

SECTION A

Answer **all** questions in the spaces provided.

1. Complete the table below by putting a tick (✓) in the boxes that correctly describe graphite. [1]

<i>Conducts electricity</i>		<i>Melting temperature</i>		<i>Bonding</i>	
Yes	No	High	Low	Covalent	Ionic

2. (i) Give the equation for the reaction of barium metal with water. [1]

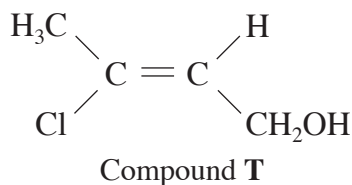
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- (ii) The solution obtained in (i) contains barium ions.
State a reagent that would be added to this solution to show the presence of barium ions, giving the result of the test.

Reagent [1]

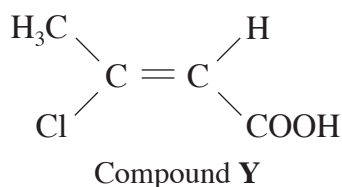
Observation [1]

3. (i) Explain why Compound **T** has E-Z (trans-cis) isomers. [1]



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- (ii) State a reagent, used in acid solution, that reacts with Compound **T** to give Compound **Y**. [1]



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(iii) State the **type** of reaction occurring in part (ii). [1]

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(iv) The empirical formula of a substance is $C_4H_5ClO_2$.
State what additional information is needed so that its molecular formula can be found. [1]

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4. There is continued debate about the safety of adding fluoride ions to drinking water.

(i) Give the **ionic** half equation for the formation of fluoride ions from fluorine gas. [1]

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(ii) Explain why there is a strong tendency for fluorine to form fluoride ions. [1]

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Section A Total [10]

7. (a) (i) Petroleum (crude oil) is largely a mixture of alkane hydrocarbons. The first stage of the refining process is fractional distillation. State what is meant by fractional distillation. [1]

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- (ii) One of the alkane hydrocarbons has the skeletal formula shown below.



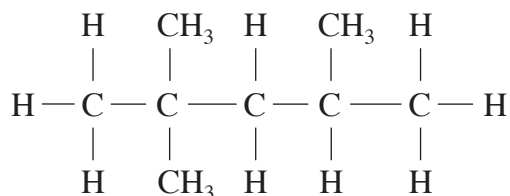
Give the molecular formula of this hydrocarbon. [1]

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- (iii) The next stage of petroleum refining is the cracking of some fractions. State what is meant by the term *cracking* and explain why this is done. [2]

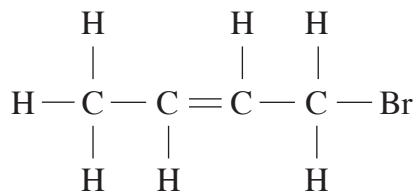
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- (iv) For effective combustion of petrol in motor vehicles, branched chain isomers are needed. One of these is 2,2,4-trimethylpentane.



Write the displayed formula (showing all the bonds) for the **straight chain isomer** of 2,2,4-trimethylpentane. [1]

8. (a) As part of a project, two students were asked to report on tests for functional groups present in the compound below.



Nia reported that, in testing for the $\text{C} = \text{C}$ group,

- aqueous bromine should be added to the compound and if the test is positive, the colour of the mixture changes from purple to colourless;
- the name of the compound formed in this test is 2,3,4-tribromobutane.

- (i) Correct the two mistakes in her report.

I. [1]

II. [1]

David reported that, in testing for the $\begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} - \text{Br}$ group,

- dilute hydrochloric acid should be added to the compound;
- aqueous silver nitrate should then be added;
- you should then see a cream precipitate that dissolves completely in dilute aqueous ammonia.

- (ii) I. State what chemical should be added before adding any acid. [1]

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II. Why is it wrong to use dilute hydrochloric acid? [1]

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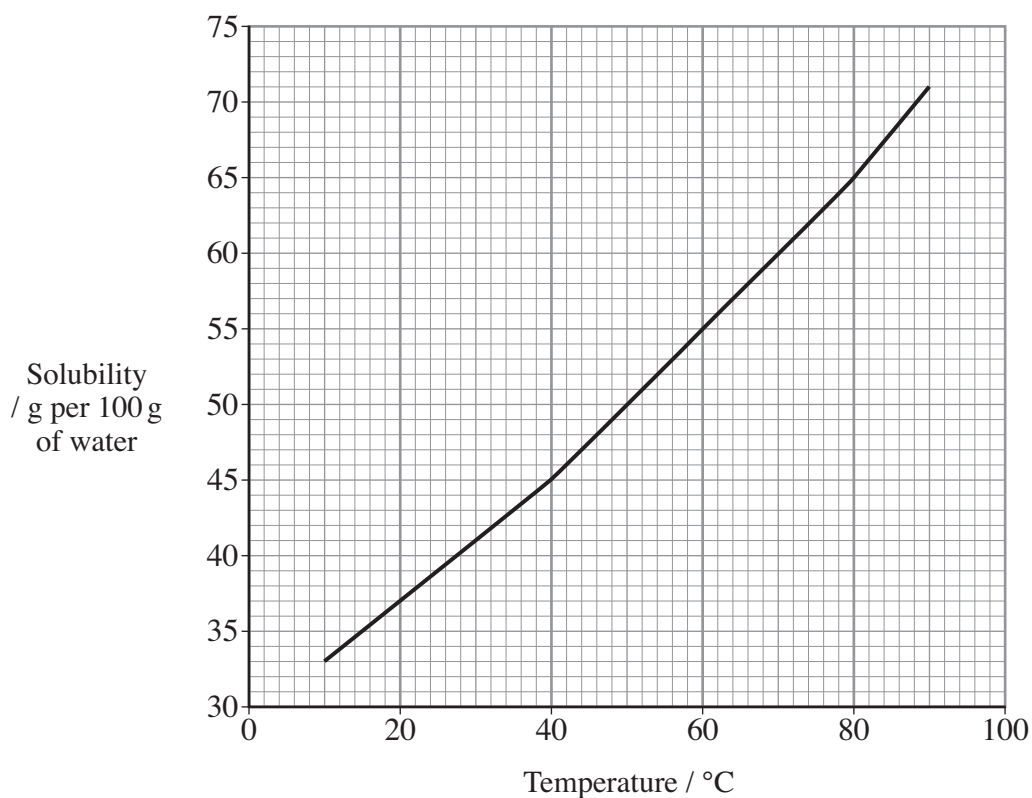
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III. State the error in the third statement. [1]

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4. Using **outer** electrons only, draw a dot and cross diagram to show the bonding in sodium oxide. Show the charges on the ions formed. [2]

5. The solubility curve for ammonium chloride is shown below.



Calculate the mass of ammonium chloride that dissolves in 50 g of water to form a saturated solution at 30°C. [2]

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6. Draw the skeletal formula of 2-chloro-3-methylhexane. [1]

Section A Total [10]

SECTION B

Answer **all** the questions in the spaces provided.

7. Petroleum, which is a mixture of hydrocarbons, is an important source of chemicals. These chemicals can be obtained by fractional distillation and further processing such as cracking and isomerisation.

- (a) During fractional distillation, explain why hydrocarbons containing few carbon atoms distil at lower temperatures than hydrocarbons with many carbon atoms. [3]

QWC [1]

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- (b) Pentane is one of the hydrocarbons obtained from petroleum.

- (i) Name the homologous series of which pentane is a member. [1]

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- (ii) Pentane has two structural isomers.

- I. Explain the meaning of the term *structural isomer*. [2]

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- II. Draw the displayed formulae of the **structural isomers** of pentane and name them. [4]

Isomer 1

Isomer 2

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(c) State what is meant by the term *cracking* and explain why this process is important. [2]

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Total [13]

9. (a) Compound **A** contains carbon, hydrogen and oxygen only. It has a molar mass of 88.1 g mol^{-1} . Quantitative analysis of the compound shows that its percentage composition by mass contains 54.5% carbon and 9.10% hydrogen. Calculate both the empirical and molecular formulae of compound **A**. [4]

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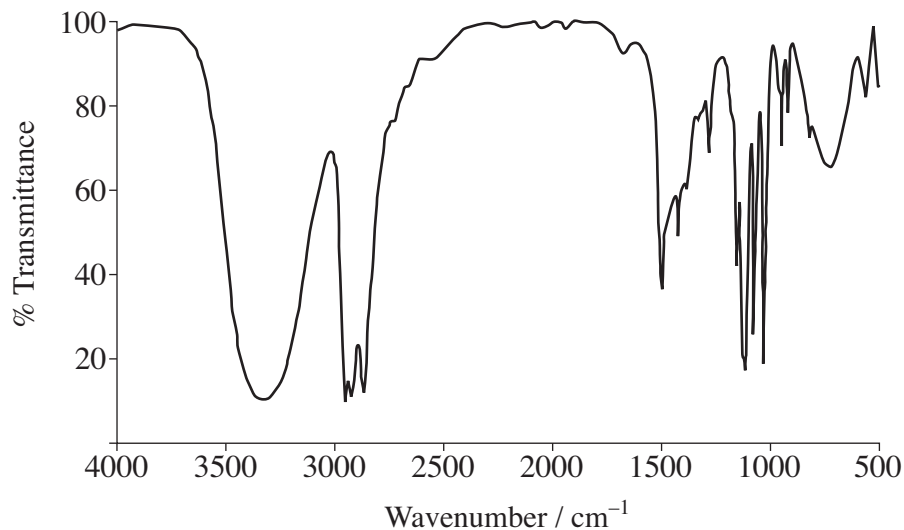
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- (b) Propan-1-ol has the infrared spectrum below.



- (i) Using the data sheet, state how this spectrum confirms which functional group is present in propan-1-ol. [1]

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- (ii) Propan-1-ol can be completely oxidised to form compound **B**. Name compound **B** and state how you would expect its infrared spectrum to differ from that of propan-1-ol. [2]

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- (c) Propan-1-ol can also form propene by a dehydration reaction. Name a suitable reagent for this reaction. [1]

- (d) Describe a test, including reagents and expected observations, to show that propene contains a C = C double bond. [2]

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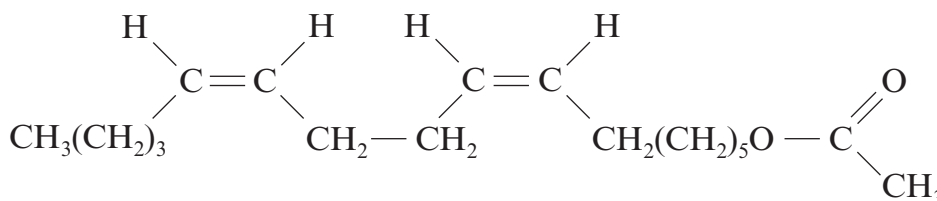
- (e) Propene can be polymerised to form poly(propene).
Give the formula of the repeating unit in poly(propene). [1]

- (f) Substituted alkenes can also be polymerised to give useful polymers.
Name an important polymer formed from a substituted alkene. [1]

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Total [12]

3. The formula for an attraction pheromone for the pink bollworm is shown below.



- (i) State a suitable catalyst for the hydrogenation of the $\text{C}=\text{C}$ bonds present. [1]

- (ii) This pheromone molecule contains two $\text{C}=\text{C}$ bonds which both have the Z (cis) configuration. Explain why an alkene can exist as either an E (trans) or a Z (cis) isomer. [1]

4. The relative molecular mass of a **branched-chain** alkane is 72.

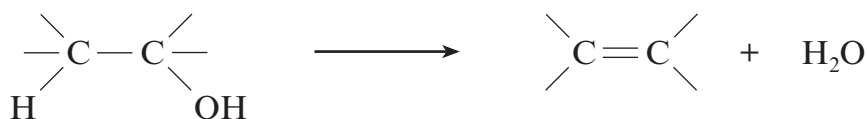
Alkanes have the general formula $\text{C}_n\text{H}_{2n+2}$.

- (i) State the **molecular** formula of the alkane. [1]
- (ii) Draw one **displayed** formula of this alkane. [1]

5. Use the words ‘increases’ or ‘decreases’ to complete the sentence below. [1]
 Each word can be used once, more than once or not at all.

As the hydrocarbon chain length in carboxylic acids increases, the boiling temperature and the solubility in water

6. State the type of reaction occurring during this chemical change. [1]



Total Section A [10]

Turn over.

9. (a) Methane reacts with gaseous chlorine giving chloromethane and hydrogen chloride.



In a report of this reaction, a student came across a number of terms. Illustrating your answer with an equation in **each** case, state what is meant by

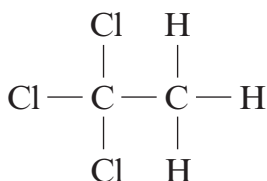
- (i) homolytic fission, [2]

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- (ii) a propagation stage. [2]

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- (b) Ethane reacts with chlorine in a similar way to methane. One of the products is 1,1,1-trichloroethane.



- (i) The manufacture and use of 1,1,1-trichloroethane is now restricted because of its adverse effects on the ozone layer. However, the corresponding fluoro-compound 1,1,1-trifluoroethane does not cause environmental problems in the ozone layer.

Explain why only the chloro-compound has these adverse effects. [2]

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10. The reaction of methane with chlorine gives a wide array of products including chloromethane, dichloromethane, trichloromethane, tetrachloromethane and ethane. Most of these products are liquids, with the boiling temperatures increasing as the number of chlorine atoms increases. This reaction only occurs in the presence of ultraviolet light.

(a) Give a balanced equation for the initiation stage of this reaction. [1]

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(b) Suggest a suitable method for separating the liquid mixture formed in this reaction to isolate pure samples of the separate products. Explain why you have chosen this method. [2]

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(c) Under similar conditions, pentane can be used to produce 1-chloropentane.

(i) Explain how decane, $C_{10}H_{22}$, could be produced as one of the products of this reaction. [2]

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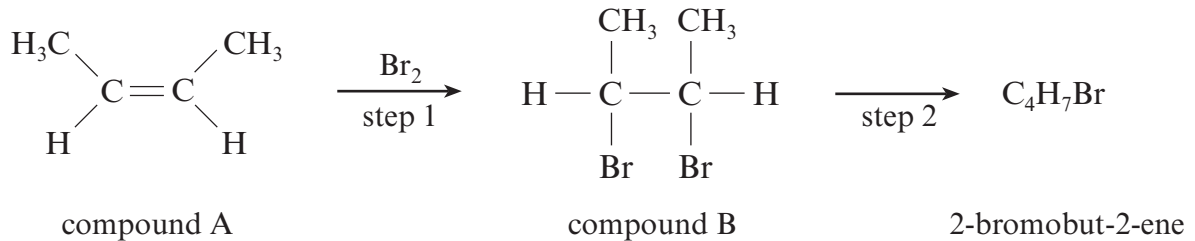
(ii) Warming 1-chloropentane with aqueous sodium hydroxide produces pentan-1-ol. Use the infrared absorption frequencies given in the data sheet to explain how you could check spectroscopically that this reaction had converted **all** the 1-chloropentane into pentan-1-ol. [2]

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8. Compound A can be converted to 2-bromobut-2-ene in two steps:



- (a) (i) Compound A exhibits *E-Z* isomerism. Explain why this type of isomerism is possible in this molecule but not in compound B. [2]

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- (ii) The 2-bromobut-2-ene produced in this reaction is a mixture of two isomers. Draw the **displayed formula** (showing all the bonds) for *E*-2-bromobut-2-ene. [2]

- (b) During step 1, compound A is bubbled through bromine water to produce a layer of compound B which does not mix with water.

- (i) Give the colour change that would be noted during step 1. [1]

- (ii) **Name** compound B. [1]

- (iii) Explain why compound B will not dissolve in water. [1]

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- (iv) Step 2 is performed using similar reagents and conditions to those used in the production of ethene from bromoethane. Give the reagents and conditions required for this reaction. [2]

Reagents

Conditions

- (c) (i) Compound A also reacts with hydrogen bromide, HBr. Give the mechanism for this reaction.

You may assume compound A reacts in a similar way to propene. [4]

- (ii) Classify the mechanism of the reaction in (c)(i) above. [1]

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Total [14]

SECTION B

Answer **all** questions in the spaces provided.

7. Petroleum is a mixture of saturated hydrocarbons, some of which are structural isomers of one another. These are separated into fractions by distillation. Some of these fractions are used to make important chemicals such as ethene while others are used as fuels.

(a) Explain what is meant by a *saturated* hydrocarbon. [1]

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(b) Propane and heptane, C_7H_{16} , are two of the hydrocarbons obtained from petroleum.

(i) Write a balanced equation for the complete combustion of propane. [2]

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(ii) 3-Ethylpentane is a structural isomer of C_7H_{16} .
Draw the **skeletal** formula of this isomer. [1]

(c) Name and briefly describe the process by which ethene is produced from a petroleum fraction. [2]

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(d) Describe the structure of and bonding in an ethene molecule.

[3]
QWC [1]

You may use a diagram in your answer.

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(e) Name the type of reaction mechanism occurring when ethene reacts with aqueous bromine and draw the displayed formula of the product formed. [2]

Type of reaction mechanism

Displayed formula

(f) Ethene can be used as the starting material in the industrial preparation of ethanol. The conditions for the reaction are a temperature of 300 °C and a pressure of 60-70 atm.

Name the catalyst used in this reaction. [1]

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(g) Another way to prepare ethanol is by the fermentation of glucose.



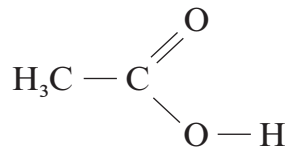
Calculate the minimum mass of glucose required to give 230 g of ethanol. [3]

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Total [16]

(c) The crystal structure of ethanoic acid shows that the molecules are found in pairs with hydrogen bonds between each pair.

(i) Complete the diagram to show how **two** molecules of CH₃COOH can join together through hydrogen bonding. [1]



(ii) Describe what is meant by *hydrogen bonding*. [3]
QWC [1]

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(d) Ethanoic acid can be formed from the oxidation of ethanol by potassium dichromate(VI).

(i) State the conditions required for this reaction to take place. [1]

(ii) State what you would observe during the reaction. [1]

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(e) The boiling temperature of ethanol is 78 °C. Giving a reason in **both** cases, state how you would expect the boiling temperatures of the following compounds to differ from that of ethanol. [2]

Propane

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Butan-1-ol

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Total [13]

Turn over.

SECTION A

Answer all questions in the spaces provided.

1. 'Smart' alloys have an increasing importance in many applications. State how 'smart' alloys differ from other alloys in the way in which they act when used for a particular purpose. [2]

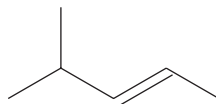
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2. A small piece of sodium metal is added to water. Give the equation for this reaction and suggest a pH value for the resulting solution. [2]

Equation

pH of solution

3. The skeletal formula of a hydrocarbon is shown below.



Give the **systematic name** of this hydrocarbon. [1]

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4. Police use a breathalyser to test motorists for the presence of alcohol.
- (a) An early type of breathalyser required the motorist to breathe into a tube that contained acidified potassium dichromate. The alcohol in their breath was oxidised to ethanal and ethanoic acid. State the colour change that occurred if the test was positive. [1]

..... to

- (b) Modern breathalysers use infrared spectroscopy to detect and measure the concentration of alcohol in breath. An absorption frequency at 2940cm^{-1} is used rather than the frequency caused by the O—H bond, as this is also present in water.

- (i) Use the Data Sheet to identify the bond that causes the absorption at 2940cm^{-1} . [1]

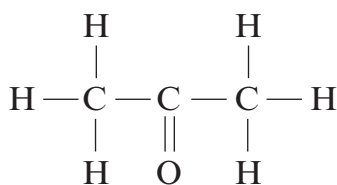
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(ii) State which **one** of the following correctly describes any change in the absorption at 2940 cm^{-1} if the concentration of alcohol in the breath increases. [1]

- A the frequency decreases to 2900 cm^{-1}
 B the frequency increases to 3000 cm^{-1}
 C the intensity of the absorption at 2940 cm^{-1} increases
 D the absorption covers the range 2900 to 3000 cm^{-1}

(iii) A false breathalyser reading can be given by a person who exhales propanone, as a result of an illness.



propanone

Identify the bond that would distinguish the infrared spectrum of propanone from that of an alcohol. Using the Data Sheet, state the absorption frequency of this bond. [1]

5. 'Superglue' is a liquid containing methyl 2-cyanopropenoate. In the presence of moisture this alkene rapidly polymerises, in a similar way to ethene. Complete the table showing the structure of the repeating unit. [1]

Monomer	Repeating unit
$ \begin{array}{ccc} \text{H} & & \text{CN} \\ & \diagdown & / \\ & \text{C} = \text{C} & \\ & / & \diagdown \\ \text{H} & & \text{COOCH}_3 \end{array} $	

Total Section A [10]



(d) A common reaction of the halogens is the formation of the anion, X^- .

(i) State, in terms of electronic structure, why this occurs. [1]

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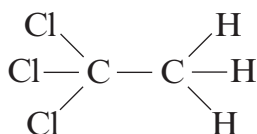
(ii) Give a reason why the tendency to form the X^- ion decreases down the halogen group. [1]

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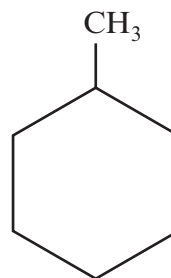
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(e) One compound previously used in correction fluid was 1,1,1-trichloroethane, but this has been replaced by compounds such as methylcyclohexane, which has a much less adverse effect on the environment.



1,1,1-trichloroethane



methylcyclohexane

(i) Explain, in terms of bond strengths, why 1,1,1-trichloroethane has an effect on the ozone layer but methylcyclohexane does not. [2]

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(ii) Hept-1-ene is an isomer of methylcyclohexane.



Describe a chemical test that gives a positive result for hept-1-ene but not for methylcyclohexane. [2]

Reagent(s)

Observation



(iii) Radicals are involved in the cracking of petroleum fractions at 600 °C.

One of the products obtained by cracking is an alkane of molar mass 100 g.
Deduce the molecular formula of this alkane.

[1]

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(iv) Radicals are produced by the homolytic bond fission of a covalent bond.
State what is meant by the term *homolytic bond fission*.

[1]

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Total [13]



9. During 2010 a serious leak of petroleum (crude oil) occurred in the Gulf of Mexico. This loss of millions of litres of petroleum caused an environmental and ecological disaster.

- (a) Petroleum consists largely of a mixture of alkanes that do not dissolve in sea water but form a surface layer. The main reason that these alkanes cannot dissolve in water is because they are unable to hydrogen bond with water. Explain what is meant by *hydrogen bonding* and use this to explain why alkanes do not dissolve in water. [4]
QWC [1]

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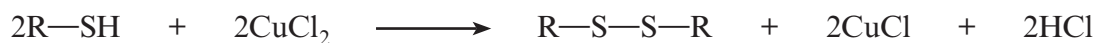
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- (b) (i) Some of the leaking oil was collected by tankers and taken to oil refineries. The petroleum was then separated into fractions by the process of fractional distillation. Describe what is meant by *fractional distillation*. [2]

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- (ii) One of the fractions was then further refined into fuel for vehicles. During refining, most of the sulfur compounds present in the fuel are removed in order to reduce the amount of oxides of sulfur released in exhaust gases. One stage in the process is to convert unpleasant-smelling thioalcohols (R—SH) into disulfides (R—S—S—R) using copper chloride, CuCl₂.



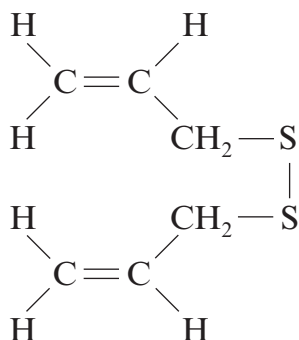
Explain, using the oxidation states (numbers) of copper, why copper chloride, CuCl₂, is reduced in this reaction. You should assume that the oxidation state of chlorine is -1. [2]

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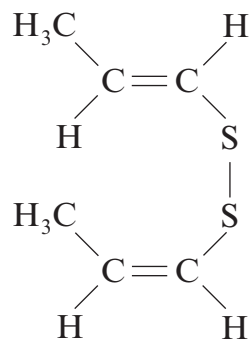
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(c) Compounds **A** and **B** are organic compounds of sulfur found naturally in some foods.



compound **A**
found in garlic



compound **B**
produced on cooking onions

- (i) These two compounds are structural isomers. State what is meant by the term *structural isomer*. [1]

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- (ii) Explain why only compound **B** can exist as E-Z isomers. Your answer should comment on the atoms/groups involved and the reason why these give rise to E-Z isomerism. [2]

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- (iii) Compound **A** is sold by the chemical suppliers at £48.00 for 100 g. The material sold is only 73% pure but this is satisfactory for the purposes needed. Calculate the cost of 1 mol of compound **A**, which has a molecular formula $\text{C}_6\text{H}_{10}\text{S}_2$. [2]

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Total [14]



SECTION A

Answer **all** questions in the spaces provided.

1. The straight-chain alkane containing 19 carbon atoms is called nonadecane.

(a) Write the **molecular** formula of nonadecane.

[1]

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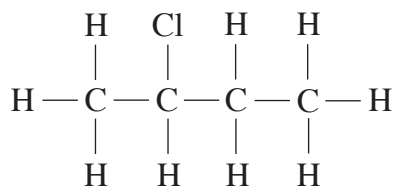
(b) When nonadecane is cracked, one of the smaller products formed can be octane.

Write an equation to show the cracking of nonadecane to produce octane.

[1]

2. Name the compound whose formula is shown below.

[1]



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3. Draw the displayed formula for (Z)-2-iodobut-2-ene.

[1]

4. Chlorine forms a series of oxides that react with water.

Suggest a pH value for the solution formed when an oxide of chlorine reacts with water.

[1]

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SECTION B

Answer **all** questions in the spaces provided.

7. Boron, B, has the atomic number 5 and it forms a fluoride, BF_3 .

(a) BF_3 is used to initiate certain types of addition polymerisation of unsaturated compounds.

(i) Ethene is an example of an unsaturated compound. Describe the bonding between the carbon atoms in ethene. You may wish to draw a labelled diagram. [2]

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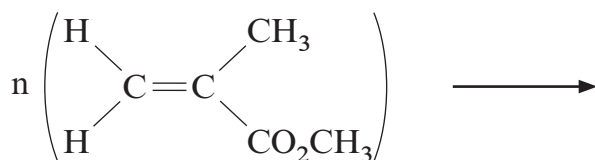
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(ii) State what is meant by *polymerisation*. [1]

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(iii) A colourless plastic used to cover lights is made from methyl methacrylate by a process similar to the polymerisation of ethene. Complete the equation by giving the formula of the repeating unit. [1]



(iv) Addition polymerisation is used to make synthetic rubber. The molecular formula of the monomer used is $\text{C}_4\text{H}_5\text{Cl}$. What is the **empirical** formula of the synthetic rubber polymer? [1]

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- (b) Butene, C_4H_8 , is an alkene. Draw **displayed** formulae for three **straight-chain** isomers of C_4H_8 . [3]

Total [9]



- (c) Describe how the structures of sodium chloride and caesium chloride are similar and how they are different. Give a reason for any difference.
You may include a diagram if you consider it helpful. [3]

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- (d) When hydrogen bromide, HBr, is added to propene, C₃H₆, two different products are possible. In practice, however, more of one of the products is formed.
Explain why more of one product is formed.

You should:

- state the type of reaction involved
- identify the two possible products
- state which of the two products predominates
- give the reason why more of this product is formed.

[4]
QWC [1]

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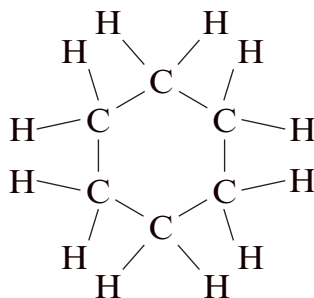
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Total [16]



4. Cyclohexane is an example of a hydrocarbon containing a ring of carbon atoms. Its structure is shown below.

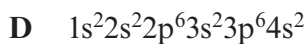
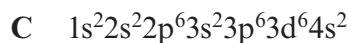
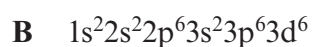
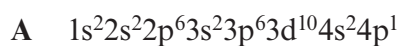


Give the **empirical** formula of this compound.

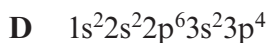
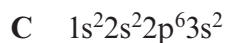
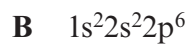
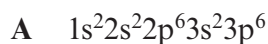
[1]

.....

5. (a) Write the letter corresponding to the correct electronic structure of an atom that is a member of the *d*-block in the box below. [1]



- (b) Write the letter corresponding to the electronic structure of the atom with the highest first ionisation energy in the box below. [1]





9. Chloromethane can be produced by the chlorination of methane gas.

(a) During the initiation stage of this process, chlorine free radicals are produced.

(i) Give the condition(s) required for this initiation stage. [1]

.....

(ii) State what is meant by a *free radical*. [1]

.....

.....

(b) Write the equation(s) for the propagation stage(s) to produce chloromethane starting with methane and chlorine free radicals. [2]

.....

.....

.....

(c) Apart from chloromethane, a range of other compounds are produced in small amounts during the reaction.

(i) One of the compounds produced in the reaction is ethane. Show how this compound is produced. [1]

.....

.....

(ii) Another of the compounds produced contains 24.3% carbon, 4.1% hydrogen and 71.6% chlorine by mass. Calculate the **empirical** formula of this compound. [2]

Empirical formula



12. But-2-ene is a useful starting material for the production of synthetic rubber.

(a) But-2-ene can be produced from crude oil by fractional distillation and then cracking.

(i) Explain why fractional distillation can be used to separate molecules with different numbers of carbon atoms. [1]

.....
.....

(ii) Write the equation for a cracking reaction that produces but-2-ene from decane, $C_{10}H_{22}$. [1]

.....
.....

(b) Bromine solution can be used to distinguish between but-2-ene and butane.

(i) Give the colour **change** that would be expected when bromine solution is added to but-2-ene. [1]

.....

(ii) In a similar reaction hydrogen bromide reacts with propene.

Draw the mechanism of the reaction of propene with hydrogen bromide indicating clearly all charges and the movement of electrons. [3]



- (iii) Propene can be produced from the product in part (ii) by using sodium hydroxide.
Give the condition(s) required for this reaction. [1]

.....
.....

- (c) But-2-ene can exist as *E*- and *Z*-isomers.

- (i) Explain why but-2-ene can form *E*- and *Z*-isomers whilst propene and butane cannot. [2]

.....
.....
.....
.....

- (ii) Draw the **skeletal** formula for *Z*-but-2-ene. [1]

- (d) In industry, butan-2-ol can be produced from but-2-ene. This uses the same reagent(s) and condition(s) as the production of ethanol from ethene.

- (i) Give the reagent(s) and condition(s) used for this reaction. [2]

Reagent(s)

Condition(s)

- (ii) Explain how infrared spectroscopy can be used to distinguish between butan-2-ol and but-2-ene. [1]

.....
.....
.....

Total [13]

Total Section B [70]

END OF PAPER



SECTION A

Answer **all** questions in the spaces provided.

1. State which **one** of the following formulae represents an **alkane**. [1]



2. In order to form a magnesium atom, a magnesium ion must: [1]

A gain one electron

B gain two electrons

C lose two electrons

D lose two protons

3.

ammonium nitrate

calcium chloride

magnesium carbonate

potassium hydroxide

sodium sulfate

From the list of compounds above choose one that

(a) gives a brick-red flame test, [1]

.....

(b) is insoluble in water, [1]

.....

(c) in solution forms a white precipitate with aqueous barium chloride. [1]

.....



4. Classify the following species as electrophile, nucleophile or radical by completing the table below. [2]

Species	Cl•	NH ₃
Classification		

5. Nanoscience involves the study of very small particles. Nano-sized silver particles have antibacterial and antifungal properties. Give **one** use of nano-sized silver particles. [1]

.....

.....

6. State and explain which two of the following elements combine to form the **most** ionic bond. [2]

chlorine magnesium potassium sulfur

.....

.....

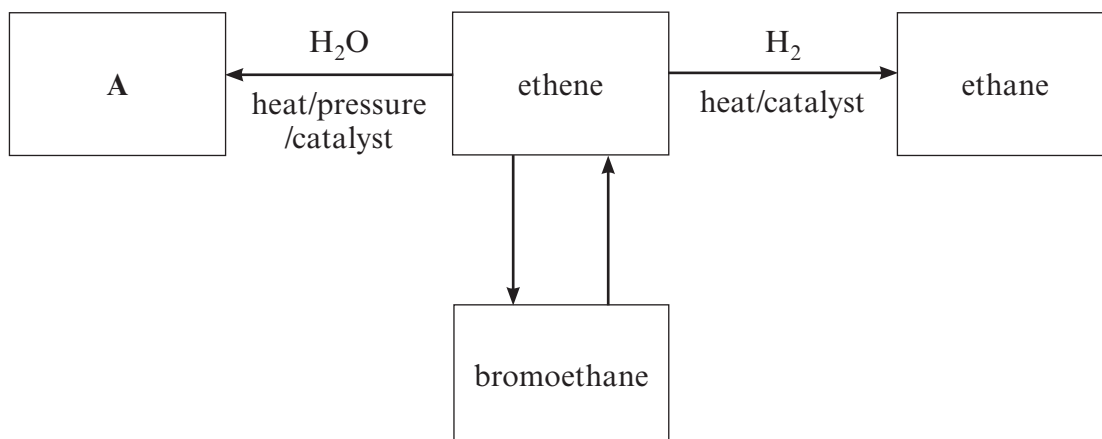
Total Section A [10]



SECTION B

Answer **all** questions in the spaces provided.

7. (a) Ethene can be used to make many useful compounds. Study the reaction scheme shown below then answer the following questions.



- (i) Draw the **displayed** formula of compound **A**. [1]

- (ii) Name the catalyst used in the conversion of ethene to ethane. [1]
-

- (iii) Name the reagent(s) and condition(s) necessary to convert bromoethane to ethene. [2]
-
-

- (iv) Classify the type of reaction taking place when ethene is formed from bromoethane. [1]
-



(b) In the same way that ethene can be polymerised to give the polymer poly(ethene), propene can form poly(propene).

(i) Draw the repeating unit in poly(propene). [1]

(ii) Calculate how many monomer units are joined together to give poly(propene) if it has a relative molecular mass of 1.05×10^6 . [2]

Number of monomer units =

(c) (i) A bromoalkane was shown to contain 22.0% carbon and 73.4% bromine by mass. Calculate the **empirical** formula of the compound. [3]

Empirical formula

(ii) State what other information would be needed to be able to deduce the **molecular** formula of this compound. [1]

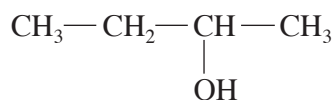
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Total [12]



(c) Butan-1-ol has the molecular formula $C_4H_{10}O$.

Two other isomers of $C_4H_{10}O$ are butan-2-ol and methylpropan-1-ol.



butan-2-ol

(i) Draw the **skeletal** formula of methylpropan-1-ol. [1]

(ii) Name the type of isomerism shown by these isomers. [1]

.....

(iii) Butan-1-ol can be oxidised by acidified potassium dichromate(VI) to form butanoic acid. State what you would **observe** during this reaction. [1]

.....

(iv) Butan-1-ol can also be dehydrated. Name a suitable dehydrating agent and write an equation for this reaction. [2]

Dehydrating agent

Equation

.....



9. (a) Petroleum is one of the most important resources in the world. It is estimated that we consume about 88 million barrels each day. Describe the general chemical composition of petroleum. [1]

.....
.....

- (b) Butane is a useful fuel obtained from petroleum. Write an equation for the complete combustion of butane. [1]

.....

- (c) Another fuel is methane. Give the $\text{H}-\hat{\text{C}}-\text{H}$ bond angle in a methane molecule. [1]

.....

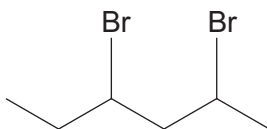
- (d) Explain why the $\text{H}-\hat{\text{O}}-\text{H}$ bond angle in water is less than the $\text{H}-\hat{\text{C}}-\text{H}$ bond angle in methane. [3]

QWC [1]

.....
.....
.....
.....
.....



4. (a) State the **molecular** formula of compound **L** that has the skeletal formula shown.



..... [1]

- (b) Compound **L** reacts with alcoholic sodium hydroxide solution to give hex-1,3-diene as one of the products.

State the type of reaction that has occurred. [1]

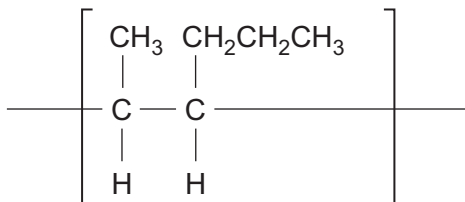
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5. In industry, ethanol is produced by reacting ethene with water / steam.

State the conditions of temperature and pressure used for this reaction. [1]

Temperature °C Pressure atm.

6. A section of an addition polymer is shown below.



State the **systematic name** of the monomer that gives this polymer. [1]

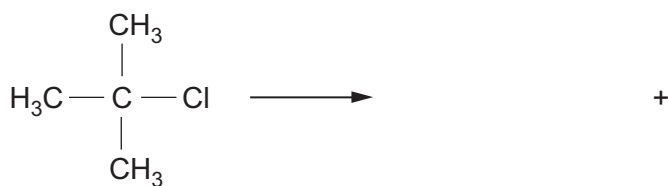
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7. (a) State the meaning of the term *heterolytic fission*.

[1]

Examiner
only

- (b) Complete the equation below to show the products of the heterolytic fission of the C—Cl bond in 2-methyl-2-chloropropane. [1]

**Total Section A [10]**

SECTION B

Answer all questions in the spaces provided.

8. Sulfur difluoride dioxide (sulfuryl fluoride), SO_2F_2 , is used as a gaseous insecticide to control termite infestations in wooden houses.

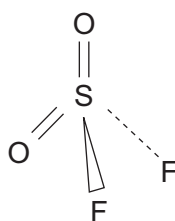
- (a) It can be produced by reacting together sulfur dioxide and fluorine.



Use the oxidation numbers of sulfur to show that sulfur has been oxidised in this reaction. In your answer you should state how changes in oxidation number are related to oxidation.

[2]

- (b) Sulfuryl fluoride is a tetrahedral molecule where the sulfur atom has no lone pairs of electrons.



Use the valence shell electron pair repulsion theory (VSEPR) to state why sulfuryl fluoride has this shape.

[1]

- (c) Ammonia reacts with sulfuryl fluoride to give sulfamide, $\text{SO}_2(\text{NH}_2)_2$. During this reaction ammonia reacts as a nucleophile.

- (i) State the meaning of the term *nucleophile*.

[1]

- (ii) Give the **formula** of another nucleophile.

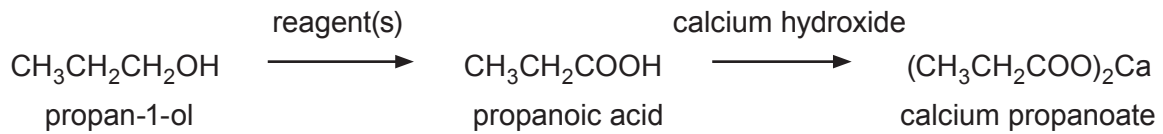
[1]

- (iii) Organic reaction mechanisms involving nucleophiles (for example the conversion of 1-chlorobutane into butan-1-ol) often use a curly arrow ().

State what this curly arrow represents.

[1]

- (b) Calcium propanoate, $(\text{CH}_3\text{CH}_2\text{COO})_2\text{Ca}$, is added to bread to prevent mould formation. It can be made from propan-1-ol by the following reactions.



- (i) State the name of the reagent(s) used in the first stage. [1]

- (ii) Propanoic acid, in its liquid state, exists as a dimer, where two molecules of the acid bond together using hydrogen bonding.

Draw the structural formula of this dimer and show the hydrogen bonding between the two molecules. [1]

- (iii) In an experiment to make calcium propanoate, 50.0 cm^3 of a solution of propanoic acid of concentration 1.00 mol dm^{-3} was completely neutralised by calcium hydroxide.

- I Calculate the number of moles of propanoic acid used. [1]

..... mol

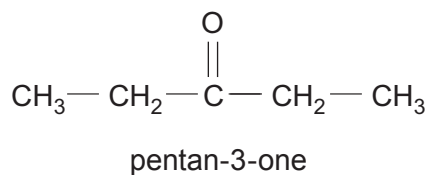
- II State the number of moles of calcium hydroxide needed to just react with all the propanoic acid. [1]

..... mol

- III Calculate the maximum mass of calcium propanoate ($M_r = 186$) which could be formed. [1]

..... g

- (iv) Calcium propanoate produces pentan-3-one when it is strongly heated.



Write the displayed formula of **two** structural isomers of pentan-3-one. [2]

- (c) A dicarboxylic acid, $\text{HOOC}-(\text{CH}_2)_n-\text{COOH}$, contains 49.3% of carbon and 43.8% of oxygen by mass. In both parts (i) and (ii) **show your working**.

- (i) Use these figures to find the ratio of carbon atoms to oxygen atoms in the acid. [2]

Ratio C : O

- (ii) Use this ratio to find the value of n in the formula of the acid.
You are reminded that 1 molecule of the acid contains four oxygen atoms. [1]

$n =$

Total [16]

12. (a) Petroleum (crude oil) is separated into useful parts by fractional distillation.

(i) Briefly describe how *fractional distillation* can be carried out. [2]

.....

.....

.....

(ii) A fraction is treated further to give a **branched-chain** alkane. The mass spectrum of this alkane shows a molecular ion, M^+ , at m/z 72.

Use this information to give the molecular formula and then suggest a displayed formula for this alkane. [2]

(b) Cracking is a process that is used in the petroleum industry to obtain smaller alkanes and alkenes from larger alkanes.

(i) State why this process of making smaller molecules is carried out. [1]

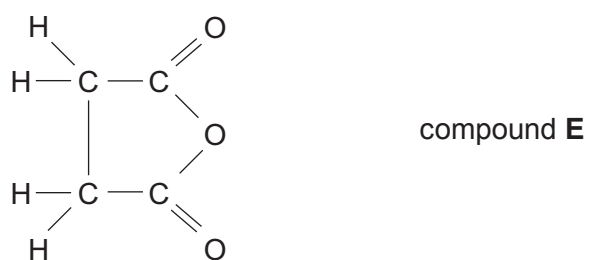
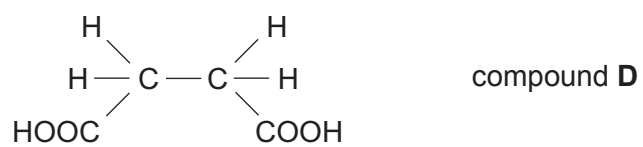
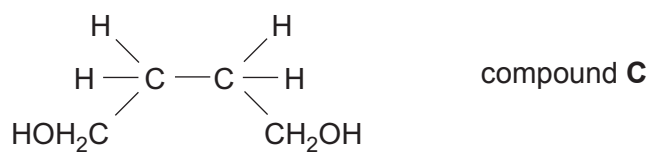
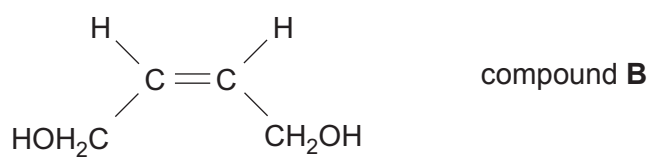
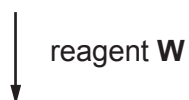
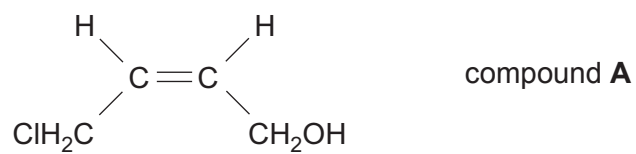
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(ii) Methane is one of the products when nonane, C_9H_{20} , is cracked. The other products are butane and butadiene, C_4H_6 .
Give an equation that represents this reaction. [1]

.....

(d) Study the reaction sequence below and then answer the questions that follow.



- (i) Compound **A** is a (*Z*)-isomer.

Write the displayed formula of the (*E*)-isomer of compound **A**.

[1]

- (ii) State the name of reagent **W** and the solvent in which it is dissolved.

[1]

- (iii) State the name of a catalyst used in the hydrogenation of compound **B** to produce compound **C**.

[1]

- (iv) The infrared spectra of compounds **D** and **E** are taken.

Use the Data Sheet to explain how the infrared spectra can be used to distinguish between compounds **D** and **E**.

[2]

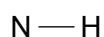
Total [14]

Total Section B [70]**END OF PAPER**

4. The table below gives the electronegativity values of some elements.

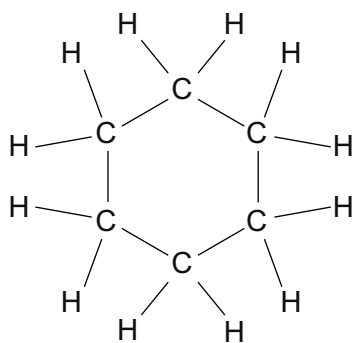
Atom	H	N	O	Al	Cl
Electronegativity value	2.1	3.0	3.5	1.6	3.0

- (a) Use the data in the table to identify any dipoles present in the following bonds. Mark their polarity clearly. [1]

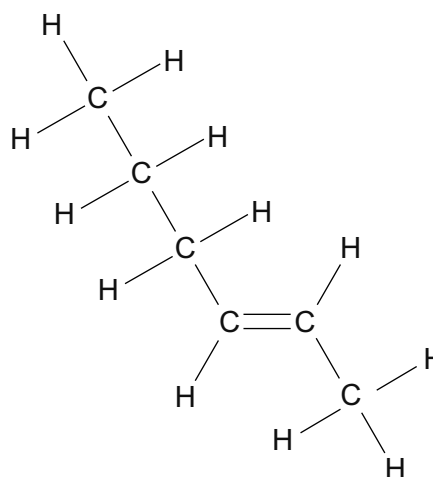


- (b) Use the data to give a reason why aluminium chloride is considered to be a covalent compound, while aluminium oxide is an ionic compound. [1]
-
-
-

5. Cyclohexane and hex-2-ene are isomers. Give a chemical test to distinguish between these two compounds. [2]



cyclohexane



hex-2-ene

Reagent(s)

Observations

.....



8. Crude oil is a complex mixture of hydrocarbons, with samples from different locations in the world having different compositions. The table below gives the composition of crude oil from two locations.

Fraction	Percentage by mass	
	Brent Crude	Gulf of Suez
petroleum gases	2.4	1.2
naphtha	19.1	13.6
kerosene	14.2	12.7
gas oil	20.9	18.7
residue	43.4	53.8

- (a) The different fractions are separated by fractional distillation. Explain why the different fractions have different boiling temperatures. [2]

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.....

- (b) The petroleum gases produced from crude oil can contain both propane and butane.
- (i) A barrel of Gulf of Suez crude oil has a mass of 145 kg. Assuming all the petroleum gas released from the oil is butane, calculate the volume that this gas would occupy at 1 atmosphere pressure. [3]
 [1 mol of gas occupies 24.0 dm³ under these conditions]

Volume = dm³

1092
010009



(ii) Propane can be chlorinated by a similar method to methane.

I Give the condition(s) required for the chlorination of propane. [1]

.....
II Write an equation for the initiation stage of the chlorination of propane. [1]

.....
III The chlorination of propane also produces hexane as a minor product.
Explain how this compound forms. [2]

.....
.....
.....



(c) Naphtha is used as a starting material for the production of alkenes, and these are then used to produce polymers such as poly(ethene). Discuss how poly(ethene) is produced, starting from naphtha. Your answer should include:

- An explanation of which of the two types of crude oil given would be more useful for producing alkenes.
- How the naphtha is converted into alkenes.
- An equation for the production of ethene from decane, an alkane with 10 carbon atoms.
- An explanation of what is meant by polymerisation.
- An equation for the polymerisation of ethene, clearly stating the type of polymerisation that is occurring.
- A different polymer in common use, with the structure of the monomer used in its production.

[6]

QWC [1]

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Total [16]



11. (a) Propene reacts with hydrogen bromide to give 2-bromopropane.

(i) Draw the mechanism for this reaction.

[3]

(ii) Explain why the product of this reaction is mainly 2-bromopropane rather than 1-bromopropane. [2]

.....

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