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;

$(+)$ $2Cl^- \rightarrow Cl_2 + 2e^-$;

$(-)$ $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ / $2H^+ + 2e^- \rightarrow H_2$;

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”.

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]

CH_3COO^-(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:

$$Zn\ (s) + Cu^{2+}\ (aq) \rightarrow Zn^{2+}\ (aq) + Cu\ (s) \qquad E^{\theta}_{cell} = +1.10\ V$$

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

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

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, I^-, and triiodide ions, I_3^-, in the DSSC.

Markscheme

a. *Negative electrode (anode):* CH_3COO^- (aq) + $2H_2O$ (l) → $2CO_2$ (g) + $7H^+$ (aq) + $8e^-$

Positive electrode (cathode): O_2 (g) + $4H^+$ (aq) + $4e^-$ → $2H_2O$ (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

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

(+) 1.19 «V»
3 significant figures needed for mark.

iii

more spontaneous because $E > E^{\theta}_{cell}$

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/TiO_2

ii

I_3^- + $2e^-$ → $3I^-$ «at cathode»
OR
triiodide ions/I_3^- reduced into/produce iodide ions/I^- «at cathode»

iodide ions/I^- reduce dye/act as reducing agent ***AND*** oxidized into/produce triiodide ions/I_3^-
OR
dye^+ + e^- → dye ***AND*** $3I^-$ → I_3^- + $2e^-$

Examiners report

[N/A]

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