Answer **all** the questions.

1. During the electrolysis of molten potassium chloride, what is made at the cathode?

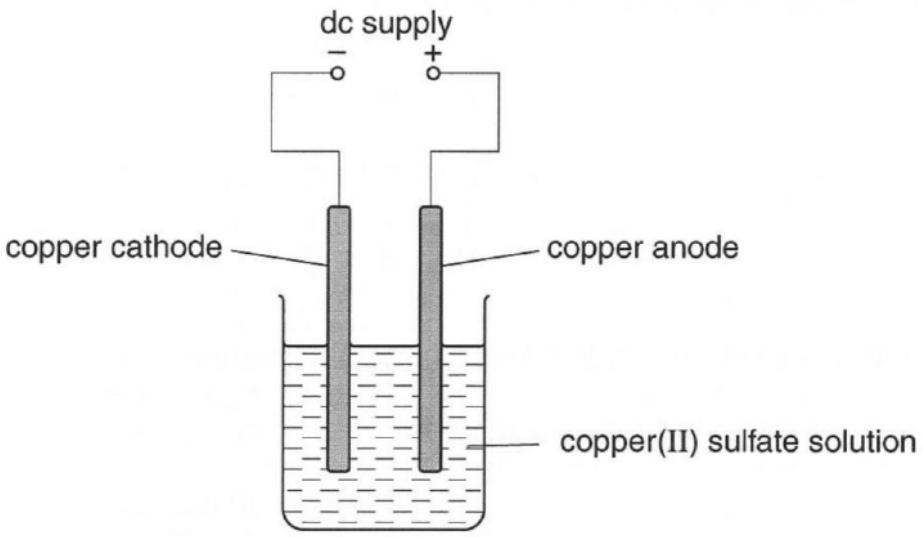
A chlorine
B hydrogen
C potassium
D potassium hydroxide

Your answer ☐

[1]

2(a). Meena electrolyses copper sulfate using copper electrodes.

Look at the diagram. It shows the apparatus she uses.



She investigates the change in mass at each electrode before and after the electrolysis.

Look at Meena's method.

1. Using a balance, measure the mass of the copper cathode and copper anode. 2. Set up the apparatus and run the electrolysis for 30 seconds. 3. Remove the copper cathode and the copper anode and immediately place them on the balance and measure their masses again.

What improvements could you make to Meena's experiment?

Explain your answers.

---

[4]

(b). Meena finds that

- the cathode gains mass
- the anode loses mass.

Explain these observations in terms of the reactions at each electrode.

[2]

3(a). Molten aluminium oxide contains Al^{3+} and O^{2-} ions.

The electrolysis of molten aluminium oxide makes aluminium and oxygen.

(i) Write the **balanced symbol** equation for the electrode reaction that happens at the cathode.

Use the symbol e^- to represent an electron.

[1]

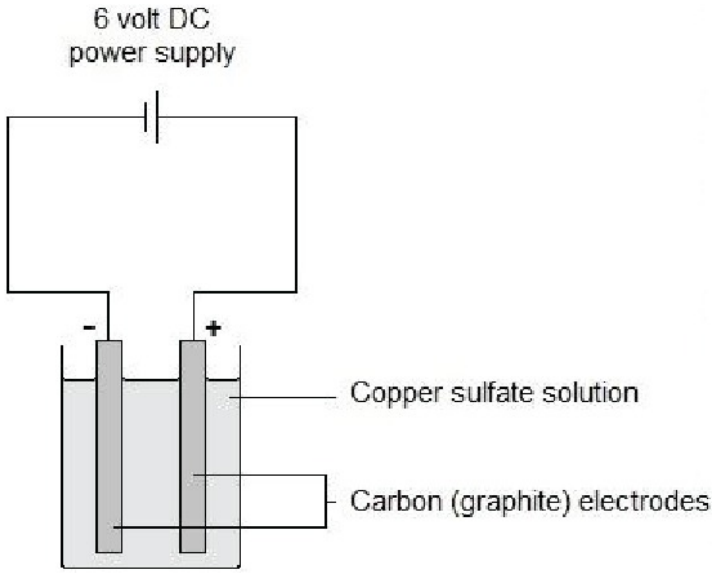
(ii) Solid aluminium oxide cannot be electrolysed.

Explain why.

[1]

(b). Copper is also made by electrolysis of copper sulfate solution.

Look at the diagram of the apparatus used in this electrolysis.



Describe what you would **see** at each of the electrodes.

At the anode: _____

At the cathode: _____

[2]

4(a). Molten (liquid) potassium chloride can be electrolysed.

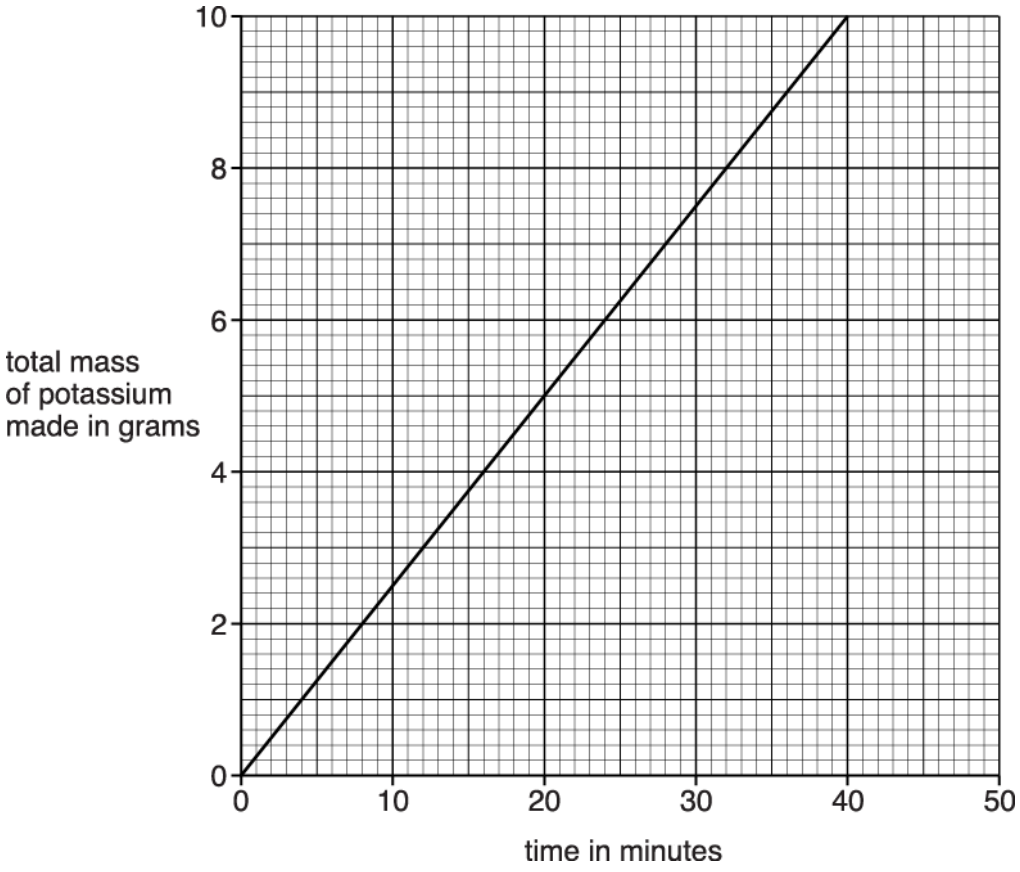
Potassium is made.

Manjit investigates the mass of potassium made when molten potassium chloride is electrolysed.

She always uses a current of 10.3 amps.

She does the electrolysis for different lengths of time.

Look at the graph of her results.



What is the total mass of potassium made in 30 minutes?

_____ g

[1]

(b). Manjit electrolyses molten potassium chloride for 120 minutes.

She uses a current of 20.6 rather than 10.3 amps.

Predict the mass of potassium made.

---

[2]

5(a). Molten (liquid) salts can be electrolysed.

Sanjay does an electrolysis experiment using potassium bromide.

Solid potassium bromide cannot be electrolysed.

Molten (liquid) potassium bromide can be electrolysed. It makes two products.

(i) Write down the names of the **two** products made during this electrolysis.

---

[2]

(ii) Explain why molten (liquid) potassium bromide can be electrolysed.

---

[1]

(b). Molten (liquid) potassium chloride can be electrolysed.

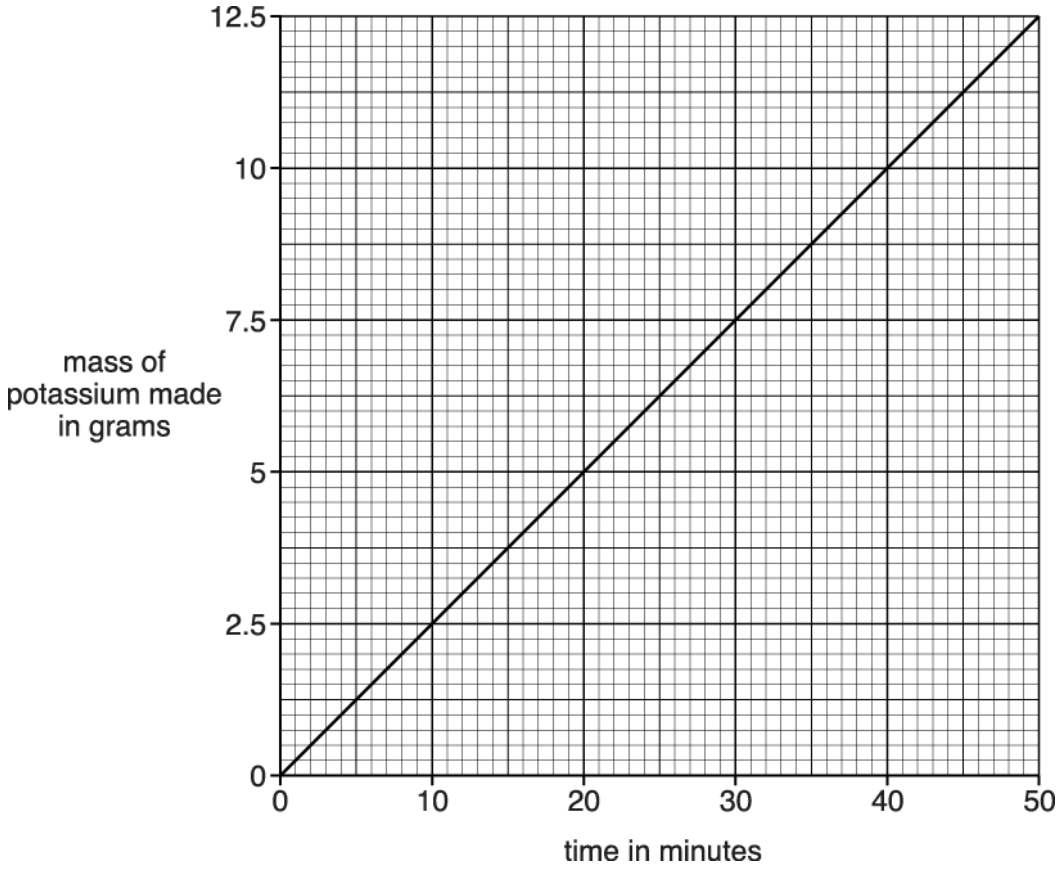
It makes potassium.

Sanjay investigates the mass of potassium made when molten potassium chloride is electrolysed.

He always uses a current of 10.3 amps.

He changes how long, in minutes, he does the electrolysis.

Look at the graph of his results.



(i) What mass of potassium is made after 30 minutes?

_____ g

[1]

(ii) Sanjay electrolyses molten potassium chloride for 300 minutes.

Predict the mass of potassium made.

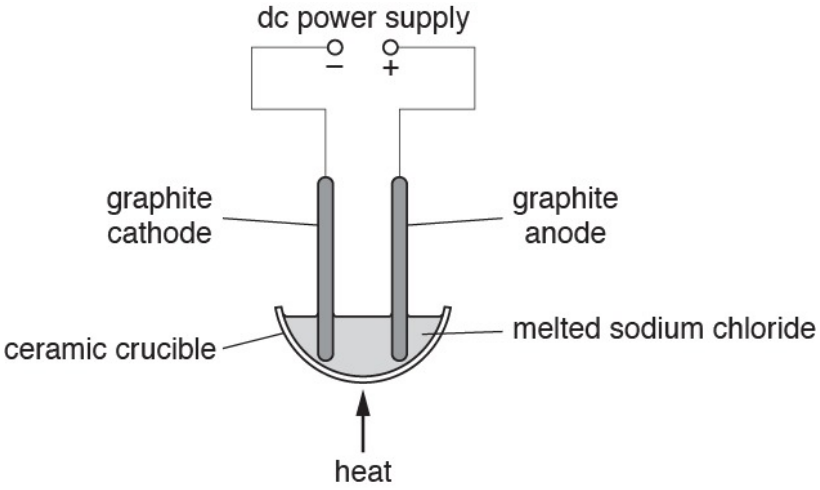
_____ g

[1]

6(a). This question is about electrolysis.

Joel's teacher investigates the electrolysis of melted sodium chloride.

Look at the apparatus he uses.



Sodium chloride contains sodium ions, Na^+, and chloride ions, Cl^-.

(i) Chloride ions, Cl^-, react at the anode.

Chlorine gas, Cl_2, and electrons are the products.

Write a **balanced symbol** equation for the electrode process at the anode.

Use $\mathbf{e}^-$ to show an electron.

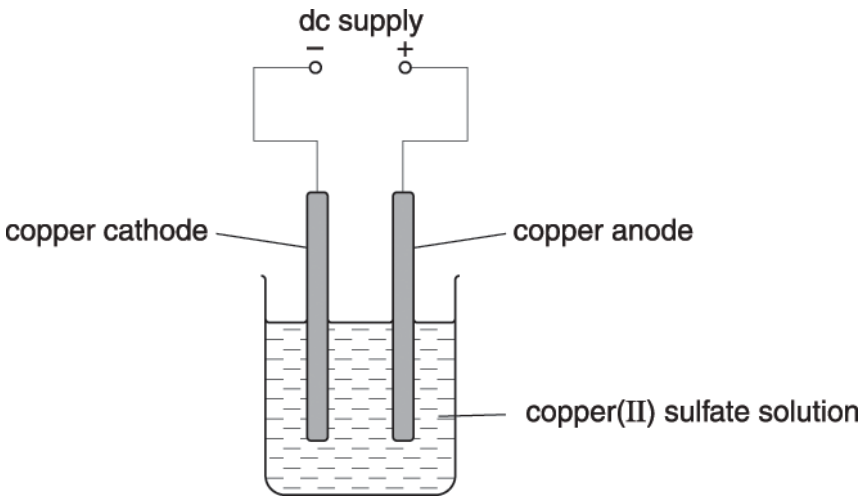
[2]

(ii) **Solid** sodium chloride does **not** conduct electricity, but **melted** sodium chloride **does** conduct electricity.

Explain why.

[2]

(b). Joel passes an electric current through **copper(II) sulfate solution.**



Joel does four experiments.

Joel changes either the **time** or the **current**.

Copper is made at the cathode.

He measures how much copper is made in each experiment.

Experiment	Current in amps	Time in minutes	Mass of copper made in g
1	0.15	5	0.20
2	0.30	5	0.40
3	0.15	10	0.40
4	0.60	10	1.60

Joel concludes that the amount of copper made is **proportional** to both the current and to the time.

Show how the results support this conclusion.

---

[2]

7(a). During the electrolysis of sodium bromide solution, bromide ions make bromine molecules.

Complete the equation for this reaction.

$$\ldots\ldots Br^- - \ldots\ldots e^- \rightarrow Br_2$$

[1]

(b). Explain why this reaction is an example of **oxidation**.

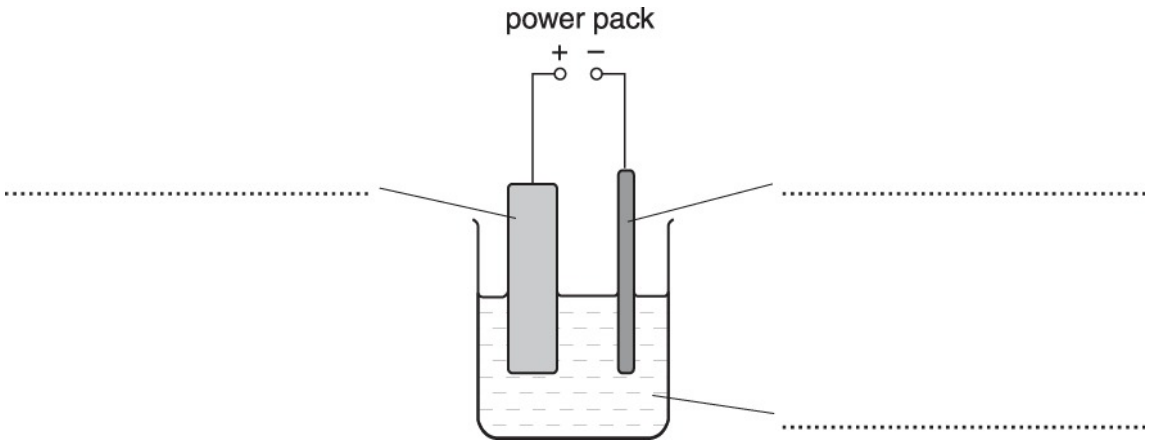
---

[1]

8. Pure copper is used for electrical wiring.

The copper is purified by **electrolysis**.

The diagram shows the apparatus used to purify copper.



Complete the labels on the diagram.

Choose your answers from the list.

copper sulfate solution

dilute sulfuric acid

impure copper anode

impure copper cathode

pure copper anode

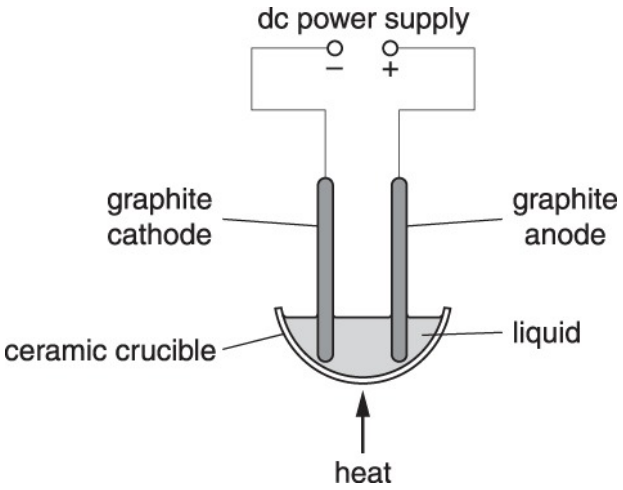
pure copper cathode

[2]

9(a). Joel's teacher investigates the electrolysis of four liquids.

The first liquid he uses is melted sodium chloride.

Look at the apparatus he uses.



The table shows the products made.

Liquid	Product at cathode	Product at anode
lead bromide	lead	bromine
lead iodide	lead	iodine
sodium chloride	sodium	_____
potassium iodide	_____	iodine

[2]

(i) Complete the table.

(ii) Sodium chloride contains sodium ions, Na+, and chloride ions, Cl –.
Solid sodium chloride does not conduct electricity, but melted sodium chloride does conduct electricity.
Explain why.

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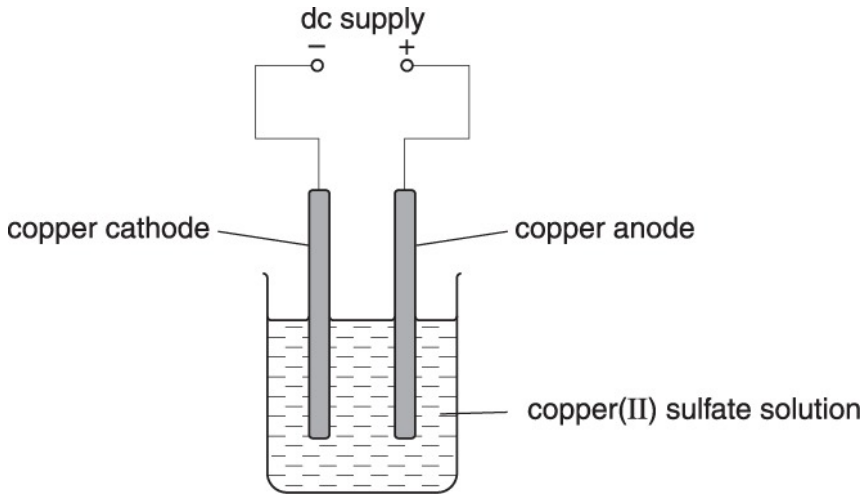
[2]

(b). Joel passes an electric current through **copper(II) sulfate solution**.



Joel does four experiments.

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Experiment	Current in amps	Time in minutes	Mass of copper made in g
1	0.15	5	0.20
2	0.30	5	0.40
3	0.15	10	0.40
4	0.60	10	1.60

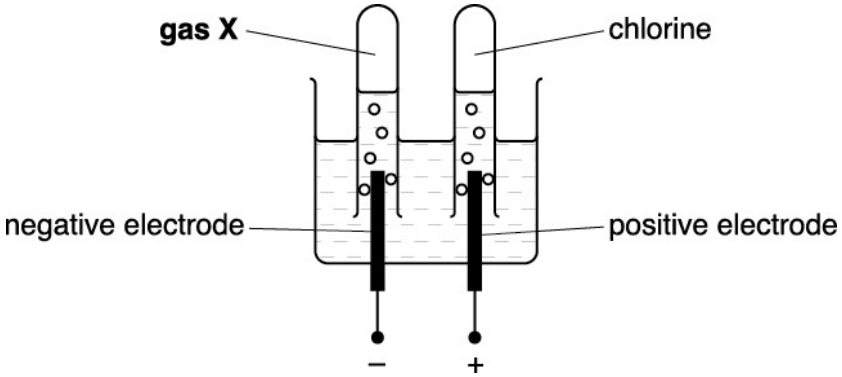
Joel concludes that the amount of copper made is **proportional** to both the current and to the time.

Show how the results support this conclusion.

[2]

10. Anita investigates the electrolysis of concentrated sodium chloride solution (brine).

Look at the diagram. It shows the apparatus she uses.



What is the name of gas **X**?

Choose your answer from the list.

carbon dioxide

hydrogen

hydrogen chloride

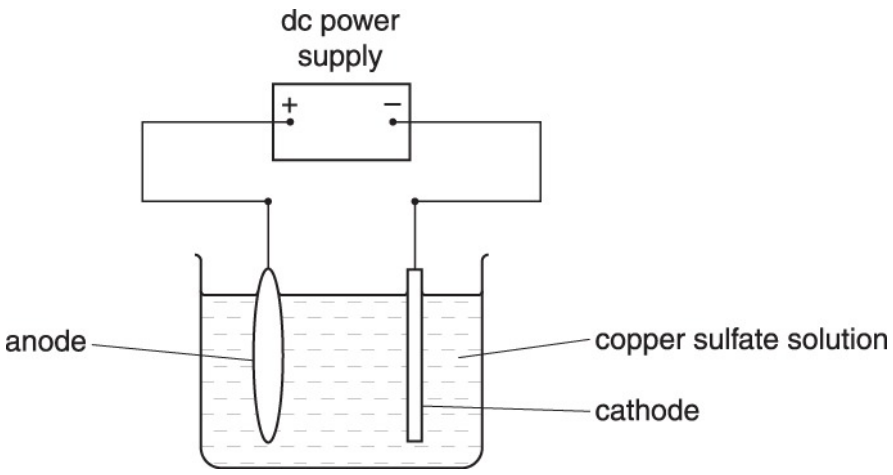
oxygen

answer

[1]

11.

Look at the diagram. It shows the apparatus used to purify copper.



What is the name of the process used to purify copper?

Choose from the list.

crystallisation

electrolysis

eutrophication

neutralisation

thermal decomposition

answer _____ **[1]**

END OF QUESTION PAPER

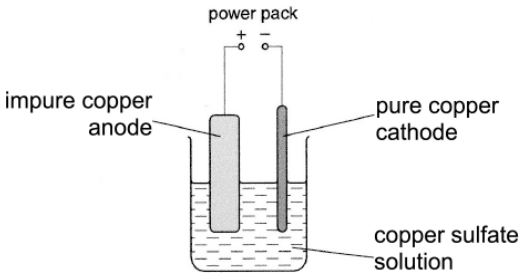
Question			Answer/Indicative content	Marks	Guidance
1			C	1	
			Total	**1**	
2	a		electrolysis needs to run for longer than 30 seconds (1) otherwise insufficient change at electrodes (1) after electrolysis anode and cathode need to be washed (1) and then dried (1) before measuring the mass	4	
	b		copper is deposited at the cathode (1) copper anode dissolves / copper ions produced at anode (1)	2	**ALLOW** higher level answers in terms of half equations e.g. at cathode $Cu^{2+} + 2e^- \rightarrow Cu$ (1) e.g. at anode $Cu \rightarrow Cu^{2+} + 2e^-$ / $Cu - 2e^- \rightarrow Cu^{2+}$ (1)
			Total	**6**	
3	a	i	$Al^{3+} + 3e^- \rightarrow Al$ (1)	1	**ALLOW** any correct multiple **ALLOW** = instead of → **DO NOT ALLOW** & or and instead of +
		ii	Ions cannot move (1)	1	**IGNORE** electrons cannot move
	b		Anode: bubbles / effervescence (1) Cathode: Brown / salmon pink deposit / layer / coating (1)	2	Both correct descriptions but at wrong electrodes
			Total	**4**	
4	a		7.5 (g) (1)	1	**allow** 7.4 to 7.6 **Examiner's Comments** This question focused on the electrolysis of molten potassium chloride. Most candidates were able to interpret the graph and give an answer of 7.5 g.

Question			Answer/Indicative content	Marks	Guidance
	b		**LOOK FOR ANSWER FIRST OF ALL** **IF mass = 60 g AWARD 2 MARKS** idea that must multiply (7.5) by 4 / idea that must multiply (30) by 2 / idea that must multiply (7.5) by 8 (1)	2	**allow** ecf answer to (a) × 8 e.g. 60.8 if 7.6g and 59.2 if 7.4 **allow** ecf **Examiner's Comments** This question focused on the electrolysis of molten potassium chloride. Candidates were able to use their result to get an answer of 60.0 g. Some candidates used Q=It in their answer and went through complex calculations even remembering 96500 to get the correct answer. Other candidates used the correct method of appreciating that the current was doubled and the time quadrupled so that overall the mass will be 8 times the original mass.
			Total	**3**	

Question			Answer/Indicative content	Marks	Guidance
5	a	i i	potassium (1) bromine (1)	2	**allow** K (1) **allow** Br_2 (1) **do not allow** bromide **Examiner's Comments** The products were usually correctly identified as potassium and bromine. Bromide was a common error.
		ii	ions can move / ions go to electrodes (1)	1	**allow** ions move to anode / ions move to cathode (1) **do not allow** electrons can move **Examiner's Comments** A very common misconception was that molten potassium bromide can be electrolysed because the *electrons* can move.
	b	i	7.5 (g) (1)	1	**allow** 7.4 to 7.6 (1) **Examiner's Comments** Most candidates correctly interpreted the graph and scored the marks.
		ii	75 (g) (1)	1	**allow** ecf from (i) i.e. 10 x answer to (i) **Examiner's Comments** Most candidates correctly interpreted the graph and scored the marks.
			Total	**5**	

Question			Answer/Indicative content	Marks	Guidance
6	a	i	$2Cl^{?}$? $Cl_2 + 2e^{?}$ / $2Cl^{?}$? $2e^{?}$? Cl_2 formulae correct including electrons (1) balancing — dependent on correct formulae (1)	2	**allow** = instead of ? **not** and or & instead of + **allow** any correct multiples including fractions **allow** $e^{?}$ or e for electrons **allow** $2Cl^{?}$? $e^{?}$? $Cl_2 + e^{?}$ for two marks **allow** one mark for correct balanced equation with minor errors of case, subscript and/or superscript eg 2CL? ? Cl2 + $2e^{?}$ **allow** one mark for $Cl^{?}$? $e^{?}$? Cl / $Cl^{?}$? Cl + $e^{?}$ **allow** one mark for $2Cl^{?}$? Cl_2 **Examiner's Comments** Candidates found the electrode reaction challenging and often candidates had the electrons on the wrong side of the equation or had the formula of chlorine incorrect. A small proportion of candidates did not attempt this question.
		ii	solid sodium chloride has ions in fixed positions / ions do not move in a solid (1) liquid sodium chloride has ions that move (1)	2	**allow** solid does not have free ions **ignore** electrons cannot move in a solid **allow** liquid sodium chloride has free ions **not** electrons can move in a liquid **allow** if no other marks scored award one mark for particles can move in a liquid but not in a solid / liquid has mobile charge carriers but solid does not **Examiner's Comments** Candidates often appreciated that the charge carrier could not move in a solid but could move in a liquid, however most candidates referred to electrons rather than ions as the charge carrier.
	b			2	**allow** reference to the correct data in the table to identify which experiments they are using

Question			Answer/Indicative content	Marks	Guidance
			experiments **1** and **3** show that as time doubles mass (of copper made) doubles (1) experiments **3** and **4** show that as the current quadruples, the mass also quadruples (1) **OR** experiments **1** and **2** show that as current doubles mass (of copper made) doubles (1)		**allow** when the time doubles and the current stays the same the mass doubles **allow** when the current doubles and the time stays the same the mass doubles **allow** if no other marks awarded then as time and current increase the mass (of copper) increases for one mark **Examiner's Comments** In this evaluation question many candidates could use the data to show that as current increases so does the mass and as the time increases so does the mass but were less confident at explaining why this indicated direct proportionality. Only the best answers referred to the experiment numbers in their explanations. Candidates did not always choose sets of experiments where only one variable changed and as a result did not justify the patterns they were describing.
			Total	**6**	

Question			Answer/Indicative content	Marks	Guidance
7	a		**2**$Br^{?}$ - **2**$e^{?}$? Br_2(1)	1	**allow** any correct multiple, including fractions **not** any additional symbols, other than balancing **Examiner's Comments** Most candidates correctly balanced the equation.
	b		(oxidation because) electrons are lost (from $Br^{?}$) (1)	1	**allow** oxidation number of Br increases (1) **not** bromine (atoms) lose electrons **but allow** ions lose electrons (1) **Examiner's Comments** Most candidates explained that oxidation is loss of electrons. Candidates who did not gain credit either stated that electrons were gained, or suggested that the wrong species was losing electrons, e.g. bromine loses electrons.
			Total	**2**	
8				2	**all three** labels correct scores 2 marks **one or two** labels correct scores 1 mark **Examiner's Comments** Many candidates scored both marks. Candidates who only scored 1 mark usually correctly identified the electrolyte as copper sulfate solution.
			Total	**2**	

Question			Answer/Indicative content	Marks	Guidance
9	a	i	chlorine (1) potassium (1)	2	**allow** Cl_2 / Cl / CL **not** chloride **allow** K **Examiner's Comments** Generally well known, but a few gave " chloride“ as their answer instead of chlorine.
		ii	solid sodium chloride has ions in fixed positions / ions do not move in a solid (1) liquid sodium chloride has ions that move (1)	2	**Ignore** electrons cannot move in a solid **allow** solid has no free ions **allow** liquid sodium chloride has free ions **NOT** electrons can move in a liquid if no other mark scored 1 mark for particles cannot move in a solid but can move in a liquid / liquid has mobile charge carriers but solid does not for one mark **Examiner's Comments** Very few correct answers here. Common errors were to discuss moving electrons or that there is space for the electricity to get through the liquid.

Question			Answer/Indicative content	Marks	Guidance
	b		experiments **1** and **3** show that as time doubles mass (of copper made) doubles (1) experiments **3** and **4** show that as the current quadruples, the mass also quadruples (1) **OR** experiments **1** and **2** show that as current doubles mass (of copper made) doubles (1)	2	**allow** reference to the correct data in the table to identify which experiments they are using **allow** when the time doubles and the current stays the same the mass doubles **allow** when the current doubles and the time stays the same the mass doubles **allow** if no other marks awarded then as time and current increase the mass (of copper) increases for one mark **Examiner's Comments** Few candidates scored 2 marks here; many candidates were able to score a mark for explaining that as the time and current were increased, the mass of copper deposited increased.
			Total	**6**	
10			hydrogen (1)	1	**allow** correct answer ticked, circled or underlined in list if answer line is blank **Examiner's Comments** ??Most candidates correctly identified gas X as hydrogen. Hydrogen chloride was the most common misconception.
			Total	**1**	

Question			Answer/Indicative content	Marks	Guidance
11			electrolysis (1)	1	**allow** other ways of indicating correct response eg ringing or ticking the correct answer but answer on answer line takes precedence **Examiner's Comments** Electrolysis was the most common correct answer.
			Total	**1**	