Question 3

$$2\ H_2(g)\ +\ O_2(g)\ \rightarrow\ 2\ H_2O(l)$$

In a hydrogen-oxygen fuel cell, energy is produced by the overall reaction represented above.

(a) When the fuel cell operates at 25°C and 1.00 atm for 78.0 minutes, 0.0746 mol of $O_2(g)$ is consumed. Calculate the volume of $H_2(g)$ consumed during the same time period. Express your answer in liters measured at 25°C and 1.00 atm.

$(0.0746 \text{ mol } O_2) \times \dfrac{2 \text{ mol } H_2}{1 \text{ mol } O_2} = 0.149 \text{ mol } H_2$ $V = \dfrac{n_{H_2}RT}{P} = \dfrac{(0.149 \text{ mol } H_2)(0.0821 \text{ L atm mol}^{-1}\text{ K}^{-1})(298 \text{ K})}{1.00 \text{ atm}}$ $= 3.65 \text{ L } H_2$	One point is earned for calculation of moles of H_2. One point is earned for substitution into $PV = nRT$. One point is earned for the answer.

(b) Given that the fuel cell reaction takes place in an acidic medium,

(i) write the two half reactions that occur as the cell operates,

$O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O$ $H_2 \rightarrow 2\ H^+ + 2\ e^-$	One point is earned for each of the two half reactions.

(ii) identify the half reaction that takes place at the cathode, and

$O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O$	One point is earned for either the equation of the correct half reaction, or for indicating "the reduction half reaction" if the correct equation is given in (b)(i).

(iii) determine the value of the standard potential, $E°$, of the cell.

$E° = 1.23\text{V} + 0.00\text{ V} = 1.23\text{ V}$	One point is earned for the standard potential.

Question 3 (continued)

(c) Calculate the charge, in coulombs, that passes through the cell during the 78.0 minutes of operation as described in part (a).

$(0.0746 \text{ mol } O_2) \times \frac{4 \text{ mol } e^-}{1 \text{ mol } O_2} \times \frac{96{,}500 \text{ C}}{1 \text{ mol } e^-} = 2.88 \times 10^4 \text{ C}$	One point is earned for the stoichiometry. One point is earned for the answer.

$$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$$

3. In a hydrogen-oxygen fuel cell, energy is produced by the overall reaction represented above.

(a) When the fuel cell operates at 25°C and 1.00 atm for 78.0 minutes, 0.0746 mol of $O_2(g)$ is consumed. Calculate the volume of $H_2(g)$ consumed during the same time period. Express your answer in liters measured at 25°C and 1.00 atm.

(b) Given that the fuel cell reaction takes place in an acidic medium,

(i) write the two half reactions that occur as the cell operates,

(ii) identify the half reaction that takes place at the cathode, and

(iii) determine the value of the standard potential, $E°$, of the cell.

(c) Calculate the charge, in coulombs, that passes through the cell during the 78.0 minutes of operation as described in part (a).

a) $0.0746 \text{ mol } O_2 \times \frac{2 \text{ mol } H_2}{1 \text{ mol } O_2} = 0.1492 \text{ mol } H_2$ consumed.

$PV = nRT$

$(1)(V) = (0.1492)(.0821)(298)$

$V = \boxed{3.65 \text{ L } H_2}$

b) i. $H_2(g) \rightarrow 2H^+ + 2e^-$ $E^0 = 0.00V$

$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O(l)$ $E^0 = 1.23V$

ii. the reduction reaction takes place at the cathode, thus...

$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O(l)$

↑ takes place at the cathode.

iii. $0.00V + 1.23V = \boxed{1.23V}$

c) ?

$0.1492 \text{ mol } H_2 \times \frac{2 \text{ mol } e^-}{1 \text{ mol } H_2} \times \frac{96500}{\text{mol } e^-} = 28800$ Coulombs

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$$2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(l)$$

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   (a) When the fuel cell operates at 25°C and 1.00 atm for 78.0 minutes, 0.0746 mol of $O_2(g)$ is consumed. Calculate the volume of $H_2(g)$ consumed during the same time period. Express your answer in liters measured at 25°C and 1.00 atm.

   (b) Given that the fuel cell reaction takes place in an acidic medium,

   (i) write the two half reactions that occur as the cell operates,

   (ii) identify the half reaction that takes place at the cathode, and

   (iii) determine the value of the standard potential, $E°$, of the cell.

   (c) Calculate the charge, in coulombs, that passes through the cell during the 78.0 minutes of operation as described in part (a).

3) (a) $V = \frac{nRT}{P}$

$0.0746 \text{ mol } O_2 \times \frac{2}{1} = 0.1492 \text{ mol } H_2$

$V = \frac{(0.1492)(0.08206)(298)}{1}$

$V = 3.65\ L$

(b) (i) $O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O(l)$ $E° = 1.23V$

$2H^+ + 2e^- \rightarrow H_2(g)$ $E° = 0.00$

$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O(l)$

$4H_2(g) \rightarrow 4H^+ + 4e^-$ $E°_{cell} = 1.23V$

$4H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

(ii) $O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O(l)$

(iii) making in (i)

$E°cell = 1.23V$

(c) $I = q/t$

$1.23 = q/78$

$q = 95.94\ C$

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0.1492 0.0746

$$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$$

3C

3. In a hydrogen-oxygen fuel cell, energy is produced by the overall reaction represented above.

(a) When the fuel cell operates at 25°C and 1.00 atm for 78.0 minutes, 0.0746 mol of $O_2(g)$ is consumed. Calculate the volume of $H_2(g)$ consumed during the same time period. Express your answer in liters measured at 25°C and 1.00 atm.

(b) Given that the fuel cell reaction takes place in an acidic medium,

(i) write the two half reactions that occur as the cell operates,

(ii) identify the half reaction that takes place at the cathode, and

(iii) determine the value of the standard potential, $E°$, of the cell.

(c) Calculate the charge, in coulombs, that passes through the cell during the 78.0 minutes of operation as described in part (a).

(a) 2 H2 : 1 O2 since 0.0746 moles of O2 is consumed, 0.1492 moles of H2 were consumed.

0.1492 moles × (22.4 L / mole) = 3.34 L

(b)

(i) $H_2(g) \rightarrow 2H^+ + 2e^-$

$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O$

(ii) cathode = where the cation goes to get reduced. (where reduction takes place.)

reduction = gaining electrons, so

$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O$ occurs at the cathode

↑ gain of electrons

(iii) $H_2(g) \rightarrow 2H^+ + 2e^-$ $E° = 0$ V

$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O$ $E° = 1.23$ V

$E°_{cell} = 1.23$ V

(c) $E_{cell} = E°_{cell} - \frac{0.0592}{n} \log(Q)$

$= 1.23V - \frac{0.0592}{4 \text{ moles } e^-} \log(0.0017)$

= 1.27 coulombs

or → assume I = 3 amperes.

$I = \frac{q}{t}$

$3 = \frac{q}{4680}$ q = 14040 coulombs

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Question 3

Sample: 3A
Score: 9

This response earned all 9 points: 3 for part (a), 2 for part (b)(i), 1 for part (b)(ii), 1 for part (b)(iii), and 2 for part (c).

Sample: 3B
Score: 7

This response earned all 7 points for parts (a) and (b). No points were earned for part (c) because the student incorrectly substitutes the voltage as current into an incorrect equation.

Sample: 3C
Score: 6

In part (a) 1 point was earned for the correct ratio of moles of oxygen to moles of hydrogen; only 1 of the remaining 2 points for this part was earned because the student incorrectly attempts to calculate the volume under STP conditions. All 4 points were earned for part (b). No points were earned for part (c) because use of the Nernst equation is inappropriate.