READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in. Write in dark blue or black pen. You may use a soft pencil for any diagrams, graphs or rough working. Do not use staples, paper clips, highlighters, glue or correction fluid. DO NOT WRITE IN ANY BARCODES.

Section A
Answer all questions. Write your answers in the spaces provided in the Question Paper.

Section B
Answer any three questions. Write your answers in the spaces provided in the Question Paper.

Electronic calculators may be used. You may lose marks if you do not show your working or if you do not use appropriate units.

A copy of the Periodic Table is printed on page 16. At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.
A1 Choose from the following elements to answer the questions below.

chlorine
hydrogen
iron
lithium
nickel
nitrogen
oxygen
potassium
silver
sulfur
vanadium
zinc

Each element can be used once, more than once or not at all.

Which element

(a) is liberated at the anode when an aqueous solution of potassium sulfate is electrolysed,
......................................................................................................................................[1]

(b) is used as a catalyst in the manufacture of margarine,
......................................................................................................................................[1]

(c) is a non-metallic solid, an atom of which contains only six valency electrons,
......................................................................................................................................[1]

(d) is higher than sodium in the reactivity series,
......................................................................................................................................[1]

(e) is in Period 5 of the Periodic Table,
......................................................................................................................................[1]

(f) forms a white oxide which is amphoteric?
......................................................................................................................................[1]

[Total: 6]
A2 Carboxylic acids are a homologous series containing the –CO₂H group. The table shows some properties of the first four carboxylic acids in the series.

<table>
<thead>
<tr>
<th>carboxylic acid</th>
<th>molecular formula</th>
<th>density in g/cm³</th>
<th>boiling point in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>methanoic acid</td>
<td>CH₂O₂</td>
<td>1.220</td>
<td>101</td>
</tr>
<tr>
<td>propanoic acid</td>
<td>CH₃CO₂H</td>
<td>0.993</td>
<td>141</td>
</tr>
<tr>
<td>butanoic acid</td>
<td>CH₄CO₂H</td>
<td>0.958</td>
<td>165</td>
</tr>
<tr>
<td>C₂H₄O₂</td>
<td>1.049</td>
<td>118</td>
<td></td>
</tr>
</tbody>
</table>

(a) (i) Describe how the density of these carboxylic acids varies with the number of carbon atoms in the molecule.
..............................................................................................................................[1]

(ii) Name the carboxylic acid with the molecular formula C₂H₄O₂.
..............................................................................................................................[1]

(iii) Draw the structure of propanoic acid, showing all atoms and bonds.

[b] The next carboxylic acid in this homologous series is pentanoic acid. Pentanoic acid has five carbon atoms.

(i) Deduce the molecular formula for pentanoic acid.
..............................................................................................................................[1]

(ii) Suggest a value for the boiling point of pentanoic acid.
..............................................................................................................................°C [1]

(c) Butanoic acid, C₃H₇CO₂H, reacts with sodium to form a salt and a gas.

(i) Name the gas.
..............................................................................................................................[1]

(ii) Give the formula of the salt.
..............................................................................................................................[1]
(d) Esters are formed when carboxylic acids react with alcohols. The reaction is catalysed by hydrogen ions.

(i) Describe and explain the effect of a catalyst on reaction rate.

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

(ii) State one commercial use of esters.

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

(iii) The structure of an ester is shown below.

\[
\text{O} \quad \text{H} \quad \text{H} \quad \text{H}
\]
\[
\text{H} - \text{C} - \text{O} - \text{C} - \text{C} - \text{C} - \text{H}
\]
\[
\text{H} \quad \text{H} \quad \text{H}
\]

Name this ester.

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

[Total: 11]
A3 Silicon is an element in Group IV of the Periodic Table.

(a) Give the electronic configuration for a silicon atom.

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

(b) Silicon has three naturally occurring isotopes.

Complete the following table for two of these isotopes.

<table>
<thead>
<tr>
<th>isotope</th>
<th>$^{28}\text{Si}$</th>
<th>$^{30}\text{Si}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of protons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>number of electrons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>number of neutrons</td>
<td></td>
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</tbody>
</table>

[3]

(c) Silicon reacts with chlorine on heating to form silicon(IV) chloride, SiCl$_4$.

Construct an equation for this reaction.

[1]

(d) Silicon(IV) chloride is a simple molecular compound.

(i) Suggest two physical properties of silicon(IV) chloride other than solubility.

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

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

(ii) Draw a ‘dot-and-cross’ diagram for silicon(IV) chloride.

You only need to show the outer shell electrons for each atom.

[2]
(e) Silicon(IV) chloride reacts with water to form silicon(IV) oxide. Part of the structure of silicon(IV) oxide is shown below.

Key
- silicon atom
- oxygen atom

Explain, in terms of structure and bonding, why silicon(IV) oxide has a very high melting point.

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...........................................................................................................................................................................................................................................................................................................[2]
[Total: 11]
A4  The carbon cycle regulates the amount of carbon dioxide in the atmosphere.

(a)  (i) State two processes which release carbon dioxide into the atmosphere.

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

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

(ii) Name one process which removes carbon dioxide from the atmosphere.

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

(b) Carbon dioxide is a greenhouse gas.

(i) What is the meaning of the term greenhouse gas?

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

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

(ii) Name another greenhouse gas and give a natural source of this gas.

 name ................................................................................................................................

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

(c) Carbon dioxide dissolves in water to form a weakly acidic solution.

\[ \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HCO}_3^-(\text{aq}) + \text{H}^+(\text{aq}) \]

(i) What is the meaning of the term weak acid?

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

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

(ii) Describe how you could measure the pH of this solution other than by using a pH meter.

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

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

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

(d) Sodium hydrogencarbonate, NaHCO\textsubscript{3}, decomposes on heating to form a carbonate, water and a gas which turns limewater milky. Construct an equation for this reaction.
A student reacts magnesium ribbon with excess hydrochloric acid. She follows the course of the reaction by measuring the volume of gas produced against time.

(a) Write the equation for the reaction of magnesium with hydrochloric acid.

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

(b) (i) On the axes below draw a sketch graph to show how the volume of gas produced during the reaction varies with time and label this line ‘A’. Label the axes with the appropriate units.

(ii) The student then carries out the experiment at a lower temperature. All the other conditions remain the same.

On the axes above draw another line to show how the volume of gas produced varies with time and label this line ‘B’. [1]

(c) Magnesium reacts with carbon to form the compound magnesium carbide.

Calculate the percentage by mass of magnesium in magnesium carbide, MgC₂.

[2]

[Total: 6]
Section B

Answer three questions from this section in the spaces provided.

The total mark for this section is 30.

B6 Aluminium is extracted from purified bauxite by electrolysis.

(a) Describe how this electrolysis is carried out and construct equations for the reactions occurring at both the anode and cathode.

(b) What properties of aluminium make it useful for

(i) making aircraft, ..............................................................

(ii) making electricity cables. .............................................[2]

(c) Aluminium is high in the reactivity series.

(i) Explain why aluminium does not react with aqueous copper(II) sulfate.

(ii) When a few drops of aqueous sodium chloride are added to a mixture of aluminium and aqueous copper(II) sulfate, a vigorous reaction occurs.

\[
\text{copper(II) sulfate} + \text{aluminium} \rightarrow \text{aluminium sulfate} + \text{copper}
\]

What type of reaction is this?

(iii) State the formula of aluminium sulfate.

[Total: 10]
B7 Ethene is an unsaturated hydrocarbon.

(a) What is the meaning of each of these terms?

unsaturated ............................................................................................................................................

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

(b) Ethene can be manufactured by cracking.

(i) State the conditions used for cracking.

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

(ii) Construct an equation for the cracking of tetradecane, $C_{14}H_{30}$, to form ethene and one other hydrocarbon.

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

(c) Alkenes such as ethene can undergo addition polymerisation.

(i) State one use of poly(ethene).

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

(ii) The diagram below shows a section of a polymer chain.

CH —CH₂ —CH —CH₂ —CH —CH₂ —CH —CH₂ —

C₂H₅ C₂H₅ C₂H₅

Deduce the structure of the monomer which is used to make this polymer.
(d) Ethanol can be manufactured by the catalytic addition of steam to ethene.

\[ \text{C}_2\text{H}_4 \ + \ \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH} \]

If the reactants are not recycled, only 5% of the ethene is converted to ethanol.

Calculate the mass of ethanol formed from 0.4 tonnes of ethene when only 5% of the ethene is converted to ethanol.  
[1 tonne is 1 000 000 grams]  

mass of ethanol  ...................................... tonnes [3]

[Total: 10]
When hydrogen iodide, HI, is heated in a closed tube, the following dynamic equilibrium is established.

\[ 2\text{HI}(g) \rightleftharpoons \text{H}_2(g) + \text{I}_2(g) \quad \Delta H = +9.6 \text{ kJ/mol} \]

(a) What is meant by the term *dynamic equilibrium*?

(b) The table shows the concentrations of HI(g), H\(_2\)(g) and I\(_2\)(g) in the equilibrium mixture at 25°C and 450°C.

<table>
<thead>
<tr>
<th>substance</th>
<th>concentration at 25°C / mol/dm(^3)</th>
<th>concentration at 450°C / mol/dm(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HI(g)</td>
<td>0.94</td>
<td>0.79</td>
</tr>
<tr>
<td>H(_2)(g)</td>
<td>0.033</td>
<td>0.11</td>
</tr>
<tr>
<td>I(_2)(g)</td>
<td>0.033</td>
<td>0.11</td>
</tr>
</tbody>
</table>

(i) The tube has a volume of 50 cm\(^3\).

Calculate the mass of hydrogen iodide in the equilibrium mixture at 25°C.

(ii) Describe and explain the differences in the concentrations of reactant and products at 25°C and 450°C.
(c) Complete the energy profile diagram for the decomposition of hydrogen iodide. On your diagram label
- the products,
- the enthalpy change of the reaction, $\Delta H$.

\[ \text{energy} \]
\[ \text{reactants} \]
\[ \text{progress of reaction} \]

(d) An aqueous solution of hydrogen iodide contains iodide ions.

Describe a test for iodide ions.

..............................................................................................................................
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[Total: 10]
B9 The compounds ammonium nitrate and ammonium sulfate are both fertilisers.

(a) Explain why farmers add these fertilisers to soils.
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..........................................................................................................................................[1]

(b) Ammonium sulfate can be prepared by adding sulfuric acid to aqueous ammonia.

Construct the equation for this reaction.
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(e) Describe how to obtain pure dry crystals of calcium chloride from an aqueous solution of calcium chloride.

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[Total: 10]
### The Periodic Table of the Elements

#### Data Sheet

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

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

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<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
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* 58–71 Lanthanoid series
† 90–103 Actinoid series