1 Fig. 1.1 shows the electronic configurations of five atoms, A, B, C, D and E.

![Fig. 1.1](image)

(a) Answer the following questions.

Each letter may be used once, more than once or not at all.

Give the letter of the atom, A, B, C, D or E, that:

(i) is in Group III of the Periodic Table

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

(ii) has 13 protons

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

(iii) is a noble gas

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

(iv) forms a stable ion with a single negative charge.

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

(b) Complete Table 1.1 to show the number of electrons, neutrons and protons in the sulfur atom and oxide ion.

<table>
<thead>
<tr>
<th></th>
<th>number of electrons</th>
<th>number of neutrons</th>
<th>number of protons</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{34}_{16}$S</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{18}_{8}$O$^{2-}$</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[3]

[Total: 7]
2 (a) Table 2.1 shows the mass of ions present in a 100 cm$^3$ sample of milk.

<table>
<thead>
<tr>
<th>ion</th>
<th>formula of ion</th>
<th>mass of ion in 100 cm$^3$ milk / mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>calcium</td>
<td>Ca$^{2+}$</td>
<td>125</td>
</tr>
<tr>
<td>chloride</td>
<td>Cl$^-$</td>
<td>120</td>
</tr>
<tr>
<td>magnesium</td>
<td>Mg$^{2+}$</td>
<td>12</td>
</tr>
<tr>
<td>negative ions of organic acids</td>
<td>PO$_4^{3-}$</td>
<td>95</td>
</tr>
<tr>
<td>phosphate</td>
<td></td>
<td>160</td>
</tr>
<tr>
<td>potassium</td>
<td>K$^+$</td>
<td>140</td>
</tr>
<tr>
<td>sodium</td>
<td>Na$^+$</td>
<td>58</td>
</tr>
<tr>
<td>sulfate</td>
<td>SO$_4^{2-}$</td>
<td>30</td>
</tr>
</tbody>
</table>

(i) Calculate the mass of calcium ions present in a 20 cm$^3$ sample of this milk.

mass of calcium ions = .................................................... mg [1]

(ii) Identify the positive ion present in the highest concentration in the 100 cm$^3$ sample of milk.

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

(iii) Complete Fig. 2.1 to show the electronic configuration of a potassium ion.

Fig. 2.1

(iv) Describe a test for chloride ions.

test ....................................................................................................................................

positive result ..................................................................................................................[2]
(v) Explain why the solutions used in qualitative chemical tests are made using distilled water and **not** tap water.

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

(b) Which one of these salts is soluble in water?

Tick one box.

- barium sulfate
- calcium carbonate
- ammonium sulfate
- iron(II) hydroxide

[1]

(c) One of the organic acids present in milk is lactic acid. The displayed formula of lactic acid is shown in Fig. 2.2.

![Fig. 2.2](image)

(i) Draw a circle around the carboxylic acid functional group on the structure. [1]

(ii) Deduce the molecular formula of lactic acid.

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

[Total: 9]
Fig. 3.1 shows a coloured crystal of cobalt(II) chloride is placed at the bottom of a beaker containing water.

After two days, the colour has spread throughout the water.

![Fig. 3.1](image)

(a) Explain these observations.

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

(b) Cobalt(II) chloride can be used to test for the presence of water.

\[
\text{CoCl}_2 + 6\text{H}_2\text{O} \rightleftharpoons \text{CoCl}_2 \cdot 6\text{H}_2\text{O}
\]

(i) State the meaning of the symbol \(\rightleftharpoons\).

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

(ii) State the colour change when water is added to anhydrous cobalt(II) chloride.

from .............................................. to .............................................. [2]
(c) (i) Table 3.1 compares the reactivity of cobalt with that of three other metals.

<table>
<thead>
<tr>
<th>metal</th>
<th>reactivity with cold water</th>
<th>reactivity with steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>barium</td>
<td>reacts rapidly</td>
<td></td>
</tr>
<tr>
<td>cobalt</td>
<td>no reaction</td>
<td>reacts slowly when heated</td>
</tr>
<tr>
<td>magnesium</td>
<td>reacts very slowly</td>
<td>reacts rapidly</td>
</tr>
<tr>
<td>zinc</td>
<td>no reaction</td>
<td>reacts easily when heated</td>
</tr>
</tbody>
</table>

Use this information to put the four metals in order of their reactivity. Put the least reactive metal first.

least reactive ➔ most reactive

(ii) State the boiling point of pure water at room temperature and pressure.

...................................................... °C [1]

(d) Cobalt is a transition element. Lithium is a Group I element.

Describe two ways in which the properties of cobalt differ from those of lithium.

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

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

(e) When cobalt(II) oxide, CoO, is heated in air an oxide with the formula Co₃O₄ is formed.

Balance the equation for this reaction.

......... CoO + O₂ → 2Co₃O₄ [1]

(f) When the oxide Co₃O₄ is heated in hydrogen, cobalt metal is formed.

Co₃O₄ + 4H₂ → 3Co + 4H₂O

Explain how this equation shows that Co₃O₄ is reduced.

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

[Total: 13]
A student investigates the reaction of small pieces of zinc with dilute sulfuric acid at 20 °C. The zinc is in excess.

(a) Fig. 4.1 shows the volume of hydrogen gas released as the reaction proceeds.

![Graph showing volume of hydrogen gas vs time](image)

**Fig. 4.1**

(i) Suggest why the volume of hydrogen gas stays the same after 10 minutes.

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

(ii) Deduce the time taken from the start of the experiment to collect 20 cm$^3$ of hydrogen gas.

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

(iii) The student repeats the experiment at 30 °C.

All other conditions stay the same.

Draw a line **on the grid** in Fig. 4.1 to show how the volume of hydrogen gas changes with time when the reaction is carried out at 30 °C. [2]
(b) The student repeats the experiment using zinc powder instead of small pieces of zinc.

Describe how the rate of reaction differs when zinc powder is used.

Give a reason for your answer.

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

(c) Sulfuric acid is a compound.

(i) Define the term compound.

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

(ii) State the formula of the ion that is present in an aqueous solution of all acids.

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

(iii) A few drops of the indicator methyl orange are added to aqueous dilute sulfuric acid.

State the colour change observed.

from orange to .............................................................................................................. [1]

(iv) The formula of sulfuric acid is H₂SO₄.

Complete Table 4.1 to calculate the relative molecular mass of sulfuric acid.

<table>
<thead>
<tr>
<th>atom</th>
<th>number of atoms</th>
<th>relative atomic mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>hydrogen</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>sulfur</td>
<td></td>
<td></td>
</tr>
<tr>
<td>oxygen</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

table 4.1

relative molecular mass = ........................................  [2]

[Total: 11]
Table 5.1 shows the properties of four substances.

Table 5.1

<table>
<thead>
<tr>
<th>Substance</th>
<th>Boiling Point</th>
<th>Electrical Conductivity of Solid</th>
<th>Electrical Conductivity When Molten</th>
<th>Density in g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>High</td>
<td>Conducts</td>
<td>Conducts</td>
<td>2.70</td>
</tr>
<tr>
<td>Diamond</td>
<td></td>
<td></td>
<td></td>
<td>3.51</td>
</tr>
<tr>
<td>Potassium Bromide</td>
<td>High</td>
<td>Does not conduct</td>
<td>Conducts</td>
<td>2.75</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Low</td>
<td>Does not conduct</td>
<td></td>
<td>2.07</td>
</tr>
</tbody>
</table>

(a) Complete Table 5.1 to show the electrical conductivity of solid diamond and molten sulfur. [2]

(b) State one piece of evidence from Table 5.1 that shows that sulfur is a simple molecular substance.

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

(c) (i) State the meaning of the term ionic bonding.

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

(ii) Identify which information in Table 5.1 shows that potassium bromide is an ionic compound.

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

(d) State the property of aluminium given in Table 5.1 which makes it suitable for the manufacture of aircraft.

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

(e) Molten potassium bromide can be electrolysed.

Predict the products of this electrolysis at:

the anode ........................................................................................................................................... [2]

the cathode ........................................................................................................................................ [2]

[Total: 10]
6 Aqueous sodium hydroxide is a base.

(a) Complete this sentence about the different types of bases.
Bases are metal hydroxides or metal ................................................................. [1]

(b) Describe the reaction of aqueous sodium hydroxide with:
- a named acid
...................................................................................................................................................
...................................................................................................................................................
...................................................................................................................................................
- an ammonium salt.
...................................................................................................................................................
...................................................................................................................................................
...................................................................................................................................................
..................................................................................................................................................... [4]

(c) Ammonia is a soluble base.

Draw a circle around the pH value of aqueous ammonia.

<table>
<thead>
<tr>
<th>pH 1</th>
<th>pH 5</th>
<th>pH 7</th>
<th>pH 10</th>
</tr>
</thead>
</table>

[1]

(d) Ammonia is used in the manufacture of nitrogen-containing fertilisers.

Which two of these compounds are present in fertilisers?

Tick two boxes.

- copper(II) oxide □
- potassium chloride □
- sodium phosphate □
- strontium fluoride □
- sulfur dioxide □

[2]
(e) Bacteria in the soil convert ammonium compounds to oxides of nitrogen. The oxides of nitrogen escape into the atmosphere.

(i) State one other source of oxides of nitrogen in the atmosphere.

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

(ii) Oxides of nitrogen contribute to photochemical smog.

Describe one other adverse effect of oxides of nitrogen on the environment.

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

[Total: 10]
7  (a) Table 7.1 shows some properties of some of the halogens.

<table>
<thead>
<tr>
<th>halogen</th>
<th>melting point / °C</th>
<th>boiling point / °C</th>
<th>colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>chlorine</td>
<td>−101</td>
<td>−35</td>
<td>yellow-green</td>
</tr>
<tr>
<td>bromine</td>
<td>−7</td>
<td></td>
<td>red-brown</td>
</tr>
<tr>
<td>iodine</td>
<td>+114</td>
<td>+184</td>
<td>grey-black</td>
</tr>
<tr>
<td>astatine</td>
<td>+302</td>
<td>+337</td>
<td></td>
</tr>
</tbody>
</table>

Use the information in Table 7.1 to suggest:

- the colour of astatine
- the boiling point of bromine
- the state of iodine at 190 °C.

(b) Aqueous chlorine reacts with aqueous potassium bromide as shown.

\[ \text{Cl}_2 + 2\text{KBr} \rightarrow \text{Br}_2 + 2\text{KCl} \]

(i) Name the salt formed in this reaction.

(ii) Explain why aqueous bromine does not react with aqueous potassium chloride.

(iii) Complete the dot-and-cross diagram in Fig. 7.1 of a molecule of chlorine.

Show outer shell electrons only.

**Fig. 7.1**

[Total: 7]
Hydrogen is a fuel which can be obtained from water by electrolysis.

Refinery gas and petrol are fuels obtained by the fractional distillation of petroleum.

(a) (i) Complete the equation for the burning of hydrogen.

\[ \text{......... } \text{H}_2 \text{(g)} + \text{O}_2 \text{(g)} \rightarrow \text{.........H}_2\text{O(l)} \]  

[1]

(ii) State the meaning of (g) and (l).

(g) ................................................................................................................................................

(l) ...................................................................................................................................................  

[2]

(iii) Thermal energy is released to the surroundings when hydrogen is burnt.

State the name of the type of reaction which transfers heat to the surroundings.

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

[1]

(b) Some cars use hydrogen–oxygen fuel cells as a source of energy.

Explain one advantage to the environment of using a hydrogen–oxygen fuel cell instead of a petrol engine.

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

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

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

[2]

(c) Refinery gas contains methane.

Methane is a gas which is responsible for climate change.

State two strategies to reduce the amount of methane entering the atmosphere.

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

2 ...................................................................................................................................................  

[2]

(d) Petrol is a mixture of alkanes.

One of the alkanes in petrol is octane, \( \text{C}_8\text{H}_{18} \).

Name the two products formed when octane is burnt in excess air.

................................................................................................................................................ and ..............................................................................................................................................  

[2]
(e) More petrol can be made by cracking less useful petroleum fractions.

(i) Define the term cracking.

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

(ii) Complete the equation for the cracking of dodecane, $\text{C}_{12}\text{H}_{26}$, to form ethene and one other hydrocarbon.

$$\text{C}_{12}\text{H}_{26} \rightarrow \text{C}_2\text{H}_4 + \text{.........} \quad [1]$$

[Total: 13]
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>1</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>He</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<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>
</tr>
<tr>
<td>4</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
<td>S</td>
<td>Cl</td>
<td>Ar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Na</td>
<td>Mg</td>
<td>P</td>
<td>S</td>
<td>K</td>
<td>Ca</td>
<td>Sc</td>
<td>Ti</td>
</tr>
<tr>
<td>6</td>
<td>Mg</td>
<td>Ca</td>
<td>Sc</td>
<td>Ti</td>
<td>V</td>
<td>Cr</td>
<td>Mn</td>
<td>Fe</td>
</tr>
<tr>
<td>7</td>
<td>P</td>
<td>S</td>
<td>K</td>
<td>Cr</td>
<td>Mn</td>
<td>Fe</td>
<td>Co</td>
<td>Ni</td>
</tr>
<tr>
<td>8</td>
<td>S</td>
<td>Cl</td>
<td>Ar</td>
<td>Mn</td>
<td>Co</td>
<td>Ni</td>
<td>Cu</td>
<td>Zn</td>
</tr>
<tr>
<td>9</td>
<td>Cl</td>
<td>Ar</td>
<td>Kr</td>
<td>Ni</td>
<td>Cu</td>
<td>Zn</td>
<td>Ga</td>
<td>Ge</td>
</tr>
<tr>
<td>10</td>
<td>Ar</td>
<td>Kr</td>
<td>Rn</td>
<td>Ga</td>
<td>Ge</td>
<td>As</td>
<td>Se</td>
<td>Br</td>
</tr>
<tr>
<td>85</td>
<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>
<td>86</td>
<td>Cs</td>
<td>Ba</td>
<td>La</td>
<td>Hf</td>
<td>Ta</td>
<td>W</td>
<td>Re</td>
<td>Os</td>
</tr>
<tr>
<td>87</td>
<td>Fr</td>
<td>Ra</td>
<td>Lanthanoids</td>
<td>Hf</td>
<td>Ta</td>
<td>W</td>
<td>Re</td>
<td>Os</td>
</tr>
<tr>
<td>88</td>
<td>Ra</td>
<td>Lanthanoids</td>
<td>Actinoids</td>
<td>Hf</td>
<td>Ta</td>
<td>W</td>
<td>Re</td>
<td>Os</td>
</tr>
</tbody>
</table>

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