1 The Periodic Table is very useful to chemists.

Refer only to elements with atomic numbers 1 to 36 in the Periodic Table provided when answering Question 1.

(a) Use information from the Periodic Table provided to identify one element which:

(i) has atoms with exactly 9 protons ................................................................. [1]
(ii) has atoms with 0 neutrons ........................................................................... [1]
(iii) has atoms with exactly 23 electrons .......................................................... [1]
(iv) has atoms with an electronic structure of 2,8,6 ........................................... [1]
(v) forms ions with a charge of 3– containing 18 electrons ............................. [1]
(vi) forms ions with a charge of 2+ containing 10 electrons ............................ [1]
(vii) has a relative atomic mass that shows it has at least two isotopes. ........... [1]

(b) State which metal in the first 36 elements:

(i) is the Group I element which reacts most vigorously with water ................ [1]
(ii) reacts with air to form lime. ........................................................................ [1]

(c) One element in the first 36 elements is used as the fuel in a fuel cell.

(i) Name this element.
................................................................................................................................. [1]

(ii) Write the overall chemical equation for the reaction which occurs when the element in (c)(i) reacts in a fuel cell.
................................................................................................................................. [2]

[Total: 12]
2 The gases Ar, CO₂, N₂ and O₂ are in clean, dry air.

CO, NO, NO₂ and SO₂ are gases commonly found in polluted air.

(a) What percentage of clean, dry air is N₂?

Give your answer to the nearest whole number.

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

(b) Name the process used to separate O₂ from clean, dry air.

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

(c) State one major adverse effect of the pollutant SO₂.

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

(d) NO and NO₂ are produced in car engines.

Describe how oxides of nitrogen form in a car engine.

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

(e) Many cars have catalytic converters in their exhaust systems. In a catalytic converter, most of the CO and NO formed in a car engine is changed into less harmful products.

Identify these products and state the metal catalyst used.

products ....................................................................................................................................
catalyst ...................................................................................................................................... [3]

(f) CO is formed from the incomplete combustion of fossil fuels such as methane.

Write a chemical equation to show the incomplete combustion of methane.

.............................................................................................................................................. [2]
(g) The CO₂ in air is part of the carbon cycle.

The scheme shows a simple representation of part of the carbon cycle.

![Diagram of the carbon cycle]

(i) State the scientific terms for each of process A and process B.

A .................................................................

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

(ii) Plants convert glucose into complex carbohydrates.

A unit of glucose can be represented as HO—[ — ]—OH.

Complete the diagram to show the complex carbohydrate formed from three units of glucose. Show all of the atoms and all of the bonds in the linkages.

[Diagram with three glucose units]

[2]

(iii) Complex carbohydrates break down to form simple sugars.

State two ways that complex carbohydrates can be broken down into simple sugars.

1 .................................................................

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

(iv) Name a suitable technique for separating and identifying the individual sugars formed when complex carbohydrates are broken down.

.................................................................  [1]
Ammonia is an important chemical.

(a) Ammonia is manufactured by the Haber process. The reaction is reversible.

(i) What is the sign for a reversible reaction?
............................................................................................................................................ [1]

(ii) State the essential conditions for the manufacture of ammonia by the Haber process starting from hydrogen and nitrogen. Include a chemical equation to show the reaction which occurs.
............................................................................................................................................
............................................................................................................................................
............................................................................................................................................
............................................................................................................................................
............................................................................................................................................
............................................................................................................................................ [5]

(iii) Name one raw material which is a source of the hydrogen used in the Haber process.
............................................................................................................................................ [1]

(b) Ammonia is a base and reacts with sulfuric acid to form the salt, ammonium sulfate.

(i) What is meant by the term base?
............................................................................................................................................ [1]

(ii) Name the industrial process used to manufacture sulfuric acid.
............................................................................................................................................ [1]

(iii) Write a chemical equation for the reaction between ammonia and sulfuric acid.
............................................................................................................................................ [2]
(c) When aqueous ammonia is added to aqueous iron(II) sulfate a green precipitate is seen. This green precipitate turns red-brown at the surface.

(i) Name the green precipitate.
........................................................................................................................................................................... [1]

(ii) Suggest why the green precipitate turns red-brown at the surface.
........................................................................................................................................................................... [2]

(iii) State what happens when an excess of aqueous ammonia is added to the green precipitate.
........................................................................................................................................................................... [1]
(d) Ammonia reacts with oxygen as shown.

\[ 4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g}) \]

(i) Calculate the volume of oxygen at room temperature and pressure, in dm\(^3\), that reacts with 4.80 dm\(^3\) of ammonia.

volume = ......................... dm\(^3\) [3]

(ii) The chemical equation for the reaction can be represented as shown.

\[
\begin{align*}
4 \text{H–N–H} & + 5 \text{O=O} \rightarrow 4 \text{N=O} + 6 \text{H–O–H} \\
\end{align*}
\]

Use the bond energies in the table to calculate the energy change, in kJ/mol, which occurs when one mole of NH\(_3\) reacts.

<table>
<thead>
<tr>
<th>bond</th>
<th>N–H</th>
<th>O=O</th>
<th>N=O</th>
<th>O–H</th>
</tr>
</thead>
<tbody>
<tr>
<td>bond energy in kJ/mol</td>
<td>391</td>
<td>498</td>
<td>587</td>
<td>464</td>
</tr>
</tbody>
</table>

● Energy needed to break bonds.

......................... kJ

● Energy released when bonds are formed.

......................... kJ

● Energy change when one mole of NH\(_3\) reacts.

energy change = ......................... kJ/mol

[Total: 22]
Many substances conduct electricity.

(a) Identify all the particles responsible for the passage of electricity in:

- graphite ...............................................................................................................................
- magnesium ribbon ...........................................................................................................
- molten copper(II) bromide. ............................................................................................. [4]

(b) A student used the following apparatus to electrolyse concentrated aqueous sodium chloride using inert electrodes.

(i) Suggest the name of a metal which could be used as the inert electrodes.

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

(ii) Name the gas formed at the positive electrode.

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

(iii) Write an ionic half-equation for the reaction occurring at the negative electrode. Include state symbols.

............................................................................................................................................... [3]

(iv) How, if at all, does the pH of the solution change during the electrolysis? Explain your answer.

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

............................................................................................................................................... [3]
(c) A student used the following electrochemical cell.

The reading on the voltmeter was +1.10 V.

(i) Draw an arrow on the diagram to show the direction of electron flow. [1]

(ii) Suggest the change, if any, in the voltmeter reading if the zinc electrode was replaced with an iron electrode. Explain your answer.

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

(iii) The zinc electrode was replaced with a silver electrode. The reading on the voltmeter was –0.46 V.

Suggest why the sign of the voltmeter reading became negative.

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

[Total: 16]
5 Methanol, CH₃OH, is a member of the homologous series of alcohols.

(a) Methanol can be made from methane in a two-step process.

**step 1** Methane is reacted with chlorine gas to produce chloromethane, CH₃Cl.

**step 2** CH₃Cl is reacted with sodium hydroxide to produce CH₃OH and one other product.

(i) What conditions are needed in **step 1**?

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

(ii) Write the chemical equation for the reaction which occurs in **step 1**.

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

(iii) State the type of organic reaction occurring in **step 1**.

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

(iv) Complete the chemical equation for **step 2**.

CH₃Cl + NaOH → CH₃OH + .............................. [1]

(b) Draw a dot-and-cross diagram to show the electron arrangement in a molecule of methanol. Show outer shell electrons only.

![Dot-and-cross diagram of methanol](image) [2]
(c) Methanol reacts with propanoic acid to form an ester with a molecular formula $\text{C}_4\text{H}_8\text{O}_2$.

(i) Name the ester formed when methanol reacts with propanoic acid.  

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

(ii) Name one other substance formed when methanol reacts with propanoic acid.  

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

(iii) Draw the structure of an ester which is a structural isomer of the ester named in (c)(i). Show all of the atoms and all of the bonds.  

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

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

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

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

[3]

(iv) State the conditions needed to form an ester from a carboxylic acid and an alcohol.  

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

[Total: 12]
The Periodic Table of Elements

<table>
<thead>
<tr>
<th>Group</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Li</td>
<td>Be</td>
<td>B</td>
<td>C</td>
<td>N</td>
<td>O</td>
<td>F</td>
<td>Ne</td>
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<td>4</td>
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<td>Mg</td>
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<td>Mn</td>
<td>Fe</td>
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<td>Rb</td>
<td>Sr</td>
<td>Y</td>
<td>Zr</td>
<td>Nb</td>
<td>Mo</td>
<td>Tc</td>
<td>Ru</td>
</tr>
<tr>
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<td>Ba</td>
<td>La</td>
<td>Hf</td>
<td>Ta</td>
<td>W</td>
<td>Re</td>
<td>Os</td>
</tr>
<tr>
<td>8</td>
<td>Fr</td>
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<td>actinoids</td>
<td>actinoids</td>
<td>actinoids</td>
<td>actinoids</td>
<td>actinoids</td>
<td>actinoids</td>
</tr>
</tbody>
</table>

The volume of one mole of any gas is 24 dm$^3$ at room temperature and pressure (r.t.p.).