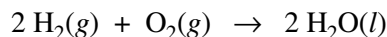


AP[®] CHEMISTRY
2007 SCORING GUIDELINES (Form B)

Question 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 $\text{O}_2(g)$ is consumed. Calculate the volume of $\text{H}_2(g)$ consumed during the same time period. Express your answer in liters measured at 25°C and 1.00 atm.

$(0.0746 \text{ mol O}_2) \times \frac{2 \text{ mol H}_2}{1 \text{ mol O}_2} = 0.149 \text{ mol H}_2$ $V = \frac{n_{\text{H}_2} RT}{P} = \frac{(0.149 \text{ mol H}_2)(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(298 \text{ K})}{1.00 \text{ atm}}$ $= 3.65 \text{ L H}_2$	<p>One point is earned for calculation of moles of H_2.</p> <p>One point is earned for substitution into $PV = nRT$.</p> <p>One point is earned for the answer.</p>
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- (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,

$\text{O}_2 + 4 \text{H}^+ + 4 e^- \rightarrow 2 \text{H}_2\text{O}$ $\text{H}_2 \rightarrow 2 \text{H}^+ + 2 e^-$	<p>One point is earned for each of the two half reactions.</p>
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- (ii) identify the half reaction that takes place at the cathode, and

$\text{O}_2 + 4 \text{H}^+ + 4 e^- \rightarrow 2 \text{H}_2\text{O}$	<p>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).</p>
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- (iii) determine the value of the standard potential, E° , of the cell.

$E^\circ = 1.23\text{V} + 0.00 \text{ V} = 1.23 \text{ V}$	<p>One point is earned for the standard potential.</p>
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AP[®] CHEMISTRY
2007 SCORING GUIDELINES (Form B)

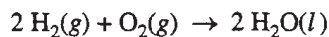
Question 3 (continued)

- (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.



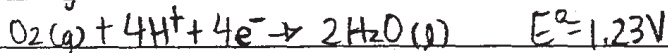
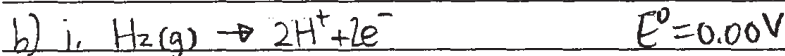
3. In a hydrogen-oxygen fuel cell, energy is produced by the overall reaction represented above.
- (a) When the fuel cell operates at 25°C and 1.00 atm for 78.0 minutes, 0.0746 mol of $\text{O}_2(\text{g})$ is consumed. Calculate the volume of $\text{H}_2(\text{g})$ consumed during the same time period. 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,
- write the two half reactions that occur as the cell operates,
 - identify the half reaction that takes place at the cathode, and
 - 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).

$$\text{a) } 0.0746 \text{ mol O}_2 \times \frac{2 \text{ mol H}_2}{1 \text{ mol O}_2} = 0.1492 \text{ mol H}_2 \text{ consumed.}$$

$$PV = nRT$$

$$(1)(V) = (0.1492)(0.0821)(298)$$

$$V = \boxed{3.65 \text{ L H}_2}$$



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

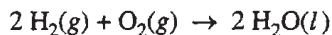


↑ takes place at the cathode.

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

c) ?

$$0.1492 \text{ mol H}_2 \times \frac{2 \text{ mole}^-}{1 \text{ mol H}_2} \times \frac{96500}{\text{mole}^-} = 28800 \text{ Coulombs}$$



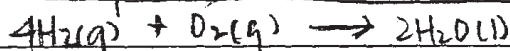
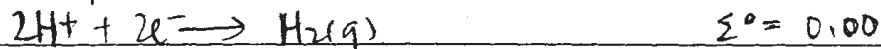
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- (b) Given that the fuel cell reaction takes place in an acidic medium,
- write the two half reactions that occur as the cell operates,
 - identify the half reaction that takes place at the cathode, and
 - determine the value of the standard potential, 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).

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

$$0.0746 \text{ mol O}_2 \times \frac{2}{1} = 0.1492 \text{ mol H}_2$$

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

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



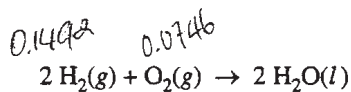
(iii) mixing in (i)

$$\Sigma^\circ_{\text{cell}} = 1.23\text{V}$$

$$\text{c) } I = \frac{q}{t}$$

$$1.23 = \frac{q}{78}$$

$$q = 95.94 \text{ C}$$



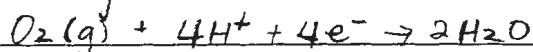
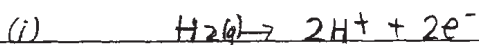
3C

3. In a hydrogen-oxygen fuel cell, energy is produced by the overall reaction represented above.
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- (b) Given that the fuel cell reaction takes place in an acidic medium
- write the two half reactions that occur as the cell operates,
 - identify the half reaction that takes place at the cathode, and
 - 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) $2 \text{H}_2 : 1 \text{O}_2$ Since 0.0746 moles of O_2 is consumed, 0.1492 moles of H_2 were consumed.

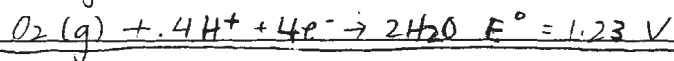
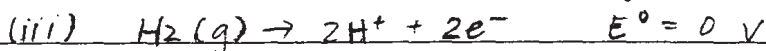
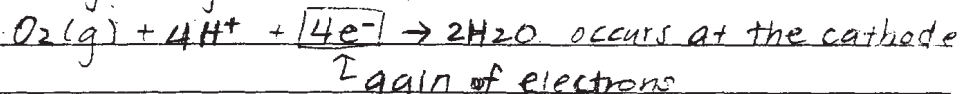
$$0.1492 \text{ moles} \times (22.4 \text{ L/mole}) = 3.34 \text{ L}$$

(b)



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

reduction = gaining electrons, so



$$E^\circ_{\text{cell}} = 1.23 \text{ V}$$

(c) $E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.0592}{n} \log(Q)$
 $= 1.23 \text{ V} - \frac{0.0592}{4 \text{ moles e}^-} \log(0.0017)$
 $= 1.27 \text{ coulombs}$

or → assume $I = 3 \text{ amperes}$.

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

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

AP[®] CHEMISTRY
2007 SCORING COMMENTARY (Form B)

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.