<table>
<tr><th>Qn</th><th>Marking Scheme</th><th>Remarks</th><th>Mks</th></tr>
<tr><td>1ai</td><td>Calcium oxide</td><td>CaO</td><td>1</td></tr>
<tr><td>1aii</td><td>Nitrogen monoxide</td><td>NO</td><td>1</td></tr>
<tr><td>1aiii</td><td>Aluminium oxide</td><td>Al_2O_3</td><td>1</td></tr>
<tr><td>1aiv</td><td>Sulfur dioxide</td><td>SO_2</td><td>1</td></tr>
<tr><td>1av</td><td>Iron(II) oxide</td><td>FeO</td><td>1</td></tr>
<tr><td>1b</td><td>
<table>
<tr><th></th><th>true</th><th>false</th></tr>
<tr><td>They all float on water.</td><td></td><td>✓</td></tr>
<tr><td>They lose electrons more easily down the group.</td><td>✓</td><td></td></tr>
<tr><td>They rapidly tarnish in air.</td><td>✓</td><td></td></tr>
<tr><td>They react with water to form two alkaline products.</td><td></td><td>✓</td></tr>
</table>
</td><td>1 mark for every 2 ticks</td><td>2</td></tr>
<tr><td>2a</td><td>Average mass of one atom of that element relative to 1/12 the mass of an atom of carbon-12.</td><td>Specify 1/12 the mass of a carbon-12 atom</td><td>1</td></tr>
<tr><td>2b</td><td>∑ isotope mass × isotope abundance ÷ 100
Let x be the relative abundance of Mg-24.
Let y = 0.9 − x be the relative abundance of Mg-26.

A_r(Mg) = 24.3
A_r(Mg) = (24 × x) + (25 × 0.1) + [26 × (0.9 − x)]
24.3 = 24x + 2.5 + 23.4 − 26x
2x = 1.6
x = 0.8
y = 0.9 − 0.8 = 0.1

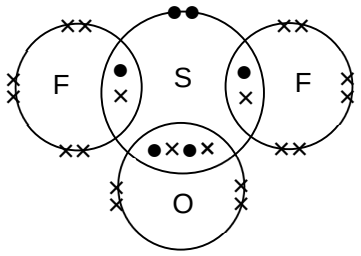
relative abundance of Mg-24 = 80%
relative abundance of Mg-26 = 10%</td><td>1 mark for each relative abundance in %</td><td>2</td></tr>
<tr><td>2c</td><td>Mg-24 will diffuse the fastest, followed by Mg-25, and Mg-26 will diffuse the slowest.

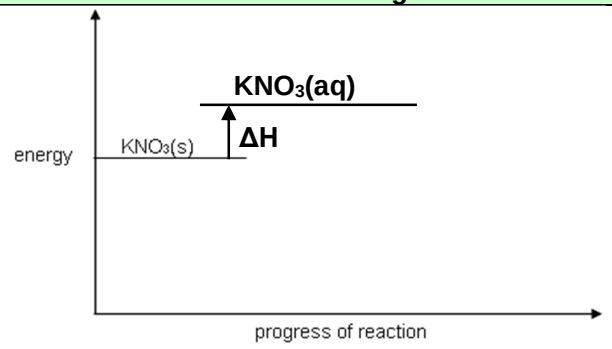
OR
Mg-24 will diffuse the fastest.
Mg-25 will diffuse slower than Mg-24, but faster than Mg-26.
Mg-26 will diffuse the slowest.

OR
Mg-24 will diffuse faster than Mg-25 and Mg-26.
Mg-25 will diffuse faster than Mg-26.</td><td>Need to compare and order all 3 isotopes</td><td>1</td></tr>
<tr><td>2d</td><td>
<table>
<tr><td>element</td><td>Mg</td><td>B</td><td>O</td></tr>
<tr><td>mass / g</td><td>18.9</td><td>5.8</td><td>25.3</td></tr>
<tr><td>A_r</td><td>24</td><td>11</td><td>16</td></tr>
<tr><td>mol</td><td>0.7875</td><td>0.52727</td><td>1.58125</td></tr>
<tr><td>÷</td><td>1.4935</td><td>1</td><td>2.9989</td></tr>
<tr><td>mole ratio</td><td>3</td><td>2</td><td>6</td></tr>
</table>

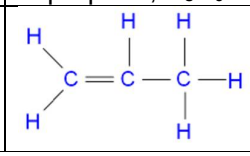
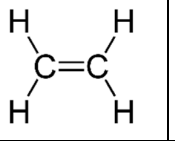
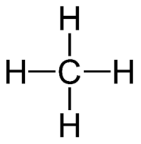
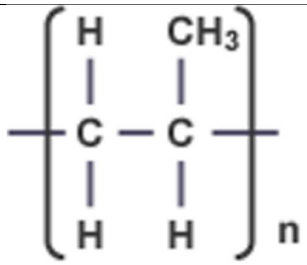
empirical formula, $Mg_3B_2O_6$
</td><td>1 mark for finding moles

1 mark for $Mg_3B_2O_6$</td><td>2</td></tr>
<tr><td>2e</td><td>x = 7 and y = 4</td><td>cao</td><td>1</td></tr>
</table>

Qn	Marking Scheme	Remarks	Mks
3a	In SF_4, **sulfur** atom has **10** valence **electrons**. In XeF_4, **xenon** atom **forms** single **bonds** with fluorine atoms, despite xenon being a noble gas.	1 mark for S 1 mark for Xe	2
3b		1 mark for bonding electrons 1 mark for lone pairs	2
3c	These fluoride compounds are covalent substances with **simple molecular** structure. **Little energy** is needed to **overcome weak intermolecular forces of attraction** between molecules.	1 mark for structure 1 mark for energy and bonding	2
4a	$2Ca(NO_3)_2 \rightarrow 2CaO + 4NO_2 + O_2$ Calcium nitrate is reduced as the **oxidation state of nitrogen decreases from +5 in calcium nitrate to +4 in nitrogen dioxide**. Calcium nitrate is oxidised as the **oxidation state of oxygen increases from −2 in calcium nitrate to 0 in oxygen**.	1 mark for changes to N 1 mark for changes to O	
4b	Place a glowing splint near the gas. If the **glowing splint relights**, the gas is oxygen.	Describe test and result	1
4ci	**Lead(II) nitrate** will take the shortest time for nitrogen dioxide to appear, as it will be the first or fastest or easiest to decompose. In the reactivity series, calcium is the most reactive metal, followed by zinc, and **lead** is the **least reactive metal**. Lead forms the **least thermally stable** metal **nitrate**.	1 mark for $Pb(NO_3)_2$ 1 mark for explanation	2
4cii	**Zinc oxide**	ZnO	1
5a	**Titration**	cao	1
5b	**$KOH(aq) + HNO_3(aq) \rightarrow KNO_3(aq) + H_2O(l)$** OR $K_2CO_3(aq) + 2HNO_3(aq) \rightarrow 2KNO_3(aq) + H_2O(l) + CO_2(g)$	1 mark for formulae and coefficients 1 mark for state symbols	2
5c	**Heat** the aqueous solution until it is **saturated**. Allow the saturated solution to **cool** so that the salt can crystallise. Filter to collect the crystals. **Wash** the crystals with a little cold **distilled water**. **Dry** the crystals between a few sheets of **filter paper**.	1 mark for heat, cool 1 mark for wash, dry	2
5di	**Endothermic**	cao	1
5dii	ΔH $= c \times m \times \Delta T$ $= 4.2 \times 0.050 \times (20.4 - 18.7)$ $= 4.2 \times 0.050 \times 1.7$ $= +$ **0.357** kJ	Show working	1

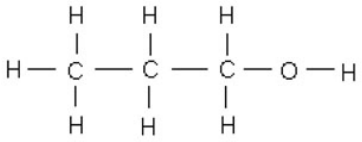
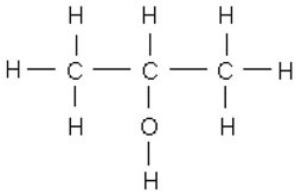
Qn	Marking Scheme	Remarks	Mks
5diii		Product $KNO_3(aq)$ at higher level and arrow head for positive ΔH, no need show value or unit	1
6a	Experiment 1, dilute $CuSO_4(aq)$, graphite electrodes At negative electrode: **$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$** At positive electrode: **$4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$** Experiment 2, dilute $CuSO_4(aq)$, copper electrodes At negative electrode: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ At positive electrode: **$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$**	1 mark for 1 ionic equation, must show state symbols	3
6b	In graphite, each carbon atom is **bonded** to **three** other carbon atoms. This leaves 1 unbonded **electron** per carbon atom, which is free and **mobile** to conduct electricity.	1 mark for bonding 1 mark for mobile electron(s)	2
6c	In experiment 1, colour of electrolyte changes or slowly fades from **blue to colourless**, and its pH becomes more **acidic**. In experiment 2, there is no change in the colour and pH of the electrolyte / the colour and pH of electrolyte remain the same.	Mention changes to colour and pH	1
6d	Increase in mass of Cu = 53 − 50 = 3 g Number of moles of Cu = **3 ÷ 64** = **0.046875** mol $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ Number of moles of electrons = 0.046875 × 2 = 0.09375 mol = **0.0938** mol (3 s.f.)	1 mark for moles of Cu 1 mark for moles of e^- in 3 s.f.	2
7a	Property of transition metals: - They have **high melting points**. - They have high densities. - They form ions with variable or different oxidation states. - They form coloured compounds.	Any 1 property	1

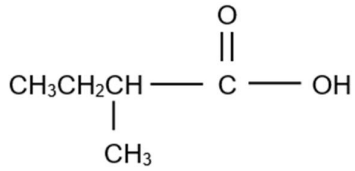
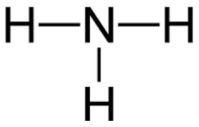
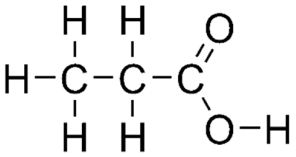
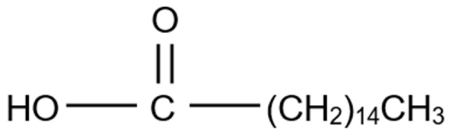
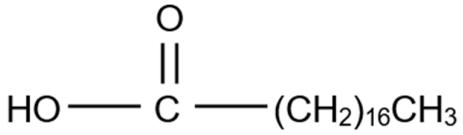
Qn	Marking Scheme	Remarks	Mks
7bi	A reversible reaction can go both **forward and backward** at the same time.	Mention both directions	1
7bii	Pressure of **250 atm** and temperature of **450 °C**	Values and units	1
7c	Using powdered form **increases surface area** of catalyst. With more surface area in contact with reactant particles, the **rate** of reaction **increases**.	More surface area + faster reaction rate	1
7d	An increase in temperature results in an **increase in rate** of reaction. At a higher temperature, reacting particles have more kinetic energy. They gain energy and move faster. More reacting particles possess **energy** that is **greater than** or equal to **activation energy**. **Frequency of effective collisions** between reacting particles **increases**.	1 mark for energy > E_a 1 mark for increase frequency of effective collisions and rate	2
7e	Reasons to not increase temperature: - If reaction is slow due to low temperature, **catalyst** added can help to increase reaction rate / speed up reaction - Decrease or **lower yield** of product / product yield / yield - Incur **higher** operational / energy / production **costs** - **Increase energy consumption** and **greater environmental impact** (more industrial emissions) - Need to purchase specialised materials that are heat-resistant / able to withstand high temperatures as well as schedule regular maintenance to keep equipment in optimal condition - Pose safety concerns when too high temperatures cause too fast uncontrolled reactions, or increase the risk of explosions, fires and other hazardous conditions - Promote unwanted side reactions / formation of by-products, affecting purity and quality of desired product	1 mark for 1 reason	2
8a	Petroleum (crude oil) is first **heated** in a furnace and the **vapour** is passed into the fractionating (distillation) column. The fractions with **lower boiling points** rise up the column, **cool** and **condense**, and are collected at the **top** of the column. The fractions with **higher boiling points** condense at higher temperatures and are collected at the lower levels or sections or **bottom** of the column.	1 mark for processes and states (heat to vapour, cool to liquid) 1 mark for different boiling points and collection positions	2
8bi	Use of kerosene: - **Fuel for aircraft / jet engines** - Fuel for cooking using oil stoves Use of diesel: - **Fuel for diesel engines** (in buses, lorries, trains) - Fuel for power generation, e.g. power heavy machinery	Both uses, 1 use each	1

Qn	Marking Scheme	Remarks	Mks
8bii	Other fractions: - **Bitumen** - Lubricating oil - Petroleum gas	Any 1 fraction name	1
8ci	<table><tr><td>product</td><td>propene, C_3H_6</td><td>ethene, C_2H_4</td><td>methane, CH_4</td></tr><tr><td>**full structure**</td><td>  </td><td>  </td><td>  </td></tr></table>	Any 1 structure	1
8cii	Process A **circle reforming** Process B **circle cracking**	Both circles	1
8d	Reasons for choosing poly(propene) - Its **useable temperature** is **above 100 °C** - It is **insoluble in oil**	1 mark for 1 reason	2
8e		Repeat unit and brackets, subscript n	1
8f	Plastics / polymers are **macromolecules**. Each polymer molecule consists of **covalent** bonding or strong covalent bonds between atoms.	Structure and bonding	1
8gi	Physical (mechanical) method of recycling: - Small pieces of plastics are **melted**, cooled, pulled into long, thin strands, and cut into **pellets** - These pellets can then be made into new products Chemical method of recycling: - Plastic waste can undergo **cracking** to form **short chains** of alkanes and alkenes, which are different raw materials that can be used to make other useful chemicals - Plastic polymer can undergo **depolymerisation** to form back into its **monomers** to be converted to other useful chemicals	Any 1 method, describing how and product	1
8gii	Challenges of recycling plastics: - Plastic recycling processes can be **labour-intensive and energy-intensive**, as all the **processes** involved in recycling plastic waste **require manpower, machines and energy** - Recycling plastic waste can cost much more than disposal in landfills or incineration, due to cost of transporting the waste to the processing plant, costs of sorting and cleaning the waste, and carrying out either physical or chemical recycling methods, plastic recycling technologies are expensive	Any 1 challenge / issue, providing **elaboration** or **example**	1

<table>
<tr><th>Qn</th><th>Marking Scheme</th><th>Remarks</th><th>Mks</th></tr>
<tr><td></td><td>- Recycling plastics may not be worthwhile or economically viable or profitable / Difficult for plastic recycling businesses to survive, as recycled plastics have lower market value than virgin plastics / recycled plastics are sold at a lower value than virgin plastics
- Degradation of plastic quality after multiple recycling cycles, which can restrict the range of uses for the recycled material / lower market demand for recycled plastics
- It takes time and effort for communities to adopt recycling plastics as a lifestyle, as many people find it more convenient to throw all their plastic waste away / Many people are not aware of the proper way to recycle plastic, increasing time and effort and slowing down recycling process
- Wastewater generated from the plastic recycling processes is not treated properly before being discharged into water bodies, contaminating the water and causing water pollution</td><td></td><td></td></tr>
<tr><td>9a</td><td>$2H_2 + O_2 \rightarrow 2H_2O$

OR
$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$</td><td>Formulae and coefficients
No need state symbols</td><td>1</td></tr>
<tr><td>9b</td><td>Volume of oxygen
= Volume of hydrogen ÷ 2
= 250 ÷ 2
= 125 dm^3</td><td>Answer in dm^3</td><td>1</td></tr>
<tr><td>9c</td><td>Reduction takes place at the positive electrode, due to gain of electrons.</td><td>Reduction and explain</td><td>1</td></tr>
<tr><td>9d</td><td>The electrolyte, aqueous sodium hydroxide, conducts electricity due to mobile ions.</td><td>Name electrolyte + mobile ions</td><td>1</td></tr>
<tr><td>9e</td><td>Disadvantages of hydrogen fuel:
- Obtaining hydrogen from electrolysis is expensive / more expensive than other fuels
- It is difficult to store and transport hydrogen, as hydrogen is very light / has a low energy density by volume and requires a larger storage volume or tanks / high pressures and/or low temperatures to store sufficient amounts for practical use / specialised insulated containers to store liquid hydrogen / heavy expensive high-pressure tanks to store compressed gas
- It is difficult to handle and store hydrogen safely / Special precautions or stringent safety measures must be taken in the handling and storing hydrogen, as hydrogen is a highly flammable or extremely explosive / hydrogen is often transported in high-pressure cylinders which can be dangerous to handle</td><td>1 mark for 1 disadvantage</td><td>2</td></tr>
<tr><td>9f</td><td><table><tr><th>error</th><th>corrections to error</th></tr><tr><td>Biofuels, derived from inorganic materials such as plastic waste and metals</td><td>Biofuels are derived from plants, algae, and organic waste</td></tr></table></td><td>1 mark for correcting 1 error</td><td>2</td></tr>
</table>

Qn	Marking Scheme	Remarks	Mks
	Biofuels involve practices that exhaust natural resources and cause ecological damage / Biofuels are considered more environmentally sustainable Biofuels increase greenhouse gas emissions / Biofuels can potentially reduce greenhouse gas emissions **Biofuels do not require oxygen to burn / Biofuels require oxygen to burn**		
10a	Alcohols are a homologous series: - **Melting and boiling points** of members **increase** - Miscibility or solubility in water of members decreases - Down the series, the size of molecules increases	Any 1 evidence from information	1
10b	**$C_nH_{2n+1}OH$**		1
10c	Propan-1-ol and propan-2-ol  	1 mark for 1 structure	2
10di	**Ethyl ethanoate** and **water**	Name products	1
10dii	$M_r(C_2H_5OH) = 46$ Number of moles of ethanol = **5 ÷ 46** = 0.10870 mol (5 s.f.) $M_r(CH_3COOH) = 60$ Number of moles of ethanoic acid = **5 ÷ 60** = 0.083333 mol (5 s.f.) Limiting reactant is **ethanoic acid** Mole ratio ethanoic acid : ethyl ethanoate = 1 : 1 $M_r(CH_3COOC_2H_5) = 88$ Theoretical mass of ethyl ethanoate = 0.083333 **× 88** = 7.3333 g (5 s.f.) Actual mass of ethyl ethanoate = 7.3333 × (60 ÷ 100) = **4.4 g**	1 mark for finding moles / limiting reactant 1 mark for multiply 88 1 mark for 60% of mass in g	3
10e	Hydrolysis of amide produces carboxylic acid and amine. Hydrolysis of compound X produces carboxylic acid and ammonia.	1 mark for 1 structure	2

Qn	Marking Scheme	Remarks	Mks
	 and 		
11a	**$C_4H_9CO_2H$, 102**	Formula and M_r value	1
11b	It is easier to predict the **boiling point**. There is an **increasing trend** for boiling points of members, however there is no trend for their melting points.	1 mark for boiling point 1 mark for explain	2
11c		Full structure; show all bonds between all atoms	1
11d	By **heat**ing a mixture of **ethanol** and **acidified potassium manganate(VII)** solution. The solution turns from **purple to colourless**.	1 mark for ethanol, acidified $KMnO_4$, heat 1 mark for colour change	2
11ei	Add **aqueous bromine** to two separate test tubes containing sample of each fatty acid. If aqueous bromine **remains red-brown**, the test tube contains **saturated** fatty acid. If aqueous bromine turns **red-brown to colourless**, the test tube contains **unsaturated** fatty acid.	1 mark for $Br_2(aq)$ 1 mark for comparison of results and conclusion	2
11eii	 AND 	1 mark for 1 structure	2