Electrolysis, Electrode Potentials & Cells

Mark Scheme 4

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Electrochemistry
Sub-Topic	Electrolysis, Electrode Potentials & Cells
Paper Type	Theory
Booklet	Mark Scheme 4

Time Allowed: **72 minutes**

Score: **/60**

Percentage: **/100**

Grade Boundaries:

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

1 **(a** **(i)** $2H_2O - 4e \rightarrow 4H^+ + O_2$ (1)

(ii) $2Cl^- - 2e \rightarrow Cl_2$ (1) **[2]**

(b) **(i)** E^o = (1.23 – (–0.83)) = <u>2.06V</u> (1)

(ii) E^o = (1.36 – (–0.83)) = <u>2.19V</u> (1)
(in **(i)** if **(a)(i)** as $4(OH^-) - 4e \rightarrow 2H_2O + O_2$ ecf is <u>0.4 – (–0.83) = 1.23</u> (1) – needs working shown) **[2]**

(c) **(** <u>no change</u> (because $[H_2O]$ does not change) (1)
smaller/less positive (1)

(ii) The (overall) <u>E^o for Cl_2 production will decrease</u>, (whereas that) for <u>O_2 production will stay the same</u>. (answer could be in terms of 1st E^o decreasing and becoming lower than 2nd)(or E^o for Cl_2 becomes less than for O_2) (1) **[3]**

(d) **(i)** $Cl^- + 3H_2O \rightarrow ClO_3^- + 3H_2$ (1)

(ii) n(C) = 250 × 60 × 60 = (**9 × 10^5** C) (1)
$n(e^-) = 9 \times 10^5/96500 = 9.33$ mol
$n(NaClO_3)$ = 9.33/6 = (**1.55** mol) – allow ecf (1)
$Mr(NaClO_3)$ = 106.5
mass $(NaClO_3)$ = 1.55 × 106.5 = **165.5** g (1) (165 – 166 gets 3 marks, 993 gets 2 marks as ecf) **[4]**

[Total: 11]

2 **(a** Graphite / graphene (1)

(b) They do not exist as sheets / layers of carbon atoms (1)

(c) The lengths of nanotubes are much shorter than the curvature of the paper / they are so small that they are not effected by rolling (1)

(d) Any molten ionic salt (or plausible organic ionic compounds) (1)

[Total: 4]

3 **(a (i)** **A** is Cl_2/chlorine

B is NaC*l* *or* HC*l* *or* Cl^- [or words], etc. [1]

C is salt bridge or KC*l*/KNO_3, etc. [1]

D is platinum/Pt [1]

E is Fe^{2+} + Fe^{3+} or mixture of Fe(II) + Fe(III) salts [1]

mention of standard conditions ([Cl^-] of 1 mol dm^{-3} *or* Cl_2 at 1 atmos *or* T = 25°C/298 K) [1]

(ii) $E^\ominus = E^\ominus_R - E^\ominus_L$= 0.77 – 1.36 = (–)**0.59** (V) (ignore sign) [1]

(since R.H. electrode is negative) electrons flow (from right) **to left** *or* to the chlorine electrode *or* anticlockwise *or* from (beaker) **E** to (beaker) **B** [1] **[8]**

(b) ΔH = 3 ×(–167.2) + (–48.5) – (–399.5) [1]
= **–150.6** *or* **151** (kJ mol^{-1}) [1
(correct ans [2])

(ii) $2Fe^{3+} + Cu \longrightarrow 2Fe^{2+} + Cu^{2+}$ [1]
(*or* molecular: $2FeCl_3 + Cu \longrightarrow 2FeCl_2 + CuCl_2$)

$E^\ominus$ = 0.77 – 0.34 = (+) **0.43** (V) [1]
(no mark for –0.43V) **[4]**

[Total: 12 max 11]

4 **(a** anode $Cl^-(aq) \rightarrow \frac{1}{2} Cl_2(g) + e^-$ (1)

cathode $H^+(aq) + e^- \rightarrow \frac{1}{2}H_2(g)$

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

correct state symbols (1) [2]

(b) because the iron in steel will react with chlorine (1) [1]

(c) **(i)** sodium hydroxide/NaOH (1)

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

or $2H^+ + 2e^- \rightarrow H_2$ (1)

leaving OH^- in solution as NaOH (1) [3]

(d) **Na** burns with a yellow flame/forms a white solid (1)

$2Na + Cl_2 \rightarrow 2NaCl$ (1)

P burns with a white flame/forms a colourless liquid (PCl_3) **or** a white solid (PCl_5) (1)

$P + 1\frac{1}{2}Cl_2 \rightarrow PCl_3$ **or** $P_4 + 6Cl_2 \rightarrow 4PCl_3$

or $P + 2\frac{1}{2}Cl_2 \rightarrow PCl_5$ **or** $P_4 + 10Cl_2 \rightarrow 4PCl_5$ (1) [4]

(e) $MgCl_2$ 6 to 7 (1)

$SiCl_4$ 0 to 3 (1)

$MgCl_2$ dissolves without reaction (1)

$SiCl_4$ reacts with water/hydrolyses (1)

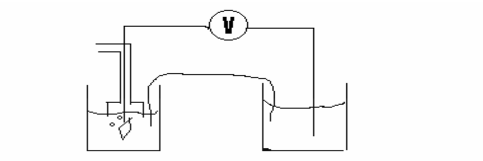
$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ **or**

$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$ **or**

$SiCl_4 + 4H_2O \rightarrow SiO_2.2H_2O + 4HCl$ (1) [5]

[Total: 15 max]

5 **(a)**



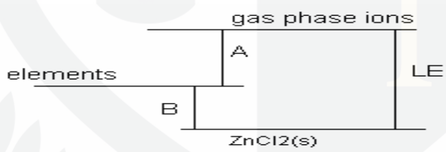
salt bridge + voltmeter [1]
zinc metal + Zn^{2+} [1]
H_2 (in, *not* out) + H^+ [1]
Pt electrode [1]
all solutions at 1 mol dm^{-3} [1]
T = 298K *or* 25°C [1] **[6]**

(b)

conditions	**product at anode**	**product at cathode**
$ZnCl_2$(l)	*(chlorine)*	***zinc* [1]**
$ZnCl_2$(conc aq)	***chlorine* [1]**	*(H_2 or zinc) (ignore)*
$ZnCl_2$(dil aq)	***oxygen* [1]**	***hydrogen* [1]**

[1] for each product in correct place [**[4]**

(c)



LE = B – A
= –415 – (131 + 908 + 1730) – {244 + 2(–349)}
[1] [1]
= –415 – 2315
= –2730 (kJ mol^{-1}) [1]
(correct answer = [3]: deduct [1] for each error) **[3]**

(d) (i)

- instrumental method (e.g. spectrophotometer/colorimeter/conductance meter)
- what is measured (e.g. absorbance/transmission at a **stated** wavelength *or* by use of a "suitable" (green) filter *or* conductance/resistance)
- measurement of time
- relation of time to rate (e.g. gradient of absorbance/time graph, *or* rate $\propto$ 1/t)
- repeat with different [Zn^{2+}], (but the same [PAR])
- relation of rate to [Zn^{2+}] (either by a plot or by simple proportion)

(all 6 points are unconditional on each other) any 5 points **[5]**

(ii) e.g. add Br_2(aq)
decolourises *or* produces a white ppt. [1]
or add $FeCl_3$(aq or "neutral"); purple colour produced *[1] + [* **[2]**

[Total: 20]