Electrolysis, Electrode Potentials & Cells

Mark Scheme 3

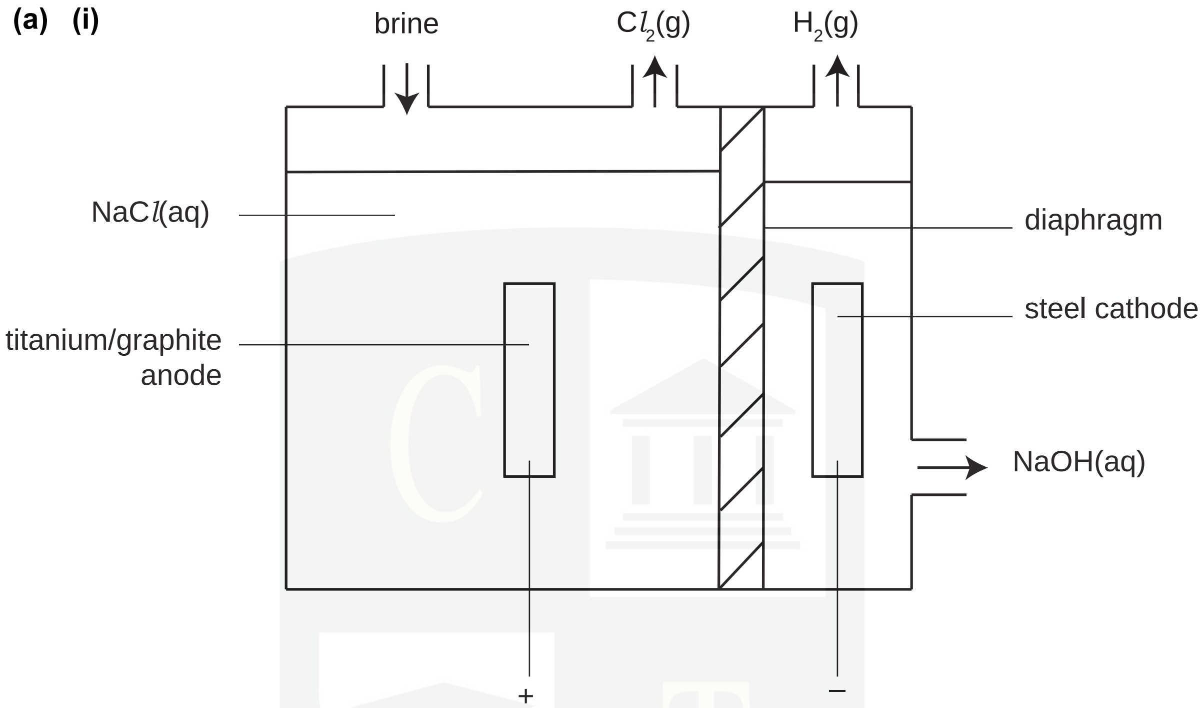
Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Electrochemistry
Sub-Topic	Electrolysis, Electrode Potentials & Cells
Paper Type	Theory
Booklet	Mark Scheme 3

Time Allowed:	**68 minutes**
Score:	**/56**
Percentage:	**/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 **(a) (i)**



titanium/graphite anode identified correctly (1)
steel cathode identified correctly (1)
diaphragm identified correctly (1)
all three outlets correctly shown (1) [4]

(ii) **anode** $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ (1)

cathode $2H^+(aq) + 2e^- \rightarrow H_2(g)$

or $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ (1) [2]

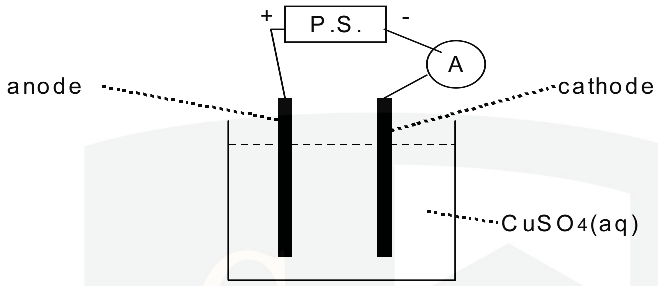
(iii) sodium hydroxide (1) [1]

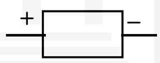
[Total: 7]

2 **(a)** L = F/e *or* F = Le [1]

[1]

(b) (i)



[allow the conventional symbol  to represent  (the "P.S." is not required)]

correct cell (2 electrodes + PS circuit) [1]
ammeter in series [1]
anode and cathode of the right polarity [IN WORDS] [1]
$CuSO_4$(aq) *or* $CuCl_2$(aq) *or* Cu^{2+}(aq) *or* soln *or* 1 mol dm^{-3} [1]

(ii) n(Cu) = (52.542–52.243)/63.5 = 4.71×10^{-3} mol (4.67×10^{-3}) [1]
n(e^-) required = $4.71 \times 10^{-3} \times 2$ = **9.42×10^{-3}** mol (9.34×10^{-3}) ecf [1]

amount of electricity passed = 0.5 × 30 × 60 = 900 C [1]
no. of electrons passed = 900/1.6×10^{-19} = **5.625×10^{21}** ecf [1]

no of electrons/n(e^-) = L = $5.625 \times 10^{21}/9.42 \times 10^{-3}$ = **5.97×10^{23}** mol^{-1} (6.02×10^{23})
ecf [1]

(values in italics are if candidate has used A_r = 64, not 63.5. No last mark if not 3 s.f.: correct ans = [5]) **[9]**

(c)

compound	**product at anode**	**product at cathode**
AgF	$_2$	Ag
$FeSO_4$	O_2	H_2
$MgBr_2$	Br_2	H_2

6 correct ⇒ [5]
5 correct⇒ [4] etc.

Names can be used instead of symbols. If the atomic symbol (e.g. Br or H or O) is used instead of the molecular formula (e.g. Br_2 etc.) then deduct [1] mark only for the whole table.
[5]

[Total: 15]

3 **(a** **(i)** $E^o = 0.40 - (-0.83) = 1.23V$ (1)

(ii) $2H_2 + O_2 \longrightarrow 2H_2O$ (1

(iii) LH electrode will become more negative (1)
RH electrode will also become more negative / less positive (1)

(iv) no change ecf from **(iii)** (1)

(v) increased conductance *or* lower cell resistance *or* increased rate of reaction (1) [6]

(b) **(i)** $E^o = 1.47 - (-0.13) = 1.60V$ (1)
(ii) $PbO_2 + Pb + 4H^+ \longrightarrow 2Pb^{2+} + 2H_2O$ (1

(iii) $PbO_2 + Pb + 4H^+ + 2SO_4^{2-} \longrightarrow 2PbSO_4(s) + 2H_2O$ (1

(iv) E^o_{cell} will increase (1)

as $[Pb^{2+}]$ decreases, $E_{electrode}(PbO_2)$ will become more positive, but $E_{electrode}(Pb)$ will become more negative (1) [5]

[Total: 11]

4 **(a)** Reaction II – since electrons are used up / required / gained / received (from external circuit) (1) [1]

(b) ($Pb^{2+} + 2e^- \rightarrow Pb$) $E^\ominus = -0.13V$
($PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$) $E^\ominus = +1.47V$
two correct $E^\ominus$ values (1)

Cell voltage is **1.6(0)** (V) (1) [2]

(c) **(i)** 3(+) (1)

(ii) They are less heavy / poisonous / toxic / polluting *or* are safer due to no (conc) H_2SO_4 within them (1) [2]

(d) **(i)** Platinum or graphite / carbon (1)

(ii) They need large quantities of **compressed** gases which take up space *or* the hydrogen would need to be **liquefied** *or* the reactant is (highly) **flammable / explosive / combustible** (1) [2]

(e) *Glass*: saves **energy** – the raw materials are easily accessible / cheap
or making glass is energy-intensive (1)

Steel: saves **energy** – extracting iron from the ore
or mining the ore is energy intensive
or saves a **resource** – iron **ore** (NOT just "iron") is becoming scarce
either one (1)

Plastics: saves a valuable / scarce **resource**: (crude) **oil / petroleum** (1) [3]

[Total: 10]

5 **(a** **(i)** $Cu(s) - 2e^- \rightarrow Cu^{2+}(aq)$ allow electrons on RHS (1)

(ii) $E^\ominus$ for Ag^+/Ag is +0.80V which is more positive than +0.34V for Cu^{2+}/Cu, (1)
so it's less easily oxidised (owtte) (1)

(iii) $E^\ominus$ for Ni^{2+} is –0.25V, (1)
Ni is readily oxidised and goes into solution as $Ni^{2+}(aq)$ (1) [Mark **(ii)** and **(iii)** to max 3]

(iv) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ (1)

(v) $E^\ominus$ for Zn^{2+}/Zn is negative / = –0.76V, so Zn^{2+} is not easily reduced. (1)

(vi) The blue colour fades because $Cu^{2+}(aq)$ is being replaced by $Zn^{2+}(aq)$ *or* $Ni^{2+}(aq)$ *or* $[Cu^{2+}]$ decreases (1) **[7]**

(b) amount of copper = 225/63.5 = **3.54**(3) mol (1)
amount of electrons needed = 2 × 3.54 = **7.08/9** (7.087) mol (1)

no. of coulombs = 20 × 10 × 60 × 60 = 7.2×10^5 C
no. of moles of electrons = $7.2 \times 10^5 / 9.65 \times 10^4$ = **7.46** mol (1)

percentage "wasted" = 100 × (7.461 – 7.087)/7.461 = 5.01 (**5.0**)% (accept 4.98–5.10) (1)
[4]

(c) $E^\ominus$ data: Ni^{2+}/Ni = –0.25V
Fe^{2+}/Fe = –0.44V (1)

Because the Fe potential is more negative than the Ni potential, the iron will dissolve (1) **[2]**

[Total: 13]