1 (a) The major gases in unpolluted air are 79% nitrogen and 20% oxygen.

(i) Name another gaseous element in unpolluted air.

............................................................................................................................................. [1]

(ii) Name two compounds in unpolluted air.

............................................................................................................................................. [2]

(b) Two common pollutants in air are sulfur dioxide and the oxides of nitrogen.

(i) Name another pollutant in air.

............................................................................................................................................. [1]

(ii) Describe how sulfur dioxide is formed.

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

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

............................................................................................................................................. [2]

(iii) How are the oxides of nitrogen formed?

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

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

............................................................................................................................................. [2]

(c) How is oxygen obtained from air?

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

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

............................................................................................................................................. [2]

[Total: 10]
2 Oxides are classified as acidic, basic, neutral and amphoteric.

(a) Complete the table.

<table>
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<th>pH of solution of oxide</th>
<th>example</th>
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[6]

(b) (i) Explain the term *amphoteric*.

.............................................................................................................................................
............................................................................................................................................. [1]

(ii) How could you distinguish between an acidic oxide and an amphoteric oxide using hydrochloric acid and aqueous sodium hydroxide?

............................................................................................................................................. [2]

[Total: 9]
3 (a) An important ore of zinc is zinc blende, ZnS.

(i) How is zinc blende changed into zinc oxide?

........................................................................................................................................... [1]

(ii) Write a balanced equation for the reduction of zinc oxide to zinc by carbon.

............................................................................................................................................... [2]

(b) A major use of zinc is galvanizing; steel objects are coated with a thin layer of zinc. This protects the steel from rusting even when the layer of zinc is broken.

Explain, by mentioning ions and electrons, why the exposed steel does not rust.

........................................................................................................................................... [3]
(c) Zinc electrodes have been used in cells for many years, one of the first was the Daniel cell in 1831.

(i) Give an explanation for the following in terms of atoms and ions.

observation at zinc electrode – *the electrode becomes smaller*

explanation ........................................................................................................................... [1]

observation at copper electrode – *the electrode becomes bigger*

explanation ........................................................................................................................... [1]

(ii) When a current flows, charged particles move around the circuit.

What type of particle moves through the electrolytes?

........................................................................................................................................... [1]

Which particle moves through the wires and the voltmeter?

........................................................................................................................................... [1]

[Total: 10]
4 The distinctive smell of the seaside was thought to be caused by ozone, \(O_3\). Ozone is a form of the element oxygen.

(a) A mixture of oxygen and ozone is formed by passing electric sparks through oxygen.

\[3O_2 \leftrightarrow 2O_3\]

Suggest a technique that might separate this mixture. Explain why this method separates the two forms of oxygen.

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(b) Ozone is an oxidant. It can oxidise an iodide to iodine.

\[2I^- + O_3 + 2H^+ \rightarrow I_2 + O_2 + H_2O\]

(i) What would you see when ozone is bubbled through aqueous acidified potassium iodide?

(ii) Explain in terms of electron transfer why the change from iodide ions to iodine molecules is oxidation.

(iii) Explain, using your answer to b(ii), why ozone is the oxidant in this reaction.
(c) It is now known that the smell of the seaside is due to the chemical dimethyl sulfide, \((\text{CH}_3)_2\text{S}\).

(i) Draw a diagram that shows the arrangement of the valency electrons in one molecule of this covalent compound.
   Use \(x\) to represent an electron from a carbon atom.
   Use \(o\) to represent an electron from a hydrogen atom.
   Use \(●\) to represent an electron from a sulfur atom.

(ii) Name the three compounds formed when dimethyl sulfide is burnt in excess oxygen.

[Total: 11]
The first three elements in Group IV are carbon, silicon and germanium. The elements and their compounds have similar properties.

(a) The compound, silicon carbide, has a macromolecular structure similar to that of diamond.

(i) A major use of silicon carbide is to reinforce aluminium alloys which are used in the construction of spacecraft. Suggest three of its physical properties.

(ii) Draw a diagram to show the arrangement of silicon atoms around one carbon atom in silicon carbide. Label this diagram 1.

Draw a diagram to show the arrangement of carbon atoms around one silicon atom in silicon carbide. Label this diagram 2.

(b) Germanium(IV) oxide, GeO$_2$, has the same macromolecular structure as silicon(IV) oxide. Draw the structural formula of germanium(IV) oxide.
(c) Germanium forms a series of hydrides comparable to the alkanes.

(i) Draw the structural formula of the hydride which contains three germanium atoms per molecule.

(ii) Predict the products of the complete combustion of this hydride.

.......................................................................................................................................................................................................................................................... [2]

[Total: 11]
6 (a) Sulfuric acid is made by the Contact process.

\[2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3\]

This is carried out in the presence of a catalyst at 450°C and 2 atmospheres pressure.

(i) Sulfur dioxide is made by burning sulfur. Name a source of sulfur.

.................................................................................................................................................. [1]

(ii) Give another use of sulfur dioxide.

.................................................................................................................................................. [1]

(iii) Name the catalyst used.

.................................................................................................................................................. [1]

(iv) If the temperature is decreased to 300°C, the yield of sulfur trioxide increases. Explain why this lower temperature is not used.

.................................................................................................................................................. [1]

(v) Sulfur trioxide is dissolved in concentrated sulfuric acid. This is added to water to make more sulfuric acid. Why is sulfur trioxide not added directly to water?

.................................................................................................................................................. [1]
(b) Sulfuric acid was first made in the Middle East by heating the mineral, green vitriol, FeSO₄·7H₂O. The gases formed were cooled.

\[
\text{FeSO}_4\cdot7\text{H}_2\text{O(s)} \rightarrow \text{FeSO}_4\text{(s)} + 7\text{H}_2\text{O(g)}
\]

green crystals yellow powder

\[
2\text{FeSO}_4\text{(s)} \rightarrow \text{Fe}_2\text{O}_3\text{(s)} + \text{SO}_2\text{(g)} + \text{SO}_3\text{(g)}
\]

On cooling

\[
\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 \quad \text{sulfuric acid}
\]

\[
\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3 \quad \text{sulfurous acid}
\]

(i) How could you show that the first reaction is reversible?

...........................................................................................................................................................................................................................................................................[2]

(ii) Sulfurous acid is a reductant. What would you see when acidified potassium manganate(VII) is added to a solution containing this acid?

...........................................................................................................................................................................................................................................................................[2]

(iii) Suggest an explanation why sulfurous acid in contact with air changes into sulfuric acid.

...........................................................................................................................................................................................................................................................................[1]

(c) 12.16 g of anhydrous iron(II) sulfate was heated. Calculate the mass of iron(III) oxide formed and the volume of gases, at r.t.p., formed.

\[
2\text{FeSO}_4\text{(s)} \rightarrow \text{Fe}_2\text{O}_3\text{(s)} + \text{SO}_2\text{(g)} + \text{SO}_3\text{(g)}
\]

mass of one mole of FeSO₄ = 152 g

number of moles of FeSO₄ used = .................

number of moles of Fe₂O₃ formed = .................

mass of one mole of Fe₂O₃ = ................. g

mass of iron(III) oxide formed = ................. g

total number of moles of gases formed = .................

total volume of gases formed = ................. dm³

[6]

[Total: 16]
7 Butan-1-ol is used as a solvent for paints and varnishes, to make esters and as a fuel. Butan-1-ol can be manufactured from but-1-ene, which is made from petroleum. Biobutanol is a fuel of the future. It can be made by the fermentation of almost any form of biomass - grain, straw, leaves etc.

(a) But-1-ene can be obtained from alkanes such as nonane, C₉H₂₀, by cracking.

(i) Give the reaction conditions.

(ii) Complete an equation for the cracking of nonane, C₉H₂₀, to give but-1-ene.

C₉H₂₀ → .......................................................... [2]

(iii) Name the reagent that reacts with but-1-ene to form butan-1-ol.

.......................................................... [1]

(b) (i) Balance the equation for the complete combustion of butan-1-ol.


(ii) Write a word equation for the preparation of the ester butyl propanoate.

.......................................................... [2]
(c) The fermentation of biomass by bacteria produces a mixture of products which include biobutanol, propanol, hydrogen and propanoic acid.

(i) Draw the structural formula of propanol and of propanoic acid. Show all the bonds.

propanol

propanoic acid

(ii) Why is it important to develop these fuels, such as biobutanol, as alternatives to petroleum?

................................................................. [1]

(d) How could you show that butanol made from petroleum and biobutanol are the same chemical?

................................................................. [1]

[Total: 13]
### DATA SHEET
The Periodic Table of the Elements

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**Key**
- a = relative atomic mass
- X = atomic symbol
- b = proton (atomic) number

*58-71 Lanthanoid series
t90-103 Actinoid series

The volume of one mole of any gas is 24 dm³ at room temperature and pressure (r.t.p.).