Figure 1 shows a reactor used to produce titanium from titanium(IV) chloride.

![Figure 1](image)

The chemical equation for the reaction of titanium(IV) chloride with sodium is:

$$\text{TiCl}_4 + 4\text{Na} \rightarrow \text{Ti} + 4\text{NaCl}$$

titanium(IV) chloride + sodium → titanium + sodium chloride

(a) For one reaction:

- 1615 kg titanium(IV) chloride reacted completely with 782 kg sodium
- 1989 kg sodium chloride was produced.

Calculate the mass of titanium produced from this reaction.

________________________________________________________

________________________________________________________

Mass of titanium = _________________ kg

(1)
(b) The table below shows the solubility of sodium chloride in 100 cm³ of aqueous solution at different temperatures.

<table>
<thead>
<tr>
<th>Solubility of sodium chloride in g per 100 cm³</th>
<th>Temperature in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.72</td>
<td>10</td>
</tr>
<tr>
<td>35.89</td>
<td>20</td>
</tr>
<tr>
<td>36.09</td>
<td>30</td>
</tr>
<tr>
<td>37.37</td>
<td>40</td>
</tr>
<tr>
<td>36.69</td>
<td>50</td>
</tr>
<tr>
<td>37.04</td>
<td>60</td>
</tr>
</tbody>
</table>

On Figure 2:
- plot this data on the grid
- draw a line of best fit.

Figure 2
(c) The product sodium chloride is dissolved in water to separate it from titanium.

At 30 °C the solubility of sodium chloride is 36 kg per 100 dm³.

Calculate the minimum volume of water in dm³, at 30 °C, needed to dissolve 1989 kg sodium chloride.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

Volume of water = ____________________ dm³

(2)

(d) Calculate the percentage by mass of titanium in titanium(IV) chloride (TiCl₄).

Give your answer to 3 significant figures.

Relative atomic masses (A_r): Cl = 35.5; Ti = 48

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

Percentage of titanium by mass = _______________ %

(3)

(e) Suggest why the reaction is done in an atmosphere of dry argon instead of air containing water vapour.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

___________________________________________________________________

(3)
Copper can be produced from copper(II) sulfate solution by two different methods.

**Method 1 – Electrolysis**

(a) To produce copper by electrolysis a student has inert electrodes, a d.c. power supply, a switch and electrical wires for the external circuit.

Draw and label the apparatus set up to produce copper from copper(II) sulfate solution by electrolysis.

(b) Suggest why the colour of the copper(II) sulfate solution fades during the electrolysis.

(f) Explain why titanium conducts electricity.
(c) Explain how copper is produced from copper(II) sulfate solution by electrolysis.

Method 2 – Displacement

(d) The chemical equation for the displacement of copper using iron is:

$$\text{CuSO}_4 + \text{Fe} \rightarrow \text{Cu} + \text{FeSO}_4$$

Calculate the minimum mass of iron needed to displace all of the copper from 50 cm$^3$ of copper(II) sulfate solution.

The concentration of the copper(II) sulfate solution is 80 g CuSO$_4$ per dm$^3$.

Relative atomic masses ($A_r$): O = 16; S = 32; Fe = 56; Cu = 63.5

Give your answer to 2 significant figures.

Mass of iron = __________________ g

(Total 13 marks)
Aqamed is a medicine for children.

(a) The medicine is a formulation.

What is meant by a formulation?

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(1)

(b) Children often do not like taking medicine.

Suggest a substance that could be added to Aqamed to increase the desire for children to take it.

Give a reason for your suggestion.

Substance _________________________________________________________

Reason ____________________________________________________________
___________________________________________________________________

(2)

(c) The main ingredient in Aqamed is a painkiller called paracetamol.

The figure below represents a molecule of paracetamol.

![Molecule of paracetamol]

Give the molecular formula of paracetamol.

Calculate its relative formula mass ($M_r$).

Relative atomic masses ($A_r$): H = 1; C = 12; N = 14; O = 16

Molecular formula ____________________________________________________

Relative formula mass ________________________________________________

___________________________________________________________________

$M_r =$ _________________________________________________

(2)
(d) Aspirin is a medicine for use by adults.

An aspirin tablet contains 300 mg of acetylsalicylic acid.

Calculate the number of moles of acetylsalicylic acid in one aspirin tablet.

Give your answer in standard form to three significant figures.

Relative formula mass \( (M_r) \) of aspirin = 180

Number of moles = ______________________

(Formulae and equations are used to describe chemical reactions.

(a) Aluminium reacts with sulfuric acid \( (H_2SO_4) \) to produce aluminium sulfate, \( Al_2(SO_4)_3 \) and hydrogen \( (H_2) \).

Complete and balance the equation for this reaction.

____Al + _____________ → ______________ + _____________

(b) Calcium carbonate reacts with nitric acid to produce calcium nitrate.

Calculate the relative formula mass \( (M_r) \) of calcium nitrate, \( Ca(NO_3)_2 \)

Relative atomic masses \( (A_r): \) N = 14; O = 16; Ca = 40

Relative formula mass \( (M_r) = \) __________________
(c) Zinc carbonate decomposes when heated.

A student heated 25 g zinc carbonate (ZnCO₃).

The figure below shows how he set up the apparatus.

![Crucible diagram]

The balanced chemical equation for the decomposition reaction is:

\[
\text{ZnCO}_3 (s) \rightarrow \text{ZnO (s)} + \text{CO}_2 (g)
\]

The student measured the mass of solid product after heating until there was no further change in mass.

The student did the experiment four times. The table below shows the results.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of solid product in g</td>
<td>17.4</td>
<td>19.7</td>
<td>17.6</td>
<td>16.9</td>
</tr>
</tbody>
</table>

Calculate the mean mass of the solid product.

Do not use any anomalous results in your calculation.

\[
\text{Mean mass} = \text{(sum of masses) / number of experiments} = \frac{17.4 + 19.7 + 17.6 + 16.9}{4}
\]

Mean mass = _________________ g

(Total 6 marks)
The salt copper sulfate can be made by reacting copper carbonate with dilute sulfuric acid.

\[
\text{CuCO}_3 (s) + \text{H}_2\text{SO}_4 (aq) \rightarrow \text{CuSO}_4 (aq) + \text{H}_2\text{O}(l) + \text{CO}_2 (g)
\]

(a) Write a method that a student could use to prepare a pure, dry sample of copper

You do \textbf{not} need to write a risk assessment or include safety points.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(b) Calculate the \textbf{number of molecules} in 14 g of carbon dioxide.

Give your answer in standard form.

Relative atomic masses \((A_i)\): \(C = 14; O = 16\)

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

Answer = __________________ molecules

(4)

(Total 10 marks)
(a) Iron is extracted in a blast furnace. Figure 1 is a diagram of a blast furnace.

Figure 1

![Diagram of a blast furnace](image)

(i) Calcium carbonate decomposes at high temperatures.

Complete the word equation for the decomposition of calcium carbonate.

\[
\text{calcium carbonate} \rightarrow \underline{\quad} + \underline{\quad}
\]

(ii) Carbon burns to produce carbon dioxide.

The carbon dioxide produced reacts with more carbon to produce carbon monoxide.

Balance the equation.

\[
\text{C(s)} + \text{CO}_2(g) \rightarrow \underline{\quad} \text{CO}(g)
\]
(iii) Carbon monoxide reduces iron(III) oxide:

\[ \text{Fe}_2\text{O}_3(s) + 3 \text{CO}(g) \rightarrow 2 \text{Fe}(s) + 3 \text{CO}_2(g) \]

Calculate the maximum mass of iron that can be produced from 300 tonnes of iron(III) oxide.

Relative atomic masses \((A_r)\): O = 16; Fe = 56

Maximum mass = _______________ tonnes

(b) Aluminium is extracted by electrolysis, as shown in Figure 2.

(i) Why can aluminium not be extracted by heating aluminium oxide with carbon?

(1)
(ii) Explain why aluminium forms at the negative electrode during electrolysis.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(iii) Explain how carbon dioxide forms at the positive electrodes during electrolysis.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

This question is about carbon and gases in the air.

(a) Carbon atoms have protons, neutrons and electrons.

Complete the table by writing the relative mass of a neutron and an electron.

<table>
<thead>
<tr>
<th>Name of particle</th>
<th>Relative mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>proton</td>
<td>1</td>
</tr>
<tr>
<td>neutron</td>
<td></td>
</tr>
<tr>
<td>electron</td>
<td></td>
</tr>
</tbody>
</table>
(b) What is the total number of protons and neutrons in an atom called?

Tick (✓) one box.

- The atomic number
- The mass number
- One mole of the atom

(c) An atom of carbon has six electrons.

Which structure, A, B or C, represents the electronic structure of the carbon atom?

The carbon atom is structure

(d) Carbon reacts with oxygen to produce carbon dioxide (CO₂).

(i) How many different elements are in one molecule of carbon dioxide?

(ii) What is the total number of atoms in one molecule of carbon dioxide?
(e) Sometimes carbon reacts with oxygen to produce carbon monoxide (CO).

(i) Calculate the relative formula mass ($M_r$) of carbon monoxide.

Relative atomic masses ($A_r$): C = 12; O = 16

\[
M_r \text{ of carbon monoxide} = \frac{12 + 16}{1} = 28
\]

(ii) Calculate the percentage by mass of carbon in carbon monoxide.

\[
\text{Percentage by mass of carbon in carbon monoxide} = \frac{12}{28} \times 100 = \frac{12}{0.28} \%
\]
(f) Carbon dioxide is one of the gases in the air.

(i) The graph shows the percentage of argon and the percentage of carbon dioxide in the air.

![Graph showing percentage of argon and carbon dioxide](image)

What is the percentage of argon in the air?

Percentage of argon = ____________________ %

(ii) An instrumental method is used to measure the amount of carbon dioxide in the air.

Give one reason for using an instrumental method.

______________________________________________________________

______________________________________________________________

(1)

(Total 10 marks)
(a) Atoms contain protons, neutrons and electrons.

A lithium atom has the symbol $\text{^7}_3\text{Li}$

Explain, in terms of sub-atomic particles, why the mass number of this lithium atom is 7.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(b) Amounts of substances can be described in different ways.

Complete the sentences.

One mole of a substance is the relative formula mass in

___________________________________________________________________

The relative atomic mass of an element compares the mass of an atom of an element with the mass of an atom of

___________________________________________________________________

(c) Two isotopes of oxygen are $\text{^{18}_8\text{O}}$ and $\text{^{16}_8\text{O}}$

Describe the similarities and differences between the isotopes $\text{^{18}_8\text{O}}$ and $\text{^{16}_8\text{O}}$

You should refer to the numbers of sub-atomic particles in each isotope.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(Total 8 marks)
(a) The diagram shows an atom of magnesium and an atom of chlorine.

Describe, in terms of electrons, how magnesium atoms and chlorine atoms change into ions to produce magnesium chloride (MgCl$_2$).

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(b) Calculate the relative formula mass ($M_r$) of magnesium chloride (MgCl$_2$).

Relative atomic masses ($A_r$): magnesium = 24; chlorine = 35.5

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

Relative formula mass ($M_r$) = ________

(Total 6 marks)
Some students were investigating the rate at which carbon dioxide gas is produced when metal carbonates react with an acid.

One student reacted 1.00 g of calcium carbonate with 50 cm$^3$, an excess, of dilute hydrochloric acid.

The apparatus used is shown in Diagram 1.

Diagram 1

![Diagram of apparatus](image)

(a) Complete the two labels for the apparatus on the diagram.

(b) The student measured the volume of gas collected every 30 seconds.

The table shows the student's results.

<table>
<thead>
<tr>
<th>Time in seconds</th>
<th>Volume of carbon dioxide collected in cm$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>104</td>
</tr>
<tr>
<td>60</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>198</td>
</tr>
<tr>
<td>120</td>
<td>221</td>
</tr>
<tr>
<td>150</td>
<td>232</td>
</tr>
<tr>
<td>180</td>
<td>238</td>
</tr>
<tr>
<td>210</td>
<td>240</td>
</tr>
<tr>
<td>240</td>
<td>240</td>
</tr>
</tbody>
</table>
(i) **Diagram 2** shows what the student saw at 60 seconds.

![Diagram 2](image)

What is the volume of gas collected?

Volume of gas = __________ cm$^3$

(1)

(ii) Why did the volume of gas stop changing after 210 seconds?

______________________________________________________________

______________________________________________________________

(1)

c) Another student placed a conical flask containing 1.00 g of a Group 1 carbonate (M$_2$CO$_3$) on a balance.

He then added 50 cm$^3$, an excess, of dilute hydrochloric acid to the flask and measured the mass of carbon dioxide given off.

The equation for the reaction is:

$$\text{M}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{MCl} + \text{H}_2\text{O} + \text{CO}_2$$

The final mass of carbon dioxide given off was 0.32 g.

(i) Calculate the amount, in moles, of carbon dioxide in 0.32 g carbon dioxide.

Relative atomic masses (A$_r$): C = 12; O = 16

______________________________________________________________

______________________________________________________________

______________________________________________________________

Moles of carbon dioxide = __________ moles

(2)
(ii) How many moles of the metal carbonate are needed to make this number of moles of carbon dioxide?

________________________________________________________________________

________________________________________________________________________

Moles of metal carbonate = __________ moles

(1)

(iii) The mass of metal carbonate used was 1.00 g.

Use this information, and your answer to part (c) (ii), to calculate the relative formula mass (M_r) of the metal carbonate.

If you could not answer part (c) (ii), use 0.00943 as the number of moles of metal carbonate. This is **not** the answer to part (c) (ii).

________________________________________________________________________

________________________________________________________________________

Relative formula mass (M_r) of metal carbonate = __________

(1)

(iv) Use your answer to part (c) (iii) to calculate the relative atomic mass (A_r) of the metal in the metal carbonate (M_2CO_3) and so identify the Group 1 metal in the metal carbonate.

If you could not answer part (c) (iii), use 230 as the relative formula mass of the metal carbonate. This is **not** the answer to part (c) (iii).

To gain full marks, you must show your working.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Relative atomic mass of metal is _____________________________________________

Identity of metal ____________________________________________________________

(3)
(d) Two other students repeated the experiment in part (c).

(i) When the first student did the experiment some acid sprayed out of the flask as the metal carbonate reacted.

Explain the effect this mistake would have on the calculated relative atomic mass of the metal.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(ii) The second student used 100 cm$^3$ of dilute hydrochloric acid instead of 50 cm$^3$.

Explain the effect, if any, this mistake would have on the calculated relative atomic mass of the metal.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(Total 17 marks)
Scientists found that a compound contained:

22.8% sodium; 21.8% boron; and 55.4% oxygen.

Use the percentages to calculate the empirical formula of the compound.

Relative atomic masses (A_r): B = 11; O = 16; Na = 23

To gain full marks you must show all your working.

Empirical formula = ______________________________

(Total 5 marks)
A company manufactures ethanol (C\textsubscript{2}H\textsubscript{5}OH).

The reaction for the process is:

\[
\text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{C}_2\text{H}_5\text{OH}(\text{g}) \quad \Delta H = -45 \text{ kJ per mole}
\]

The temperature and pressure can be changed to increase the yield of ethanol at equilibrium.

(a) Explain what is meant by equilibrium.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(b) (i) How would increasing the temperature change the yield of ethanol at equilibrium?

Give a reason for your answer.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(ii) How would increasing the pressure change the yield of ethanol at equilibrium?

Give a reason for your answer.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

___________________________________________________________________
Some students investigated reactions to produce magnesium.

(a) The students used electrolysis to produce magnesium from magnesium chloride, as shown in the figure below.

(i) Magnesium chloride contains magnesium ions and chloride ions. Why does solid magnesium chloride \textbf{not} conduct electricity?

(ii) One of the products of the electrolysis of molten magnesium chloride is magnesium. Name the other product.

(iii) Why do magnesium ions (Mg^{2+}) move to the negative electrode?

(c) A catalyst is added to increase the rate of the reaction.

Explain how adding a catalyst increases the rate of a chemical reaction.
(iv) At the negative electrode, the magnesium ions (Mg\(^{2+}\)) gain electrons to become magnesium atoms.

How many electrons does each magnesium ion gain?

______________________________

(1)

(b) The students did the experiment four times and weighed the magnesium produced.

The table below shows their results.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Mass of magnesium produced in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.13</td>
</tr>
<tr>
<td>2</td>
<td>0.63</td>
</tr>
<tr>
<td>3</td>
<td>1.11</td>
</tr>
<tr>
<td>4</td>
<td>1.09</td>
</tr>
</tbody>
</table>

(i) There is an anomalous result.

Suggest one possible reason for the anomalous result.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(1)

(ii) Calculate the mean mass of magnesium produced, taking account of the anomalous result.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Mean mass = ____________________ g

(2)
(c) The formula of magnesium chloride is MgCl₂.

The relative formula mass of magnesium chloride is 95.

The relative atomic mass of magnesium is 24.

(i) Use the equation to calculate the percentage mass of magnesium in magnesium chloride.

\[
\text{Percentage mass of magnesium} = \frac{\text{mass of magnesium}}{\text{mass of magnesium chloride}} \times 100\%
\]

Percentage mass of magnesium in magnesium chloride = __________ %

(2)

(ii) Draw a ring around the relative mass of chlorine in MgCl₂

71 95 119

(1)

(d) Magnesium is also produced from the reaction of magnesium oxide with silicon.

(i) The equation for the reaction is:

\[
2 \text{MgO(s)} + \text{Si(s)} \rightleftharpoons \text{SiO}_2\text{(s)} + 2 \text{Mg(s)}
\]

What is the meaning of this symbol \(\rightleftharpoons\)?

Draw a ring around the correct answer.

\[\text{neutralisation reaction} \quad \text{precipitation reaction} \quad \text{reversible reaction}\]

(1)

(ii) The forward reaction is endothermic.

Draw a ring around the correct answer to complete the sentence.

In an endothermic reaction the temperature of the surroundings

decreases.
increases.
stays the same.

(1)

(Total 12 marks)
Thermosoftening polymers can be used to make plastic bottles and food packaging.

(a) Why are thermosoftening polymers \textbf{not} suitable for storing very hot food?

___________________________________________________________________
___________________________________________________________________

(b) The reaction to produce the polymers uses a catalyst.

Why are catalysts used in chemical reactions?

___________________________________________________________________
___________________________________________________________________

(c) Compounds from food packaging must not get into food.

Gas chromatography can be used to separate compounds in food.

The output from the gas chromatography column can be linked to an instrument which can identify the compounds.

(i) Name the instrument used to identify the compounds.

___________________________________________________________________
___________________________________________________________________

(ii) \textbf{Give one reason why instrumental methods of analysis are used to identify the compounds.}

___________________________________________________________________
___________________________________________________________________

(d) Poly(ethene) is a thermosoftening polymer.

Poly(ethene) can be made with different properties. The properties depend on the conditions used when poly(ethene) is made.

\textbf{Suggest two} conditions which could be changed when poly(ethene) is made.

___________________________________________________________________
___________________________________________________________________

(Total 6 marks)
This question is about compounds of copper.

(a) A student made some copper(II) sulfate crystals.

The flow diagram shows the stages of the preparation of copper(II) sulfate crystals.

Stage 1: Mixture of sulfuric acid and excess copper(II) oxide
Stage 2: Copper(II) sulfate solution and unreacted copper(II) oxide
Stage 3: Blue copper(II) sulfate crystals

(i) The reaction mixture is heated in Stage 1. Suggest why.

(ii) Complete the equation for this reaction.

CuO + ______________ → CuSO₄ + ______________

(iii) How would the student remove the unreacted copper(II) oxide in Stage 2?

(iv) How would the student obtain copper(II) sulfate crystals from the copper(II) sulfate solution in Stage 3?

(v) The mass of crystals obtained was less than the student had calculated. Suggest one reason why.
(b) The student heated the blue copper(II) sulfate crystals.

The word equation for the reaction is shown below.

\[
\text{hydrated copper(II) sulfate} \quad \rightleftharpoons \quad \text{anhydrous copper(II) sulfate} \quad + \quad \text{water} \\
\quad \text{blue} \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \text{white}
\]

(i) What does the symbol \( \rightleftharpoons \) mean?

______________________________________________________________________________

(1)

(ii) 300 J of energy are taken in when some blue copper(II) sulfate crystals are heated.

What is the energy change when an excess of water is added to the anhydrous copper(II) sulfate produced?

______________________________________________________________________________

______________________________________________________________________________

(2)

(c) A sample of copper nitride contains 3.81 g of copper and 0.28 g of nitrogen.

Calculate the empirical formula.

You **must** show all your working to get full marks.

Relative atomic masses (\( A_r \)): \( \text{N} = 14; \text{Cu} = 63.5 \).

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

Empirical formula = _________________________

(4)

(Total 13 marks)
Etching is a way of making printed circuit boards for computers.

Printed circuit boards are made when copper sheets are etched using iron(III) chloride solution. Where the copper has been etched, only plastic remains.

(a) Copper is a good conductor of electricity.

Explain why.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(b) Iron(III) chloride can be produced by the reaction shown in the equation:

\[ 2 \text{Fe} + 3 \text{Cl}_2 \rightarrow 2 \text{FeCl}_3 \]

(i) Calculate the maximum mass of iron(III) chloride (FeCl₃) that can be produced from 11.20 g of iron.

Relative atomic masses (Aᵣ): Cl = 35.5; Fe = 56.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

Maximum mass of iron(III) chloride = _______________ g
(ii) The actual mass of iron(III) chloride (FeCl₃) produced was 24.3 g.

Calculate the percentage yield.

(If you did not answer part (b)(i) assume that the maximum theoretical mass of iron(III) chloride (FeCl₃) is 28.0 g. This is not the correct answer to part (b)(i).)

Percentage yield = ____________%

(Total 6 marks)

This apparatus is used for the reaction of copper oxide (CuO) with methane (CH₄).

(a) The symbol equation for this reaction is shown below.

\[ 4 \text{CuO(s)} + \text{CH}_4(\text{g}) \rightarrow 4 \text{Cu(s)} + 2 \text{H}_2\text{O(g)} + \text{CO}_2(\text{g}) \]

The water and carbon dioxide produced escape from the test tube.

Use information from the equation to explain why.

___________________________________________________________________

___________________________________________________________________

(1)

(b) (i) Calculate the relative formula mass \( (M_r) \) of copper oxide (CuO).

Relative atomic masses \( (A_r) \): O = 16, Cu = 64

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

Relative formula mass \( (M_r) = \) ____________

(2)
(ii) Calculate the percentage of copper in copper oxide.

Percentage of copper = _____________ %

(iii) Calculate the maximum mass of copper that could be produced from 4.0 g of copper oxide.

Mass of copper produced = ____________________ g

(c) The experiment was done three times.

The mass of copper oxide used and the mass of copper produced were measured each time.

The results are shown in the table.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of copper oxide used in g</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Mass of copper produced in g</td>
<td>3.3</td>
<td>3.5</td>
<td>3.2</td>
</tr>
</tbody>
</table>

(i) Calculate the mean mass of copper produced in these experiments.

Mean mass of copper produced = _____________ g

(ii) Suggest how the results of the experiment could be made more precise.
(iii) The three experiments gave different results for the amount of copper produced. This was caused by experimental error.

Suggest two causes of experimental error in these experiments.
1. ____________________________________________________________
   ____________________________________________________________
2. ____________________________________________________________
   ____________________________________________________________

(Total 10 marks)

Saturated hydrocarbons, for example methane and octane, are often used as fuels.

(a) Methane can be represented as:

   \[
   \begin{align*}
   &H \\
   &\text{H--C--H} \\
   &\text{H}
   \end{align*}
   \]

(i) The formula of methane is _________________________________.

(ii) Draw a ring around the correct answer to complete the sentence.

   In a saturated hydrocarbon molecule all of the bonds are
   \begin{itemize}
   \item double.
   \item ionic.
   \item single.
   \end{itemize}

(iii) Draw a ring around the correct answer to complete the sentence.

   The homologous series that contains methane and octane is called the
   \begin{itemize}
   \item alcohols.
   \item alkanes.
   \item alkenes.
   \end{itemize}
(b) (i) The complete combustion of petrol produces carbon dioxide, water vapour and sulfur dioxide.

Name three elements petrol must contain.

1. ____________________________________________________________
2. ____________________________________________________________
3. ____________________________________________________________

(ii) The exhaust gases from cars can contain oxides of nitrogen.

Complete the sentence.

Nitrogen in the oxides of nitrogen comes from __________________ .

(iii) The sulfur dioxide and oxides of nitrogen from cars cause an environmental problem.

Name the problem and describe one effect of the problem.

Name of problem _______________________________________________

Effect of problem _______________________________________________

______________________________________________________________

(c) When a fuel burns without enough oxygen, there is incomplete combustion.

One gaseous product of incomplete combustion is carbon monoxide.

Name one solid product of incomplete combustion.

_________________________________________________________________
A student investigated how well different hydrocarbon fuels would heat up 100 g of water.

Her hypothesis was:

**The more carbon atoms there are in a molecule of any fuel, the better the fuel is.**

The apparatus the student used is shown in the diagram.

She burned each hydrocarbon fuel for 2 minutes.

Her results are shown in the table.

<table>
<thead>
<tr>
<th>Name of hydrocarbon fuel</th>
<th>Number of carbon atoms in a molecule of hydrocarbon fuel</th>
<th>Temperature change of water in °C after 2 minutes</th>
<th>Temperature change per g of fuel burned</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentane</td>
<td>5</td>
<td>30</td>
<td>60</td>
<td>no smoke</td>
</tr>
<tr>
<td>Hexane</td>
<td>6</td>
<td>40</td>
<td>57</td>
<td>very small amount of smoke</td>
</tr>
<tr>
<td>Octane</td>
<td>8</td>
<td>55</td>
<td>55</td>
<td>small amount of smoke</td>
</tr>
<tr>
<td>Decane</td>
<td>10</td>
<td>57</td>
<td>52</td>
<td>large amount of smoke</td>
</tr>
<tr>
<td>Dodecane</td>
<td>12</td>
<td>60</td>
<td>43</td>
<td>very large amount of smoke</td>
</tr>
</tbody>
</table>

The student investigated only hydrocarbons.

Look carefully at her results.

How well do the student’s results support her hypothesis?

**The more carbon atoms there are in a molecule of any fuel, the better the fuel is.**
Give reasons for your answer.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(e) A 0.050 mol sample of a hydrocarbon was burned in excess oxygen.
The products were 3.60 g of water and 6.60 g of carbon dioxide.

(i) Calculate the number of moles of carbon dioxide produced.
Relative atomic masses: C = 12; O = 16.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

Moles of carbon dioxide = __________________

(ii) When the hydrocarbon was burned 0.20 mol of water were produced.
How many moles of hydrogen atoms are there in 0.20 mol of water?

___________________________________________________________________
___________________________________________________________________

Moles of hydrogen atoms = __________________
(iii) The amount of hydrocarbon burned was 0.050 mol.

Use this information and your answers to parts (e) (i) and (e) (ii) to calculate the molecular formula of the hydrocarbon.

If you could not answer parts (e) (i) or (e) (ii) use the values of 0.20 moles carbon dioxide and 0.50 moles hydrogen. These are not the answers to parts (e) (i) and (e) (ii).

______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________

Formula = ________________________________

(2)
(Total 19 marks)

19

This question is about lithium and sodium.

(a) Use the Chemistry Data Sheet to help you to answer this question.

In which group of the periodic table are lithium and sodium? Group

(b) A lithium atom can be represented as $^7_3\text{Li}$

The diagram represents the lithium atom.

(i) Some particles in the nucleus have a positive charge.

What is the name of these particles?

______________________________________________________________

(1)
(ii) Some particles in the nucleus have no charge.
What is the name of these particles?
____________________________________

(iii) Use the correct answer from the box to complete the sentence.

```
3  4  7
```

The mass number of this atom of lithium is __________

(c) Sodium reacts with chlorine to produce sodium chloride.

\[
\text{sodium} + \text{chlorine} \rightarrow \text{sodium chloride}
\]

The diagram shows how the reaction happens.

Only the outer electrons are shown.

Draw a ring around the correct answer to complete each sentence.

(i) A sodium atom changes into a sodium ion by __________ an electron.

(ii) A sodium ion has __________ charge.

\[
\text{gaining} \quad \text{losing} \quad \text{sharing}
\]

\[
\text{a negative} \quad \text{no} \quad \text{a positive}
\]
(iii) The ions in sodium chloride are held together by

| Strong forces         | covalent
|-----------------------|---------|
|                       | electrostatic
|                       | magnetic

(d) Sodium chloride is an ionic compound.

Tick (✓) two properties of ionic compounds.

<table>
<thead>
<tr>
<th>Property</th>
<th>Tick (✓)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not dissolve in water</td>
<td></td>
</tr>
<tr>
<td>High melting points</td>
<td></td>
</tr>
<tr>
<td>Low boiling points</td>
<td></td>
</tr>
<tr>
<td>Strong bonds</td>
<td></td>
</tr>
</tbody>
</table>

(e) (i) The formula of sodium chloride is NaCl

Calculate the relative formula mass of sodium chloride.

Relative atomic masses: Na = 23; Cl = 35.5

\[
\text{Relative formula mass} = \text{Na} + \text{Cl} = 23 + 35.5 = 58.5
\]

(ii) Draw a ring around the correct answer to complete each sentence.

The relative formula mass of a substance, in grams,

| ion is one isotope of the substance. | mole |

(1)
Nanoparticles of sodium chloride (salt) are used to flavour crisps.

What are nanoparticles?

___________________________________________________________________
___________________________________________________________________

(1) (Total 12 marks)
(a) Some students did an experiment to find the temperature change when hydrochloric acid reacts with sodium hydrogen carbonate.

The results are in the table.

<table>
<thead>
<tr>
<th>Number of spatula measures of sodium hydrogen carbonate</th>
<th>Start temperature in °C</th>
<th>Final temperature in °C</th>
<th>Change in temperature in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>20</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>19</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>20</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

(i) Describe, as fully as you can, the trends shown in the students’ results.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(3)
(ii) State the type of energy transfer for this reaction.
________________________________________________________________________
________________________________________________________________________

(1) (b) Sodium hydrogencarbonate is used as baking powder for making cakes.
When the cake mixture is baked the sodium hydrogencarbonate decomposes.
The equation for the reaction is:

\[
2 \text{NaHCO}_3(\text{s}) \overset{\text{Heat}}{\rightarrow} \text{Na}_2\text{CO}_3(\text{s}) + \text{H}_2\text{O}(\text{g}) + \text{CO}_2(\text{g})
\]

(i) The cake mixture rises when baked.

Use the equation to suggest why.
________________________________________________________________________
________________________________________________________________________

(1) (ii) The same reaction can be reversed to produce sodium hydrogencarbonate from
sodium carbonate.

\[
\text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2 \rightarrow 2\text{NaHCO}_3
\]

Do the reactants need to be heated?
Give a reason for your answer.
________________________________________________________________________
________________________________________________________________________

(1)
(c) (i) Calculate the relative formula mass of sodium hydrogencarbonate (NaHCO₃).

Relative atomic masses (Aᵣ): H=1; C=12; O=16; Na=23

______________________________________________________________

______________________________________________________________

______________________________________________________________

Relative formula mass (Mᵣ) = ______________________

(ii) Calculate the percentage by mass of carbon in sodium hydrogencarbonate.

______________________________________________________________

______________________________________________________________

______________________________________________________________

Percentage of carbon = _________________________ %

(Total 9 marks)

Ammonia is produced from nitrogen and hydrogen.

The equation for this reaction is:

\[ \text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \]

(a) (i) A company wants to make 6.8 tonnes of ammonia.

Calculate the mass of nitrogen needed.

Relative atomic masses (Aᵣ): H = 1; N = 14

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

Mass of nitrogen = _____________________ tonnes

(3)
(ii) The company expected to make 6.8 tonnes of ammonia. The yield of ammonia was only 4.2 tonnes.

Calculate the percentage yield of ammonia.

________________________________________________________________________

________________________________________________________________________

Percentage yield of ammonia = ________________ %

(2)

(iii) Use the equation above to explain why the percentage yield of ammonia was less than expected.

________________________________________________________________________

________________________________________________________________________

(1)

(b) Complete the diagram to show the arrangement of the outer shell electrons of the nitrogen and hydrogen atoms in ammonia.

Use dots (●) and crosses (x) to represent the electrons.

(c) Ammonia dissolves in water to produce an alkaline solution.

(i) Which ion makes ammonia solution alkaline?

________________________________________________________________________

(1)

(ii) Name the type of reaction between aqueous ammonia solution and an acid.

________________________________________________________________________

(1)

(iii) Name the acid needed to produce ammonium nitrate.

________________________________________________________________________

(1)
(iv) The reaction of ammonia with sulfuric acid produces ammonium sulfate.

Use the formulae of the ions on the Chemistry Data Sheet.

Write the formula of ammonium sulfate.

______________________________________________________________

(1)

(Total 12 marks)

Some students investigated magnesium oxide.

(a) Magnesium oxide has the formula MgO.

(i) Calculate the relative formula mass \( (M_r) \) of magnesium oxide.

Relative atomic masses: O = 16; Mg = 24.

______________________________________________________________

________________________________________________________________

Relative formula mass = ___________________

(2)

(ii) Calculate the percentage by mass of magnesium in magnesium oxide.

________________________________________________________________

________________________________________________________________

Percentage by mass of magnesium in magnesium oxide = _______%

(2)

(iii) Calculate the mass of magnesium needed to make 25 g of magnesium oxide.

________________________________________________________________

Mass of magnesium = ___________________ g

(1)
(b) The students calculated that if they used 0.12 g of magnesium they should make 0.20 g of magnesium oxide.

They did this experiment to find out if this was correct.

The students weighed 0.12 g of magnesium ribbon into a crucible.
They heated the magnesium ribbon.
They lifted the lid of the crucible slightly from time to time to allow air into the crucible.
The students tried to avoid lifting the lid too much in case some of the magnesium oxide escaped.
When all of the magnesium appeared to have reacted, the students weighed the magnesium oxide produced.

The results of the experiment are shown below.

<table>
<thead>
<tr>
<th>Mass of magnesium used in grams</th>
<th>0.12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of magnesium oxide produced in grams</td>
<td>0.18</td>
</tr>
</tbody>
</table>

(i) The mass of magnesium oxide produced was lower than the students had calculated. They thought that this was caused by experimental error.

Suggest two experimental errors that the students had made.

______________________________________________________________
______________________________________________________________
______________________________________________________________
Aluminium is extracted from aluminium oxide.

(a) The formula of aluminium oxide is $\text{Al}_2\text{O}_3$

The relative formula mass ($M_r$) of aluminium oxide is 102.

Calculate the percentage of aluminium in aluminium oxide.

Relative atomic masses ($A_r$): $\text{O} = 16; \text{Al} = 27$.


Percentage of aluminium = ________________ %
(b) Aluminium is extracted from aluminium oxide using electrolysis.

The diagram shows a cell used for the extraction of aluminium.

(i) The electrolyte contains cryolite.

Explain why.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(2)

(ii) Oxygen is formed at the positive electrode. Complete and balance the equation for this reaction.

$$\text{____O}^{2-} \rightarrow \text{O}_2 + \text{____}$$

(2)

(iii) The positive electrode in the cell is used up during the process.

Explain why.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

(2)

(Total 8 marks)
(a) Calcium chloride is made from limestone. Limestone contains mainly calcium carbonate and a small amount of magnesium carbonate.

\[
\text{Limestone} \quad \text{Acid } X \\
\begin{array}{c}
\text{Stage 1} \\
\rightarrow \text{Carbon dioxide}
\end{array}
\]

(i) In stage 1 calcium carbonate reacts with acid \(X\) to form calcium chloride.

Draw a ring around the name of acid \(X\).

- hydrochloric
- nitric
- sulfuric

(ii) Stage 1 produces a concentrated solution of calcium chloride. The solution also contains magnesium chloride.

Calcium hydroxide solution is added in stage 2 to remove the magnesium chloride.

The equation for this reaction is:

\[
\text{MgCl}_2(\text{aq}) + \text{Ca(OH)}_2(\text{aq}) \rightarrow \text{Mg(OH)}_2(\text{s}) + \text{CaCl}_2(\text{aq})
\]

Draw a ring around the correct answer to complete each sentence.

In stage 2 a precipitate is made because

magnesium hydroxide is dissolved

insoluble

soluble

in water.

In stage 3 the solid magnesium hydroxide can be separated from the calcium chloride solution using

- chromatography.
- electrolysis.
- filtration.
(iii) What method can be used to change the calcium chloride solution into solid calcium chloride?
Draw a ring around your answer.

- crystallisation
- electrolysis
- reduction

(1)

(b) Calcium chloride can also be made by reacting calcium with chlorine:

\[
\text{calcium} + \text{chlorine} \rightarrow \text{calcium chloride}
\]

The diagram shows what happens to atoms of calcium and chlorine in this reaction.

The dots (●) and crosses (x) are used to represent electrons.

Only the outer electrons are shown.

Use the diagram to help you to answer this question.

Describe, as fully as you can, what happens when calcium reacts with chlorine to make calcium chloride.
Some students did an experiment to find the relative formula mass \( (M_r) \) of a gas.

This is the method they used.

- The mass of the canister of gas was measured using a balance, which weighed to two decimal places.
- The measuring cylinder was filled with 1 dm\(^3\) of the gas from the canister.
- The mass of the canister of gas was measured again.
- The temperature of the laboratory was measured.
- The air pressure in the laboratory was measured.

The students repeated the experiment three times.

(a) The results for one of the experiments are shown in the table below.

| Mass of the canister of gas before filling the measuring cylinder | 53.07 g |
| Mass of the canister of gas after filling the measuring cylinder | 51.21 g |

Calculate the mass of the 1 dm\(^3\) of gas in the measuring cylinder.

\[
\text{Mass} = \quad \text{g} \\
\]

(b) How could the results be made more precise?

___________________________________________________________________
___________________________________________________________________
(c) The students used their results to calculate values for the relative formula mass \((M_r)\) of this gas. The results are shown in the table below.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative formula mass ((M_r))</td>
<td>45.4</td>
<td>51.5</td>
<td>46.3</td>
<td>45.8</td>
</tr>
</tbody>
</table>

(i) Calculate the mean value for these results.

\[
\text{Mean} = \frac{45.4 + 51.5 + 46.3 + 45.8}{4}
\]

(ii) The four results are different. The students thought this was because of experimental error. Suggest two causes of experimental error in this experiment.

(iii) It was important for the students to repeat the experiment. Suggest why.

(d) The teacher told the students that the formula of the gas is \(C_3H_8\). Calculate the relative formula mass \((M_r)\) of this gas. You should show your working.

Relative atomic masses: \(H = 1\); \(C = 12\).

\[
\text{Relative formula mass} = \frac{3(12) + 8(1)}{4}
\]
Calamine lotion is used to treat itching. The main ingredients are two metal oxides.

(a) One of the metal oxides has a relative formula mass \( (M_r) \) of 81.

The formula of this metal oxide is MO.
(M is not the correct symbol for the metal.)

The relative atomic mass \( (A_r) \) of oxygen is 16.

(i) Calculate the relative atomic mass \( (A_r) \) of metal M.

\[
\text{Relative atomic mass \( (A_r) \)} = \_
\]

(ii) Use your answer to part (a)(i) and the periodic table on the Data Sheet to name metal M.

The name of metal M is _______________________________.

The name of metal M is ___________________________________.

(1)
(b) The other metal oxide is iron(III) oxide.

This contains iron(III) ions (Fe\(^{3+}\)) and oxide ions (O\(^{2-}\)).

(i) Explain in terms of electrons how an iron atom (Fe) can change into an iron(III) ion (Fe\(^{3+}\)).

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

(ii) The diagram below represents the electronic structure of an oxygen atom (O).

Complete the diagram below to show the electronic structure of an oxide ion (O\(^{2-}\)).

![Diagram of an oxygen atom]

Complete the diagram below to show the electronic structure of an oxide ion (O\(^{2-}\)).

![Diagram of an oxide ion]
An experiment was done on the reaction of copper oxide (CuO) with methane (CH₄).

(a) The equation for this reaction is shown below.

\[
4\text{CuO}(s) + \text{CH}_4(g) \rightarrow 4\text{Cu}(s) + 2\text{H}_2\text{O}(g) + \text{CO}_2(g)
\]

The water and carbon dioxide produced escapes from the test tube.

Use information from the equation to explain why.

___________________________________________________________________

(1)

(b) (i) Calculate the relative formula mass \( (M_r) \) of copper oxide (CuO).

Relative atomic masses \( (A_r) \): O = 16; Cu = 64.

______________________________________________________________

______________________________________________________________

______________________________________________________________

Relative formula mass \( (M_r) \) = ________________

(2)

(ii) Calculate the percentage of copper in copper oxide.

______________________________________________________________

______________________________________________________________

______________________________________________________________

Percentage of copper = ________________ %

(2)

(iii) Calculate the mass of copper that could be made from 4.0 g of copper oxide.

______________________________________________________________

______________________________________________________________

______________________________________________________________

Mass of copper = ________________ g

(1)
The experiment was done three times. The mass of copper oxide used and the mass of copper made was measured each time. The results are shown in the table.

<table>
<thead>
<tr>
<th>Experiment</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Mass of copper oxide used in g</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Mass of copper made in g</td>
<td>3.3</td>
<td>3.5</td>
<td>3.2</td>
</tr>
</tbody>
</table>

(i) Calculate the mean mass of copper made in these experiments.

Mean mass of copper made = ______________ g

(ii) Suggest how the results of these experiments could be made more precise.

(iii) The three experiments gave slightly different results for the mass of copper made. This was caused by experimental error.

Suggest two causes of experimental error in these experiments.

1. __________________________________________________________________________

2. __________________________________________________________________________

(Total 10 marks)
Firework rockets contain fuel and potassium nitrate.

The potassium nitrate provides oxygen for the fuel to react.

(a) The table shows how a student worked out the relative formula mass \( (M_r) \) of potassium nitrate.

Some of the numbers are missing.

Relative atomic masses \( (A_r) \): N = 14; O = 16; K = 39.

<table>
<thead>
<tr>
<th>Name of atom (symbol)</th>
<th>Number of atoms</th>
<th>( A_r )</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>potassium (K)</td>
<td>1</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>nitrogen (N)</td>
<td>1</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>oxygen (O)</td>
<td>16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The \( M_r \) of potassium nitrate = 101

(i) The mass of oxygen is not shown in the table.

Draw a ring around the correct mass of oxygen.

16 32 48

(ii) Draw a ring around the number of oxygen atoms in the formula of potassium nitrate.

1 2 3

(1)
(b) When the fuel reacts with the oxygen an *exothermic* reaction takes place.

What does *exothermic* mean?

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(2)

(c) The fuel contains carbon. Carbon reacts with oxygen to make carbon dioxide.

Which two statements in the table explain why carbon dioxide is a gas at room temperature?

Tick (✓) the two statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Tick (✓)</th>
</tr>
</thead>
<tbody>
<tr>
<td>It has a giant structure</td>
<td></td>
</tr>
<tr>
<td>It has a low boiling point.</td>
<td></td>
</tr>
<tr>
<td>It is made of small molecules.</td>
<td></td>
</tr>
<tr>
<td>It is made of ions.</td>
<td></td>
</tr>
</tbody>
</table>

(2)

(Total 6 marks)
(a) The table gives information about two isotopes of hydrogen, hydrogen-1 and hydrogen-2.

<table>
<thead>
<tr>
<th></th>
<th>Hydrogen-1</th>
<th>Hydrogen-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic number</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mass number</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

An atom of hydrogen-1 is represented as: \( ^1 \text{H} \)

Show how an atom of hydrogen-2 is represented.

(b) (i) Calculate the relative formula mass \( (M_r) \) of water, \( \text{H}_2\text{O} \)

Relative atomic masses: H = 1; O = 16.

Relative formula mass \( (M_r) \) = ______________________

(ii) Simple molecules like water have low boiling points.

Explain why, in terms of molecules.

-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------

-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------

-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------

-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------

-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------
(c) Molecules of heavy water contain two atoms of hydrogen-2 instead of two atoms of hydrogen-1.

Explain why a molecule of heavy water has more mass than a normal water molecule. You should refer to the particles in the nucleus of the two different hydrogen atoms in your answer.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(2)
(Total 6 marks)

(a) Alkanes are important hydrocarbon fuels. They have the general formula \( \text{C}_n\text{H}_{2n+2} \).

The points on the graph show the amount of energy released when 1 mole of methane \( (\text{CH}_4) \), ethane \( (\text{C}_2\text{H}_6) \), propane \( (\text{C}_3\text{H}_8) \) and butane \( (\text{C}_4\text{H}_{10}) \) are burned separately.

(i) Draw a line through the points and extend your line to the right-hand edge of the graph.
(ii) Use the graph to estimate the amount of energy released when 1 mole of octane (C₈H₁₈) is burned.

   Energy released = ____________________ kJ

   (1)

(iii) Suggest why we can make a good estimate for the energy released by 1 mole of pentane (C₅H₁₂).

   ________________________________________________________________
   ________________________________________________________________

   (1)

(iv) A student noticed that octane (C₈H₁₈) has twice as many carbon atoms as butane (C₄H₁₀), and made the following prediction:

   “When burned, 1 mole of octane releases twice as much energy as 1 mole of butane.”

   Use the graph to decide if the student’s prediction is correct. You must show your working to gain credit.

   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

   (2)
Some information about four fuels is given in the table.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Type</th>
<th>Heat released in kJ per g</th>
<th>CO₂</th>
<th>SO₂</th>
<th>H₂O</th>
<th>Type of flame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-ethanol</td>
<td>Renewable</td>
<td>29</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Not smoky</td>
</tr>
<tr>
<td>Coal</td>
<td>Non-renewable</td>
<td>31</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Smoky</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Renewable</td>
<td>142</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>Not smoky</td>
</tr>
<tr>
<td>Natural gas</td>
<td>Non-renewable</td>
<td>56</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>Not smoky</td>
</tr>
</tbody>
</table>

From this information a student made two conclusions.

For each conclusion, state if it is correct and explain your answer.

(i) “Renewable fuels release more heat per gram than non-renewable fuels.”

(ii) “Non-renewable fuels are better for the environment than renewable fuels.”

(Total 9 marks)
Iron is an essential part of the human diet. Iron(II) sulfate is sometimes added to white bread flour to provide some of the iron in a person’s diet.

(a) The formula of iron(II) sulfate is FeSO₄.

Calculate the relative formula mass (M_r) of FeSO₄.

Relative atomic masses: O = 16; S = 32; Fe = 56.

The relative formula mass (M_r) = ________________

(b) What is the mass of one mole of iron(II) sulfate? Remember to give the unit.

_______________

(c) What mass of iron(II) sulfate would be needed to provide 28 grams of iron? Remember to give the unit.

_______________

(Total 4 marks)

This question is about methods of treating water.

(a) Chlorine is used to kill microorganisms in water. When chlorine is added to water a chemical reaction takes place. The equation for this reaction is shown below.

Cl₂(g) + H₂O(l) ⇌ 2H⁺(aq) + OCl⁻(aq) + Cl⁻(aq)

An acidic solution is produced when chlorine reacts with water.

Which ion, shown in the equation, makes the solution acidic? _________________

(1)
(b) Calcium hypochlorite tablets are added to water in some swimming pools to kill microorganisms.

The formula of calcium hypochlorite is CaCl₂O₂

(i) Calculate the relative formula mass (\(M_r\)) of calcium hypochlorite.

Relative atomic masses: O = 16; Cl = 35.5; Ca = 40.

\[
M_r = \text{Ca} \times 40 + \text{Cl} \times 71 + \text{O} \times 32
\]

\[
M_r = 40 + 2\times35.5 + 2\times16 = 143.0 \text{ g mol}^{-1}
\]

(ii) Calculate the percentage by mass of chlorine in calcium hypochlorite.

\[
\text{Percentage by mass of Cl} = \left( \frac{2 \times 35.5}{143.0} \right) \times 100 \%
\]

\[
\text{Percentage by mass of Cl} = 49.86 \%
\]

(iii) Calculate the mass of chlorine in a 20 g tablet of calcium hypochlorite.

\[
\text{Mass of Cl in 20 g tablet} = (20 \text{ g}) \times 0.4986 = 9.972 \text{ g}
\]

(c) Waste water from some industrial processes sometimes contains harmful metal ions, such as chromium ions. These ions must be removed from the water before it can be returned to a river.

A method of removing chromium ions (\(\text{Cr}^{3+}\)) from water is represented by this equation.

\[
\text{Cr}^{3+}(\text{aq}) + 3\text{OH}^- (\text{aq}) \rightarrow \text{Cr(OH)}_3(\text{s})
\]

(i) What type of substance would be added to the water to provide the \(\text{OH}^-\) ions?

\[
\text{Hydroxide ion (OH}^-\text{) is added as a base to provide OH}^-\text{ ions.}
\]
(ii) A precipitate is formed in this reaction.

What is a precipitate?

____________________________________________________________________________________

____________________________________________________________________________________

(1)

(iii) What method could be used to separate the precipitate from the solution?

____________________________________________________________________________________

____________________________________________________________________________________

(1)

(Total 9 marks)

(a) A chemist was asked to identify a nitrogen compound. The chemist carried out an experiment to find the relative formula mass ($M_r$) of the compound.

The $M_r$ of the compound was 44.

Relative atomic masses: N = 14, O = 16

Draw a ring around the formula of the compound.

NO  NO$_2$  N$_2$O$_4$  N$_2$O

(1)

(b) Potassium nitrate is another nitrogen compound. It is used in fertilisers. It has the formula KNO$_3$.

The $M_r$ of potassium nitrate is 101.

Calculate the percentage of nitrogen by mass in potassium nitrate.

Relative atomic mass: N = 14.

____________________________________________________________________________________

____________________________________________________________________________________

Percentage of nitrogen = _______________ %

(2)

(Total 3 marks)
Toothpastes often contain fluoride ions to help protect teeth from attack by bacteria.

Some toothpastes contain tin(II) fluoride.

This compound has the formula SnF$_2$.

(a) Calculate the relative formula mass ($M_r$) of SnF$_2$.

Relative atomic masses: F = 19; Sn = 119

\[
M_r = 19 \times 2 + 119 \times 1 = 157
\]

Relative formula mass ($M_r$) = 157

(2)

(b) Calculate the percentage by mass of fluorine in SnF$_2$.

\[
\text{Percentage by mass of fluorine} = \left( \frac{19 \times 2}{157} \right) \times 100 = 21.66\%
\]

Percentage by mass of fluorine = 21.66%  

(2)
(c) A tube of toothpaste contains 1.2 g of SnF₂.

Calculate the mass of fluorine in this tube of toothpaste.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

Mass of fluorine = _____________________ g

(1)

(d) The diagram represents the electron arrangement of a fluorine atom.

Explain how a fluorine atom can change into a fluoride ion, F⁻.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(2)
(Total 7 marks)

Iron ore contains iron oxide.

(i) Calculate the relative formula mass of iron oxide, Fe₂O₃.

Relative atomic masses: O = 16; Fe = 56.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

Answer = _____________________

(2)
(ii) Calculate the percentage by mass of iron in iron oxide.

Percentage of iron = _____________________ %

(2)

(iii) Calculate the mass of iron that could be extracted from 1000 kg of iron oxide.

Use your answer to part (c) (ii) to help you with this calculation.

Mass of iron = _____________________ kg

(1)

(Total 5 marks)
Mark schemes

(a) 408 kg

(b) all points correct

   $\pm \frac{1}{2}$ small square

   allow 1 mark if 5 points correct

   best fit line

(c) $\frac{1989 \times 100}{36}$

   5525 dm³

(d) relative formula mass of TiCl₄ is 190

   25.26 %

   Answer given to 3 significant figures = 25.3 %

   25.23% with or without working gains 3 marks

(e) argon is unreactive

   water (vapour) would react with sodium

   allow water (vapour) would react with titanium(IV) chloride

   and air contains oxygen that would react with reactants

   allow and air contains oxygen that would react with products

(f) (titanium conducts electricity) because electrons in the outer shell of the metal atoms are delocalised

   and so electrons are free to move

   allow the delocalised electrons in the metal carry electrical charge through the metal

   through the whole structure

   [15]
(a) electrodes connected to d.c. power supply by wires
for this diagram ignore the material used for the electrodes as long as they are made from carbon or metals that are inert

electrodes labelled anode (+) and cathode (−)

(b) copper ions cause the blue colour
answer must be in terms on copper ions

copper ions are reduced / converted to copper ions

so the concentration of copper ions decreased

if no other mark awarded allow 1 mark for copper ions are used up during electrolysis

(c) copper ions are positive

so are attracted to the inert cathode or inert negative electrode

copper ions gain electrons at the inert cathode or inert negative electrode

so they are reduced to form copper atoms

(d) 50 cm$^3$ contains 4 g CuSO$_4$

$M_r$ CuSO$_4$ = 159.5

4 g CuSO$_4$ reacts with $\frac{4}{159.5} \times 56$ g Fe

= 1.40(43877)

= 1.4 (g)

accept 1.4(g) with no working shown for 4 marks
allow 1.40(43887) without working shown for 3 marks

(a) medicine is) a mixture and (designed as) a useful product
(b) sugar / flavouring

to make it taste better

or

colouring

to make it look more attractive

(c) \( C_8H_9NO_2 \)

any order of elements

151

(d) mass of acetylsalicylic acid = 0.3 g

\[
\frac{0.3}{100} \text{ (mol)}
\]

method mark – divide mass by \( M_r \)

= 0.00167 (mol)

allow 0.00166666(66)

\( 1.67 \times 10^{-3} \) (mol)

correct answer with or without working scores 4 marks

allow ecf from steps 1, 2 and 3

(b) \[ 2\text{Al} + 3\text{H}_2\text{SO}_4 \rightarrow \text{Al}_2(\text{SO}_4)_3 + 3\text{H}_2 \]

formulae correct

balancing correct

4

(b) \[ 40 + 2(14 + (3 \times 16)) \]
(c) \[
\frac{17.4 + 17.6 + 16.9}{3} = 17.3
\]
allow 17.3 with no working shown for 2 marks

(a) 

Level 3 (5–6 marks):
A full, detailed and coherent plan covering all the major steps is provided, which outlines
the apparatus required and sets out the steps needed in a logical manner that could be
followed by another person to produce a pure, dry sample of copper nitrate.

Level 2 (3–4 marks):
The substantive content of a plan is present but may be missing some steps. The plan
may not be in a completely logical sequence but leads towards the production of a pure,
dry sample of copper nitrate.

Level 1 (1–2 marks):
Simple statements relating to relevant apparatus or steps are made but they may not be
in a logical order. The plan would not allow another person to produce the sample.

0 marks:
No relevant content

Indicative content

- pour a suitable volume of nitric acid into a suitable container
- add a small amount of copper carbonate to the acid and stir until the
effervescence stops
- continue to add small amounts of copper carbonate to the acid and each time
stir until any effervescence stops
- eventually when there is no reaction / effervescence when the copper
carbonate is added filter the mixture to remove the excess copper carbonate
- pour the filtrate (copper nitrate solution) into an evaporating basin and heat to
evaporate a small amount of the water
- leave the copper nitrate solution to crystallise
- remove the crystals from the solution remaining and dry the crystals
(b) 1 mole carbon dioxide = 14 + (16 × 2) = 46 g

14 g is 0.30 mole

1 mole is 6.02 × 10^{23} molecules

so 14 g has 1.81 × 10^{23} molecules

allow 1.81 × 10^{23} with no working shown for 4 marks

answer not given in standard form max. 3 marks

(a) (i) calcium oxide

in either order
carbon dioxide

accept correct formulae

(ii) C(s) + CO_2(g) → 2CO(g)

allow multiples

(iii) 210 (tonnes)

award 3 marks for the correct answer with or without working
allow ecf for arithmetical errors
if answer incorrect allow up to 2 marks for any of the steps below:
160 → 112
300 → 112 / 160 × 300

or
moles Fe_2O_3 = 1.875 (× 10^6) or 300 / 160
moles of Fe = 3.75 (× 10^6) or 2 × moles Fe_2O_3
mass Fe = moles Fe × 56
105 (tonnes) scores 2 (missing 1:2 ratio)
420 (tonnes) scores 2 – taken Mr of iron as 112
(b) (i) aluminium is more reactive than carbon or carbon is less reactive than aluminium

must have a comparison of reactivity of carbon and aluminium
accept comparison of position in reactivity series.

(ii) (because) aluminium ions are positive

ignore aluminium is positive

and are attracted / move / go to the negative electrode / cathode

where they gain electrons / are reduced / $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$

accept equation or statements involving the wrong number of electrons.

(iii) (because) the anodes or (positive) electrodes are made of carbon / graphite

oxygen is produced (at anode)

which reacts with the electrodes / anodes

do not accept any reference to the anodes reacting with oxygen from the air

equation $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$ gains 1 mark (M3)

[13]

(a) 1

must be in this order

very small

accept negligible, 1 / 2000

allow zero

(b) The mass number

1

(c) C

1
(d) (i) 2
(ii) 3

(e) (i) 28
(ii) 42.9
   accept ecf from (e)(i)
   accept 42 - 43

(f) (i) 0.9
(ii) any one from:
   • accurate
   • sensitive
   • rapid
   • small sample.

(a) because this lithium atom has
   3 protons
   and 4 neutrons
   mass number is total of neutrons and protons
   accept protons and neutrons have a mass of 1
   accept number of neutrons = 7 - 3(protons)
   ignore mass of electron is negligible

(b) grams
   accept g
   \(^{12}\text{C}\)
   allow carbon-12 or C-12
   ignore hydrogen or H
(c) any three from:

- both have 8 protons
  accept same number of protons
- \( ^{18}\text{O} \) has 10 neutrons
- \( ^{16}\text{O} \) has 8 neutrons
  accept different number of neutrons or \( ^{18}\text{O} \) has two more neutrons for 1 mark
- both have 8 electrons.
  accept same number of electrons

(a) magnesium loses electrons

there are four ideas here that need to be linked in two pairs.

- two electrons
- chlorine gains electrons
  magnesium loses electrons and chlorine gains electrons scores 2 marks.

(b) 95
correct answer with or without working gains 2 marks
if answer incorrect, allow 24 + 35.5 + 35.5 for 1 mark

(a) left hand: (conical) flask
do not accept round bottomed flask or container which is not a flask
right hand: beaker / trough
accept plastic box

(b) (i) 157
(ii) all calcium carbonate used up or reaction stopped
   do not accept all acid used up

(c) (i) 0.007(272727…)
   correct answer with or without working gains 2 marks
   if answer incorrect, allow (0.32 / 44) for 1 mark

(ii) 0.007(272727…)
   allow ecf from (c)(i)

(iii) \( \text{M}_r = \frac{\text{mass}}{\text{moles}} = \frac{1}{0.00727…} \) = 137.5 or 138
   allow ecf from (c)(ii)
   if use 0.00943 moles then = 106
   if use 0.007 allow 143 (142.857)

(iv) (138) – 60 (= 78)
   23 / 85

   (78 / 2) = 39

   potassium
   sodium / rubidium
   identity of metal ecf on \( A_n \) but **must** be Group 1
   If no working max 1 mark

(d) (i) (relative atomic mass) would decrease
   because the mass lost greater
   so moles carbon dioxide larger or moles metal carbonate greater

(ii) no change
   because the acid (already) in excess
   so the amount carbon dioxide lost is the same
Divide by $A_r$:

Na = $22.8 / 23$

B = $21.8 / 11$

O = $55.4 / 16$

if student has calculated moles upside down they can score mp 3 mp 4 and mp 5 as follows:

Na $23 / 22.8$

B $11 / 21.8$

O $16 / 55.4$

Values

0.991

1.01

1.98

0.505

3.46

0.289

Divide by the smallest

1 : 2 : 3.5

$Divide by the smallest (1)$

3.5 : 1.75 : 1

Whole number ratio

2 : 4 : 7

$Whole number ratio (1)$

14 : 7 : 4

Empirical formula

$Na_2B_4O_7$

$Empirical formula (1)$

$Na_{14}B_7O_4$

if no working shown allow 4 marks for $Na_2B_4O_7$
at (exactly) the same rate

in a closed system

allow therefore the concentrations / amounts of the reactants and products remain the same

(b) (i) increasing the temperature would lower the yield of ethanol or the (position of) equilibrium moves to the left

if student has stated that increasing the temperature increases the yield then award 0 marks

since the backwards reaction is endothermic or the forward reaction is exothermic

(ii) increasing the pressure would increase the yield of ethanol or the (position of) equilibrium moves to the right

if student has stated that increasing the pressure decreases the yield then award 0 marks

because the position (of equilibrium) moves in the direction of the lower number of moles (of gas)

2 (moles / molecules / volumes / particles) on lhs / 1 (mole / molecule / volume / particle) on rhs

(c) (a catalyst) provides an alternative pathway

with lower activation energy

or

(a catalyst) lowers the activation energy (1)

so less energy is needed to react or more particles react (1)
(a) (i) ions cannot move

*allow only conducts as a liquid*

(ii) chlorine

(iii) they are positively / oppositely charged

*or*

they are attracted

(iv) 2

(b) (i) any one from:

• not all the magnesium was collected

*allow some magnesium was lost*

• used less time or lower current or different battery / power pack or

*different balance or lower voltage*

• error in reading balance

• error in recording result

(ii) 1.11

*correct answer with or without working gains 2 marks.*

*If answer incorrect, allow 1 mark for 0.99 or for 1.13 + 1.11 + 1.09*

(c) (i) \(25 - 25.3\)

*correct answer with or without working gains 2 marks.*

*If answer incorrect, allow 1 mark for 24 / 95*

(ii) 71

(d) (i) reversible reaction

(ii) decreases

(a) would melt

*accept they have a low melting point*

*allow lose their shape*

*ignore would soften when hot*

*ignore boiling point*
(b) to speed up the reaction
   accept can use a lower temperature
   accept less energy needed

(c) (i) mass spectrometer
    allow mass spectroscopy

(ii) any one from:
    ignore reliable
    ignore more precise
    • accurate
    • sensitive
    • rapid / quicker
    • small amount of sample

(d) any two from:
    allow concentration
    • pressure
    • temperature
    • catalyst or initiator
    • solvent

(a) (i) to increase the rate of reaction
(ii) $\text{H}_2\text{SO}_4$ on the left hand side
    $\text{H}_2\text{O}$ on right hand side
(iii) filtration
    allow centrifuging or decanting
    ignore evaporation if after filtration
(iv) crystallisation
   
   ignore reference to filtration
   unless given as an alternative

or

evaporation / heating / boiling / cooling

(v) any one from:

• because of an incomplete reaction
   accept not all acid reacted
   accept impure reactants
   accept unexpected reaction
   ignore reversible reaction

• because some (copper sulfate) lost on filtering or when poured into evaporating basin or boiled over or left in apparatus
   must specify when lost
   accept some (copper sulfate or acid) spilt

• weighing error (of copper sulfate)

(b) (i) reversible (reaction)

(ii) 300(J)

   allow the same

   (energy) given out / released
   accept exothermic / –
   ignore increasing or decreasing energy
(c) \[
\begin{array}{cc}
3.81 & 0.28 \\
63.5 & 14 \\
\end{array}
\]

1 mark for dividing mass by A_r (max 2 if A_r divided by mass)  

\[= 0.06 \quad = 0.02\]  

1 mark for correct proportions  

3 \quad 1  

1 mark for correct whole number ratio (allow multiples). Can be awarded from formula  

Cu_3N  

**ecf** allowed from step 2 to step 3 and step 3 to step 4 if sensible attempt at step 1  
correct formula gains 1 mark  

(a) copper has delocalised electrons  

*accept copper has free electrons  
ignore sea of electrons or mobile electrons*  

(electrons) which can move through the metal / structure  

*allow (electrons) which can carry a charge through the metal / structure*
(b) (i) \( \text{Mr FeCl}_3 = 162.5 \)

*correct answer with or without working gains 3 marks*

*can be credited from correct substitution in step 2*

or

2 (moles of) \( \text{FeCl}_3 = 325 \)

or

\( 112 \rightarrow 325 \)

\[
\frac{11.20}{56} \times 162.5
\]

*allow ecf from step 1*

accept \( \frac{325}{112} \times 11.2 \)

= 32.5

accept 32.48

(ii) 74.8

*accept 74.77 – 75*

*accept ecf from (b)(i)*

*if there is no answer to part(i)*

or

*if candidate chooses not to use their answer then accept 86.79 – 87*

(a) because they are *gases*

*ignore vapours / evaporate / (g)*

*allow it is a gas*

17

(b) (i) \( 80 / 79.5 \)

*correct answer with or without working = 2 marks*

*ignore units*

*if no answer or incorrect answer then evidence of*

\( 64 / 63.5 + 16 \) gains 1 mark
(ii) 79.375 - 80

correct answer with or without working = 2 marks
if no answer or incorrect answer then evidence of
\[
\frac{64}{80} \quad \text{or} \quad \frac{63.5}{79.5} \times 100 \quad \text{gains 1 mark}
\]
accept (ecf) \( \frac{64 \text{ or } 63.5}{\text{answer (b)(i)}} \times 100 \) for 2 marks

if answer correctly calculated.

if incorrectly calculated evidence of \( \frac{64 \text{ or } 63.5}{\text{answer (b)(i)}} \times 100 \) gains 1 mark

(iii) 3.2

correct answer with or without working = 1 mark
allow (ecf)
\[4 \times \left( \frac{\text{(b)(ii)}}{100} \right)\] for 1 mark if correctly calculated

(c) (i) 3.3

accept 3.33\ldots or 3 \frac{1}{3} or 3.3\dot{r}
or 3.3r

(ii) (measure to) more decimal places or (use a) more sensitive balance / apparatus
allow use smaller scale (division) or use a smaller unit
ignore accurate / repeat
any two from:

- ignore systematic / human / apparatus / zero / measurement /
- random / weighing / reading / recording errors unless qualified

different balances used or faulty balance

- ignore dirty apparatus

reading / using the balance incorrectly

- accept incorrect weighing of copper / copper oxide

spilling copper oxide / copper

- allow some copper left in tube

copper oxide impure

- allow impure copper (produced)

not all of the copper oxide was reduced / converted to copper or not enough / different amounts of methane used

- accept not all copper oxide (fully) reacted

heated for different times

- heated at different temperatures

  - if neither of these points awarded allow different amounts of heat used
  
  - accept Bunsen burner / flame at different temperatures

some of the copper produced is oxidised / forms copper oxide

some of the copper oxide / copper blown out / escapes (from tube)

- ignore some copper oxide / copper lost

some water still in the test tube

(a) (i) CH$_4$

- allow H$_4$C

  - do not allow lower-case h

  - do not allow superscript

(ii) single

(iii) alkanes

(b) (i) carbon / C

  - any order
hydrogen / H

allow phonetic spelling

sulfur / sulphur / S

(ii) air / atmosphere

(iii) acid rain

damages trees / plants or kills aquatic organisms or damages buildings / statues or causes respiratory problems

allow harmful to living things

(c) carbon / C

accept soot / particulates / charcoal

(d) any four from:

• (supports hypothesis) because when the fuel contained more carbon the temperature of the water went up more / faster (in 2 minutes)
• (does not support hypothesis as) temperature change per gram decreases as the number of carbons increases
• (does not support hypothesis) because the more carbon in the fuel the more smoke or the dirtier / sootier it is
• only tested hydrocarbons / alkanes / fuels with between 5 and 12 carbon atoms
• valid, justified, conclusion

accept converse statements

(e) (i) 0.15

correct answer with or without working gains 2 marks

if answer incorrect, \( M_r \) carbon dioxide = 44 gains 1 mark

allow 0.236 / 0.24 / 0.2357142 (ecf from \( M_r \) of 28) for 1 mark

(ii) 0.4(0)
(iii) \( \text{C}_3\text{H}_8 \)

*correct formula with or without working scores 2 marks*

\[ 0.15 / 0.05 = 3 \]

*allow ecf from (e)(i)*

and

\[ 0.4 / 0.05 = 8 \] (1)

*allow ecf from (e)(ii)*

*allow 1 mark for correct empirical formula from their values*

If use 'fall-back-values:

\[ 0.50 / 0.05 = 10 \]

and

\[ 0.20 / 0.05 = 4 \]

*1 mark*

\( \text{C}_4\text{H}_{10} \)

*1 mark*

*if just find ratio of C to H using fall-back values, get \( \text{C}_2\text{H}_5 \) allow 1 mark*

(a) 1 / one

(b) (i) protons

(ii) neutrons

(iii) 7

(c) (i) losing

(ii) a positive

(iii) electrostatic

(d) high melting points

*strong bonds*
(e) (i) 58.5

(ii) mole

(f) very small (particles) or

ignore tiny / small / smaller / microscopic etc.

1-100nm in size or

(particle with a) few hundred atoms

(a) (i) the more sodium hydrogencarbonate the greater the temperature change

accept examples from the table

up to 8 spatula measures

accept any correct indication of when change occurs

then the temperature change is constant

if no marks awarded allow 1 mark for:
the more sodium hydrogencarbonate the lower the final temperature

(ii) energy is taken in from the surroundings or endothermic

(b) (i) gas / carbon dioxide / steam / water is produced

accept carbon dioxide is a gas or steam / water is a gas

allow gas / air expands when heated

(ii) no, because (reaction) is exothermic

or

yes, to start the reaction

allow no, because (reactants) were formed by heating

ignore references to cooling

(c) (i) 84

correct answer with or without working gains 2 marks

if no answer or incorrect answer then evidence of
23 +1 + 12 + (3 × 16) gains 1 mark
(ii) 14.29
accept rounding to 14.3 or 14
allow ecf from (c)(i)

(a) (i) \( M_r \) of \( \text{NH}_3 = 17 \)
correct answer with or without working gains 3 marks
accept correct rounding of intermediate answers
can be credited from correct substitution from step 2

or

2 (moles of) \( \text{NH}_3 = 34 \)
or
14 \( \rightarrow \) 17
or
28 \( \rightarrow \) 34

\((28/34) \times 6.8\)
allow ecf from step 1

or

\((14/17) \times 6.8\)
= 5.6
allow ecf from step 1

(ii) 61.8
accept 61.76 or 62 or 61.76...
correct answer with or without working gains 2 marks
if answer is not correct evidence of 4.2 \( / \) 6.8 \( \times \) 100 gains 1 mark
if answer not correct 0.618 or 0.62 gains 1 mark

(iii) reaction is reversible
accept reaction reaches equilibrium
allow reaction does not reach completion
ignore some is lost

(b) 3 bonding pairs
do not accept extra electrons on hydrogen
1 lone pair

accept 2 non-bonding electrons on outer shell of nitrogen

(c) (i) hydroxide / OH

accept phonetic spelling

(ii) neutralisation

accept acid-base
allow exothermic

(iii) nitric (acid)

allow HNO

ignore incorrect formula

(iv) (NH

allow (NH

1

1

1

2

2

1

2

1

2

1

2

1

2

1

1

2

1

1

[12]

(a) (i) 40

correct answer with or without working or incorrect working

if the answer is incorrect then evidence of 24 + 16 gains 1 mark
ignore units

(ii) 60

correct answer with or without working or incorrect working

if the answer is incorrect then evidence of 24/40 or 24/(i) gains 1 mark
ecf allowed from part(i)

ie 24/(i) x 100
ignore units

(iii) 15

ecf allowed from parts(i) and (ii)

24/(i) x 25 or (ii)/100 x 25
ignore units
(b) (i) any two from:

- ignore gas is lost
- error in weighing magnesium / magnesium oxide
  allow some magnesium oxide left in crucible
- loss of magnesium oxide / magnesium
  allow they lifted the lid too much
  allow loss of reactants / products
- not all of the magnesium has reacted
  allow not heated enough
  allow not enough oxygen / air

(ii) any two from:

- ignore fair test
- check that the result is not anomalous
- to calculate a mean / average
  allow improve the accuracy of the mean / average
- improve the reliability
  allow make it reliable
- reduce the effect of errors

(a) 52.9(411765) / 53

**correct answer with or without working = 2 marks**

if answer incorrect allow 2 x 27 = 54 or 27/102 x 100 or 26.5 for 1 mark

(b) (i) because it lowers the melting point (of the aluminium oxide)

- allow lowers the temperature needed
- do not accept lowers boiling point

so less energy is needed (to melt it)

- accept so that the cell / equipment does not melt

(ii) 2 \( O^{2-} \) on left hand side

- accept correct multiples or fractions
(iii) because the electrode reacts with oxygen or because the electrode burns to form carbon dioxide or electrode made from carbon / graphite

(a) (i) hydrochloric

(ii) insoluble filtration

(iii) crystallisation

(b) any four from:

any reference to incorrect bonding = max 3

• calcium atom reacts with 2 chlorine atoms
• calcium atoms lose electrons accept calcium ion is formed
• lose two electrons accept calcium has a 2+ charge / calcium ion has a 2+ charge allow Ca$^{2+}$
• chlorine atoms gain electrons accept chloride ion formed
• gain one electron accept chlorine / chloride has a negative charge / is a negative ion / is a negative particle allow Cl$^-$ if no other marks awarded allow ionic bonding or complete outer shell for 1 mark
(a) 1.86
ignore units / 1.9

(b) use a balance which weighs to more decimal places
accept (use a measuring cylinder with) smaller (scale) divisions / intervals

or use more sensitive balance
allow reference to more decimal places allow smaller units / scale

(c) (i) 45.8(3333333)
correct answer gains 2 marks with or without working
ignore units / 46
if the answer is not correct then evidence of:
(45.4 + 46.3 + 45.8) ÷ 3
or 137.5 ÷ 3
or 47.25 / 47.3 / 47.2 gains 1 mark

(ii) any two from:
ignore zero error / faulty equipment

• loss of gas or leak
• error in measurement of volume of gas / gas in cylinder / 1 dm³
• error in weighing the canister / gas at start
• error in weighing the canister / gas at end
error in weighing the canister / gas = 1 mark
• change in temperature
allow incorrect measurement of temperature
• change in pressure
allow incorrect measurement of pressure
if no other mark awarded allow error in weighing for 1 mark

(iii) any one from:
ignore fair test / precise / valid or to check for errors / mistakes

• check for anomalous results
• to find the mean / average
allow improve (accuracy of) mean / average
• (improve) reliability / make reliable
correct answer gains 2 marks with or without working
ignore units
if the answer is incorrect evidence of $(3 \times 12) / 36$ and $(8 \times 1) / 8$
gains 1 mark

(a) (i) 65

correct answer with or without working = 2 marks
if answer incorrect
evidence of $(81 - 16)$ for 1 mark
ignore units

(ii) zinc
accept error carried forward from (a)(i)
allow correct symbol
answer given should be element / metal closest to their answer
do not allow compounds

(b) (i) • it loses electrons
sharing / covalency = max 1 mark
• three electrons

(ii) 8 electrons shown in second shell.
accept dots / crosses / mixture of dots and crosses / e
electrons do not need to be paired
do not allow extra electrons in first shell

(a) because they are gases
ignore vapours / evaporate / (g)
allow it is a gas

(b) (i) 80 / 79.5

correct answer with or without working = 2 marks
ignore units
if no answer or incorrect answer then evidence of $64 / 63.5 + 16$
gains 1 mark
(ii) \[ \frac{64}{80} \text{ or } \frac{63.5}{79.5} \times 100 \] gains 1 mark

Accept (ecf) \[ \frac{64 \text{ or } 63.5}{\text{answer} \times 100} \] for 2 marks if correctly calculated

If incorrectly calculated

Evidence of \[ \frac{64 \text{ or } 63.5}{\text{answer} \times 100} \] gains 1 mark

(iii) 3.2

correct answer with or without working = 1 mark

Allow (ecf)

\[ 4 \times \left( \frac{b(ii)}{100} \right) \times 100 \] for 1 mark if correctly calculated

(c) (i) 3.3

Accept 3.33... or \( \frac{1}{3} \) or 3.3 or 3.3'

(ii) measure to more decimal places

Or use a more sensitive balance / apparatus

Allow use smaller scale (division)

Or use a smaller unit

Ignore accurate / repeat
(iii) any two from:

- ignore systematic / human / apparatus / zero / measurement / random / weighing / reading errors unless qualified
- different balances used or faulty balance
  ignore dirty apparatus
- reading / using the balance incorrectly or recording error
  accept incorrect weighing of copper / copper oxide
- spilling copper oxide / copper
  allow some copper left in tube
- copper oxide impure
  allow impure copper (produced)
- not all of the copper oxide was reduced / converted to copper or not enough / different amounts of methane used
  accept not all copper oxide (fully) reacted
- heated for different times
- heated at different temperatures
  accept Bunsen burner / flame at different temperatures
- some of the copper made is oxidised / forms copper oxide
- some of the copper oxide / copper blown out / escapes (from tube)
  ignore some copper oxide / copper lost
- some water still in the test tube

2

(a) (i) 48
   1

(ii) 3
   1

(b) heat / energy
   1
given out / transfers to surroundings
the mark for given out / transfers to cannot be awarded without heat / energy
allow given off
   1

(c) it has a low boiling point
   1
it is made of small molecules

(a) 

\[ \begin{array}{c} \mathbf{2} \\ \mathbf{H} \\ \mathbf{1} \end{array} \]

2 and 1 must be on the left
2 must be above half-way on the H and the 1 below half-way
accept diagram with 2 different particles in centre and 1 particle on circle

(b) (i) 18

ignore working
ignore units

(ii) forces (of attraction) between molecules or bonding between molecules or intermolecular forces / intermolecular bonds

are weak or not much energy needed to break them or easily overcome
must be linked to first mark
if no other mark awarded allow small molecules / small Mr, for 1 mark
allow forces / bonds are weak for 1 mark
do not allow covalent bonding is weak

(c) any reference to more protons = 0 marks

H-2 atoms have 1 proton and 1 neutron
allow H-2 has more neutrons / particles for 1 mark
H-1 atoms have one proton

allow H-2 has two particles and H-1 has one particle for 1 mark

or

H-2 atom has one neutron (1)

allow H-2 atom has one more neutron for 2 marks

H-1 atom has no neutrons (1)

**NB** heavy water (molecule) has 2 more neutrons = 2 marks

heavy water (molecule) has more neutrons / particles = 1 mark

if no other mark awarded then heavy water molecule has \( M_r \) of 20 = 1 mark

ignore reference to electrons

(a) 
   (i) straight line through the ‘points’ and extended to \( C_8H_{18} \)

   *do not* accept multiple lines

   1

(ii) 5500

range 5400 to 5600

accept ecf from their graph

1

(iii) it is a straight line graph

allow directly proportional

accept constant difference between (energy) values

accept \( C_5H_{12} \) close to values on the graph

or \( C_5H_{12} \) comes in middle of the graph

ignore ‘fits the pattern’ unqualified

ignore ‘line of best fit’

ignore ‘positive correlation’

1
(iv) expected ranges for working are:

\[
(5400 \text{ to } 5600) - (2800 \text{ to } 2900) = (2500 \text{ to } 2800)
\]

or

their value from (a)(ii) – a value from 2800 to 2900

or

\[
(5400 \text{ to } 5600) / \text{their (a)(ii) divided by 2}
\]

or

a value from 2800 to 2900 - 2

no / not quite / almost / yes

\[\text{this mark is only awarded on evidence from their correct working}\]

(b) (i) incorrect / no or partially correct

\[\text{ignore references to hydrogen}\]

bio-ethanol produces least energy

\[\text{mark independently}\]

or

bio-ethanol produces 29 kJ
ignore incorrect / correct any two from:

• hydrogen produces only $H_2O$
  accept hydrogen does not produce harmful gases / $CO_2$ / $SO_2$

• coal produces $SO_2$
  allow coal causes acid rain / respiratory problems

• coal produces smoke
  allow coal causes global dimming

• both renewable and non-renewable fuels produce $CO_2$
  accept bio-ethanol and natural gas / coal produce $CO_2$ / global warming

• (both) the non-renewable fuels produce $CO_2$
  accept coal and natural gas produce $CO_2$ / global warming

• (both) renewable fuels produce no smoke
  accept hydrogen and bio-ethanol do not produce smoke / global dimming

• (both) renewable fuels produce no $SO_2$
  accept hydrogen and bio-ethanol
do not produce $SO_2$ / acid rain

(a) 152 correct answer with or without working = 2 marks

56 + 32 + (4 × 16) gains 1 mark

ignore any units

(b) 152g(rams)

ecf from the answer to (a) and $g$
must have unit $g$ / gram / gramme / grams etc
accept $g$ / mol or $g$ per mole or $g$ mole$^{-1}$ or $g/mol$ or $g$ per mol or $g$ mol$^{-1}$
do not accept $g$ m
do not accept G

(c) 76(g)

ecf from their answer to (a) or (b) divided by 2
ignore units
(a) hydrogen / \( \text{H}^+ / 2\text{H}^+ / \text{H}_3\text{O}^+ \)

\(\text{allow } \text{H} / 2\text{H} \)

\(\text{do not accept } \text{H}_2 \)

\(\text{apply list principle} \)

(b) (i) 143

Correct answer with or without working = 2 marks

Ignore units

If answer is not correct

\(40 + (2 \times 35.5) + (2 \times 16) \) gains 1 mark

(ii) 49.7% (49.6 to 50)

Correct answer with or without working = 2 marks

Answer 49 gains 1 mark

If answer is not correct:

\((71 \div 143) \times 100 \) gains 1 mark

Allow error carried forward from part (b)(i)

IE. \((71 \text{ or their } (2 \times 35.5) \div \text{answer to (b)(i)}) \times 100 \) gains 2 marks if calculated correctly and 1 mark if not calculated correctly.

Special case \(35.5 \div 143 \times 100 = 24.8\)

To 25% or \(35.5 \div \text{answer to (b)(i)} \times 100 \) correctly calculated for 1 mark

(iii) 9.9 to 10g

Allow ECF from (b)(i) or (b)(ii)

(c) (i) an alkali

Apply list principle

Accept named alkali

Accept hydroxide

Accept soluble base

Ignore base

(ii) a solid / insoluble substance (owtte)

(iii) filter / filtration

Allow decant / centrifuge

Accept filtration followed by evaporation or filtration and evaporation

Do not accept filtration or evaporation

Do not accept evaporation and filtration
(a) $\text{N}_2\text{O}$

(b) 13.8 to 14

gains full marks without working
if answer incorrect
13 gains 1 mark
or
$14/101 \times 100$ gains 1 mark

(a) 157
correct answer with or without working
$(2 \times 19 + 119)$ for 1 mark only
allow $(119 + 19 =) 138$ for 1 mark only
ignore units

(b) 24.2
accept answers in the range 24 to 24.2038....
ignore incorrect rounding after correct answer
25 only without working gains 1 mark or
$38/157 \times 100$ gains 1 mark or
$(19/157 \times 100 =) 12.1$ gains 1 mark
allow error carried forward from part(a)
$38/(a) \times 100$ gains 2 marks if calculated correctly
$(19/138 \times 100 =) 13.8$ gains 1 mark

(c) 0.29
accept answers in the range 0.28 to 0.3
allow error carried forward from part (b)
$(b)/100 \times 1.2$ correctly calculated
ignore units
(d) an electron

allow electrons
allow electron shared / lost for 1 mark
apply list principle for additional particles

is gained outtte
must be linked to electron
accept can hold / take in if in correct context
eg it can hold another electron (in its outer shell) = 2 marks
it can take an electron (from another atom) = 2 marks
ignore reference to fluoride ions
incorrect number of electrons gained does not gain the second mark

(i) 160 ignore units

\[(2 \times 56) + (3 \times 16)\] for 1 mark

(ii) 70

\[
\frac{2 \times 56}{160} (\times \text{100})
\] for 1 mark

allow ecf from part (i)

(iii) 700

allow ecf from part (ii)