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# HL Paper 3

Discuss the production of chlorine and sodium hydroxide from brine using a membrane cell. Include in your answer the materials used for the electrodes, the equations taking place at each electrode and why this method has replaced the mercury cell.

## Markscheme

(+) electrode made of titanium and (−) electrode made of steel;

(+)  $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$ ;

(−)  $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$  /  $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ ;

environmental as poisonous mercury leaks from mercury cell / *OWTTE* / membrane cell is much cheaper to run;

## Examiners report

Like C1, this was a question that demanded knowledge of basic chemistry, but it was poorly done. Vague answers were given as to “toxic mercury”.

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A fuel cell is an energy conversion device that generates electricity from a spontaneous redox reaction.

- a. The *Geobacter* species of bacteria can be used in microbial fuel cells to oxidise aqueous ethanoate ions, [2]  
 $\text{CH}_3\text{COO}^-$ (aq), to carbon dioxide gas.

State the half-equations for the reactions at both electrodes.

Negative electrode (anode):

.....

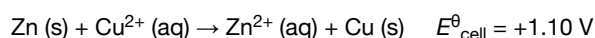
Positive electrode (cathode):

.....

- b. A concentration cell is an example of an electrochemical cell. [3]

(i) State the difference between a concentration cell and a standard voltaic cell.

(ii) The overall redox equation and the standard cell potential for a voltaic cell are:



Determine the cell potential  $E$  at 298 K to three significant figures given the following concentrations in  $\text{mol dm}^{-3}$ :

$$[\text{Zn}^{2+}] = 1.00 \times 10^{-4} \quad [\text{Cu}^{2+}] = 1.00 \times 10^{-1}$$

Use sections 1 and 2 of the data booklet.

(iii) Deduce, giving your reason, whether the reaction in (b) (ii) is more or less spontaneous than in the standard cell.

c. Dye-sensitized solar cells (DSSC) convert solar energy into electrical energy.

[4]

(i) Describe how a DSSC converts sunlight into electrical energy.

(ii) Explain the role of the electrolyte solution containing iodide ions,  $\text{I}^-$ , and triiodide ions,  $\text{I}_3^-$ , in the DSSC.

## Markscheme

a. *Negative electrode (anode):*  $\text{CH}_3\text{COO}^- (\text{aq}) + 2\text{H}_2\text{O} (\text{l}) \rightarrow 2\text{CO}_2 (\text{g}) + 7\text{H}^+ (\text{aq}) + 8\text{e}^-$

*Positive electrode (cathode):*  $\text{O}_2 (\text{g}) + 4\text{H}^+ (\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O} (\text{l})$

*Accept equilibrium signs in equations.*

*Award [1 max] if correct equations are given at wrong electrodes.*

b. i

concentration cell has different concentrations of electrolyte «solutions» «but same electrodes and electrolytes»

**OR**

standard voltaic cell has different electrodes/electrolytes «but same concentration of electrolytes»

*Accept “both half-cells in concentration cell made from same materials”.*

ii

$$\text{«}E = 1.10 - \left(\frac{RT}{nF}\right) \ln \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} = 1.10 - \left(\frac{8.31 \times 298}{2 \times 96500}\right) \ln \frac{10^{-4}}{10^{-1}} = 1.10 + 0.0886 \text{ = »}$$

(+) 1.19 «V»

*3 significant figures needed for mark.*

iii

more spontaneous because  $E > E^\ominus_{\text{cell}}$

c. i

photon/«sun»light absorbed by the dye/photosensitizer/«transition» metal complex

**OR**

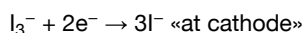
dye/photosensitizer/«transition» metal complex excited by photon/«sun»light

electron«s» move«s» to conduction band

**OR**

electron«s» transferred to semiconductor/ $\text{TiO}_2$

ii



**OR**

triiodide ions/ $\text{I}_3^-$  reduced into/produce iodide ions/ $\text{I}^-$  «at cathode»

iodide ions/ $\text{I}^-$  reduce dye/act as reducing agent **AND** oxidized into/produce triiodide ions/ $\text{I}_3^-$

**OR**



## Examiners report

[N/A]

- b. [N/A]
- c. [N/A]

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