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A' Level Chemistry
Year 2

Unit 16: Electrochemistry

Summer Examination Revision Pack

The questions in this pack should be attempted **AFTER** completing all other revision.

Grade Accelerator
Recall Definitions
Drawing Diagrams
Using Equations
Drawing Graphs

Quizlet

Quizlet Classes
Flashcard Based
Games
Tests & Quizzes
Keyword Spell Checker

Condensed Notes
Keywords & Definitions
Key Concepts
Application
Key Skills

Online Forms
Take Time to Answer
Use Paper & Calculator
Work It Out
Review Missed Marks

Use the 3 Wave Process when completing these revision packs.

1. Complete the questions without assistance
(Can't answer a question? Leave it and move on)
2. Use your notes to fill any gaps after step 1
3. Use the mark scheme to fill in any remaining gaps.

1. Having gaps after step 1 is normal, that's why we are doing revision!
2. If your notes don't help during step 2, they are not good enough!
(Change your note taking method and try to understand the problem)
3. If you don't understand why the mark scheme answer is correct, **see Andy.**

STOP If you struggle with the questions in the pack, **STOP!** and complete some more revision.

STOP If you come to a complete dead-end, **STOP!** and speak to **Andy** asap.

Do not write outside the box

1 0 **Table 4** shows some electrode half-equations and their standard electrode potentials.

Table 4

Electrode half-equation	***E*° / V**
$Cl_2(g) + 2e^- \rightarrow 2Cl^- (aq)$	+1.36
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(aq) + 2H_2O(aq)$	+0.96
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow SO_2(g) + 2H_2O(aq)$	+0.17
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44

1 0 . 1 Deduce the oxidation state of nitrogen in NO_3^- and in NO

[2 marks]

Nitrogen in NO_3^- ______________________________

Nitrogen in NO ______________________________

1 0 . 2 State the weakest reducing agent in **Table 4**.

[1 mark]

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1 0 . 3 Write the conventional representation of the cell that has an EMF of +0.43 V

[2 marks]

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1 0 . 4 Use data from **Table 4** to identify an acid that will oxidise copper.

Explain your choice of acid.

Use these data to suggest a possible equation for the reaction.

Calculate the EMF of the cell that has the same overall reaction.

[4 marks]

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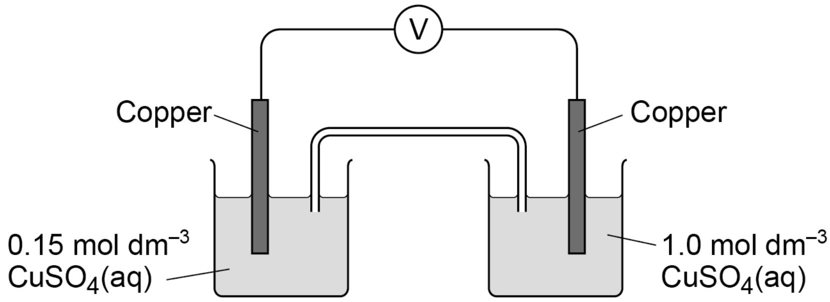
9

Question	Answers	Mark	Additional Comments/Guidance
10.1	(+) 5 (+) 2	1 1	Allow Roman numerals
10.2	Cl^- / chloride (ions)	1	Allow $2Cl^-$ Do not allow chlorine / Cl / Cl_2 Ignore (aq)
10.4	nitric acid / HNO_3	1	If not nitric acid then CE = 0 If NO_3^- ions identified, lose M1 and mark on
	the $E^{\ominus}$ <u>NO_3^-</u> (/NO) > $E^{\ominus}$ <u>Cu^{2+}</u>(/Cu) or in words	1	Allow 0.96V > 0.34V Allow <u>NO_3^-</u> is a better oxidising agent than <u>Cu^{2+}</u> Allow <u>NO_3^-</u> has a more positive $E^{\ominus}$ than <u>Cu^{2+}</u>
	$3Cu + 8H^+ + 2NO_3^- \rightarrow 3Cu^{2+} + 2NO + 4H_2O$	1	Allow $3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$
	EMF for the reaction is <u>0.62</u>(V)	1	
Total		**9**	

0 6 A student set up the cell shown in **Figure 2**.

Figure 2



The student recorded an initial voltage of +0.16 V at 25 °C

0 6 . 1 Explain how the salt bridge provides an electrical connection between the two solutions.

[1 mark]

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0 6 . 2 The standard electrode potential for the Cu^{2+}/Cu electrode is

$$Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s) \qquad E^{\ominus} = +0.34\ V$$

Calculate the electrode potential of the left-hand electrode in **Figure 2**.

[1 mark]

Electrode potential ______________________ V

0 6 . 3 Both electrodes contain a strip of copper metal in a solution of aqueous Cu^{2+} ions.

State why the left-hand electrode does **not** have an electrode potential of +0.34 V

[1 mark]

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0 6 . 4 Give the conventional representation for the cell in **Figure 2**.
Include all state symbols.

[1 mark]

0 6 . 5 When the voltmeter is replaced by a bulb, the EMF of the cell in **Figure 2** decreases over time to 0 V

Suggest how the concentration of copper(II) ions in the left-hand electrode changes when the bulb is alight.
Give **one** reason why the EMF of the cell decreases to 0 V

[2 marks]

Change in concentration of copper(II) ions in the left-hand electrode

Reason why the EMF decreases to 0 V

6

Turn over for the next question

Question	Answers	Additional Comments/Guidance	Mark
06.1	It has mobile <u>ions</u> / <u>ions</u> can move through it / free <u>ions</u>	Do not allow movement of electrons.	1
06.2	(+) 0.18 V		1
06.3	The concentration is not <u>1</u>.(0) (mol dm^{-3})		1
06.4	Cu (s) | Cu^{2+}(aq) ‖ Cu^{2+}(aq) | Cu(s)		1
06.5	(Concentration) increases or ([Cu^{2+}] ions) increase The [Cu^{2+}] ions in the two solutions become <u>equal/same</u>	Mark independently Not, concentrations are constant	1 1
Total			6

Do not write outside the box

1 1 This question is about a glucose–oxygen fuel cell.

When the cell operates, the glucose ($C_6H_{12}O_6$) molecules react with water at the negative electrode to form carbon dioxide and hydrogen ions.

Oxygen gas reacts with hydrogen ions to form water at the positive electrode.

1 1 . 1 Deduce the half-equation for the reaction at the negative electrode.

[1 mark]

1 1 . 2 Deduce the half-equation for the reaction at the positive electrode.

[1 mark]

1 1 . 3 Give the equation for the overall reaction that occurs in the Glucose–oxygen fuel cell.

[1 mark]

1 1 . 4 The negative electrode is made of carbon and the positive electrode is made of platinum.

Give the conventional representation for the glucose–oxygen fuel cell.

[2 marks]

1 1 . 5 State what must be done to maintain the EMF of this fuel cell when in use.

[1 mark]

6

END OF QUESTIONS

Question	Answers	Additional comments/Guidelines	Mark
11.1	$C_6H_{12}O_6 + 6\ H_2O \rightarrow 6\ CO_2 + 24\ H^+ + 24\ e^-$	Accept multiples	1
11.2	$O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O$	Accept multiples	1
11.3	$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$	Accept multiples	1
11.4	C(s) | $C_6H_{12}O_6$(aq), H^+(aq) | CO_2(g) || O_2(g) | H^+(aq),H_2O(l) | Pt(s) OR C|$C_6H_{12}O_6$, H^+| CO_2 || O_2 | H^+,H_2O | Pt	M1 Must see following in correct order: C | $C_6H_{12}O_6$ CO_2 || O_2 H_2O | Pt M2 Cell completely correct Ignore H_2O on LHS Ignore state symbols Allow H^+(aq) | H_2O(l) on RHS 0 marks if electrons included.	2
11.5	(Constantly) add reactants/glucose (and oxygen) OR keep concentration of reactants constant		1

Do not write outside the box

0 8 This question is about electrode potentials and electrochemical cells.

0 8 . 1 State the meaning of the term electrochemical series.

[1 mark]

Table 8 shows some electrode potentials.

Table 8

	$E^\ominus$ / V
$[Fe(H_2O)_6]^{2+}(aq) + 2e^- \rightarrow Fe(s) + 6H_2O(l)$	–0.44
$H^+(aq) + e^- \rightarrow \frac{1}{2}H_2(g)$	0.00
$[Co(NH_3)_6]^{3+}(aq) + e^- \rightarrow [Co(NH_3)_6]^{2+}(aq)$	+0.11
$[Fe(H_2O)_6]^{3+}(aq) + e^- \rightarrow [Fe(H_2O)_6]^{2+}(aq)$	+0.77
$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$[Co(H_2O)_6]^{3+}(aq) + e^- \rightarrow [Co(H_2O)_6]^{2+}(aq)$	+1.81

0 8 . 2 State **two** conditions needed for the following half-cell to have $E^\ominus = 0.00$ V

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

[1 mark]

0 8 . 3 Identify the weakest reducing agent in **Table 8**.

[1 mark]

Do not write outside the box

0 8 . 4 Use half-equations from **Table 8** to deduce an equation for the reduction of VO_2^+ to form VO^{2+} in aqueous solution by iron.

[2 marks]

0 8 . 5 Use data from **Table 8** to explain why $[Co(H_2O)_6]^{3+}(aq)$ will undergo a redox reaction with $[Fe(H_2O)_6]^{2+}(aq)$

Give an equation for this reaction.

[2 marks]

Explanation

Equation

0 8 . 6 Suggest why the **two** cobalt(III) complex ions in **Table 8** have different electrode potentials.

[1 mark]

8

Turn over for the next question

Question	Answers	Additional comments/Guidelines	Mark
08.1	(List of) electrode potentials/$E^{\ominus}$ in (numerical) order **OR** half cells/equations in (numerical) order of electrode potential/ $E^{\ominus}$	Do not allow EMF in order	1

Question	Answers	Additional comments/Guidelines	Mark
08.2	Any 2 from 298 K **or** 25 °C $[H^+]$ = 1 mol dm^{-3} 100 kPa	Ignore 1 atm	1

Question	Answers	Additional comments/Guidelines	Mark
08.3	$[Co(H_2O)_6]^{2+}$	Do not penalise absence of brackets	1

Question	Answers	Additional comments/Guidelines	Mark
08.4	$3\ VO_2^+ + 6\ H^+ + Fe + 3\ H_2O \rightarrow 3\ VO^{2+} + [Fe(H_2O)_6]^{3+}$ or $3\ VO_2^+ + 6\ H^+ + Fe \rightarrow 3\ VO^{2+} + 3\ H_2O + Fe^{3+}$ 1 mark for Fe^{3+} as product and one mark for equation.	Ignore state symbols Allow 1 mark for balanced equation that gives Fe^{2+} as product $2VO_2^+ + 4H^+ + Fe + 4H_2O \rightarrow 2VO^{2+} + [Fe(H_2O)_6]^{2+}$ or $2VO_2^+ + 4H^+ + Fe \rightarrow 2VO^{2+} + Fe^{2+} + 2H_2O$	2

Question	Answers	Additional comments/Guidelines	Mark
08.5	$E^{\ominus}$ Co^{3+}(/Co^{2+}) > Fe^{3+}(/Fe^{2+}) $[Co(H_2O)_6]^{3+} + [Fe(H_2O)_6]^{2+} \rightarrow [Co(H_2O)_6]^{2+} + [Fe(H_2O)_6]^{3+}$	Allow electrode potential for Co^{3+} greater than for Fe^{3+} **OR** 1.81 > 0.77 / EMF cell = 1.04 V Insist of reference to $E^{\ominus}$ in M1	1 1

Question	Answers	Additional comments/Guidelines	Mark
08.6	Different ligands	Penalise different concentrations/oxidation states	1

0 9 This question is about the development of lithium cells.
The value of $E^{\ominus}$ for lithium suggests that a lithium cell could have a large EMF.

Table 9 shows some electrode potential data.

Table 9

	$E^{\ominus}$ / V
$Li^+(aq) + e^- \rightarrow Li(s)$	–3.04
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	–0.83
$\frac{1}{2}I_2(s) + e^- \rightarrow I^-(aq)$	+0.54

0 9 . 1 Use data in **Table 9** to explain why an aqueous electrolyte is **not** used for a lithium cell.

[2 marks]

0 9 . 2 In the 1970s lithium-iodine cells became a common power source for heart pacemakers. Lithium iodide is the final product of the cell reaction.

Use the data in **Table 9** to calculate the cell EMF of a standard lithium-iodine cell.

[1 mark]

0 9 . 3 An EMF value for a commercial lithium-iodine cell is 2.80 V

Suggest why this value is different from the value calculated in Question **09.2**.

[1 mark]

Do not write outside the box

0 9 . 4 In some lithium cells, lithium perchlorate ($LiClO_4$) is used as the electrolyte.

Deduce the oxidation state of chlorine in $LiClO_4$

[1 mark]

In other lithium cells, lithium cobalt oxide electrodes **and** lithium electrodes are used.

0 9 . 5 Give an equation for the reaction that occurs at the positive lithium cobalt oxide electrode.

[1 mark]

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0 9 . 6 Give an equation for the reaction that occurs at the negative lithium electrode.

[1 mark]

7

END OF QUESTIONS

Question	Answers	Additional comments/Guidelines	Mark
09.1	Lithium would react with the electrolyte/water $E^\ominus$ for Li^+(/Li) more negative than for water or EMF= 2.21(V) or $E^\ominus$ Li^+ (/Li) < H_2O(/H_2 ,OH^-)	Allow water will oxidise Li to Li^+ or Li will reduce water to hydrogen Ignore EMF is negative	1 1

Question	Answers	Additional comments/Guidelines	Mark
09.2	0.54 – (–3.04) = 3.58 (V)		1

Question	Answers	Additional comments/Guidelines	Mark
09.3	Non-standard conditions	Allow non-aqueous conditions or different conditions	1

Question	Answers	Additional comments/Guidelines	Mark
09.4	(+) 7	Accept VII	1

Question	Answers	Additional comments/Guidelines	Mark
09.5	$Li^+ + CoO_2 + e^- \rightarrow Li^+CoO_2^-$ or $Li^+ + CoO_2 + e^- \rightarrow LiCoO_2$		1

Question	Answers	Additional comments/Guidelines	Mark
09.6	$Li \rightarrow Li^+ + e^-$		1

Do not write outside the box

0 8 This question is about cells.

0 8 . 1 The half-equations for two electrodes that combine to make a non-rechargeable cell are

$Zn^{2+}(aq) + 2e^{-} \rightarrow Zn(s)$ $E^{\ominus} = -0.76$ V

$2\,MnO_2(s) + 2\,NH_4^{+}(aq) + 2e^{-} \rightarrow Mn_2O_3(s) + 2\,NH_3(aq) + H_2O(l)$ $E^{\ominus} = +0.52$ V

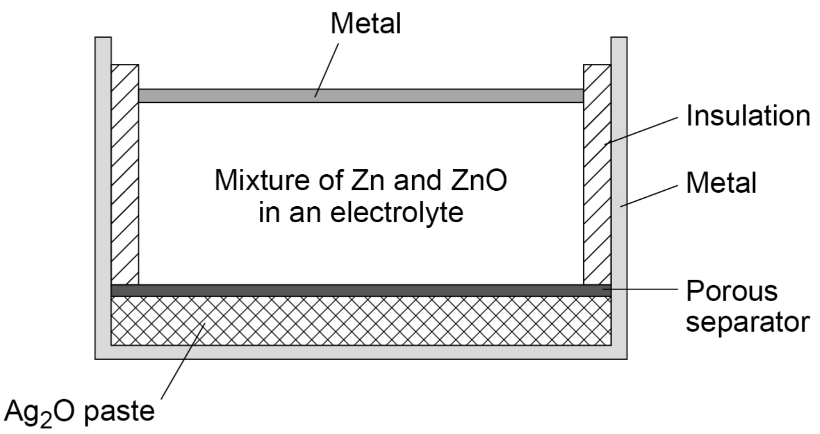
Identify the oxidising agent in this cell.

[1 mark]

____

Figure 1 shows a cross-section through a rechargeable silver–zinc cell.

Figure 1



0 8 . 2 Suggest the function of the porous separator in **Figure 1**.

[1 mark]

____

0 8 . 3 The standard electrode potentials for two half-equations for the silver–zinc cell are

$Ag_2O(s) + H_2O(l) + 2e^{-} \rightarrow 2\,Ag(s) + 2\,OH^{-}(aq)$ $E^{\ominus} = +0.34$ V

$ZnO(s) + H_2O(l) + 2e^{-} \rightarrow Zn(s) + 2\,OH^{-}(aq)$ $E^{\ominus} = -1.26$ V

Give an equation for the overall reaction that occurs when the cell is recharging.

[1 mark]

____

Turn over ►

Do not write outside the box

The EMF of an alkaline hydrogen–oxygen fuel cell is +1.23 V
The standard electrode potential for one of the electrodes in the alkaline hydrogen–oxygen fuel cell is

$$2H_2O(l) + 2e^- \rightarrow 2OH^-(aq) + H_2(g) \qquad E^\ominus = -0.83\ V$$

0 8 . 4 Give the half-equation for the other electrode and calculate its standard electrode potential.

[2 marks]

Equation

____

$E^\ominus$ ____

0 8 . 5 Suggest why the EMF values of the acidic and alkaline hydrogen–oxygen fuel cells are the same.

[1 mark]

____

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6

END OF QUESTIONS

Question	Answers	Additional Comments/Guidelines	Mark
08.1	MnO_2		1 AO2

Question	Answers	Additional Comments/Guidelines	Mark
08.2	allows ions to move/flow/transfer **or** to complete the circuit **or** acts as a salt bridge	ignore to allow current/charge to flow do **not** accept electrons to flow	1 AO1

Question	Answers	Additional Comments/Guidelines	Mark
08.3	$2\,Ag + ZnO \rightarrow Zn + Ag_2O$	ignore state symbols	1 AO3

Question	Answers	Additional Comments/Guidelines	Mark
08.4	$O_2(g) + 2\,H_2O(l) + 4\,e^- \rightarrow 4\,OH^-(aq)$ $E^\ominus$ = (+)0.4(0) (V)	ignore state symbols allow multiples	1 1 AO1 AO2

Question	Answers	Additional Comments/Guidelines	Mark
08.5	same <u>overall</u> reaction **or** $2\,H_2 + O_2 \rightarrow 2\,H_2O$		1 AO2