24. Electrochemistry

24.1 Electrolysis

Paper 4

Marking Scheme

Q1.

(d)(i)	$HCOOH \rightarrow CO_2 + 2H^+ + 2e^-$	1
(d)(ii)	**M1** Q = 3.75 × 40 × 60 **OR** 9000 C **AND** use of 96500 **OR** $1.6 \times 10^{-19} \times 6.02 \times 10^{23}$ **M2** moles of oxygen = 9000 ÷ 386000 = 0.0233 volume of O_2 = 0.0233 × 24000 = 559.6 / 559.8 / 560 cm^3 ecf min 2sf **ALLOW** [use of Q ÷ ($1.6 \times 10^{-19} \times 6.02 \times 10^{23)}$] = 560.6 cm^3	2

Q2.

(e)	0.64 × 17 × 60 = 653 / 652.8 Coulombs [1] 652.8 ÷ $1.6 \text{x} 10^{-19} = 4.08 \times 10^{21}$ (number of electrons) $4.08 \times 10^{21} \div 2 = 2.04 \times 10^{21}$ (number of atoms Fe) [1] $0.185 \div 55.8 = 3.31 \times 10^{-3}$ (number of moles Fe atoms $2.04 \times 10^{21} \div 3.31 \times 10^{-3} = L = 6.153 \times 10^{23}$ [1]	3

Q3.

<table>
<tr>
<td>(a)</td>
<td>
<table>
<tr><td>electrolyte</td><td>substance liberated at the anode</td><td>substance liberated at the cathode</td></tr>
<tr><td>$PbBr_2(l)$</td><td>Br_2 / bromine</td><td>Pb / lead</td></tr>
<tr><td>concentrated $NaCl(aq)$</td><td>Cl_2 / chlorine</td><td>H_2 / hydrogen</td></tr>
<tr><td>$Cu(NO_3)_2(aq)$</td><td>O_2 / oxygen (+ H_2O)</td><td>Cu / copper</td></tr>
</table>
two for one mark, four for two marks, six for three marks
</td>
<td>3</td>
</tr>
</table>

(b)(i)	*F* = *Le* **OR** F is directly proportional to L	1
(b)(ii)	number of Cu^{2+} formed = 0.35 / 63.5 = 5.51×10^{-3} Q = I × t = 0.60 × 30 × 60 = 1080 C number of electrons = 1080 / $1.6 \times 10^{-19} = 6.75 \times 10^{21}$ ecf number of Cu^{2+} ions = $6.75 \times 10^{21} / 2 = 3.375 \times 10^{21}$ ecf number of Cu^{2+} ions per mole (*L*) = $3.375 \times 10^{21} / 5.51 \times 10^{-3} = 6.12 \times 10^{23}$ ecf min 2sf all five points for four marks **ALLOW** valid alternate calculations of *L*	4

Q4.

(b)	moles of Sn = 2.95 / 118.7 = 0.0249 moles moles of Al (is 2 / 3 moles of Sn) = 0.0166 moles [1] mass of Al = 0.0166 × **27** = **0.447 / 0.448** g **to 3sf** [1] ecf	**2**

Q5.

(b)	either: 4.75 × 10^{22} × 2 × 1.60 × 10^{-19} = 15 200 C **OR** 2 × 96 500 × (4.75 × 10^{22}) / 6.02 × 10^{23} = 15 228 C [1] 15 200 / (15 × 60) = 16.9 A **OR** 15 228 / (15 × 60) = 16.9 A [1]	**2**

Q6.

(b)(i)	anode: chlorine / Cl_2 cathode: hydrogen / H_2	**1**
(b)(ii)	**M1:** Q = 0.75 × 60 × 60 = 2700 C **AND** 96 500 or 193 000 used **M2:** [a] moles of Ca = 2700 / 193 000 = 0.0140 [b] mass = 0.0140 × 40.1 = 0.56 g	**2**

Q7.

(a)	moles of H_2 = 462 / 24 000 = 0.01925[1] molecules of H_2 = 0.019 × 6.02 × 10^{23} = **1.16 x 10^{22}** (1.1×10^{22} / 1.2 × 10^{22}) [1] **min 2sf** ecf M1	**2**
(b)	number of electrons = 1.16 × 10^{22} × 2 = **2.32 x 10^{22}** [1] min 2sf ecf 1a	**1**
(c)	Q = 2.32 ×10^{22} × 1.6 × 10^{-19} = **3.71 x 10^3** [1] min 2sf ecf 1b	**1**
(d)	x = 3.71 × 10^3 / (14 × 60) = **4.4** (A) [1] min 2sf ecf 1c	**1**

Q8.

(a)	0.351 / 24 = 0.015 (mol) [1] 0.015 × 6.02 × 10^{23} = 9.0 × 10^{21} / 8.8 × 10^{21} [1]	**2**
(b)	1.76 × 10^{22} / 1.8 × 10^{22} [1]	**1**
(c)	2817 / 2816 / 2820 / 2800 C [1]	**1**
(d)	15 / 15.1 / 15.05 / 15.15 minutes [1]	**1**

Q9.

(a)	(anode =) oxygen / O_2 **AND** (cathode =) hydrogen/H_2 **BOTH** [1]	**1**
(b)	**M1:** Q = 1.5 × 60 × 60 × 4.5 = 24300 (C) [1] **M2:** no. of F / moles of e^- = 24300 / 96500 = 0.25(1813) [1] ecf **M3:** volume of Cl_2 = 24 × 0.252 / 2 = **3.02** dm^3 [1] ecf min 2sf **M4:** mass of Na = 0.252 × 23 = **5.79** (5.7917) g Na [1] ecf min 2sf	**4**

Q10.

(a)	chlorine **AND** hydrogen [1]	**1**
(b)	15 × 60 × 0.75 = 675 C [1] 675 / 96 500 = 7.0 × 10^{-3} moles e^- [1] 7.0 × 10^{-3} × 0.25 gives 1.75 × 10^{-3} moles O_2 1.75 × 10^{-3} × 24000 = 42 (41.969) cm^3 O_2 [1] **OR** 15 × 60 × 0.75 = 675 C [1] 675 / 1.60 × 10^{-19} = 4.22 × 10^{21} e^- = 7.01 × 10^{-3} moles e^- [1] gives 1.75 × 10^{-3} moles O_2 = 42 (42.047) cm^3 [1]	**3**

Q11.

(c)	**M1:** number of C (= 300 000 × 60 × 60 × 24) = 2.59 × 10^{10} (C) **M2:** number of F(= 2.592 × 10^{10} / 9.65 × 10^4) = 2.69 ×10^5 (moles of electrons) **M3:** moles of Al (= 2.69 × 10^5 / 3) = 8.95 × 10^4 **M4:** mass of Al (= 8.95 × 10^4 × 27) = **2420 kg** correct answer scores 4 marks	**4**

Q12.

(c)	**M1:** 16200 C **M2:** 1.0125×10^{23} electrons (use of 1.60×10^{-19}) **M3:** 0.0802 moles of copper (use of 5.09 and 63.5) **M4:** 0.1603 moles electrons **M5:** $L = 6.32 \times 10^{23}$ (correct answer [5] other approaches acceptable including: **M1:** 16200 C **M2:** 1.0125×10^{23} electrons (use of 1.60×10^{-19}) **M3:** 5.0625×10^{22} copper atoms **M4:** 0.0802 moles of copper (use of 5.09 and 63.5) **M5:** $L = 6.32 \times 10^{23}$ (correct answer [5])	**5**
(d)	**M1:** $Mg^{2+} + 2e^- \rightleftharpoons Mg$ $E^\ominus = -2.38$ **and** $2H^+ + 2e^- \rightleftharpoons H_2$ $E^\ominus = 0.00$ **M2:** hydrogen produced instead / hydrogen easier to reduce / hydrogen preferentially reduced / hydrogen has more positive $E^\ominus$	**2**

Q13.

<table>
<tr><td>(a)</td><td><table><tr><td></td><td>anode</td><td>cathode</td></tr><tr><td>$AgNO_3$ (aq)</td><td>oxygen / O_2</td><td>silver / Ag</td></tr><tr><td>saturated $NaCl$ (aq)</td><td>chlorine / Cl_2</td><td>hydrogen / H_2</td></tr><tr><td>$CuSO_4$ (aq)</td><td>oxygen / O_2</td><td>copper / Cu</td></tr></table></td><td>3</td></tr>
<tr><td rowspan="2">(b)(i)</td><td>$2I^- \rightarrow I_2 + 2e^-$</td><td>1</td></tr>
<tr><td>$Ca^{2+} + 2e^- \rightarrow Ca$</td><td>1</td></tr>
<tr><td>(b)(ii)</td><td>∝ Ca / Calcium reduced and I / iodine oxidised
∞ Oxidation number of calcium decreases from 2 to 0
∞ Oxidation number of iodine increases from –1 to 0

2 points = 1 mark
3 points = 2 marks</td><td>2</td></tr>
<tr><td>(b)(iii)</td><td>∞ metal / grey / silvery
∞ purple AND vapour / gas / fumes
∞ amount of melt decreases

any 2 points for 1 mark</td><td>1</td></tr>
<tr><td rowspan="3">(c)</td><td>2 × 60 × 60 × 0.8 = 5760 C
AND
5760 / 96500 = 0.060 (0.0597) F</td><td>1</td></tr>
<tr><td>1.11 / 55.8 = 0.020 (0.0199) mol of Fe</td><td>1</td></tr>
<tr><td>0.06 / 0.02 = 3 ∴ Fe^{3+} or +3 or 3</td><td>1</td></tr>
</table>