Q1.

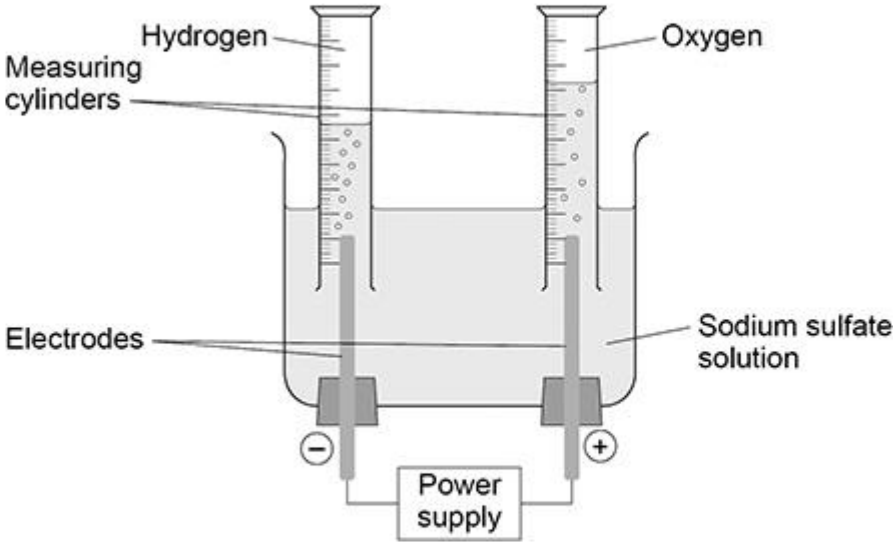
This question is about electrolysis.

Ionic compounds decompose when they are electrolysed.

A student electrolyses sodium sulfate solution.

Figure 1 shows the apparatus used.

Figure 1



(a) Sodium sulfate solution contains:

- hydrogen ions
- hydroxide ions
- sodium ions
- sulfate ions.

Oxygen is produced at the positive electrode.

Which ions are discharged at the positive electrode to produce oxygen?

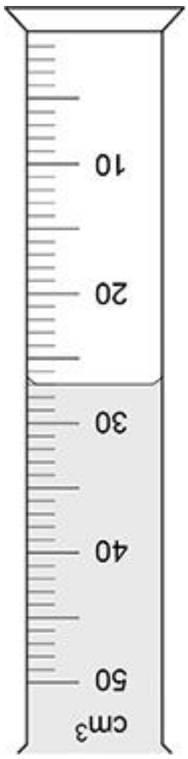
Tick (✓) **one** box.

Hydrogen ions	☐
Hydroxide ions	☐
Sodium ions	☐
Sulfate ions	☐

(1)

(b) **Figure 2** shows one of the measuring cylinders during the electrolysis.

Figure 2



What is the volume of gas in the measuring cylinder?

Volume of gas = _______ cm^3

(1)

(c) Ionic compounds can be electrolysed when molten or dissolved in water.

Why can ionic compounds **not** be electrolysed when solid?

You should answer in terms of ions.

___

___

(1)

(d) The table below shows the products of electrolysis of two molten compounds.

Molten compound	**Product at negative electrode**	**Product at positive electrode**
Potassium iodide	Potassium	___
Zinc bromide	___	Bromine

Complete the table above.

(2)

(e) The electrolysis of molten sodium chloride is used to extract sodium metal.

Why is sodium metal extracted by electrolysis instead of by reduction with carbon?

Tick (✓) **one** box.

Carbon conducts electricity.	☐
Carbon is less reactive than sodium.	☐
Carbon reduction uses more energy.	☐

(1)

(f) What is the state symbol for molten sodium chloride?

Tick (✓) **one** box.

(aq) ☐ (g) ☐ (l) ☐ (s) ☐

(1)

(g) Titanium can be produced from titanium oxide by electrolysis.

The equation for the reaction is:

$$TiO_2 \rightarrow Ti + O_2$$

Calculate the percentage atom economy for the production of titanium from titanium oxide by electrolysis.

Use the equation:

$$\text{Percentage atom economy} = \frac{\text{Relative atomic mass of desired product}}{\text{Relative formula mass of reactant}} \times 100$$

Relative atomic mass (A_r): Ti = 48

Relative formula mass (M_r): TiO_2 = 80

____

____

____

____

Percentage atom economy = ________________ %

(2)

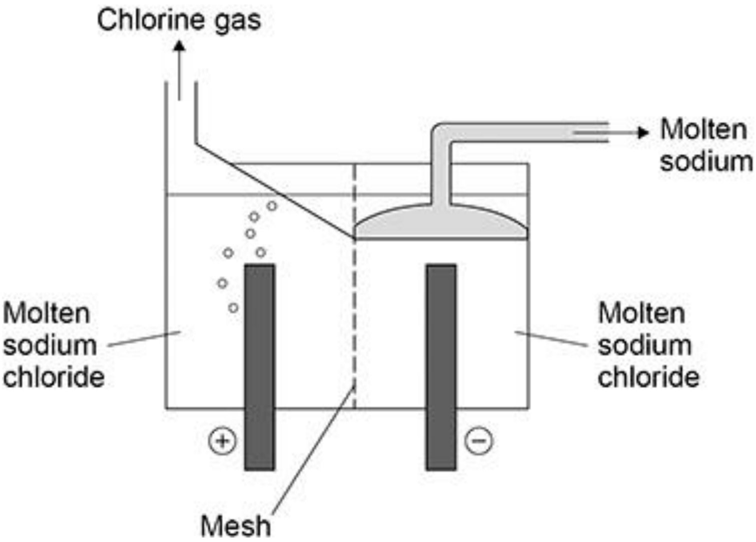
(Total 9 marks)

Q2.

This question is about electrolysis.

Molten sodium chloride is electrolysed in an industrial process to produce sodium.

The figure below shows a simplified version of the electrolysis cell used.



(a) Which is the correct half equation for the production of sodium?

Tick (✓) **one** box.

$Na + e^- \rightarrow Na^+$	☐
$Na \rightarrow Na^+ + e^-$	☐
$Na^+ + e^- \rightarrow Na$	☐
$Na^+ \rightarrow Na + e^-$	☐

(1)

A mesh is used to keep the products of the electrolysis apart.

(b) Suggest **one** reason why the products of the electrolysis must be kept apart.

____

____

(1)

(c) Which type of particle passes through the mesh in the electrolysis of molten sodium chloride?

Tick (✓) **one** box.

Atom ☐

Electron ☐

Ion ☐

Molecule ☐

(1)

Aqueous sodium chloride solution is electrolysed in a different industrial process.

Two gases and an alkaline solution are produced.

(d) Which **two** ions are present in aqueous sodium chloride solution in addition to sodium ions and chloride ions?

1 ______________________________

2 ______________________________

(2)

(e) Name the alkaline solution produced.

____

(1)

(f) Explain how the alkaline solution is produced.

You should refer to the processes at the electrodes.

____

____

____

____

____

____

(3)

(Total 9 marks)

Q3.

This question is about chemical reactions and electricity.

(a) Electrolysis and chemical cells both involve chemical reactions and electricity.

Explain the difference between the processes in electrolysis and in a chemical cell.

(2)

(b) A teacher demonstrates the electrolysis of molten lead bromide.

Bromine is produced at the positive electrode.

Complete the half equation for the production of bromine.

You should balance the half equation.

$$Br^{-} \rightarrow \qquad + $$

(2)

(c) Two aqueous salt solutions are electrolysed using inert electrodes.

Complete the table below to show the product at each electrode.

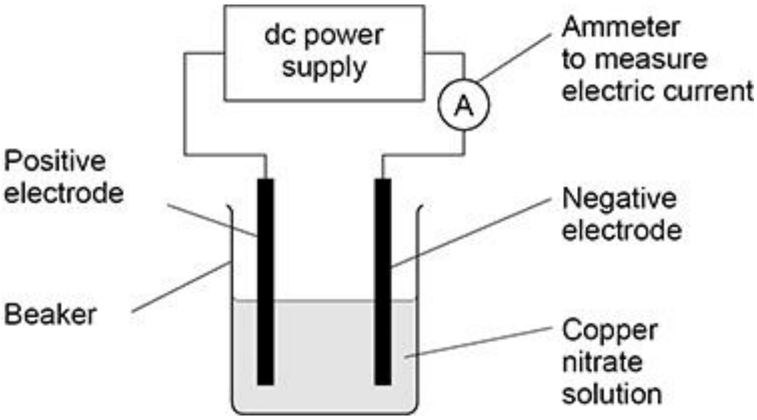
Salt solution	**Product at positive electrode**	**Product at negative electrode**
Copper nitrate		copper
Potassium iodide		

(3)

Some students investigated the electrolysis of copper nitrate solution using inert electrodes.

Figure 1 shows the apparatus.

Figure 1



The students investigated how the mass of copper produced at the negative electrode varied with:

- time

- current.

This is the method used.

1. Weigh the negative electrode.
2. Set up the apparatus shown in **Figure 1**.
3. Adjust the power supply until the ammeter shows a current of 0.3 A
4. Switch off the power supply after 5 minutes.
5. Rinse the negative electrode with water and allow to dry.
6. Reweigh the negative electrode.
7. Repeat steps 1 to 6 for different times.
8. Repeat steps 1 to 7 at different currents.

(d) Some of the copper produced did not stick to the negative electrode but fell to the bottom of the beaker.

Suggest how the students could find the total mass of copper produced.

____

____

____

____

____

____

____

____

____

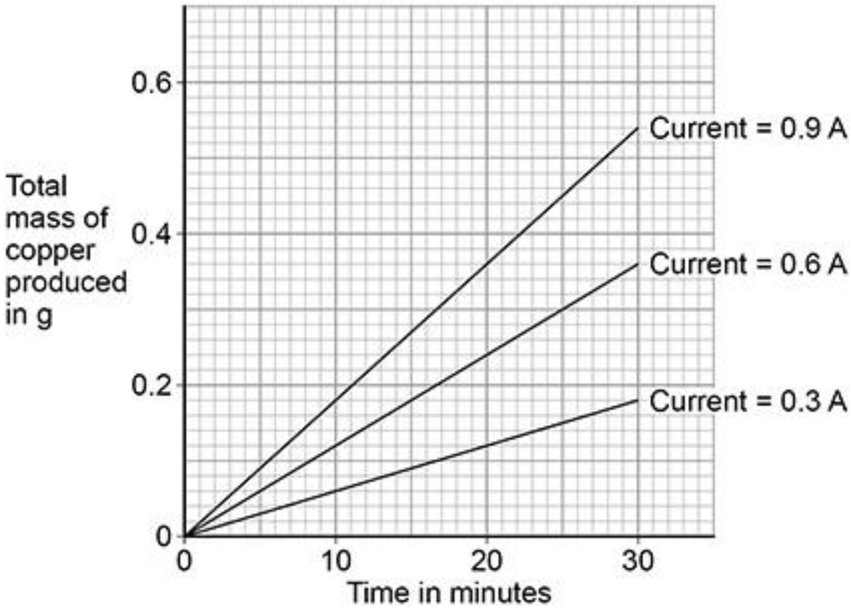
____

(4)

The students plotted their results on a graph.

Figure 2 shows the graph.

Figure 2



A student correctly concluded that the total mass of copper produced is directly proportional both to the time and to the current.

(e) How do the results in **Figure 2** support the conclusion that the total mass of copper produced is directly proportional to the time?

____

____

(1)

(f) How do the results in **Figure 2** support the conclusion that the total mass of copper produced is directly proportional to the current?

Use data from **Figure 2** in your answer.

____

____

(1)

(g) Copper nitrate solution is blue.

Suggest why the blue colour of the copper nitrate solution fades during the electrolysis.

____

____

(1)

(h) Determine the number of atoms of copper produced when copper nitrate solution is electrolysed for 20 minutes at a current of 0.6 A

Give your answer to 3 significant figures.

Use **Figure 2**.

Relative atomic mass (A_r): Cu = 63.5

The Avogadro constant = 6.02×10^{23} per mole

____

____

____

____

____

____

Number of atoms (3 significant figures) = ________________

(3)

(Total 17 marks)

Q4.

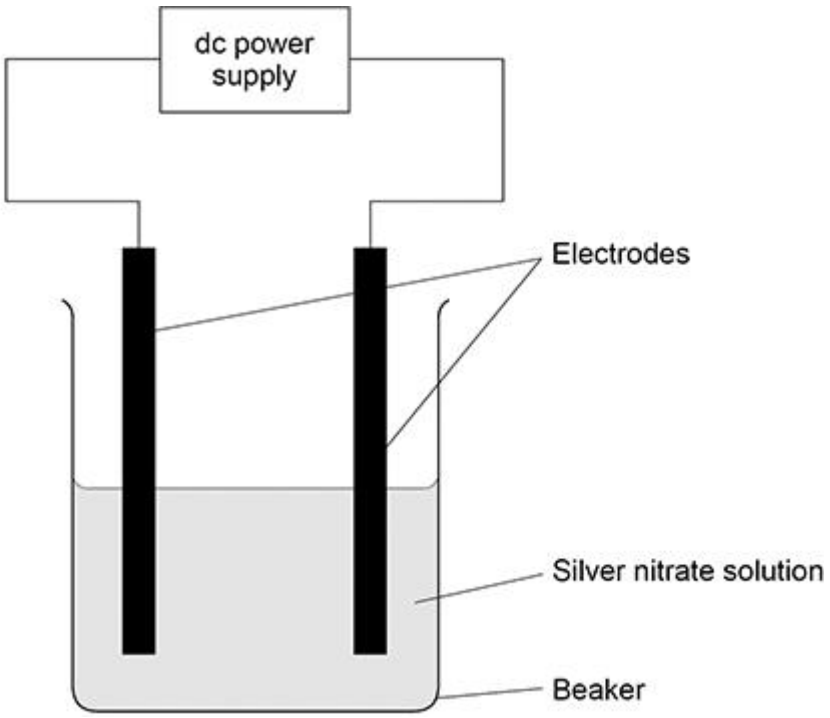
This question is about electrolysis.

Some students investigated the electrolysis of silver nitrate solution.

This electrolysis produces silver at the negative electrode.

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Weigh the negative electrode.
2. Set up the apparatus shown in **Figure 1**.

3. Switch on the power supply.
4. Switch off the power supply after five minutes.
5. Rinse the negative electrode with water and allow to dry.
6. Reweigh the negative electrode.
7. Repeat steps 1 to 6 for different times.

(a) Some silver did not stick to the negative electrode but fell to the bottom of the beaker.

The students needed to weigh this silver.

How could the students separate the silver from the silver nitrate solution?

Tick (✓) **one** box.

By chromatography ☐

By crystallisation ☐

By distillation ☐

By filtration ☐

(1)

Table 1 shows the students' results.

Table 1

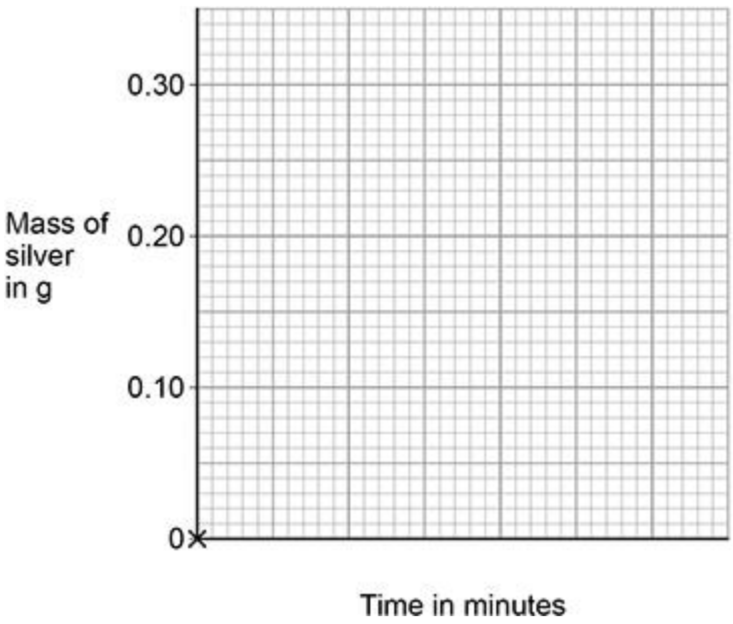
Time in minutes	**Mass of silver in g**
0	0.00
5	0.06
10	0.12
15	0.18
20	0.24
25	0.30

(b) Draw a graph on **Figure 2**.

You should:

- use a suitable scale for the x-axis
- plot the data from **Table 1**
- draw a line of best fit.

Figure 2



(4)

(c) Determine the mass of silver that would be produced after 12 minutes.

Use **Figure 2**.

Mass of silver = ________________ g

(1)

(d) A student investigated the electrolysis of two aqueous salt solutions.

Hydrogen is produced at the negative electrode when the metal in the salt solution is more reactive than hydrogen.

Complete **Table 2** to show what the student would **observe** at the negative electrode for each salt solution.

Table 2

Salt solution	**Observation at negative electrode**
Copper sulfate	
Sodium chloride	

(2)

(e) A teacher demonstrates the electrolysis of molten lead bromide.

The products at the electrodes are lead and bromine.

Why should the teacher do the demonstration in a fume cupboard?

____

____

(1)

(f) Two other molten compounds are electrolysed.

Complete **Table 3** to show the molten compounds and the products.

Table 3

Molten compound electrolysed	**Product at the negative electrode**	**Product at the positive electrode**
Zinc chloride		
	Potassium	Iodine

(3)
(Total 12 marks)

Q5.

This question is about electrolysis.

Aluminium is produced by electrolysing a molten mixture of aluminium oxide and cryolite.

(a) Explain why a mixture is used as the electrolyte instead of using only aluminium oxide.

___

___

___

___

(2)

(b) What happens at the negative electrode during the production of aluminium?

Tick (✓) **one** box.

Aluminium atoms gain electrons. ☐

Aluminium atoms lose electrons. ☐

Aluminium ions gain electrons. ☐

Aluminium ions lose electrons. ☐

(1)

(c) Oxygen is produced at the positive electrode.

Complete the balanced half-equation for the process at the positive electrode.

→ O_2 +

(2)

(d) Explain why the positive electrode must be continually replaced.

____

____

____

____

____

____

(3)

(e) The overall equation for the electrolysis of aluminium oxide is:

$$2\ Al_2O_3 \rightarrow 4\ Al + 3\ O_2$$

Calculate the mass of oxygen produced when 2000 kg of aluminium oxide is completely electrolysed.

Relative atomic masses (A_r): O = 16 Al = 27

____

____

____

____

____

____

____

____

Mass of oxygen = ____________________________ kg

(4)

Sodium metal and chlorine gas are produced by the electrolysis of molten sodium chloride.

(f) Explain why sodium chloride solution **cannot** be used as the electrolyte to produce sodium metal.

____

____

____

(2)

(g) Calculate the volume of 150 kg of chlorine gas at room temperature and pressure.

The volume of one mole of any gas at room temperature and pressure is 24.0 dm^3

Relative formula mass (M_r): Cl_2 = 71

Volume = ___________________________ dm^3

(2)

(Total 16 marks)

Q6.

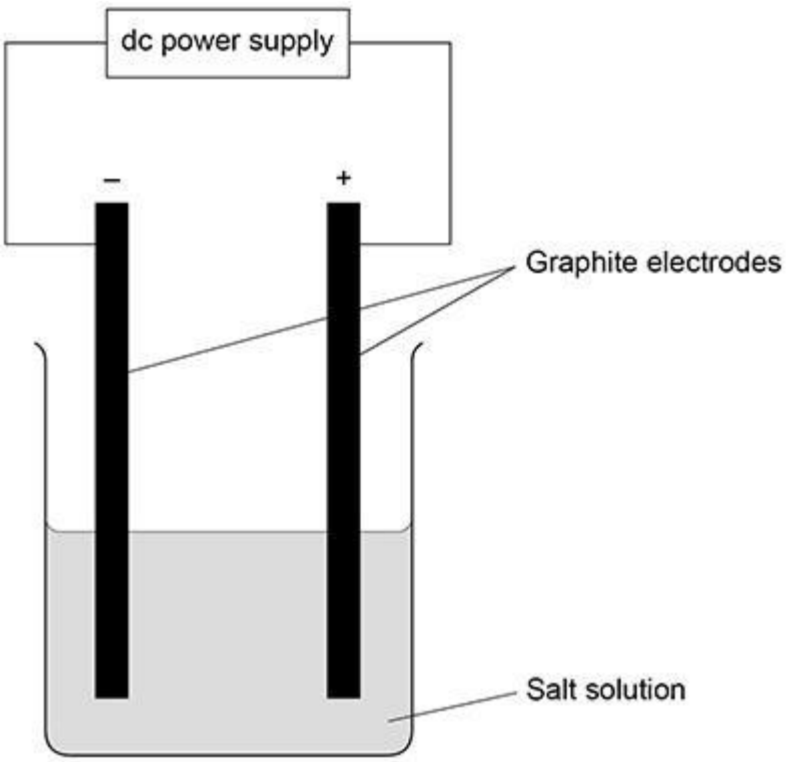
This question is about electrolysis.

A student investigated the hypothesis:

‘The electrolysis of a salt solution produces a metal at the negative electrode and a gas at the positive electrode.’

Figure 1 shows the apparatus used.

Figure 1



(a) What observation would be made at each electrode if the hypothesis is correct?

Observation if metal produced at the negative electrode

____

____

Observation if gas produced at the positive electrode

____

____

(2)

The table below shows the student's results.

Salt solution	**Product at the negative electrode**	**Product at the positive electrode**
Copper chloride	Copper	Chlorine
Potassium nitrate	Hydrogen	Oxygen
Silver nitrate	Silver	Oxygen

(b) Which salt solution in table above does **not** match the student's hypothesis?

Give **one** reason why.

Salt solution ____

Reason ____

____

(2)

(c) Give **two** reasons why graphite is used for the electrodes.

1 ____

____

2 ____

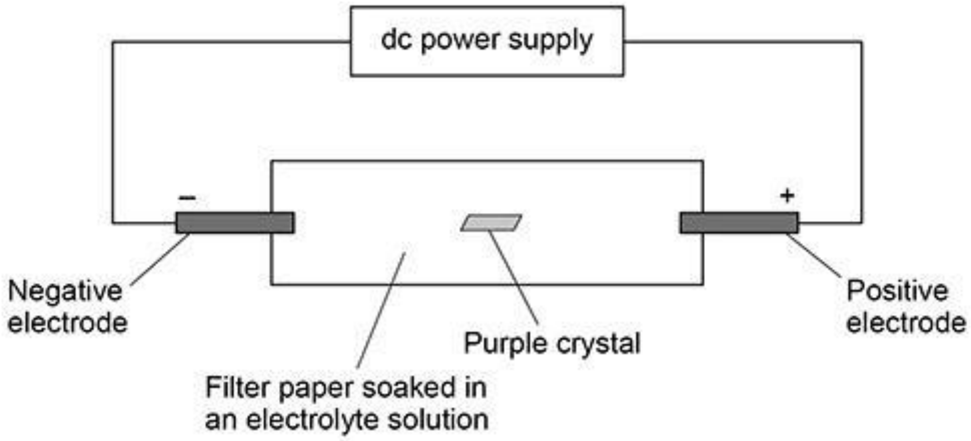
____

(2)

A different student investigated what happens during electrolysis.

Figure 2 shows the apparatus.

Figure 2



The purple crystal contained:

- colourless positive ions
- purple coloured negative ions.

The purple crystal dissolved in the electrolyte solution.

(d) What happens to the purple coloured ions?

Give **one** reason for your answer.

Tick (✓) **one** box.

The ions do not move.	☐
The ions move towards the negative electrode.	☐
The ions move towards the positive electrode.	☐

Reason ____

____

(2)
(Total 8 marks)

Mark schemes

Q1.

(a) hydroxide ions 1

(b) 27 (cm^3) 1

(c) ions cannot move (freely in a solid)

allow ions are fixed in place (in a solid) 1

(d)

Molten compound	Product at negative electrode	Product at positive electrode
Potassium iodide	Potassium	**Iodine**
Zinc bromide	**Zinc**	Bromine

2

(e) carbon is less reactive than sodium 1

(f) (l) 1

(g) (percentage atom economy =) $\frac{48}{80} \times 100$ 1

= 60 (%) 1

[9]

Q2.

(a) $Na^+ + e^- \rightarrow Na$ 1

(b) so the products do not react (to reform sodium chloride) 1

(c) ion 1

(d) hydrogen / H^+ (ions) 1

hydroxide / OH^- (ions) 1

(e) sodium hydroxide

allow NaOH 1

(f) sodium ions and hydroxide ions are left (in solution) **1**

(because) hydrogen ions are discharged / reduced (at the negative electrode to form hydrogen)

allow (because) hydrogen ions gain electrons (at the negative electrode to form hydrogen)

allow (because at the negative electrode) 2 H^+ + 2 e^- → H_2

1

(and because) chloride ions are discharged / oxidised (at the positive electrode to form chlorine)

allow (and because) chloride ions lose electrons (at the positive electrode to form chlorine)

allow (and because at the positive electrode) 2 Cl^- → Cl_2 + 2 e^-

1

[9]

Q3.

(a) electrolysis uses electricity to produce a chemical reaction

allow voltage for electricity

allow potential difference for electricity

allow (electrical) current for electricity

allow electrolysis uses electricity to decompose a compound / electrolyte

1

(but) cells use a chemical reaction to produce electricity

1

(b) $2Br^- \rightarrow Br_2 + 2e^-$

allow multiples

*allow **1** mark for Br_2 **and** e^-*

2

(c)

Salt solution	**Product at positive electrode**	**Product at negative electrode**
(copper nitrate)	oxygen (1)	(copper)
(potassium iodide)	iodi<u>n</u>e (1)	hydrogen (1)

1
2

(d) filter the mixture

1

wash and dry the copper / residue

1

weigh the copper collected

1

add to the increase in mass of the electrode

1

(e) (for given current) straight line through the origin

allow (for given current) when time doubles, mass doubles

1

(f) (for given time) when current doubles, mass doubles with supporting data

1

(g) copper ions are discharged (from the solution)

allow the solution becomes less concentrated

allow copper ions are removed (from the solution)

allow copper ions are used up (from the solution)

1

(h) (number of moles = $\frac{0.24}{63.5}$ =)
3.78×10^{-3} **or** 0.00378

1

(number of atoms =)
$0.00378 \times 6.02 \times 10^{23}$

allow correct use of an incorrectly calculated number of moles

1

$= 2.28 \times 10^{21}$

allow a correct evaluation to 3 significant figures of an incorrect expression which involves only a mass from the graph, the A_r of copper and the Avogadro constant

1

[17]

Q4.

(a) by filtration

1

(b) 10 minutes per 2 cm on x-axis

allow 5 minutes per 1 cm on x-axis

1

all points plotted correctly

allow a tolerance of ± ½ a small square

*allow **1** mark for 3 or 4 points plotted correctly*

2

line of best fit

allow line of best fit drawn using incorrect plots

1

(c) 0.14 (g)

*allow ecf from question **(b)***

allow a tolerance of ± ½ a small square

1

(d) (copper sulfate solution) pink / orange / red / brown solid

allow copper plating

allow metal for solid

1

(sodium chloride solution) bubbles / effervescence / fizzing

if no other mark awarded allow ***1*** *mark for copper* ***and*** *hydrogen*

1

(e) toxic / poisonous (fumes)

allow harmful / corrosive (fumes)

ignore dangerous / deadly / lethal

1

(f)

Molten compound electrolysed	Product at the negative electrode	Product at the positive electrode
(zinc chloride)	zinc (1)	chlori<u>n</u>e (1)
potassium iodi<u>d</u>e	(potassium)	(iodine)

allow **1** mark if zinc and chlorine the wrong way round

2
1

[12]

Q5.

(a) mixture has a lower melting point (than aluminium oxide)

allow cryolite lowers melting point (of aluminium oxide)

ignore boiling point

do ***not*** *accept cryolite is a catalyst*

1

(so) less energy needed

ignore cost

1

(b) aluminium ions gain electrons

1

(c) $2\ O^{2-} \rightarrow O_2 + 4\ e^-$

allow multiples

allow ***1*** *mark for an unbalanced equation containing correct species*

2

(d) the electrode reacts with oxygen

1

the electrode is carbon / graphite

1

(so) carbon dioxide is produced

allow (so) the electrode / carbon / graphite is used up

allow (so) the electrode / carbon / graphite is burned away

ignore (so) the electrode / carbon / graphite is worn away ignore (so) the electrode / carbon / graphite is corroded

1

(e)

*an answer of 941 (kg) scores **4** marks*

(M_r of Al_2O_3 =) 102

$\left(\frac{2\,000\,000}{102} =\right)$ 19608 (mol Al_2O_3)

allow correct calculation using incorrectly calculated value of M_r of Al_2O_3

1

$\left(19\,608 \times \frac{3}{2} =\right)$ 29412 (mol O_2)

allow correct calculation using incorrectly calculated value of moles of Al_2O_3

1

$\left(\frac{29\,412 \times 32}{1000} =\right)$ 941 (kg)

allow 941.1764706 (kg) correctly rounded to at least 2 significant figures

allow correct answer using incorrectly calculated value of moles of O_2

1

alternative approach:

(2 M_r of Al_2O_3 =) 204 (1)

204 (kg of Al_2O_3) gives 96 (kg of O_2) (1)

(2000 kg of Al_2O_3 gives)

$\frac{2000}{204} \times 96$ (kg of O_2)

or

$\frac{2000000}{204} \times 96$ (g of O_2) (1)

= 941 (kg) (1)

(f) hydrogen (gas) would be produced (instead of sodium)

1

(because) sodium is more reactive than hydrogen

1

(g)

*an answer of 50700 (dm^3) scores **2** marks*
*an answer of 50.7 (dm^3) scores **1** mark*

$\left(\frac{150\ 000}{71} =\right)$ 2113 (mol of Cl_2)

1

or

(volume of 1 g of Cl_2 = $\frac{24}{71}$ =) 0.34 (dm^3)

$(\frac{150\ 000}{71} \times 24) = 50700\ (dm^3)$

allow 50704.22535 (dm^3) correctly rounded to at least 2 significant figures

allow correct calculation using their calculated number of moles and/or calculated volume of 1 g

1

[16]

Q6.

(a) (negative electrode) solid produced

allow the electrode changes colour

ignore metal produced

1

(positive electrode) bubbles / fizzing / effervescence

ignore gas produced

1

(b) potassium nitrate

1

hydrogen is not a metal

allow hydrogen is a gas
allow hydrogen is not a solid
allow the products at both electrodes are gases
allow the product at the negative electrode is not potassium
allow potassium is more reactive than hydrogen

1

(c) (graphite) conducts (electricity)

allow (graphite) has delocalised / free electrons

1

(graphite) is inert

allow (graphite) is unreactive

1

(d) the ions move towards the positive electrode

1

the electrode attracts ions of the opposite charge

allow opposite charges attract

1

[8]