(b) Dichloromethane, CH_2Cl_2, has been an important material in many paint strippers.

(i) Describe how it can be made from chloromethane and chlorine in the presence of ultraviolet light.
Your answer should include:
• the type of bond fission occurring in the initiation stage;
• a description of the initiation stage including an equation;
• **two** equations representing the propagation stage;
• an equation for the termination stage giving dichloromethane. [6]

(QWC) [1]

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(ii) The mass spectrum of the products obtained by making dichloromethane in (i) shows a molecular ion peak at *m*/*e* 98. The compound giving this molecular ion contains two ^{35}Cl atoms in each molecule.
Suggest a molecular formula and a displayed (structural) formula for this compound, explaining how it might be formed. [3]

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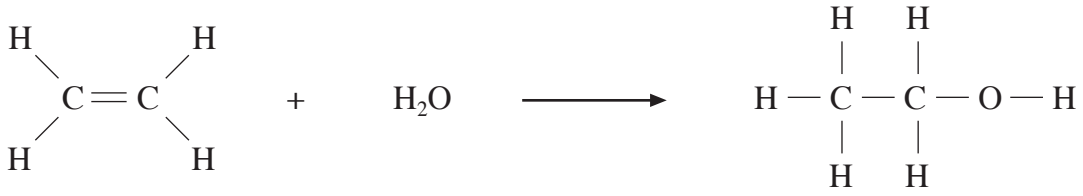
Total [15]

(c) The industrial preparation of ethanol from ethene is carried out at 300 °C in the presence of a catalyst.



(i) State the pressure used in this process ..... [1]

(ii) The **reverse** process is carried out by passing ethanol vapour over a catalyst.

I. State a catalyst that can be used ..... [1]

II. State the type of reaction that is occurring in this **reverse** process. [1]

.....

(d) (i) 1, 1, 1-Trifluoro-2-bromo-2-chloroethane (halothane) is used as a general anaesthetic. Write the displayed formula for this compound. [1]

(ii) State another use for halogenoalkanes. [1]

.....

(iii) One disadvantage of some halogenoalkanes, the CFCs, is that they cause damage to the ozone layer.
The table shows the relative ozone depletion potential (RODP) of some CFCs, taking CCl_3F as having a value of 1.0.

Compound	RODP
CHF_3	0.01
$CHC1F_2$	0.05
CCl_2F_2	0.86
CCl_3F	1.00
$CBrClF_2$	10.00

The carbon-halogen bond energies are shown below.

Bond	*Average bond enthalpy* / kJ mol^{-1}
C—Br	276
C—Cl	338
C—F	484

Use both tables to comment on how the C—halogen bond energies, and the number and type of halogen atoms per molecule, are related to their destructive effects on the ozone layer. [2]

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Total [14]

Section B Total [70]

Examiner only

8. *(a)* In 1928 an American engineer, Thomas Midgley, developed a CFC as a replacement for chloromethane and sulfur dioxide, which were in common use as refrigerants despite being toxic. He showed that the new compound was both non-flammable and non-toxic by inhaling it and using it to blow out a lighted candle.

(i) State the name of the group of compounds often abbreviated to CFC. [1]

.....

(ii) State another use to which CFCs have been put. [1]

.....

(iii) In the stratosphere, chloromethane breaks down to give chlorine radicals whereas fluoromethane does not break down.

I. Explain what the term ***radical*** means. [1]

.....

.....

II. Give a reason why chloromethane breaks down but fluoromethane does not. [1]

.....

.....

(iv) In the 1960s other halogenoalkanes such as $CBrF_3$ were developed as effective fire-fighting materials.

When $CBrF_3$ reacts with aqueous sodium hydroxide, bromide ions are produced. To test for the presence of these ions, dilute nitric acid has to be added first, followed by an appropriate reagent.

I. State why nitric acid has to be added. [1]

.....

II. Name the reagent that you would add to test for the bromide ions. [1]

.....

III. State what you would see after the addition of the reagent. [1]

.....

IV. Write an **ionic equation** for the reaction that confirms the presence of bromide ions. [1]

.....

Examiner only

(b) Draw the mechanism for the reaction of bromoethane and OH^-(aq). [3]

Assume the mechanism is the same as for the reaction of 1-chlorobutane and OH^-(aq).

(c) Bromoethane can also undergo an elimination reaction with OH^-.

(i) Name the organic product of this reaction. [1]

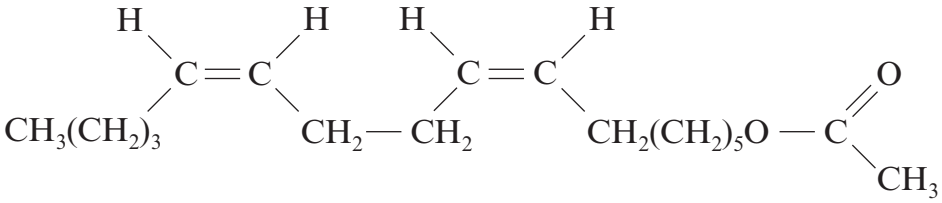
.....

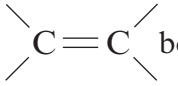
(ii) State the conditions required. [1]

.....

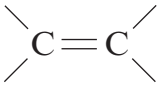
Total [13]

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



(i) State a suitable catalyst for the hydrogenation of the  bonds present. [1]

.....

(ii) This pheromone molecule contains two  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]

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.....

4. The relative molecular mass of a **branched-chain** alkane is 72.
Alkanes have the general formula C_nH_{2n+2}.

(i) State the **molecular** formula of the alkane. ..... [1]

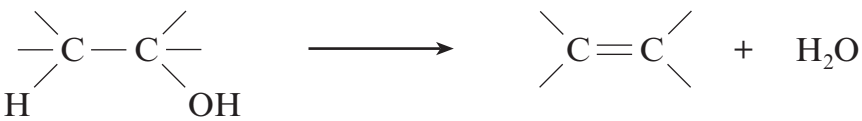
(ii) Draw one **displayed** formula of this alkane. [1]

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]

Examiner only

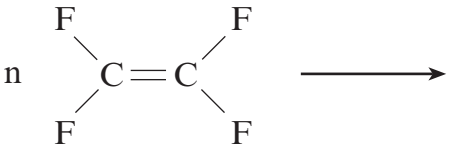
(b) Sodium fluoride is a white, ionic solid that has the same crystal structure as sodium chloride.
Give the formula of each ion present and its crystal co-ordination number. [2]

Sodium ion ..... *Crystal co-ordination number* .....

Fluoride ion ..... *Crystal co-ordination number* .....

(c) Tetrafluoroethene, C_2F_4, can be polymerised to give poly(tetrafluoroethene), PTFE, in a similar way to the polymerisation of ethene.

(i) Complete and balance the equation below, showing a repeating section of the structural formula of poly(tetrafluoroethene). [1]



(ii) A stretched form of PTFE is marketed under the name 'Goretex'. This is used to make waterproof materials that can 'breathe'. Gaseous water molecules can escape from tiny 'holes' in the fabric but larger liquid water droplets cannot enter. These liquid water droplets contain water molecules that are hydrogen bonded to each other.

Draw a diagram to show hydrogen bonding between water molecules. [3]

Total [14]

Examiner only

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

$$CH_4(g) + Cl_2(g) \longrightarrow CH_3Cl(g) + HCl(g)$$

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]

.....

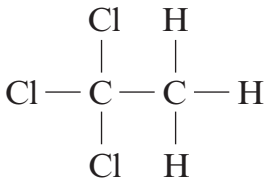
.....

(ii) a propagation stage. [2]

.....

.....

(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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(ii) A sample of 1,1,1-trichloroethane is reacted with an excess of sodium hydroxide solution and then acidified.

I. One of the organic products of this reaction is liquid **R**, whose mass spectrum shows a molecular ion at m/z 60.
The infrared spectrum of **R** shows characteristic absorption frequencies at $1725\,cm^{-1}$ and $2500 - 3500\,cm^{-1}$.
Use this information, showing your working, to suggest a structural formula for liquid **R**. [4]

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II. Chloride ions are also produced when 1,1,1-trichloroethane reacts with aqueous sodium hydroxide. The products of the reaction are then acidified with nitric acid and the mixture tested for the presence of chloride ions.
State the reagent(s) used and the observations when the mixture was tested for chloride ions. [2]

Reagent(s) .....

Observations .....

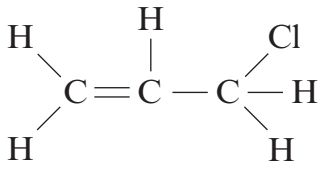
Total [12]

Examiner only

(c) 1,2-Dibromo-3-chloropropane has been used to control nematode worm attack on fruit and vegetables.

(i) Give the displayed formula of this compound. [1]

(ii) It can be made by reacting 3-chloropropene with bromine.



3-chloropropene

I. State why this is described as an addition reaction. [1]

.....

.....

II. Bromine reacts as an electrophile in this reaction.
Give the **formula** of another example of an electrophile. [1]

.....

III. The mechanism for this reaction can be shown using a curly arrow (↷).
State what this symbol is used to represent. [1]

.....

Total [14]

Examiner only

11. *(a)* One method for making butan-1-ol is to react sodium hydroxide (used as a source of hydroxide ions) and 1-chlorobutane.
Describe how butan-1-ol can be made in this way.
Your answer should

- state any necessary conditions
- show the mechanism for the reaction between hydroxide ions and 1-chlorobutane
- state the type of reaction mechanism [6]

(QWC) [2]

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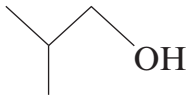
(b) Compound **G** is an isomer of butan-l-ol and its skeletal formula is



(i) Give the **systematic name** of compound **G**. [1]

.....

(ii) Compound **G**, $C_4H_{10}O$, is being developed as a possible replacement for ethanol in fuels. In a new process it is made by reacting genetically modified *E. coli* bacteria with glucose in aqueous solution.
One equation for this is

$$C_6H_{12}O_6 \longrightarrow C_4H_{10}O + 2CO_2 + H_2O$$

M_r 74

In a laboratory experiment, 0.50 mol of glucose reacted in this way to give an 86% yield, by mass, of compound **G**.
Calculate the mass of compound **G** produced. [2]

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Examiner only

(iii) Both butan-1-ol and compound **G** are primary alcohols that can be oxidised to carboxylic acids.
Give an oxidising agent that can be used, in acid solution, to oxidise primary alcohols to carboxylic acids and state what is seen as the reaction proceeds. [2]

Oxidising agent .....

Observation(s) .....

(c) One method of preparing an alcohol is from an alkene and water/steam.
State the conditions of temperature and pressure used in the preparation of ethanol from ethene. [2]

Temperature .....

Pressure .....

Total [15]

Total Section B [70]

Examiner only

SECTION A

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

1. *(a)* Ethanol is present in many intoxicating drinks. Give **one** health problem associated with the consumption of excess ethanol. [1]

.....

(b) Ethanol can be converted to ethanoic acid in an oxidation reaction. Give suitable reagents for this reaction. [1]

.....

2. Calcium compounds are important in many biological systems. Give an example of where a calcium compound is used in a living organism. [1]

.....

3. State which one of the following species has the smallest bond angle. [1]

A CH_4

B H_2O

C BF_3

D NH_4^+

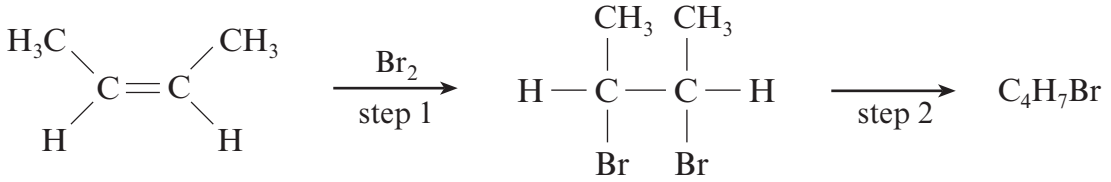
.....

4. Write a chemical equation for the displacement reaction that occurs when chlorine gas is bubbled through a solution of sodium bromide, NaBr. [1]

.....

Examiner only

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



compound A compound B 2-bromobut-2-ene

(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]

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

.....

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

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Examiner only

(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]

1092 010007

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

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Total [14]

Examiner only

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]

.....

(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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Examiner only

(e) It is possible to test for the presence of halogen atoms in a halogenoalkane by hydrolysing the molecule and testing for the halide ions released, using silver nitrate solution. This is a nucleophilic substitution reaction with the nucleophile attacking the $C^{\delta+}$ of the C-halogen bond. In each case, a precipitate is formed.

The hydrolysis of three compounds was performed under identical conditions, and the time required for a precipitate of silver halide to form was measured. The results were as follows:

Compound	Time for precipitate to form / minutes
1-chloropentane	17
1-bromopentane	4
1-iodopentane	Less than 1

The carbon-halogen bond energies and the electronegativity differences for each bond are given below.

Bond	Average bond enthalpy / kJ mol^{-1}	Electronegativity difference
C—Cl	338	0.61
C—Br	276	0.41
C—I	238	0.11

Examiner only

Use both tables to comment on the factors that affect the rate of reaction. Your answer should discuss:

- The trend in relative bond strengths for the halogenoalkanes;
- The trend in the rate of reaction expected if bond strength is the main factor affecting the ease of hydrolysis in these compounds;
- The trend in size of the δ+ charges on the carbon atoms of each halogenoalkane;
- The trend in the rate of reaction expected if dipole size is the main factor affecting the ease of hydrolysis in these compounds. [4]

QWC [1]

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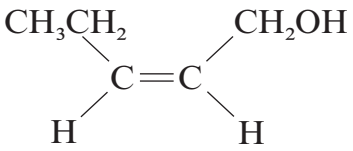
Total [19]

Examiner only

6. The compound below has a cherry odour and is used in the manufacture of fragrance agents.



(a) Name the functional groups present in this compound. [2]

.....

(b) State the **molecular** formula of the compound. [1]

.....

Section A Total [10]

Examiner only

(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]

.....

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

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

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

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Total [16]

Examiner only

8. *(a)* Chloroalkanes such as 1-chlorobutane are used in the synthesis of many organic compounds.

1-Chlorobutane can be formed from butane and chlorine in a similar way to the formation of chloromethane from methane and chlorine.

Describe the reaction of butane and chlorine to form 1-chlorobutane.

Your description should include:
- an overall equation for the reaction;
- the conditions required for the reaction to take place;
- full details of the reaction mechanism. [6]

QWC [1]

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(b) Give the equation for the reaction between 1-chlorobutane and aqueous sodium hydroxide and name the type of reaction mechanism occurring. [2]

Equation .....

Type of reaction mechanism .....

(c) A compound is known to be either 1-chlorobutane or 1-bromobutane.
Describe a test, giving any reagents used and observations, to show that the compound is 1-chlorobutane. [3]

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Examiner only

(d) Chlorofluorocarbons were used at one time as refrigerants in air-conditioning systems in cars and buildings. However, due to leakage over time, their use for this purpose is being phased out.

State the environmental consequence of leakage of chlorofluorocarbons. [1]

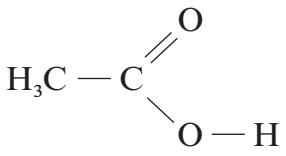
.....

Total [13]

Examiner only

(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 CH_3COOH 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]

.....

(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 .....

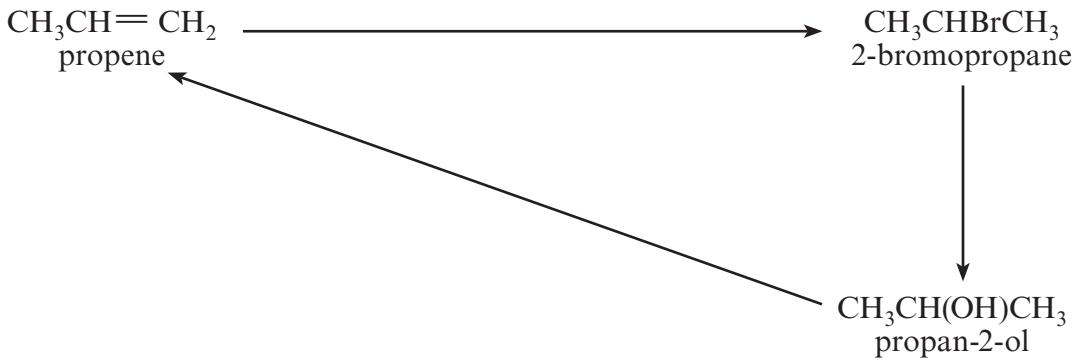
.....

.....

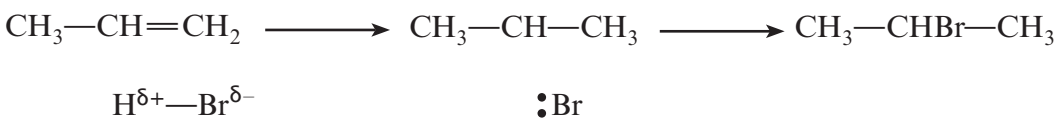
Total [13]

Examiner only

10. *(a)* This question is about the compounds and reactions shown in the diagram below.



(i) The addition of hydrogen bromide to propene gives 2-bromopropane as the main product. Complete the outline mechansim below, inserting curly arrows and charges where appropriate. [2]



(ii) The reaction of 2-bromopropane to give propan-2-ol is an example of a nucleophilic substitution reaction. Suggest a nucleophile that can be used for this reaction and give a reason why this is classed as a substitution reaction. [2]

Nucleophile .....

Reason .....

.....

(iii) The production of propene from propan-2-ol is an example of an elimination reaction. Another elimination reaction is the reaction of bromoethane with sodium hydroxide.

$$CH_3CH_2Br + NaOH \longrightarrow CH_2{=}CH_2$$

Complete the equation by giving the formulae of the other products. [1]

Examiner only

10. *(a)* Explain the fact that the melting temperature of sodium is much lower than the melting temperature of magnesium.

You should include reference to the type(s) of bonding involved and how this bonding affects melting temperatures. You may include a diagram if you consider it helpful.

[3]

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(b) In an experiment, 1-chlorobutane was heated with aqueous sodium hydroxide and the resulting solution was acidified. Aqueous silver nitrate was then added and a white precipitate was observed.

The experiment was repeated using 1-bromobutane and in this case a cream precipitate was observed.

Explain these observations.

You should include:

- the type of reaction that occurs between the halogenoalkane and sodium hydroxide
- an equation for this reaction
- the identity of the coloured precipitates
- an equation to show the formation of these precipitates. [4]

QWC [1]

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Examiner only

(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, C_3H_6, 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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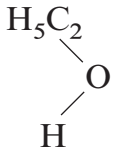
Total [16]

Examiner only

11. Ethanol, C_2H_5OH, is the alcohol that is present in alcoholic drinks.

(a) Ethanol is soluble in water. Complete the diagram below to show why ethanol is soluble in water. You should include relevant lone pairs and dipoles and label the bond responsible for this solubility. [3]



(b) If it is suspected that a driver has been drinking alcohol they can be tested in several ways.

(i) One method previously used to test for ethanol in breath involved blowing through acidified potassium dichromate(VI). A positive test was shown by the colour change from orange to green.

What type of reaction causes this colour change? [1]

.....

Examiner only

12. The elements in Group 7 in the Periodic Table can be described as *p*-block elements.

(a) State why these are described as *p*-block elements. [1]

.....

.....

(b) All halogens are oxidising agents.

(i) Why are the halogens oxidising agents? [1]

.....

.....

(ii) State, giving a reason, which halogen is the strongest oxidising agent. [1]

.....

.....

(c) $NaClO_3$ was used as a weedkiller. Give the oxidation state of chlorine in $NaClO_3$.

Oxidation state ..... [1]

(d) Methane reacts with chlorine when exposed to sunlight. The first two stages of the mechanism of this reaction are initiation and propagation.

(i) Give the equation for the initiation reaction. [1]

.....

(ii) Give equations for **two** propagation steps involved in the formation of chloromethane. [2]

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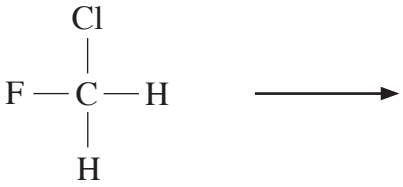
.....

Examiner only

(e) Chlorofluorocarbons, CFCs, were widely used as refrigerants but they caused serious environmental damage as a result of reactions involving radical mechanisms.

The first stage of a radical mechanism is an initiation process similar to that in *(d)*. Complete the following equation to show the most likely initiation step for chlorofluoromethane, CH_2ClF, and give a reason for your answer. [2]



Reason .....

.....

Total [9]

Total Section B [70]

Examiner only

SECTION A

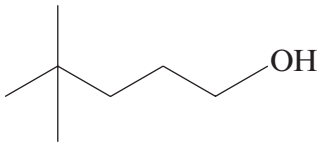
Answer **all** *questions in the spaces provided.*

1. Calcium and magnesium are essential elements in living things. Give **one** use of each element in biological systems. [1]

Magnesium .....

Calcium .....

2. Give the **systematic** name of the molecule shown below. [1]



.....

3. The electronegativity values of the halogens are listed below.

Atom	F	Cl	Br	I	At
Electronegativity value	4.0	3.0	2.9	2.6	2.2

(a) Define the term *electronegativity.* [1]

.....

.....

(b) Use the data in the table to identify any dipoles present in the following bonds, marking their polarity clearly. [1]

F — Cl At — Cl

Examiner only

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 .....

Examiner only

(d) Chloromethane can be converted into methanol by reaction with hydroxide ions.

(i) Classify the mechanism of this reaction. [1]

.....

(ii) The boiling temperatures of chloromethane and methanol are given in the table below.

Compound	Boiling temperature / K
chloromethane, CH_3Cl	249
methanol, CH_3OH	338

Explain why the boiling temperature of methanol is higher than the boiling temperature of chloromethane. [3]

.....

.....

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.....

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.....

(iii) Methanol can then be converted to methanoic acid. Give the reagent(s) and condition(s) required for this reaction. [2]

Reagent(s) .....

Condition(s) .....

Examiner only

(e) CFCs are another class of organic compounds. They contain chlorine, fluorine and carbon. These compounds once had a range of uses, however their use is now avoided due to their effect on the ozone layer which is part of the **upper** atmosphere.

The table shows the lifetime of some compounds in the **lower** atmosphere and their relative ozone depletion potential (RODP), taking CCl_3F as having a value of 1.0. The RODP is measured by mixing a compound with ozone in a laboratory experiment.

Compound	Formula	Lifetime in the lower atmosphere	Relative ozone depletion potential (RODP)
A	CHF_3	243 years	0.01
B	CCl_2F_2	20 years	0.86
C	CCl_3F	75 years	1.00
D	$CBrClF_2$	120 days	10.00

By referring to this table, explain why CFCs **B** and **C** are far more harmful than compounds **A** and **D**.
Your answer should explain how and why CFCs affect the ozone layer. [3]

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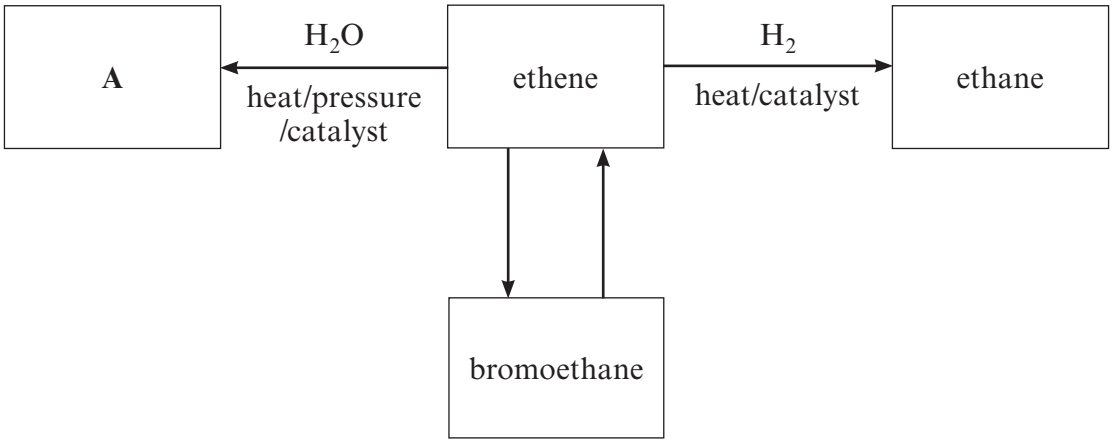
Total [16]

Examiner only

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]

.....

Examiner only

(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]

.....

Total [12]

Examiner only

8. *(a)* In March 2012 the UK Government proposed a minimum price of 40p per unit of alcohol in an effort to 'turn the tide' against binge drinking.

State **one** effect on the human body and **one** effect on society of the excessive use of alcoholic drinks. [2]

Effect on the human body .....

.....

Effect on society .....

.....

(b) Butan-1-ol can be prepared by warming 1-chlorobutane with aqueous sodium hydroxide.

(i) Classify the type of reaction occurring and give the mechanism for the reaction. [4]

Reaction type .....

Mechanism

(ii) Use the infrared absorption frequencies given in the Data Sheet to explain how you would know if all the 1-chlorobutane has been converted into butan-1-ol. [2]

.....

.....

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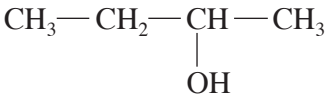
Examiner only

(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

.....

1092 010007

Examiner only

(d) 1-Chlorobutane is an example of a halogenoalkane. One group of halogenoalkanes (CFCs) has been shown to play a role in ozone depletion. Most of these ozone-depleting substances contain chlorine. Halogenoalkanes containing only fluorine do not harm the ozone layer.

Due to the Montreal Protocol of 1987, CFCs have been largely banned and have been replaced in many applications by HFCs, which contain fluorine as the only halogen.

(i) Explain why CFCs deplete the ozone layer, but HFCs do not. [2]

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.....

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(ii) Suggest a reason why there is still concern about ozone depletion. [1]

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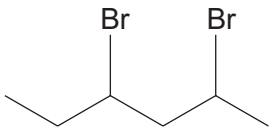
.....

Total [16]

Examiner only

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]

.....

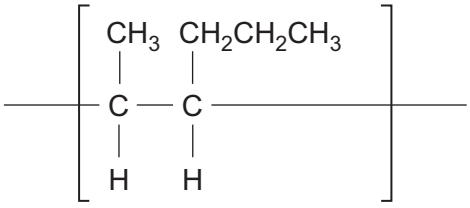
5. In industry, ethanol is produced by reacting ethene with water / steam.

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

Temperature .....°C *Pressure* ..... atm.

1092 010003

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



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

.....

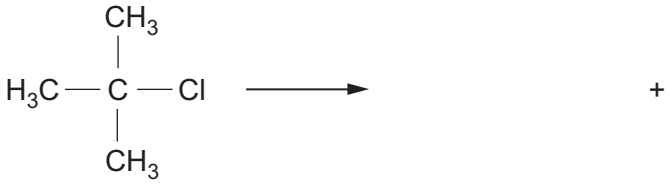
Examiner only

7. *(a)* State the meaning of the term *heterolytic fission*. [1]

.....

.....

(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]

Examiner only

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.

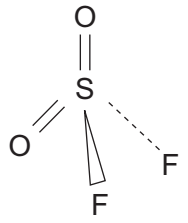
$$SO_2 + F_2 \longrightarrow SO_2F_2$$

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, $SO_2(NH_2)_2$. 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]

.....

Examiner only

(d) Sulfuryl fluoride reacts rapidly with calcium hydroxide to give calcium sulfate, calcium fluoride and water as the only products.

Give the equation for this reaction. [2]

.....

(e) Bromomethane, CH_3Br, was formerly used as a fumigant gas to remove insect infestation but has now been largely replaced by sulfuryl fluoride. One reason for this change is that bromomethane has an adverse effect on the ozone layer.

(i) Explain how **both** bromomethane and CFCs have an adverse effect on the ozone layer.

The table below should be used to help you in your response. [3]

Bond	Bond enthalpy/ kJ mol^{-1}
C—H	412
C—F	484
C—Cl	338
C—Br	276
S—F	410

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(ii) Use the information in the table in (i) above to state why sulfuryl fluoride is now preferred to bromomethane as a fumigant. [1]

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.....

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Total [12]

Examiner only

(c) Methane reacts with chlorine in a substitution reaction.

(i) The first stage of the reaction is as follows.

$$Cl_2 \longrightarrow 2Cl\bullet$$

State an essential condition for this stage. [1]

.....

(ii) State what is meant by the term *propagation stage*. [1]

.....

.....

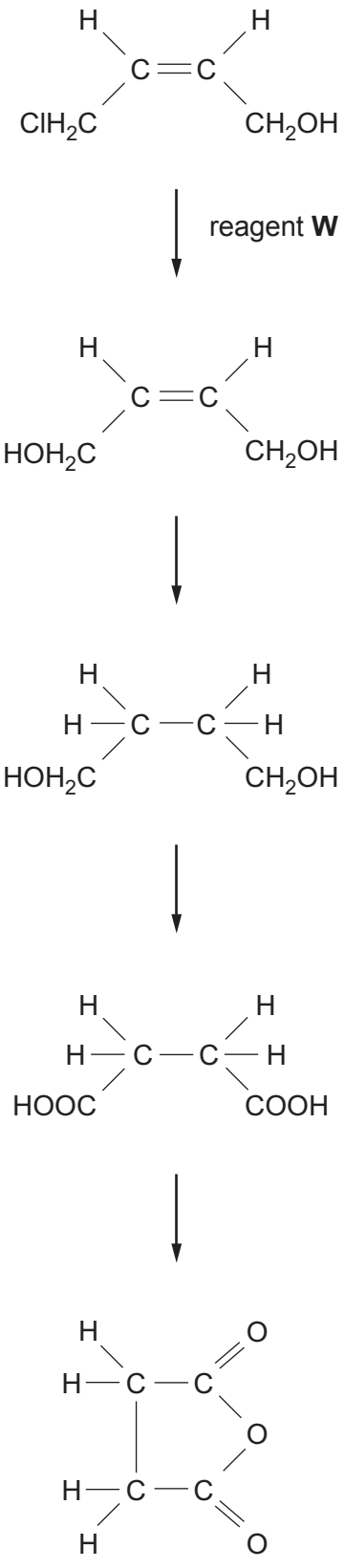
(iii) Write an equation that represents a propagation stage of this reaction. [1]

.....

QUESTION CONTINUES ON PAGE 18

Examiner only

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



Examiner only

(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

Examiner only

SECTION A

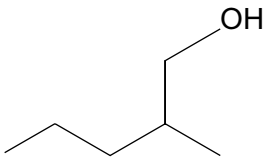
Answer **all** *questions in the spaces provided.*

1. Put the following in order of increasing strength. [1]

covalent bonds *hydrogen bonds* *van der Waals' forces*

weakest ..... *strongest*

2. Give the **systematic** name of the compound whose structure is shown below. [1]

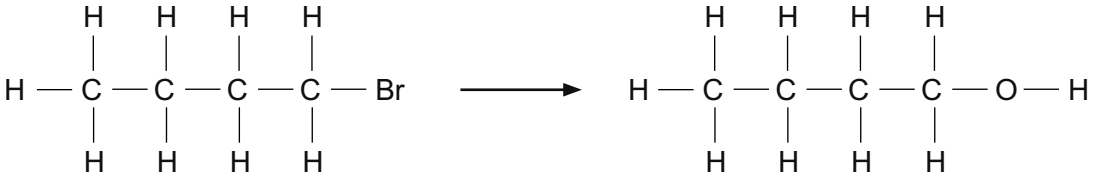


.....

3. Draw dot-and-cross diagrams to show the formation of calcium chloride from atoms of chlorine and calcium. [2]

Examiner only

10. *(a)* 1-bromobutane is a liquid that is insoluble in water. It can be converted to butan-1-ol in a one-step reaction.



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

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.....

(ii) Explain why butan-1-ol is soluble in water whilst 1-bromobutane is not. [3]

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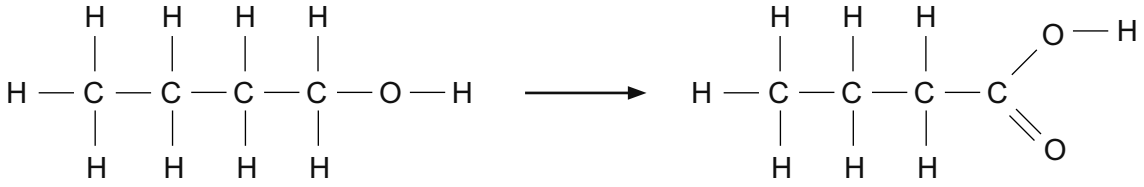
Examiner only

(b) Butan-1-ol can be converted into liquid butanoic acid in a one-step reaction.



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

.....

.....

(ii) Explain why butanoic acid has a much higher boiling temperature than 1-bromobutane. [3]

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(iii) The reaction above frequently produces a mixture containing unreacted butan-1-ol and butanoic acid. State how these two liquids could be separated. [1]

.....

.....

Total [11]

Examiner only

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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Examiner only

(b) Compound **C** is a compound of carbon, hydrogen and bromine only. Bromine has two isotopes, ^{79}Br and ^{81}Br, in equal abundance. Use all the information below to deduce the structure of compound **C**, giving your reasoning. [6]

QWC [1]

- Compound **C** contains 29.8 % carbon, 4.2 % hydrogen and 66.0 % bromine by mass.
- The mass spectrum of compound **C** contains peaks at m/z of 15, 41 and a pair of peaks at 120 and 122.
- The infrared spectrum of compound **C** has absorptions at 550 cm^{-1}, 1630 cm^{-1} and 3030 cm^{-1}.
- Compound **C** is a Z-isomer.

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Total [12]

Section B Total [70]

END OF PAPER