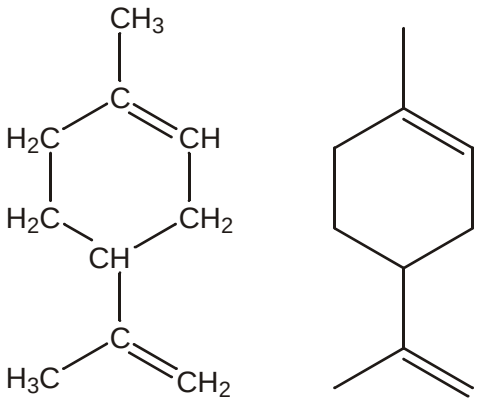
Limonene is a natural oil found in the rind of oranges and lemons.

Both isoprene and limonene contain two double bonds.

Their structural and skeletal formulae are shown below.



isoprene



limonene

(a) (i) What is the molecular formula of **isoprene**? .....

[1]

(ii) What is the empirical formula of **limonene**? .....

[1]

(b) In the presence of a suitable catalyst, isoprene and limonene both react with hydrogen.

(i) State a suitable catalyst for this reaction. .....

[1]

(ii) Write an equation for the reaction when **isoprene** reacts **completely** with hydrogen.

[2]

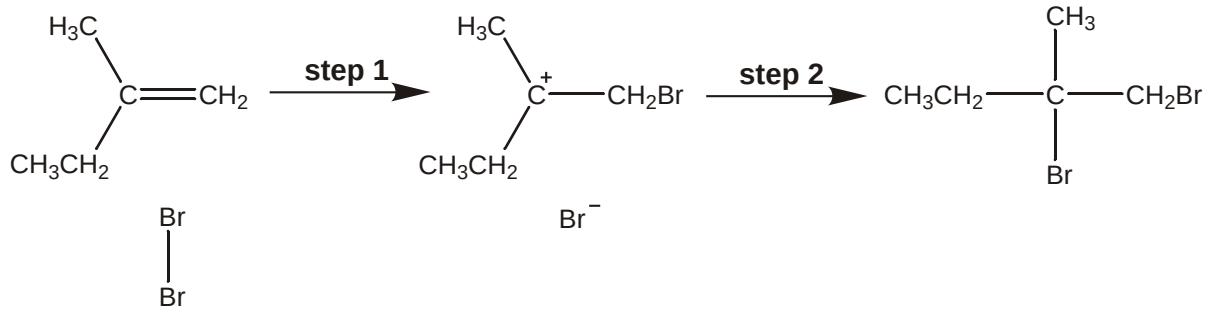
(iii) Draw the skeletal formula of a product formed when **limonene** reacts **partially** with hydrogen.

[1]

[Total 6 marks]

27. 2-Methylbut-1-ene can be formed by the partial hydrogenation of isoprene.

2-Methylbut-1-ene reacts with Br_2 to produce 1,2-dibromo-2-methylbutane by an electrophilic addition mechanism. The mechanism for the reaction is shown below.



(i) In **step 1**, Br_2 behaves as an electrophile. Explain what is meant by the term *electrophile*.

.....

[1]

(ii) Label any relevant dipoles and add 'curly arrows' to the mechanism to show the movement of electron pairs in **step 1** and in **step 2**.

[3]

[Total 4 marks]

28. Halogenoalkanes are used in the production of pharmaceuticals, polymers and flame retardants.

1-Bromo-2-methylpropane is used in the production of ibuprofen and can be prepared from the reaction between 2-methylpropan-1-ol and HBr.

$$(CH_3)_2CHCH_2OH + HBr \rightarrow (CH_3)_2CHCH_2Br + H_2O$$

A student reacted 4.44 g of 2-methylpropan-1-ol with an excess of HBr. The student produced 5.48 g of 1-bromo-2-methylpropane.

(i) Calculate the number of moles of $(CH_3)_2CHCH_2OH$ used.

answer …… mol

[2]

(ii) Calculate the number of moles of $(CH_3)_2CHCH_2Br$ collected.
$(CH_3)_2CHCH_2Br$, M_r =137

answer …… mol

[1]

(iii) Calculate the percentage yield. Quote your answer to three significant figures.

answer ……

[1]

[Total 4 marks]

29. Chloroethene, CH_2CHCl, is polymerised to form poly(chloroethene) commonly known as *pvc*.

(i) Draw a section of *pvc* showing **three** repeat units. Put a bracket round one repeat unit.

[2]

(ii) Polymers such as *pvc* are difficult to dispose of because they are non-biodegradable. Increasingly, they are disposed of by combustion.

State the problem associated with the combustion of polymers such as *pvc.*

.....

.....

[1]

(iii) State **two** ways in which chemists are trying to minimise the damage to the environment caused by the disposal of halogenated plastics such as *pvc*.

.....

.....

.....

[2]

[Total 5 marks]

30. Cyclohexane, C_6H_{12}, reacts with chlorine to produce chlorocyclohexane, $C_6H_{11}Cl$.

$$C_6H_{12} + Cl_2 \rightarrow C_6H_{11}Cl + HCl$$

The mechanism for this reaction is a free radical substitution.

(i) Write an equation to show the initiation step.

.....

[1]

(ii) State the conditions necessary for the initiation step.

.....

[1]

(iii) The reaction continues by **two** propagation steps resulting in the formation of chlorocyclohexane, $C_6H_{11}Cl$.

Write equations for these **two** propagation steps.

step 1 .....

step 2 .....

[2]

(iv) State what happens to the free radicals in the termination steps.

.....

[1]

[Total 5 marks]

31. In this question, one mark is available for the quality of use and organisation of scientific terms.

Name and give examples of the types of isomerism in compounds with formula C_4H_8. Explain how each type of isomerism arises.

[8]

Quality of Written Communication [1]

[Total 9 marks]

32. (a) Compound **A** is a chloroalkene with the percentage composition by mass: C, 24.7%; H, 2.1%; C*l*, 73.2%.

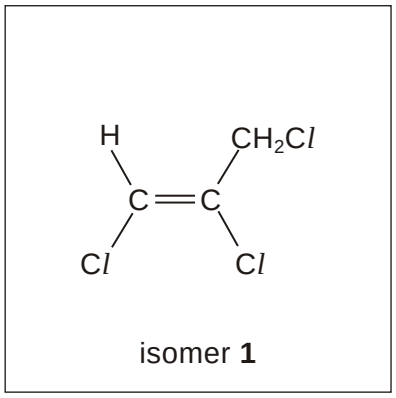
(i) Calculate the empirical formula of compound **A**. Show your working.

[2]

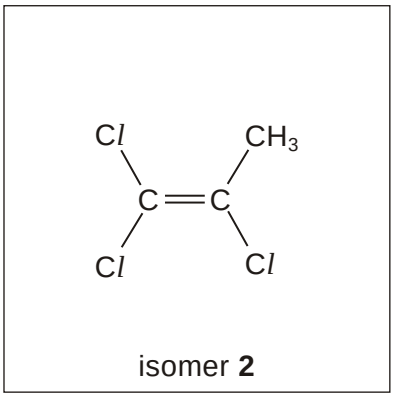
(ii) The relative molecular mass of compound **A** is 145.5. Show that the molecular formula is $C_3H_3Cl_3$.

[2]

(b) Compound **A** is one of six possible structural isomers of $C_3H_3Cl_3$ that are chloroalkenes. Two of these isomers are shown below as isomer **1** and isomer **2**.



isomer **1**



isomer **2**

(i) Draw two other structural isomers of $C_3H_3Cl_3$ that are chloroalkenes.

[2]

(ii) Name isomer **1**. .....

[2]

(c) All of the isomers in (b) readily polymerise.

(i) Draw a section of the polymer **P** that could be formed when isomer **2** polymerises.

Show two repeat units.

polymer **P**

[2]

(ii) Addition polymers can be difficult to dispose of.

State **two** general problems in the disposal of polymers and identify an extra problem when disposing of polymer **P**.

.....

.....

.....

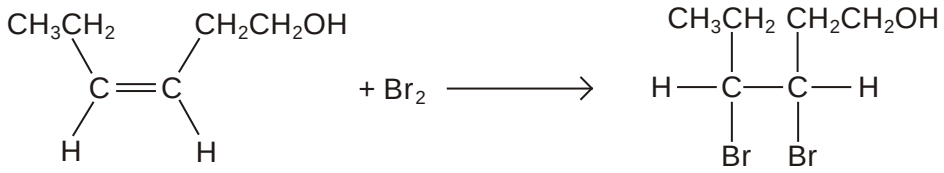
.....

.....

[3]

[Total 13 marks]

33. Leaf alcohol reacts with bromine as shown in the equation below.



(i) State what you would **see** when bromine reacts with leaf alcohol.

.....

[1]

(ii) Complete, with the aid of curly arrows, the mechanism involved in the reaction between leaf alcohol and bromine. Show any relevant dipoles, charges and lone pairs of electrons.

[4]

[Total 5 marks]

34. In this question, one mark is available for the quality of use and organisation of scientific terms.

Different cars require different grades of petrol. The first stage in the production of petrol in an oil refinery is to fractionate the crude oil. After that, refineries carry out further processes.

- Outline, with the aid of equations, **three** of these processes in the production of petrol.
- Explain why, in the long term, ethanol could replace oil-based fuels.
- Write an equation for the combustion of ethanol.

[10]

Quality of Written Communication [1]

[Total 11 marks]

35. The table below lists the boiling points of some alkanes.

alkane	number of carbon atoms	molecular formula	boiling point / °C
butane	4	C_4H_{10}	0
pentane	5	C_5H_{12}	36
hexane	6		69
heptane	7	C_7H_{16}	99
octane	8	C_8H_{18}	
nonane	9	C_9H_{20}	152
decane	10	$C_{10}H_{22}$	175

(a) What is the molecular formula of hexane?.....

[1]

(b) (i) State the trend in the boiling points of the alkanes.

.....

.....

[1]

(ii) Explain the trend in the boiling points of the alkanes.

.....

.....

[1]

(iii) Predict the boiling point of octane. ..... °C

[1]

[Total 4 marks]

36. Long chain alkanes, such as nonane, can be cracked into shorter chain alkanes and alkenes.

(i) Write a balanced equation for the cracking of nonane into heptane and ethene.

.....

[1]

(ii) Much of the ethene is then converted into ethanol.

Write a balanced equation for the conversion of ethene into ethanol. State the essential conditions.

equation .....

[1]

conditions .....

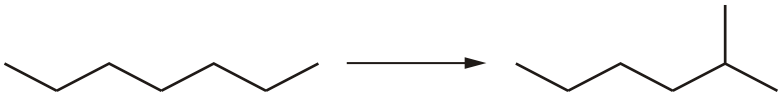
.....

[2]

[Total 4 marks]

37. (a) Heptane can be isomerised to produce branched chain alkanes such as 2-methylhexane or 2,3-dimethylpentane.

The equation below shows the isomerisation of heptane into 2-methylhexane.



(i) Using skeletal formulae, complete the balanced equation for the isomerisation of heptane into 2,3-dimethylpentane.

[1]

(ii) The boiling point of 2,3-dimethylpentane is 84 °C.

Predict the boiling point of 2-methylhexane. ..... °C

[1]

(b) Heptane can be reformed to produce methylcyclohexane which is a cycloalkane. Write a balanced equation to show the reforming of heptane to obtain methylcyclohexane

[2]

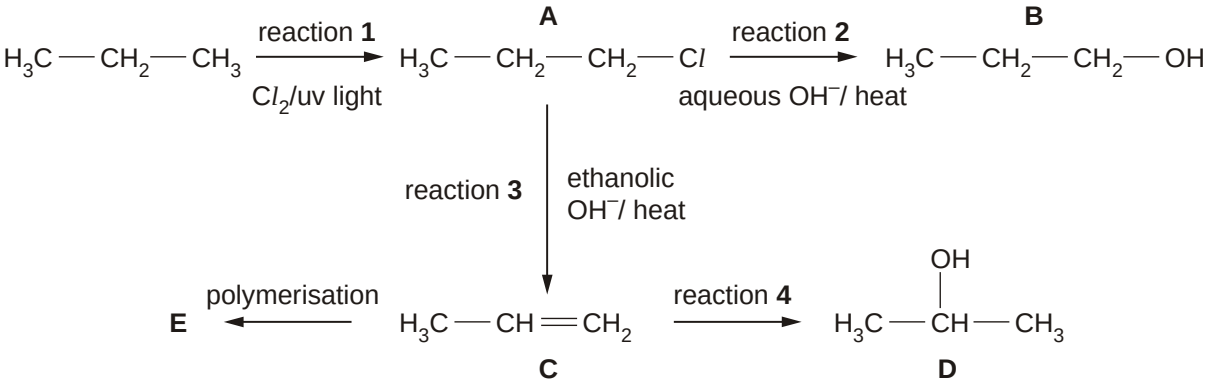
(c) State why branched chain alkanes and cycloalkanes are more useful than straight chain alkanes.

.....

[1]

[Total 5 marks]

38. Propane, C_3H_8, is used in the reaction sequence shown below.



(a) The reaction sequence shows several important reaction mechanisms. Select from reactions **1** to **4**, the reaction that shows

(i) free radical substitution, reaction .....

[1]

(ii) electrophilic addition, reaction .....

[1]

(iii) elimination, reaction .....

[1]

(b) In reaction **2**, the aqueous OH^- acts as a nucleophile.

(i) State what is meant by the term *nucleophile*.

.....

[1]

(ii) Complete, with the aid of curly arrows, the mechanism involved in reaction **2**. Show any relevant dipoles.

$H_3C—CH_2—CH_2—Cl \longrightarrow H_3C—CH_2—CH_2—OH$ + ...

OH^-

[4]

(c) Compounds **B** and **D** are structural isomers of each other.

(i) State what is meant by the term *structural isomers*.

.....

.....

[2]

(ii) Draw the skeletal formulae of compounds **B** and **D**.

Compound **B**	Compound **D**

[2]

(d) Compound **C** can be polymerised to form compound **E**.

(i) State the type of polymerisation. .....

[1]

(ii) Name compound **E**. .....

[1]

(iii) Draw a section of compound **E**. Show **two** repeat units.

[1]

[Total 15 marks]

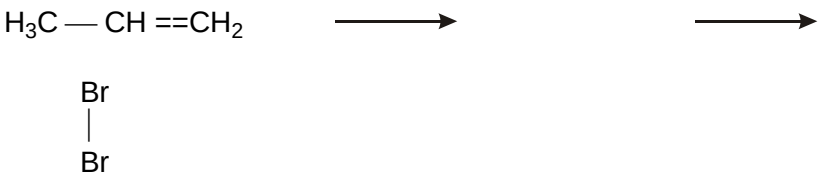
39. Propene, $CH_3CH=CH_2$, is an alkene and undergoes an addition reaction with bromine.

(i) State what you would **see** when propene reacts with bromine.

.....

[1]

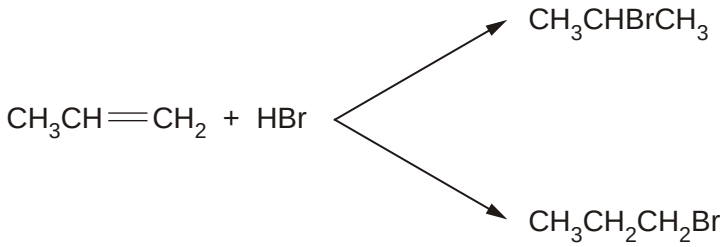
(ii) Complete, with the aid of curly arrows, the mechanism involved in the reaction between propene and bromine. Show any relevant dipoles and charges.



[4]

[Total 5 marks]

40. Propene, $CH_3CH{=}{=}CH_2$, also reacts with HBr to produce two bromoalkanes that are structural isomers.

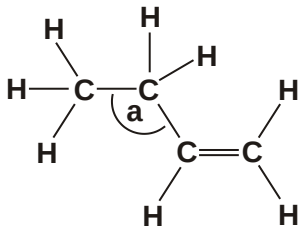


Propyne, $CH_3C{\equiv}CH$, reacts like propene. It reacts with HBr to give three isomers with molecular formula $C_3H_6Br_2$.

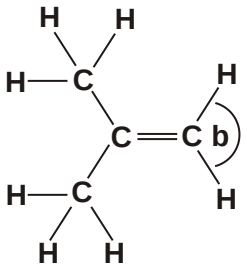
Draw the three isomers with molecular formula $C_3H_6Br_2$.

[Total 3 marks]

41. Alkenes are unsaturated hydrocarbons. The structures of but-1-ene and methylpropene are shown below.



but-1-ene



methylpropene

(i) What is meant by the terms *unsaturated* and *hydrocarbon*?

unsaturated .....

hydrocarbon .....

[2]

(ii) Suggest values for the bond angle **a** in but-1-ene and the bond angle **b** in methylpropene.

angle **a** ..... angle **b** .....

[2]

(iii) Explain, with the aid of a sketch, how p-orbitals are involved in the formation of the C==C double bond.

.....

.....

[2]

[Total 6 marks]

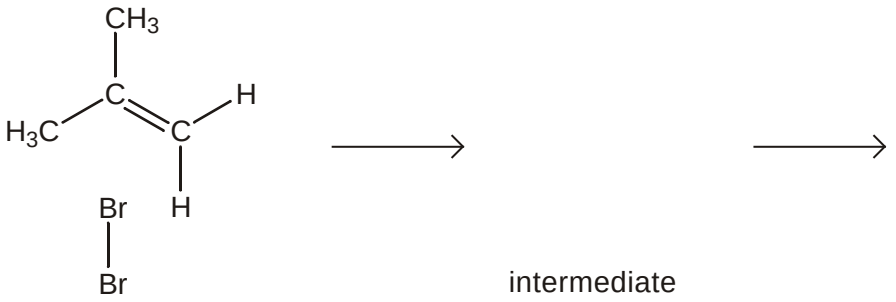
42. Alkenes undergo electrophilic addition reactions to form saturated compounds.

(i) Define the term *electrophile*.

.....

[1]

(ii) The reaction between bromine and methylpropene is an electrophilic addition.
Describe, with the aid of curly arrows, the mechanism for this reaction.
Show the intermediate and the product along with any relevant dipoles and lone pairs of electrons.

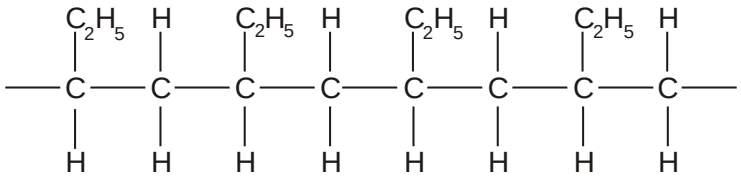


intermediate product

[4]

[Total 5 marks]

43. Polymer **A**, shown below, can be formed from an alkene.



A

polymer **A**

(i) State the type of polymerisation involved in the formation of polymer **A**.

.....

[1]

(ii) Draw a circle around the repeat unit of polymer **A**.

[1]

(iii) Identify the monomer that formed polymer **A**.

[1]

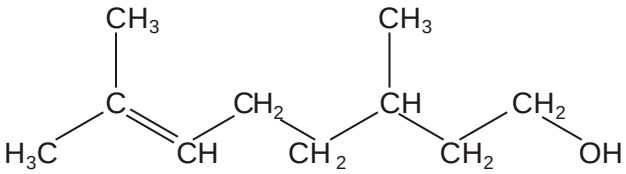
(iv) Name polymer **A**.

.....

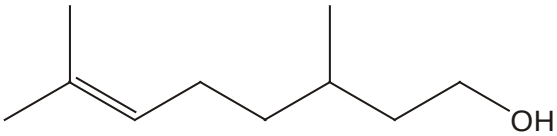
[1]

[Total 4 marks]

44. Citronellol, $C_{10}H_{20}O$, occurs naturally in both rose and geranium oils. The structural and skeletal formulae of citronellol are shown below.



structural formula



skeletal formula

(a) Name the **two** functional groups present in citronellol.

……..…….…… and .....

[2]

(b) The functional groups in citronellol can be identified either by chemical tests or by infrared spectroscopy.

(i) State which of the two functional groups you named in (a) is:

1 identified when bromine is added to citronellol, ...

2 more easily identified from the infra-red spectrum. .....

[1]

(ii) State what you would **see** when bromine is added to citronellol.

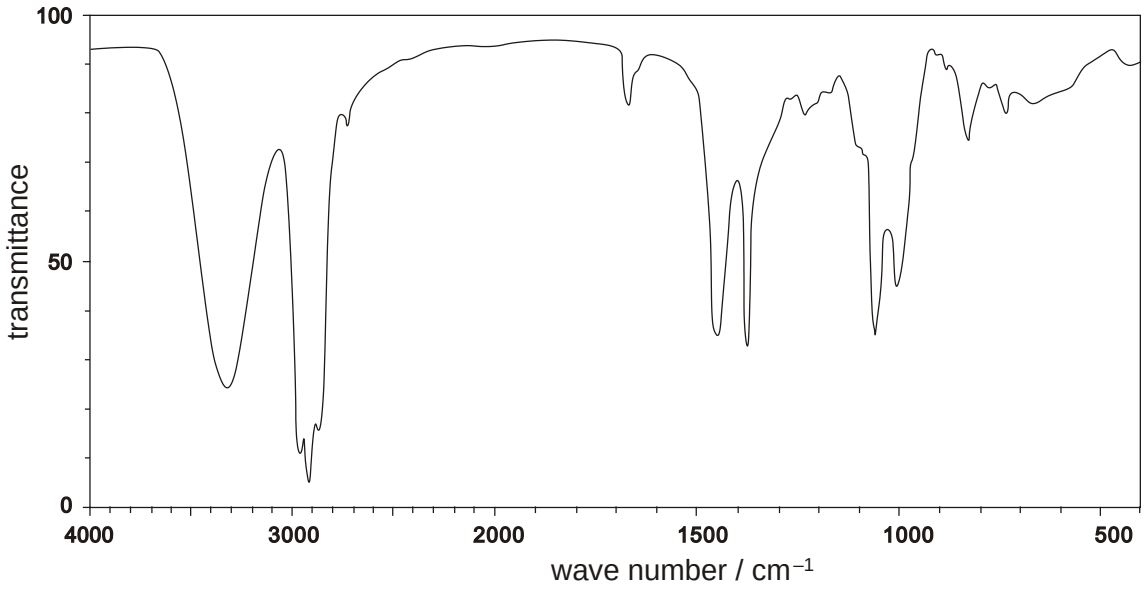
.....

[1]

(iii) Draw the skeletal formula of the organic product formed when bromine is added to citronellol.

[1]

(iv) The infra-red spectrum of citronellol is shown below. Mark on this spectrum, with the letter **X**, the absorption that confirms the presence of the functional group that is most easily identified from this spectrum.



[1]

(c) Reaction of a sample of citronellol, $C_{10}H_{20}O$, with hydrogen in the presence of a catalyst results in the formation of a saturated compound **C**.

(i) Suggest a catalyst for this reaction.

.....

[1]

(ii) Determine the molecular formula of the saturated compound **C**.

.....

[1]

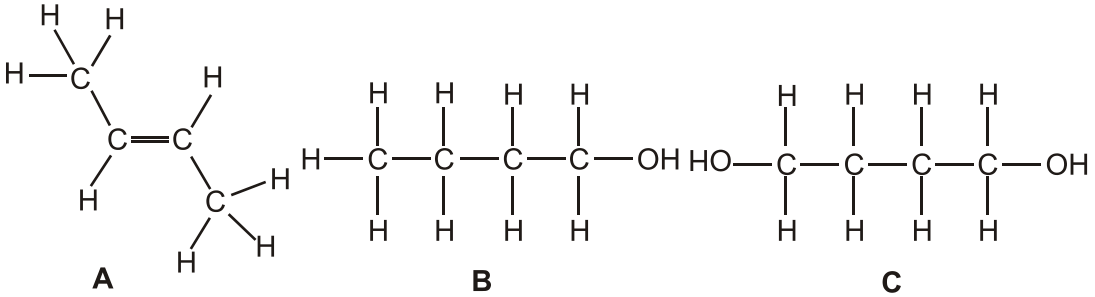
(iii) Construct a balanced equation for this reaction.

.....

[1]

[Total 9 marks]

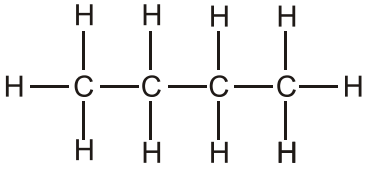
45. This question is about the compounds **A-F** below.



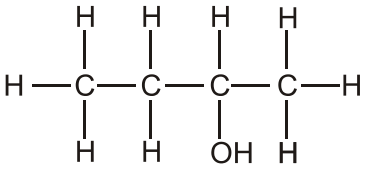
A

B

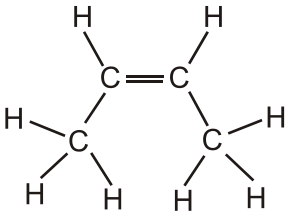
C



D



E



F

(a) Answer the following questions by referring to the compounds **A-F**.

(i) What is the molecular formula of compound **D**?

.....

[1]

(ii) What is the empirical formula of compound **C**?

.....

[1]

(iii) Which two compounds are structural isomers of each other?

..... and .....

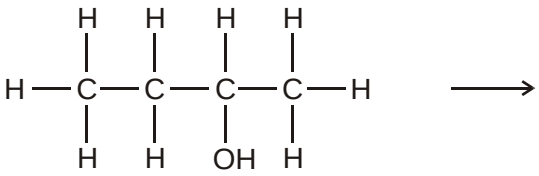
[1]

(iv) Which two compounds are *cis-trans* isomers of each other?

..... and .....

[1]

(b) Compound **E** can be dehydrated to form compound **A**. Complete a balanced equation for this reaction.



[1]

(c) Compound **C** can be dehydrated to form a new compound, **G**, with the molecular formula, C_4H_6. Suggest a structural formula and a name for **G**.

name .....

[2]

[Total 7 marks]

46. But-1-ene can undergo polymerisation. Draw a section of the polymer that can be formed from but-1-ene. Show **two** repeat units.

[Total 2 marks]

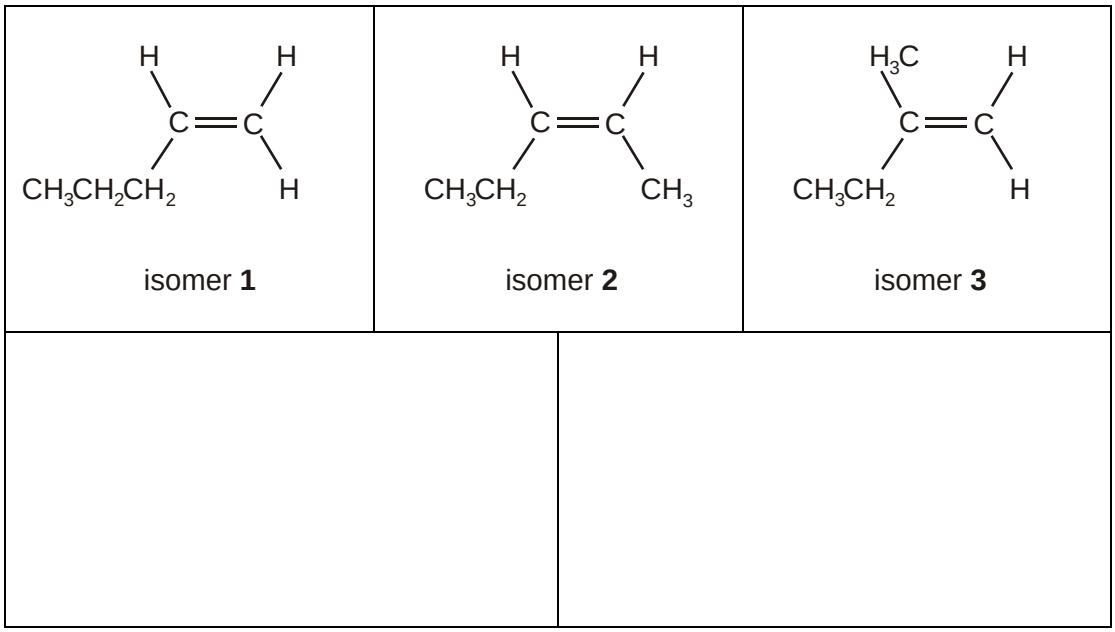
47. (a) Many organic molecules show structural isomerism. State what is meant by the term *structural isomerism*.

.....

.....

[2]

(b) Isomers **1**, **2** and **3**, shown below, are unsaturated structural isomers of C_5H_{10}.



(i) Complete the boxes by drawing two other unsaturated structural isomers of C_5H_{10}.

[2]

(ii) Name isomer **3**.

.....

[1]

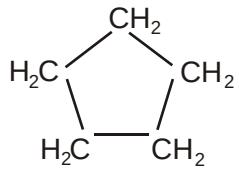
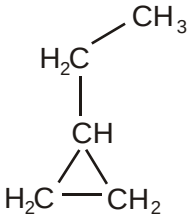
(iii) Draw the skeletal formula of isomer **2**.

[1]

[Total 6 marks]

48. There are several **cycloalkanes** that are structural isomers of C_5H_{10}.

(i) Complete the boxes by drawing two other structural isomers of C_5H_{10} that are also **cycloalkanes**.

			
Isomer **L**		**ethylcyclopropane**	

[2]

(ii) Name isomer **L** drawn in (i).

.....

[1]

(iii) Draw the skeletal formula of isomer **L**.

[1]

[Total 4 marks]

49. Isomer **L**, C_5H_{10}, reacts with CI_2 in the presence of UV light to produce the organic product $C_5\mathbf{H}_gCI$. The reaction takes place in three stages: initiation, propagation and termination.

(i) The reaction is initiated by the fission of CI_2. State the type of fission involved.

.....

[1]

(ii) Write an equation to illustrate the fission of CI_2 in (i).

.....

[1]

(iii) The fission of CI_2 leads to a chain reaction involving two propagation steps. Complete the equations for the two propagation steps.

C_5H_{10} + ... → $\bullet C_5H_9$ + ...

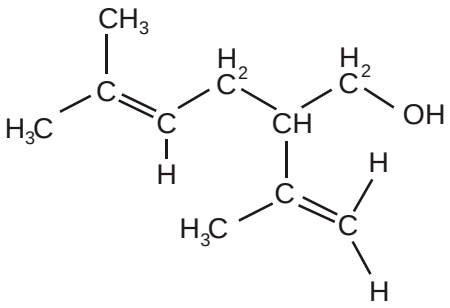
[1]

$\bullet C_5H_9$ + ... → ..... + ...

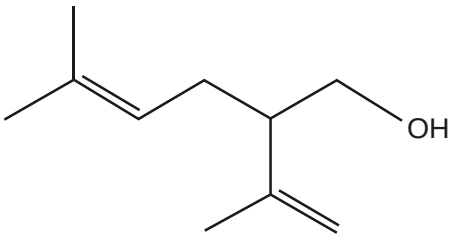
[1]

[Total 4 marks]

50. Lavandulol, $C_{10}H_{18}O$, is a fragrant oil which is found in lavender. The structural and the skeletal formulae of lavandulol are shown below.



structural formula



skeletal formula

(a) (i) Identify **two** different functional groups in lavandulol.

..... and .....

[2]

(ii) Why does lavandulol **not** have *cis-trans* isomerism?

.....

.....

[1]

(b) Lavandulol, $C_{10}H_{18}O$, also reacts with bromine to form a saturated organic product.

State what you would see in this reaction and deduce the molecular formula of the organic product.

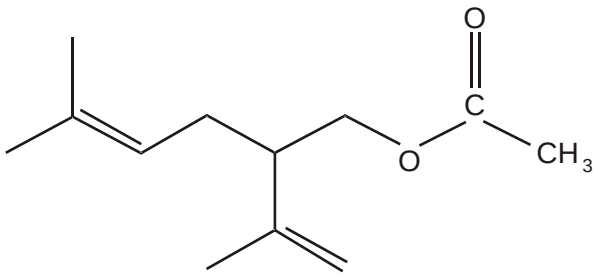
observation .....

[1]

molecular formula .....

[2]

(c) Lavandulol could be converted into an ester **X**, which is also found in lavender oil.



ester **X**

State a reagent and a catalyst that could be used to form ester **X** from lavandulol.

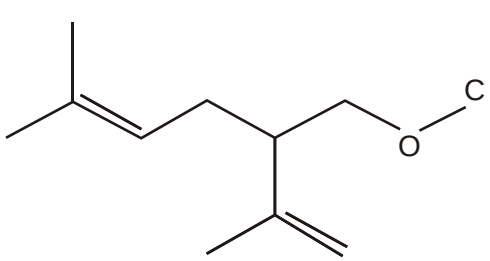
reagent .....

[1]

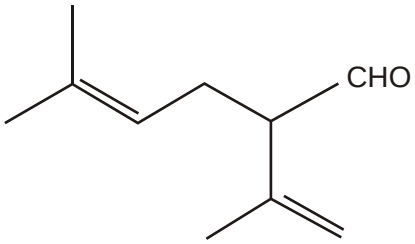
catalyst .....

[1]

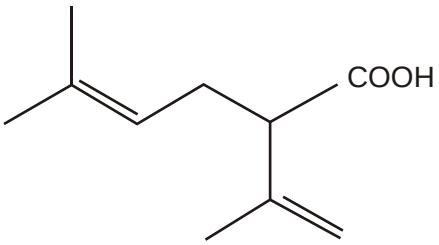
(d) Lavanduloi can be oxidised to produce either compound **Y** or compound **Z**.



lavandulol
$C_{10}H_{18}O$



compound **Y**
$C_{10}H_{16}O$



compound **Z**
$C_{10}H_{16}O_2$

(i) Write a balanced equation for the oxidation of lavandulol to produce compound **Z**. Use the molecular formulae given above and use [O] to represent the oxidising agent.

.....

[2]

(ii) An infra-red spectrum of either compound **Y** or compound **Z** was obtained and was found to contain an absorption between 1680 – 1750 cm^{-1}. However, there was no broad absorption between 2500 – 3300 cm^{-1}.

By referring to your *Data Sheet*, use this information to deduce whether the infra-red spectrum was of compound **Y** or of compound **Z**. Show your reasoning.

The infra-red spectrum was of compound ..... because .....

.....

.....

.....

[2]

[Total 12 marks]

51. In this question, one mark is available for the quality of written communication.

Alkanes can be separated from crude oil because they have different boiling points. The table below shows the boiling points of some alkanes.

alkane	boiling point/°C	M_r
ethane	–89	30
propane	–42	44
butane	0	58
pentane	36	72
2-methylbutane	28	72
2,2-dimethylpropane	10	72

Explain the variation in boiling points of the alkanes shown.

[5]

Explain why, in industry, alkanes such as octane are processed by isomerisation.

[3]

Illustrate your answers by referring to suitable examples. Write equations where appropriate.

Quality of Written Communication [1]

[Total 9 marks]