Question number	Part	Step	Answer	Additional guidance	Marks
1	a	3	**B** gold		**1 mark**
	b	7	It is better to recycle iron (1) because recycling has less impact on the environment/because the cost is lower/ because there is less energy used. (1)	Students need to justify their answer for the second mark	**2 marks**
	ci	5	sodium		**1 mark**
	cii	5	Sodium is higher than iron in the reactivity series/is more reactive.		**1 mark**
	ciii	5	silver		**1 mark**
2	a	5	Any **one** from: ● The reaction is reversible. (1) ● The reaction reaches (dynamic) equilibrium. (1)	Allow the reaction goes both ways	**1 mark**
	b	7	Nitrogen: from the air (1) Hydrogen: from natural gas (or water or steam) (1)		**2 marks**
	c	7	Temperature: any number or range from 400 to 500 °C Pressure: any number or range from 150 to 250 atmospheres Catalyst: iron	2 marks for all three conditions correct 1 mark for any two conditions correct	**2 marks**
3	a	7	Any **two** observations from: ● Moves/darts around. (1) ● Melts/forms a ball. (1) ● Effervesces/fizzes/bubbles. (1) ● Gets smaller/disappears/dissolves. (1) ● Forms a white trail. (1)	1 mark for each observation Do not award marks for statements that are not observations, e.g. hydrogen is formed.	**2 marks**
	bi	5	magnesium + copper sulfate → copper + magnesium sulfate		**1 mark**
	bii	7	**C** 9.6 ($g\,dm^{-3}$)		**1 mark**
	biii	8	63.5 + 32 + (4 × 16) = 159.5		**1 mark**

Question number	Part	Step	Answer	Additional guidance	Marks
	biv	8	159.5 g of copper sulfate forms 63.5 g of copper (1) 319 g of copper sulfate forms $\frac{63.5}{159.5} \times 319$ = 127 g Cu (1)	1 mark for some correct working 1 mark for answer Award full marks for correct answer with no working Allow error carried forward from incorrect relative formula mass in **biii**	**2 marks**
4	a	7	**C** electrolyte		**1 mark**
	bi	8	Positive electrode: An orange-brown gas is released. (1) Negative electrode: A grey liquid forms (at the bottom of the beaker). (1)	The marks are for the observations, not for any conclusions made from them	**2 marks**
	bii	8	The lead ions/Pb^{2+} gain (two) electrons (to form lead atoms) (1) at the cathode/negative electrode. (1)		**2 marks**
	biii	7	The ions/charged particles (1) cannot move (are held in fixed positions/held together by strong electrostatic forces/ionic bonds in lattice) and therefore cannot carry the current. (1)		**2 marks**
	ci	7	As the current increases, the mass change of the cathode increases.		**1 mark**
	cii	9	increase of 0.10 g		**1 mark**
	ciii	8	(Copper anode) dissolves/decreases in mass.		**1 mark**
	civ	8	oxygen		**1 mark**

Question number	Part	Step	Answer	Additional guidance	Marks
5		8	Answers will be credited according to the candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **Indicative content AO1 (3 marks) and AO2 (3 marks)** ● Aluminium can only be extracted using electrolysis of the molten ore. ● Aluminium oxide is dissolved in molten cryolite. ● Electrodes are made of graphite. ● When electricity is passed through, aluminium forms at the cathode ● and oxygen at the anode. ● The oxygen produced reacts with anodes (graphite) so they have to be replaced frequently. ● Aluminium is more reactive than carbon/is higher than carbon in the reactivity series. ● Iron is below carbon in the reactivity series/is less reactive than carbon. ● Aluminium forms stronger bonds with oxygen than iron does. ● Carbon is able to reduce iron oxide but is not able to reduce aluminium oxide. ● Heating aluminium oxide with carbon would not result in aluminium being formed/there would be no reduction reaction. ● Aluminium oxide is more stable to decomposition than iron oxide.	See below	**6 marks**

Step	Marks	Descriptor
U	0	No awardable content.
6	1–2	**Level 1** ● Demonstrates elements of chemical understanding, some of which is inaccurate. Understanding of scientific ideas, enquiry, techniques and procedures lacks detail. (AO1) ● Lines of reasoning are unsupported or unclear. (AO2)
7	3–4	**Level 2** ● Demonstrates chemical understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas, enquiry, techniques and procedures is not fully detailed and/or developed. (AO1) ● Lines of reasoning are mostly supported through the application of relevant evidence. (AO2)
8	5–6	**Level 3** ● Demonstrates accurate and relevant chemical understanding throughout. Understanding of the scientific ideas, enquiry, techniques and procedures is detailed and fully developed. (AO1) ● Lines of reasoning are supported by sustained application of relevant evidence. (AO2)

Step boundaries

Step	Marks
U	0–1
1	2–3
2	4–6
3	7–8
4	9–11
5	12–13
6	14–15
7	16–18
8	19–21
9	22+

Indicative grade boundaries

Indicative grade	Marks
U	0–3
1	4–6
2	7–11
3	12–15
4	16–18
5	19–21
6	22+

Question number	Part	Step	Answer	Additional guidance	Marks
1	a	5	Any **one** from: ● The reaction is reversible. (1) ● The reaction reaches (dynamic) equilibrium. (1)	Allow the reaction goes both ways	**1 mark**
	b	7	Nitrogen: from the air (1) Hydrogen: from natural gas (or water or steam) (1)		**2 marks**
	c	11	The yield of ammonia decreases (1) because the higher temperature favours the reverse reaction/the equilibrium position moves to the left. (1)	Allow the reverse argument for the second mark: forward reaction being exothermic means that lower temperature gives better yield	**2 marks**
2	a	7	Sodium (1) because it is most reactive. (1)		**2 marks**
	b	7	**C** it is oxidised		**1 mark**
	c	7	Any **one** from: ● Natural reserves of metal ores will last longer. (1) ● reduction in the need to mine, so less damage to the landscape (1) ● Less pollution will be produced. (1) ● Many metals need less energy to recycle them than to extract new metal from the ore. (1) ● Less waste metal ends up in landfill sites. (1)		**1 mark**
3	a	7	**C** 9.6 g dm^{-3}		**1 mark**
	b	8	63.5 + 32 + (4 × 16) = 159.5		**1 mark**
	ci	8	159.5 g of copper sulfate forms 63.5 g of copper (1) 319 g of copper sulfate forms $\frac{63.5}{159.5} \times 319$ = 127 g Cu (1)	1 mark for correct working 1 mark for answer Award full marks for correct answer with no working Allow error carried forward from incorrect relative formula mass in **b**	**2 marks**
	cii	9	Copper is reduced (1) because it has lost (two) electrons. (1)		**2 marks**
4	ai	8	Positive electrode: An orange-brown gas is released. (1) Negative electrode: A grey liquid forms (at the bottom of the beaker). (1)	The marks are for the observations, not for any conclusions made from them	**2 marks**

Question number	Part	Step	Answer	Additional guidance	Marks
	aii	8	The lead ions / Pb^{2+} gain (two) electrons (to form lead atoms) (1) at the cathode/negative electrode. (1)		**2 marks**
	aiii	7	**A** because the ions are not free to move and carry a charge		**1 mark**
	bi	7	As the current increases, the mass change of the cathode increases.		**1 mark**
	bii	10	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	1 mark for correct species and for balancing 1 mark for correct state symbols	**2 marks**
	biii	9	increase by 0.10 g		**1 mark**
	biv	8	(Copper anode) dissolves/decreases in mass.		**1 mark**
	bv	8	oxygen gas		**1 mark**
5		12	P Cl mass: 3.1 10.65 A_r: 31 35.5 = 0.1 = 0.3 (1) Ratio: 1 3 (1) Formula: PCl_3 (1)	Award 3 marks for PCl_3 with some correct working Award 1 mark for formula alone Accept Cl_3P	**3 marks**
6		12	Answers will be credited according to the candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **Indicative content AO3 (6 marks)** ● (In each experiment) the volume of hydrogen is twice the volume of oxygen ● because water molecules contain twice as many hydrogen atoms as oxygen atoms/the formula of water is H_2O. ● The overall reaction is: $2H_2O \rightarrow 2H_2 + O_2$	See below	**6 marks**

Question number	Part	Step	Answer	Additional guidance	Marks
			Comparing Experiments 1 and 2: ● As the time doubles (and the current is constant) ● the volumes of gases double ● so volumes of gases are directly proportional to the time for electrolysis ● because the number of electrons in the current doubles, so twice as many ions react to form the gases per unit time/per minute. **Comparing Experiments 1 and 3:** ● The current increases by a factor of 1.5 (and the time is constant) ● and the volumes of gases increase by a factor of 1.5 ● so volumes of gases are directly proportional to the current ● because there are 1.5 times the number of electrons in the current, so 1.5 times more ions react to form the gases.		

Step	Marks	Descriptor
U	0	No awardable content.
10	1–2	**Level 1** ● Interpretation and evaluation of the information attempted but will be limited with a focus on mainly just one variable. (AO3) ● Deconstructs scientific information but understanding and connections are flawed. An unbalanced or incomplete argument that provides limited synthesis of understanding. (AO3)
11	3–4	**Level 2** ● Interpretation and evaluation of the information on both variables, synthesising mostly relevant understanding. (AO3) ● Deconstructs scientific information and provides some logical connections between scientific concepts. An imbalanced argument that synthesises mostly relevant understanding, but not entirely coherently. (AO3)
12	5–6	**Level 3** ● Interpretation and evaluation of the information, demonstrating throughout the skills of synthesising relevant understanding. (AO3) ● Deconstructs scientific information and provides logical connections between scientific concepts throughout. A balanced, well-developed argument that synthesises relevant understanding coherently. (AO3)

Step boundaries

Step	Marks
U	0–6
5	7–8
6	9
7	10–12
8	13–16
9	17–19
10	20–22
11	23–27
12	28+

Indicative grade boundaries

Indicative grade	Marks
U	0–6
3	7–9
4	10–12
5	13–16
6	17–19
7	20–22
8	23–27
9	28+