OCR
RECOGNISING ACHIEVEMENT

AS GCE CHEMISTRY B (SALTERS)

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry B (Salters)* (inserted)
- *Advance Notice: 'Chlorine dioxide'* (inserted)

Other materials required:
- Scientific calculator

Duration: 1 hour 45 minutes

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The inserts will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Answer **all** the questions.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
- This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- The insert *'Chlorine dioxide'* is provided for use with question 5.
- A copy of the *Data Sheet for Chemistry B (Salters)* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **100**.

Answer **all** the questions.

1 Snottites are slimy colonies of bacteria that live in extreme conditions in caves. They take in hydrogen sulfide gas, H_2S, and oxygen gas and form sulfuric acid, H_2SO_4, in their slime.

(a) Hydrogen sulfide is produced by sulfur springs and stagnant water.

(i) Draw a '*dot-and-cross*' diagram to represent the bonding in a molecule of hydrogen sulfide.

Show outer electron shells only.

[1]

(ii) Suggest and explain the shape of the hydrogen sulfide molecule. Give the bond angle.

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.... **[4]**

(b) Use your answer to part **(a)(ii)** to help explain whether or not the molecule of hydrogen sulfide is polar.

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.... **[2]**

(c) Give the oxidation state of sulfur in hydrogen sulfide and in sulfuric acid.

H_2S ....

H_2SO_4 .... **[2]**

(d) Name the substance that has been reduced during the reaction of hydrogen sulfide with oxygen gas to form sulfuric acid. Explain your answer.

....

....

.... **[2]**

QUESTION 1 CONTINUES ON PAGE 4

(e) A sample of the sulfuric acid formed by snottites was collected in order to find its concentration.

A scientist measured out a 10.0 cm^3 sample of cave water containing sulfuric acid using a volumetric pipette and then diluted it to 250 cm^3 in a volumetric flask.

The scientist then carried out a titration of the diluted acid with sodium hydroxide solution.

In the titration, 20.0 cm^3 of the diluted sulfuric acid solution was found to react exactly with 26.40 cm^3 of 0.0500 mol dm^{-3} sodium hydroxide solution.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$ **equation 1.1**

(i) Name the piece of apparatus that the scientist would use to add the sodium hydroxide solution to the sulfuric acid during the titration.

.... **[1]**

(ii) Calculate the number of moles of NaOH used in the titration.

moles of NaOH = ... mol **[1]**

(iii) Use **equation 1.1** to calculate the number of moles of H_2SO_4 that took part in the titration.

moles of H_2SO_4 = ... mol **[1]**

(iv) Calculate the concentration of the diluted sulfuric acid used in the titration.

concentration of sulfuric acid = ... mol dm^{-3} **[2]**

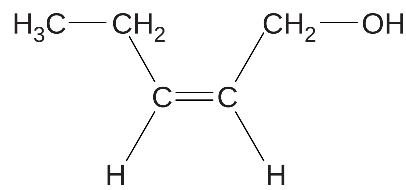
(v) Calculate the concentration of the sulfuric acid in the cave water.

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

concentration of sulfuric acid = ... mol dm^{-3} **[2]**

[Total: 18]

2 'Violet oil' is sometimes used in aromatherapy treatments for its mild pain-killing properties. The oil has a strong 'leafy' odour due partly to the presence of compound **A**.



compound A

(a) Name the functional groups present in compound **A**.

....

.... **[2]**

(b) Give the molecular formula of compound **A**.

.... **[1]**

(c) A student reacts compound **A** with bromine water.

(i) Describe the colour change the student would **see** when this reaction takes place.

from .... to .... **[2]**

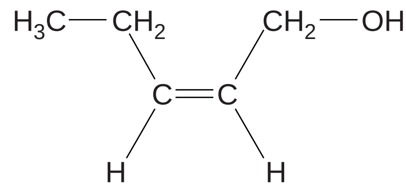
(ii) Write the equation for the reaction between compound **A** and bromine, using molecular formulae.

$\rightarrow$

[1]

(iii) Underline **two** words from the list below that best describe the mechanism for this reaction.

addition **electrophilic** **nucleophilic** **radical** **substitution** **[2]**



compound A

(d) Compound **A** is one of a pair of *E*/*Z* isomers.

(i) Draw a diagram to show the structure of the other isomer and label it as *E* or *Z*.

[1]

(ii) Explain why $CH_3CH_2CHCHCH_2OH$ can exist as a pair of *E*/*Z* isomers.

....

....

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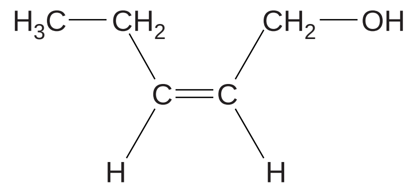
.... **[2]**

(e) Compound **A** reacts with hydrogen chloride to form **two** products with the molecular formula $C_5H_{10}Cl_2$. Draw the structures of **both** of these products.

[2]



compound A

(f) Compound **A** can also be used to produce an addition polymer that is soluble in water.

(i) Draw a diagram below to show the repeating unit of the polymer formed from compound **A**.

[1]

(ii) The polymer formed from compound **A** is soluble in water.

Explain this solubility in terms of the molecular structure of the polymer and the formation of hydrogen bonds.

You should:

- explain how hydrogen bonds form
- suggest why the polymer is soluble in water.

In your answer, you should make it clear how the structure of the polymer links to its solubility in water.

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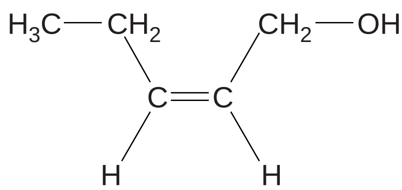
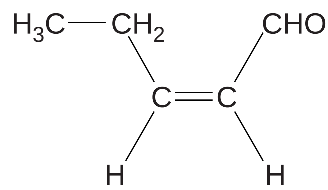
.... **[4]**

(g) A student produces compound **B** by gently heating compound **A** with suitable reagents and immediately distilling the product from the mixture.



compound A



compound B

(i) Name the reagents the student uses to convert compound **A** into compound **B**.

....

.... **[2]**

(ii) Name the functional group that is present in compound **B** that is not present in compound **A**.

.... **[1]**

(h) A student carries out a reaction using the same reagents as in part **(g)**, but by heating the reaction mixture under reflux. Compound **C** is produced.

(i) Explain what is meant by the term *heating under reflux*.

....

....

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.... **[2]**

(ii) Draw the **full** structural formula of the new functional group present in compound **C** and name this functional group.

name of functional group: .... **[2]**

[Total: 25]

3 In 2010, an Icelandic volcano erupted producing ash clouds that stopped plane flights across much of Europe. The volcano also emitted a mixture of gases.

(a) The ash produced by the volcano contained silicon dioxide, SiO_2, whilst the gas mixture contained carbon dioxide.

Silicon dioxide is a solid but carbon dioxide is a gas at room temperature.

Explain this difference in terms of the bonding and structure in both compounds.

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....

.... **[3]**

(b) Most scientists are concerned about the increasing amount of carbon dioxide in the Earth's atmosphere.

Give **two** different processes, other than volcanic activity, that are causing an increase in the amount of carbon dioxide in the atmosphere.

....

.... **[2]**

(c) Most carbon dioxide from industrial processes is allowed to escape into the atmosphere.

(i) Carrying out capture and storage of carbon dioxide is one way that a chemical manufacturing process could be changed to slow down the increase in carbon dioxide levels in the atmosphere.

Suggest **TWO** other changes that a chemical company could make to its processes to achieve a reduction in the rate of increase of carbon dioxide levels.

....

....

.... **[2]**

(ii) Suggest why capture and storage of carbon dioxide is expensive.

....

.... **[1]**

(d) The Earth absorbs visible radiation from the Sun and emits radiation from a different part of the electromagnetic spectrum. Carbon dioxide molecules absorb some of the emitted radiation.

(i) Name the type of electromagnetic radiation that is emitted from the Earth's surface.

.... **[1]**

(ii) Explain what happens to carbon dioxide molecules when they absorb the radiation emitted from the Earth.

....

.... **[1]**

(iii) Explain how the changes that happen after the process in **(ii)** result in the warming of the atmosphere.

....

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....

.... **[2]**

(e) The amount of carbon dioxide in the troposphere is affected by the fact that it can dissolve in ocean water. The following equations describe the main reactions that occur.

$$CO_2(g) \rightleftharpoons CO_2(aq)$$ **equation 3.1**

$$CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$ **equation 3.2**

(i) Using these equations, explain the effect that an increase in carbon dioxide concentration in the troposphere will have on the HCO_3^- concentration in the oceans.

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.... **[3]**

(ii) Suggest why the balance between gaseous CO_2 in the troposphere and CO_2(aq) in the oceans cannot be regarded as a true dynamic equilibrium.

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.... **[1]**

(f) There has also been concern about the amount of ozone in the atmosphere. The overall equation for the formation of ozone in the Earth's atmosphere is shown below.

$$3O_2 \rightarrow 2O_3$$

(i) Complete and balance **two** equations to show how oxygen is converted into ozone in the stratosphere.

$$O_2 \xrightarrow{h\nu}$$

$$\rightarrow$$

[2]

(ii) Explain why the formation of ozone you have described in **(i)** takes place in the stratosphere but **not** usually in the troposphere.

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.... **[2]**

(g) Ozone can be broken down by nitrogen monoxide. The mechanism for this process is shown below.

step 1 $NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$ **equation 3.3**

step 2 $NO_2(g) + O(g) \rightarrow NO(g) + O_2(g)$ **equation 3.4**

(i) Combine **equations 3.3** and **3.4** to produce the overall equation for the reaction.

[1]

(ii) In the mechanism shown above for the breakdown of ozone, NO is acting as a homogeneous catalyst.

Explain what is meant by the term *homogeneous* in the context of catalysis.

How can you tell from **equation 3.3** and **equation 3.4** that NO is a catalyst?

homogeneous: ....

....

NO is a catalyst because: ....

....

.... **[2]**

[Total: 23]

4 Chlorofluorocarbons, CFCs, were originally regarded as very useful compounds. Their physical and chemical properties meant that they could be used for a wide range of applications, including as refrigerants and cleaning solvents.

(a) Unfortunately, we now know that CFCs break down in the stratosphere, starting a sequence of reactions that lead to ozone depletion.

$$CCl_2F_2 \xrightarrow{h\nu} CClF_2 + Cl \qquad \textbf{equation 4.1}$$

$$Cl + O_3 \rightarrow ClO + O_2 \qquad \textbf{equation 4.2}$$

$$ClO + O \rightarrow Cl + O_2 \qquad \textbf{equation 4.3}$$

(i) Underline the term from the list below that describes the type of process shown in **equation 4.3**.

initiation **propagation** **termination** **[1]**

(ii) Explain why it is important that there is a certain minimum amount of ozone in the stratosphere.

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.... **[3]**

(b) The table below shows two CFCs and a former use for each of them.

Complete the table by choosing **one** property from the list below that is **essential** for the given use of **each** CFC:

non-flammable **low boiling point** **high ozone depletion potential** **low reactivity**

CFC	**use**	**essential property linked to use**
CCl_2F_2	refrigerant	
CCl_3F	blowing agent	

[2]

(c) Scientists have decided that hydrofluorocarbons, or HFCs, like F_3CCFH_2, will make good long-term replacements for CFCs.

(i) Explain, in terms of the reactivity of HFCs in the **stratosphere**, why scientists think HFCs are a good long-term solution as replacements for CFCs.

....

....

.... **[2]**

(ii) Give **one** advantage and **one** disadvantage, not linked to their ozone depleting potential, which scientists would take into account when considering the use of HFCs in place of CFCs.

Advantage: ....

....

Disadvantage:...

.... **[2]**

(d) The hydrofluorocarbon, F_3CCFH_2, can be prepared industrially by reacting hydrogen fluoride with $Cl_2C{=}CClH$.

$$Cl_2C{=}CClH + 4HF \rightarrow F_3CCFH_2 + 3HCl$$ **equation 4.4**

(i) In the reaction shown in **equation 4.4**, some of the hydrogen fluoride takes part in a nucleophilic substitution reaction with the $Cl_2C{=}CClH$.

Explain how HF can act as a *nucleophile* in this reaction.

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.... **[2]**

(ii) The reaction shown in **equation 4.4** can be catalysed by chromium(III) fluoride.

Explain why the use of a catalyst speeds up the reaction rate.

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.... **[2]**

[Total: 14]

5 This question is based on the Advance Notice article '**Chlorine dioxide**' which is provided as an insert to this paper.

(a) Explain what is meant by the term *radical* and name the type of bond breaking that forms radicals. Give an example of a radical from the article, other than chlorine dioxide.

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....

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Example: ....

.... **[3]**

(b) Write the **ionic** equation for the reaction of sodium chlorate(V) with HCl.

$$\rightarrow$$

[2]

(c) By reference to the types of intermolecular bonds that are present, explain why chlorine dioxide has a higher boiling point than chlorine.

In your answer, you should use appropriate technical terms, spelled correctly.

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.... **[4]**

(d) Chlorine dioxide can oxidise some organic compounds.

(i) Suggest a **hydrocarbon** with three carbon atoms that might be oxidised by chlorine dioxide, giving your reason.

....

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.... **[2]**

(ii) Explain why, in the reaction of chlorine dioxide with organic molecules, the chlorine dioxide is said to have been reduced.

....

.... **[1]**

(e) Calculate the percentage of ‘available chlorine’ in chlorine dioxide when it is reduced to chloride.

available chlorine = ... % **[2]**

QUESTION 5 CONTINUES ON PAGE 18

(f) Explain why chlorine dioxide is preferred to chlorine as a disinfectant.

In your answer you should make clear the chemical theory behind some of the comparisons you make.

.... **[6]**

[Total: 20]

END OF QUESTION PAPER

For Question 5

Chlorine dioxide

Adapted from www.lenntech.com/water-disinfection/disinfectants-chlorine-dioxide.htm

Chlorine dioxide is mainly used as a bleach and as a disinfectant. As a disinfectant it is effective even at low concentrations because of its unique qualities.

When was chlorine dioxide discovered?

Chlorine dioxide was discovered in 1814 by Sir Humphrey Davy. In the last few years a reaction similar to his has been used to produce large quantities of chlorine dioxide from sodium chlorate(V).

$$2NaClO_3(aq) + 4HCl(aq) \rightarrow 2ClO_2(aq) + Cl_2(aq) + 2NaCl(aq) + 2H_2O(l)$$

What are the characteristics of chlorine dioxide?

Chlorine dioxide (ClO_2) is a green-yellowish gas with a chlorine-like, irritating odour. Chlorine dioxide is a neutral chlorine compound consisting of small, volatile molecules which have a bent structure with the O–Cl–O bond angle of 117°. In aqueous solutions chlorine dioxide is a radical and reacts strongly with reducing agents. Chlorine dioxide is an unstable gas that dissociates into chlorine gas (Cl_2) and oxygen gas (O_2) exothermically. At –59 °C, solid chlorine dioxide becomes a reddish liquid. At 11 °C chlorine dioxide turns into a gas.

Can chlorine dioxide be dissolved in water?

One of the most important qualities of chlorine dioxide is its high water solubility, especially in cold water. Chlorine dioxide does not hydrolyse when it enters water; it remains a dissolved gas in solution. Chlorine dioxide is approximately 10 times more soluble than chlorine in water. Chlorine dioxide can be removed by aeration or by blowing carbon dioxide through the solution.

What are the applications of chlorine dioxide?

Chlorine dioxide has many applications. It is used in the electronics industry to clean circuit boards, in the oil industry to treat sulfides and to bleach textiles and candles. In World War II, chlorine became scarce and chlorine dioxide was used as a bleach. Nowadays, chlorine dioxide is used most often to bleach paper. It produces a clearer and stronger fibre than chlorine does. Chlorine dioxide has the advantage that it produces less harmful by-products than chlorine. Chlorine dioxide gas is used to sterilise medical and laboratory equipment, surfaces, rooms and tools. Chlorine dioxide can be used as an oxidiser or disinfectant. It is a strong oxidiser and it effectively kills pathogenic micro-organisms such as fungi, bacteria and viruses. It also prevents and removes bio-film. As a disinfectant and pesticide it is mainly used in liquid form. Chlorine dioxide can also be used against anthrax, because it is effective against spore-forming bacteria.

Chlorine dioxide as an oxidiser

Chlorine dioxide can act as an oxidiser. It has this ability due to unique one-electron exchange mechanisms. Chlorine dioxide attacks the electron-rich centres of organic molecules. One electron is transferred to chlorine dioxide from the electron-rich centre of the organic molecule and the chlorine dioxide is reduced to chlorite (ClO_2^-). In other applications it is often reduced to chloride.

In comparison to chlorine and ozone, less chlorine dioxide is required to obtain an active residual disinfectant. One way to compare different chlorine-containing chemicals' oxidising capacities, which shows how many electrons are transferred during an oxidation or reduction reaction, is to calculate their 'available chlorine'. To do this calculation, the molar mass of the compound must be known, as well as the number of electrons it exchanges during the reaction. For example, sodium hypochlorite, NaClO, has a molar mass of 74.5 and accepts two electrons when it reacts. The calculation is done by dividing the relative atomic mass of chlorine by the molar mass of the sodium hypochlorite, then multiplying by two (because the Cl in NaOCl accepts two electrons during reactions, whereas Cl in Cl_2 only accepts one electron). The answer is multiplied by 100 to give a percentage. The calculation for sodium hypochlorite would give:

$$\text{Available chlorine} = (35.5/74.5) \times 2 \times 100\% = 95.3\%$$

The chlorine atom in chlorine dioxide has an oxidation number of +4. For this reason, chlorine dioxide accepts five electrons when it is reduced to chloride. During the reduction, a chlorine radical forms, until finally stable chloride ions are produced. When we look at the molar mass, chlorine dioxide has more than 2.5 times the oxidation capacity of chlorine.

The chlorine atom remains until stable chloride is formed. This explains why no potentially toxic chlorinated substances are formed. When chlorine reacts it not only accepts electrons; it also takes part in addition and substitution reactions.

Does chlorine dioxide produce by-products?

Pure chlorine dioxide gas that is applied to water produces less disinfection by-products than oxidants such as chlorine. Unlike ozone (O_3), pure chlorine dioxide does not oxidise bromide (Br^-) ions to bromate ions (BrO_3^-). Additionally, chlorine dioxide does not produce large amounts of aldehydes, ketones, or other disinfection by-products that originate from the oxidation of organic substances.

What are the disinfection applications of chlorine dioxide?

Drinking water treatment is the main application of disinfection by chlorine dioxide. Thanks to its biocidal abilities, chlorine dioxide is also used in other branches of industry today. Examples are: sewage water disinfection, industrial process water treatment, cooling tower water disinfection, industrial air treatment, mussel control, foodstuffs production and treatment, industrial waste oxidation and gas sterilisation of medical equipment.

END OF ADVANCE NOTICE ARTICLE