Question 2

2. Answer the following questions about voltaic cells.

(a) A voltaic cell is set up using Al/Al^{3+} as one half-cell and Sn/Sn^{2+} as the other half-cell. The half-cells contain equal volumes of solutions and are at standard conditions.

(i) Write the balanced net-ionic equation for the spontaneous cell reaction.

$3\ Sn^{2+} + 2\ Al \rightarrow 3\ Sn + 2\ Al^{3+}$	One point is earned for the correct direction. One point is earned for the balanced net-ionic equation.

(ii) Determine the value, in volts, of the standard potential, $E°$, for the spontaneous cell reaction.

$E° = -0.14\ V - (-1.66\ V) = 1.52\ V$ (or, $1.52\ J\ C^{-1}$)	One point is earned for the correct answer. (Potential must be positive.)

(iii) Calculate the value of the standard free-energy change, $\Delta G°$, for the spontaneous cell reaction. Include units with your answer.

$\Delta G° = -nFE° = -\frac{6\ mol\ e^-}{1\ mol} \times \frac{96{,}500\ C}{1\ mol\ e^-} \times (1.52\ J\ C^{-1})$ $= -8.80 \times 10^5\ J\ mol^{-1}$ (or $-880\ kJ\ mol^{-1}$)	One point is earned for indicating the correct mol e^- to mol reaction ratio. One point is earned for the correct answer with correct units.

(iv) If the cell operates until $[Al^{3+}]$ is 1.08 M in the Al/Al^{3+} half-cell, what is $[Sn^{2+}]$ in the Sn/Sn^{2+} half-cell?

change in $[Sn^{2+}] = \frac{0.08\ mol\ Al^{3+}}{1\ L} \times \frac{3\ mol\ Sn^{2+}}{2\ mol\ Al^{3+}} = \frac{0.12\ mol\ Sn^{2+}}{1\ L}$ $[Sn^{2+}] = 1.00\ mol\ L^{-1} - 0.12\ mol\ L^{-1} = 0.88\ mol\ L^{-1}$	One point is earned for the correct answer.

(b) In another voltaic cell with Al/Al^{3+} and Sn/Sn^{2+} half-cells, $[Sn^{2+}]$ is 0.010 M and $[Al^{3+}]$ is 1.00 M. Calculate the value, in volts, of the cell potential, E_{cell}, at 25°C.

$E_{cell} = 1.52\ V - \frac{0.0592}{6} \log \frac{(1.00)^2}{(0.010)^3}$ $= 1.52\ V - 0.0592\ V = 1.46\ V$	Answers must be consistent with part (a)(i). One point is earned for the proper exponents. One point is earned for the correct substitution of concentrations. One point is earned for the correct answer.

2A

Answer EITHER Question 2 below OR Question 3 printed on page 12. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 20 percent.

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(b) In another voltaic cell with Al/Al^{3+} and Sn/Sn^{2+} half-cells, $[Sn^{2+}]$ is 0.010 M and $[Al^{3+}]$ is 1.00 M. Calculate the value, in volts, of the cell potential, E_{cell}, at 25°C.

a) i) $Al^{3+} + 3e^- \rightarrow Al \quad E°_{red} = -1.66V$ - anode

$Sn^{2+} + 2e^- \rightarrow Sn \quad E°_{red} = -.14V$ - cathode

$3Sn^{2+} + 2Al_{(s)} \rightarrow 2Al^{3+} + 3Sn_{(s)}$

ii) $E°_{cell} = E°_{red}(\text{cathode}) - E°_{red}(\text{anode}) = (-.14V) - (-1.66V) \quad E°_{cell} = 1.52V$

iii) $\Delta G° = -nFE° = -(6)(96500\ C)(1.52V) \quad \Delta G° = -880 \times 10^3\ J = -880\ KJ$

iv) $1.08\ M\ Al^{3+} \left| \frac{3\ mol\ Sn^{2+}}{2\ mol\ Al^{3+}} \right. = 1.62\ M\ Sn^{2+}$

b) $Q = \frac{[Al^{3+}]^2}{[Sn^{2+}]^3} \qquad E_{cell} = E°_{cell} - \frac{.0592}{n} \log Q$

$E_{cell} = 1.52V - \frac{.0592}{6} \log\left(\frac{(1.00)^2}{(.010)^3}\right) \qquad E_{cell} = 1.46\ V$

GO ON TO THE NEXT PAGE.

2B

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(i) Write the balanced net-ionic equation for the spontaneous cell reaction.

(ii) Determine the value, in volts, of the standard potential, $E°$, for the spontaneous cell reaction.

(iii) Calculate the value of the standard free-energy change, $\Delta G°$, for the spontaneous cell reaction. Include units with your answer.

(iv) If the cell operates until $[Al^{3+}]$ is 1.08 M in the Al/Al^{3+} half-cell, what is $[Sn^{2+}]$ in the Sn/Sn^{2+} half-cell?

(b) In another voltaic cell with Al/Al^{3+} and Sn/Sn^{2+} half-cells, $[Sn^{2+}]$ is 0.010 M and $[Al^{3+}]$ is 1.00 M. Calculate the value, in volts, of the cell potential, E_{cell}, at 25°C.

a) $3Sn^{2+} + 6e^- \rightarrow 3Sn$ $\quad -.14$

$2Al \rightarrow 2Al^{3+} + 6e^-$ $\quad 1.66$ (has been flipped around)

i $\boxed{3Sn^{2+} + 2Al \rightarrow 3Sn + 2Al^{3+}}$

ii flip the lower equation. (on the volt chart, Al is lower down than Sn

$-.14 + 1.66 = \boxed{1.52\,V}$

iii. $\Delta G = -nFE°$

$= -6 \cdot 96500 \cdot 1.52\,V$

$= -880080\ J/kmol$

IV. $1.52 = 1.52 - \frac{RT}{nF} \ln \left|\frac{Al}{Sn}\right|$

$\frac{RT}{nF} \ln \left|\frac{Al}{Sn}\right| = 0 \quad \therefore [Al] = [Sn] = \boxed{1.08\,M}$

b) $E_{cell} = E°_{cell} - \frac{RT}{nF} \ln \left|\frac{Al}{Sn}\right|$

$1.52 - \frac{(8.31)(298)}{6 \cdot 96500} \ln \left|\frac{1}{.010}\right|$

$= \boxed{1.5\,V}$

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2C

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(iv) If the cell operates until $[Al^{3+}]$ is 1.08 M in the Al/Al^{3+} half-cell, what is $[Sn^{2+}]$ in the Sn/Sn^{2+} half-cell?

(b) In another voltaic cell with Al/Al^{3+} and Sn/Sn^{2+} half-cells, $[Sn^{2+}]$ is 0.010 M and $[Al^{3+}]$ is 1.00 M. Calculate the value, in volts, of the cell potential, E_{cell}, at 25°C.

(i)

2 [$Al^{3+} + 3e^- \rightarrow Al(s)$] $E° = -1.66\ V$

3 [$Sn^{2+} + 2e^- \rightarrow Sn(s)$] $E° = -0.14\ V$

$2Al + 3Sn^{2+} \rightarrow 2Al^{3+} + 3\,Sn$

ii) $-0.14V - -1.66V = \boxed{1.65\ V}$

iii) $\Delta G° = -n\,FE°$

$= -6\,(96500)(1.65V)$

$= -955{,}350\ \frac{J}{mol} = \boxed{-9.55 \times 10^5\ J/mol}$

iv) $\Delta G° = -2.303\,RT \log K$

$\frac{-9.55 \times 10^5\ J}{mol}$

b)

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AP® CHEMISTRY
2006 SCORING COMMENTARY (Form B)

Question 2

Sample: 2A
Score: 8

This excellent response earned 8 out of 9 possible points: 2 points for part (a)(i), 1 point for part (a)(ii), 2 points for part (a)(iii), and 3 points for part (b). The point was not earned for part (a)(iv).

Sample: 2B
Score: 6

In this good response, 1 point was earned in part (a)(iii) for the correct number of moles of electrons, but the second point was not earned because the units are incorrect and the number of significant figures in the answer is different by more than one from the proper number. The point was not earned in part (a)(iv) because the concentrations of Al^{3+} and Sn^{2+} are not equal. In part (b) one point was earned for substitution of the correct concentrations, but the point for correct exponents was not earned. The calculation with incorrect exponents is done correctly, so a second point was earned in part (b).

Sample: 2C
Score: 4

The point was not earned in part (a)(ii) because of a math error in the calculation. This incorrect value was used correctly in part (a)(iii), so part (a)(iii) earned full credit. The point was not earned in part (a)(iv). Part (b) is not attempted.