

# Electrolysis, Electrode Potentials & Cells

## Mark Scheme 7

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Electrochemistry
Sub-Topic	Electrolysis, Electrode Potentials & Cells
Paper Type	Theory
Booklet	Mark Scheme 7

Time Allowed: 66 minutes

Score: /55

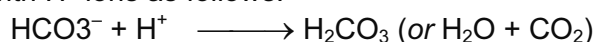
Percentage: /100

Grade Boundaries:

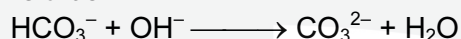
A*	A	B	C	D	E	U
>85%	77.5%	70%	62.5%	57.5%	45%	<45%

- 1 (a) (i) a solution that resists / minimises a change in its pH or **helps** maintain its pH..... [2]  
 (NOT any of: "maintains pH"; "keeps pH constant"; "no change in pH")  
 .....when small amounts of acid /  $H^+$  or base /  $OH^-$  are added (**both** acid and base are needed)

- (ii)  $HCO_3^-$  reacts with  $H^+$  ions as follows: [2]



and with  $OH^-$  ions thus:



(the equation arrows can be equilibrium arrows, as long as  $HCO_3^-$  is on the left)

- (iii) ( $pK_a = -\log(K_a) = 7.21$ ) [2]

$$pH = pK_a + \log([base] / [acid]) = 7.21 + \log(0.5 / 0.3) \\ = \mathbf{7.43 \text{ (7.4)}}$$

- (b) (i)  $K_{sp} = [Ag^+]^3[PO_4^{3-}]$  and units:  $mol^4 dm^{-12}$  [1]

- (ii) call  $[PO_4^{3-}] = x$ , then  $[Ag^+] = 3x$ , and  $K_{sp} = 27x^4$  [3]

$$x = (K_{sp} / 27)^{1/4} = (1.25 \times 10^{-20} / 27)^{1/4} = 4.64 \times 10^{-6} \text{ mol dm}^{-3}$$

$$[Ag^+] = 3x = \mathbf{1.39 \times 10^{-5} \text{ (mol dm}^{-3})} \quad (\text{allow } \mathbf{1.4 \times 10^{-5}})$$

- (c)  $H_3PO_3 + 2Fe^{3+} + H_2O \longrightarrow H_3PO_4 + 2Fe^{2+} + 2H^+$  [2]

$$E_{\text{cell}} = 0.77 - (-0.28) = (+)\mathbf{1.05 \text{ V}}$$



$$E_{\text{cell}} = -0.04 - (-0.28) = (+)\mathbf{0.24 \text{ V}}$$

[Total: 12]

2	(a) (i)	<p><b>K</b> = <math>\text{Cl}^-</math> /chloride/ <math>\text{F}^-</math> /fluoride</p> <p><math>\text{H}_2\text{SO}_4 + 2\text{NaCl} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{HCl}</math> (or equation with F or <b>K</b> for Cl) <b>OR</b>  <math>\text{H}_2\text{SO}_4 + \text{NaCl} \rightarrow \text{NaHSO}_4 + \text{HCl}</math> (or equation with F or <b>K</b> for Cl)</p> <p>ecf from identity of <b>K</b> so long as halide  <b>HK</b> is acidic/<b>HK</b> is a gas/an acidic gas is produced</p>	1 1 1	3
	(ii)	<p><b>L</b> = <math>\text{I}^-</math> /iodide</p> <p>colour = yellow  ecf from identity of <b>L</b> i.e. <math>\text{Cl}^-</math> (white) or <math>\text{Br}^-</math> (cream)  <math>\text{Ag}^+ + \text{I}^- \rightarrow \text{AgI}</math> (or equation with <b>L</b>)  <math>\text{AgNO}_3 + \text{NaI} \rightarrow \text{AgI} + \text{NaNO}_3</math> (or equation with <b>L</b>)  ecf from identity of <b>L</b> so long as halide</p>	1 1 1	3
	(iii)	<p><u><math>\text{Br}_2</math>/bromine</u> has <b>fewer electrons</b> than iodine/<b>more electrons</b> than chlorine  <b>intermolecular/van der Waals' forces</b> (in <math>\text{Br}_2/\text{M}_2</math>) <b>weaker</b> than in iodine/<b>stronger</b> than in chlorine</p>	1 1	2
	(b) (i)	<p><b>B</b> = chlorine/<math>\text{Cl}_2</math>  <b>C</b> = hydrogen/<math>\text{H}_2</math>  <b>D</b> = sodium hydroxide/<math>\text{NaOH}</math></p>	1 1 1	3

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— TUITION —

(ii)	anode: $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$ cathode: $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ <b>OR</b> $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{OH}^- + \text{H}_2$	1	
		1	2
			<b>13</b>

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— TUITION —

3 (a)  $(1s^2 2s^2 2p^6) 3s^2 3p^6 3d^9$  [1]

[Total: 1]

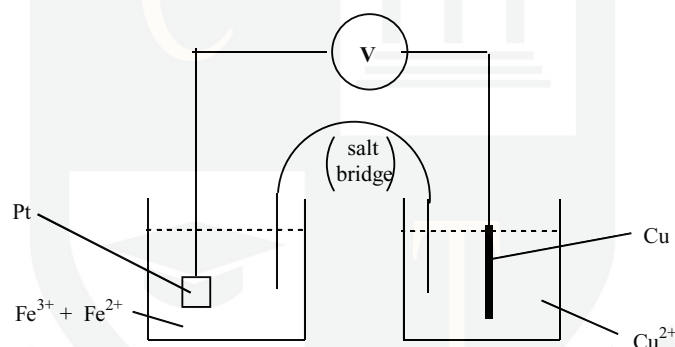
(b) electron / orbitals near ligands are at a higher energy [1]  
due to repulsion from ligand lone pairs [1]

(ii) when an electron moves to higher orbital / energy level **or** is promoted [1]  
it absorbs a photon **or** light (mention of light being *emitted* negates this mark) [1]

(iii) (different ligands produce) different (sizes of) energy gap **or**  $\Delta E$  [1]

[Total: 5]

(c)



solutions at  $1 \text{ mol dm}^{-3}$  (1 M) and 298(K)/25°C [1]

salt bridge and voltmeter [1]

platinum/carbon/graphite electrode [1]

(this mark is negated by inclusion of  $\text{H}_2$  around the electrode)

copper electrode [1]

$\text{Fe}^{3+}/\text{Fe}^{2+}$  mixture **and**  $\text{Cu}^{2+}$  **or**  $\text{CuSO}_4$  etc [1]

[Total: 5]

(d) Parts (i) – (iii) have to correspond to each other.

either

or

	ligand exchange/substitution/displacement/replacement	precipitation/acid-base/deprotonation
(i)		
(ii)	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+} + 4\text{H}_2\text{O}$ or $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+} + 6\text{H}_2\text{O}$ or $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + n\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_{6-n}(\text{NH}_3)_n]^{2+} + n\text{H}_2\text{O}$	$\text{Cu}^{2+} + 2\text{NH}_3 + 2\text{H}_2\text{O} \rightarrow \text{Cu}(\text{OH})_2 + 2\text{NH}_4^+$ or $\text{Cu}^{2+} + 2\text{NH}_4\text{OH} \rightarrow \text{Cu}(\text{OH})_2 + 2\text{NH}_4^+$ or $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{NH}_4^+$
(iii)	turns purple <b>or</b> deep/dark/royal blue	forms a pale blue ppt

[1] + [1] +

- (iv)  $E^\circ$  will decrease/ be less positive/more negative...  
...because  $[\text{Cu}^{2+}]$  decreases **or**  $\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu}$  shifts to the LHS **or**  
 $E^\circ [\text{Cu}(\text{NH}_3)_4]^{2+} = -0.05\text{V}$  **or**  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  is more stable.

[1]

[Total: 4]

- (e) (i) aldehyde

[1]

- (ii) red ppt./solid

[1]

- (iii)  $2\text{Cu}^{2+} + \text{CH}_3\text{CHO} + 5\text{OH}^- \rightarrow \text{Cu}_2\text{O} + \text{CH}_3\text{CO}_2^- + 3\text{H}_2\text{O}$

[1]

[Total: 3]

- (f)  $\text{pH} = \text{p}K_a + \log [\text{salt}]/[\text{acid}] = -\log(9.3 \times 10^{-4}) + \log (0.8/0.5)$   
 $= 3.032 + 0.204 = \mathbf{3.23/3.24}$  (3 or more sig. figs.)

[2]

[Total: 2]

[TOTAL: 20]

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— TUITION —

- 4 (a) The EMF of a cell made up of the test electrode and a standard hydrogen electrode. [1]  
(or the EMF of the electrode compared to the S.H.E.)

EMF measured under standard conditions of T, (P) and concentration. [1]  
(or at 298K and 1 mol dm<sup>-3</sup>)

2

- (b) The stronger the halogen is as an oxidising agent, the more positive is its E° value. [1]

Two examples of F<sub>2</sub>/F<sup>-</sup>, Cl<sub>2</sub>/Cl<sup>-</sup>; Br<sub>2</sub>/Br<sup>-</sup>, I<sub>2</sub>/I<sup>-</sup> quoted [1]

(data: F<sub>2</sub>/F<sup>-</sup> = +2.87V  
Cl<sub>2</sub>/Cl<sup>-</sup> = +1.36V  
Br<sub>2</sub>/Br<sup>-</sup> = +1.07V  
I<sub>2</sub>/I<sup>-</sup> = +0.54V)

2

- (c) or  $\text{H}_2\text{O}_2 + 2\text{I}^- + 2\text{H}^+ \longrightarrow \text{I}_2 + 2\text{H}_2\text{O}$  [1]  
 $\text{H}_2\text{O}_2 + 2\text{KI} + 2\text{H}^+ \longrightarrow 2\text{K}^+ + \text{I}_2 + 2\text{H}_2\text{O}$

$$E^\circ = 1.77 - 0.54 = \mathbf{1.23 \text{ V}} \quad [1]$$

- (ii) or  $\text{Cl}_2 + \text{SO}_2 + 2\text{H}_2\text{O} \longrightarrow 2\text{Cl}^- + \text{SO}_4^{2-} + 4\text{H}^+$  [1]  
 $\text{Cl}_2 + \text{SO}_2 + 2\text{H}_2\text{O} \longrightarrow 2\text{HCl} + \text{H}_2\text{SO}_4$

$$E^\circ = 1.36 - 0.17 = \mathbf{1.19 \text{ V}} \quad [1]$$

4

- (d) since E°(I<sub>2</sub>/I<sup>-</sup>) is +0.54V, tin will be oxidised to Sn<sup>4+</sup> [1]  
(E° for Sn<sup>2+</sup>/Sn = -0.14V and E° for Sn<sup>4+</sup>/Sn<sup>2+</sup> = +0.15V)

Thus:  $\text{Sn} + 2\text{I}_2 \longrightarrow \text{SnI}_4$  [1]

2

total: 10

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— TUITION —