Electrolysis, Electrode Potentials & Cells

Question Paper 3

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Electrochemistry
Sub-Topic	Electrolysis, Electrode Potentials & Cells
Paper Type	Theory
Booklet	Question Paper 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 Chlorine is manufactured by electrolysis from brine, concentrated aqueous sodium chloride.

(a) (i) Describe, with the aid of a fully labelled diagram, the industrial electrolysis of brine in a diaphragm cell. State what each electrode is made of and show clearly the inlet for the brine and the outlets for the products.

(ii) Write a half-equation, with state symbols, for the reaction at **each** electrode.

anode .....

cathode .....

(iii) Name the chemical that is produced in solution in this electrolytic process.

..... [7]

[Total: 7]

2 **(a)** State the relationship between the Faraday constant, *F*, the charge on the electron, *e*, and the Avogadro number, *L*.

.....[1]

(b) If the charge on the electron, the A_r and the valency of copper are known, the value of the Avogadro number can be determined experimentally. This is done by passing a known current for a known time through a copper electrolysis cell, and weighing the mass of copper deposited onto the cathode.

(i) Draw a diagram of suitable apparatus for carrying out this experiment.
Label the following: power supply (with + and – terminals); anode; cathode; and ammeter.
State the composition of the electrolyte.

The following are the results obtained from one such experiment.

current passed through the cell	=	0.500 A
time current was passed through cell	=	30.0 min
initial mass of copper cathode	=	52.243 g
final mass of copper cathode	=	52.542 g

(ii) Use these data and relevant information from the *Data Booklet* to calculate a value of *L* to **3 significant figures**.

L = ...
[9]

(c) Use relevant information from the *Data Booklet* to identify the substances formed at the anode and at the cathode when aqueous solutions of the following compounds are electrolysed.

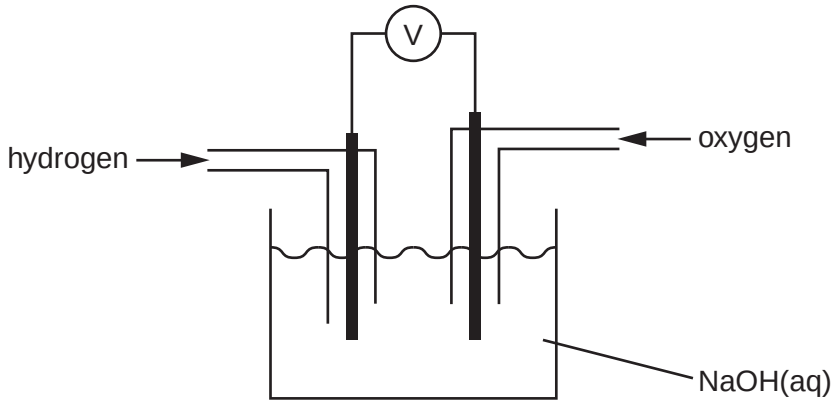
compound	product at anode	product at cathode
AgF		
$FeSO_4$		
$MgBr_2$		

[5]

[Total: 15]

3 Although standard electrode potentials are measured for solutions where the concentrations of ions are 1.0 mol dm^{-3}, cells used as sources of battery power tend to operate with more concentrated solutions. This question concerns the electrode reactions involved in the hydrogen-oxygen fuel cell and the lead-acid car battery.

(a) In the hydrogen-oxygen fuel cell, $H_2(g)$ and $O_2(g)$ are fed onto two inert electrodes dipping into NaOH(aq).



The following reactions take place.

left hand electrode (cathode): $H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$

right hand electrode (anode): $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

(i) Use the *Data Booklet* to calculate $E^{\ominus}_{cell}$ for this reaction.

.....

(ii) Construct an equation for the overall reaction.

.....

(iii) By using **one** of the phrases *more positive*, *more negative* or *no change*, deduce the effect of increasing [OH^-(aq)] on the electrode potential of

- the left hand electrode .....
- the right hand electrode .....

(iv) Hence deduce whether the overall E_{cell} is likely to *increase*, *decrease* or *remain the same*, when [OH^-(aq)] increases. Explain your answer.

.....

.....

(v) Suggest **one** other reason why a high [NaOH(aq)] is used in the fuel cell.

.....

[6]

(b) In the cells of a lead-acid car battery the following reactions take place.

cathode: $Pb(s) \rightarrow Pb^{2+}(aq) + 2e^-$

anode: $PbO_2(s) + 4H^+(aq) + 2e^- \rightarrow Pb^{2+}(aq) + 2H_2O(l)$

(i) Use the *Data Booklet* to calculate $E^{\ominus}_{cell}$ for this reaction.

.....

(ii) Construct an equation for the overall reaction.

.....

The electrolyte in a lead-acid cell is $H_2SO_4(aq)$. Most of the $Pb^{2+}(aq)$ ions that are produced at the electrodes are precipitated as the highly insoluble $PbSO_4(s)$.

(iii) Construct an equation for the overall cell reaction in the presence of H_2SO_4.

.....

(iv) By considering the effect of decreasing $[Pb^{2+}(aq)]$ on the electrode potentials of the cathode and the anode, deduce the effect of the presence of $H_2SO_4(aq)$ in the electrolyte on the overall E_{cell}.
State whether the E_{cell} will *increase*, *decrease* or *remain the same*.

Overall E_{cell} will ..... .

Explain your answer.

.....

.....

[5]

[Total: 11]

4 The design and development of batteries has been a major research area in recent years.

(a) Lead-acid batteries, used in cars, are made up of a number of rechargeable cells in series, and were first developed in 1860. They have the disadvantage of a relatively high mass compared to the energy stored. During discharge, the electrode reactions in the cells of these batteries are as follows.

I $Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^-$

II $PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$

State which of these reactions occurs at the positive electrode in a lead-acid cell during discharge, explaining your answer.

.....

..... [1]

(b) Use the *Data Booklet* and the equations **I** and **II** above to calculate the voltage produced by a lead-acid cell under standard conditions.

[2]

(c) Nickel-metal hydride batteries were developed in the 1980s and have become increasingly common particularly for small devices such as mobile phones and digital cameras that need near-constant sources of electrical energy. These cells use nickel oxohydroxide (NiO(OH)) as one electrode and a hydrogen-absorbing alloy such as $LiNi_5$ as the other electrode.

One reaction that takes place in these batteries is

$$NiO(OH) + H_2O + e^- \rightleftharpoons Ni(OH)_2 + OH^-$$

(i) State the oxidation state of nickel in NiO(OH). .....

(ii) Suggest a likely advantage of these batteries compared with lead-acid batteries.

.....

.....
[2]

(d) Hydrogen fuel cells have been suggested as the next major advance in electrically powered vehicles. In these fuel cells hydrogen is oxidized to produce water, using a catalyst and inert electrodes.

(i) Suggest a material for the electrodes.

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(ii) Use your knowledge of hydrogen to suggest a disadvantage of these fuel cells in powering vehicles.

.....

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[2]

(e) Many of the world's countries are developing ways of recycling materials which are valuable or which require large amounts of energy to produce.

For each of the following recyclable materials, state whether recycling of this material is important in saving energy or in saving resources. Use your knowledge of chemistry to explain each choice.

glass .....

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steel .....

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plastics .....

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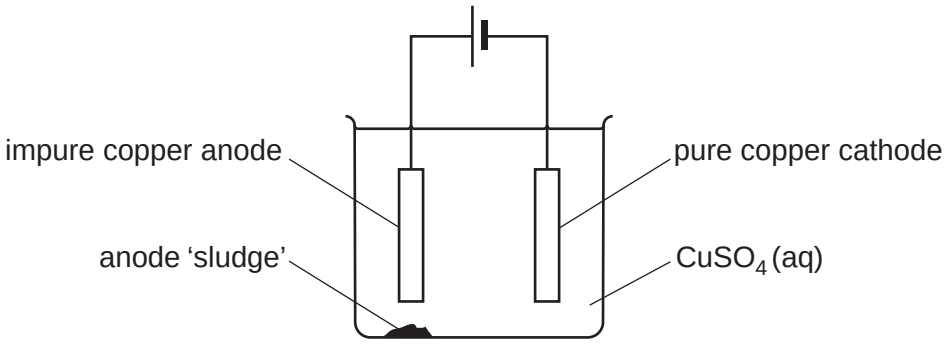
[3]

[Total: 10]

5 The electrolytic purification of copper can be carried out in an apparatus similar to the one shown below.



The impure copper anode contains small quantities of metallic nickel, zinc and silver, together with inert oxides and carbon resulting from the initial reduction of the copper ore with coke. The copper goes into solution at the anode, but the silver remains as the metal and falls to the bottom as part of the anode 'sludge'. The zinc also dissolves.

(a) (i) Write a half equation including state symbols for the reaction of copper at the anode.

.....

(ii) Use data from the *Data Booklet* to explain why silver remains as the metal.

.....

(iii) Use data from the *Data Booklet* to predict what happens to the nickel at the anode.

.....

.....

(iv) Write a half equation including state symbols for the main reaction at the cathode.

.....

(v) Use data from the *Data Booklet* to explain why zinc is not deposited on the cathode.

.....

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(vi) Suggest why the blue colour of the electrolyte slowly fades as the electrolysis proceeds.

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[7]

(b) Most of the current passed through the cell is used to dissolve the copper at the anode and precipitate pure copper onto the cathode. However, a small proportion of it is 'wasted' in dissolving the impurities at the anode which then remain in solution.
When a current of 20.0 A was passed through the cell for 10.0 hours, it was found that 225 g of pure copper was deposited on the cathode.

(i) Calculate the following, using appropriate data from the *Data Booklet*.

- number of moles of copper produced at the cathode

- number of moles of electrons needed to produce this copper

- number of moles of electrons that passed through the cell

(ii) Hence calculate the percentage of the current through the cell that has been 'wasted' in dissolving the impurities at the anode.

[4]

(c) Nickel often occurs in ores along with iron. After the initial reduction of the ore with coke, a nickel-iron alloy is formed.
Use data from the *Data Booklet* to explain why nickel can be purified by a similar electrolysis technique to that used for copper, using an impure nickel anode, a pure nickel cathode, and nickel sulfate as the electrolyte. Explain what would happen to the iron during this process.

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.....[2]

[Total: 13]