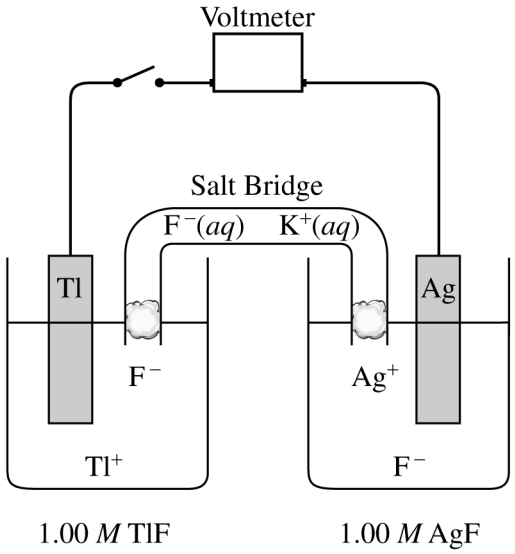
AP® CHEMISTRY
2009 SCORING GUIDELINES (Form B)

Question 6 (9 points)

Answer the following questions about electrochemical cells.



It is observed that when silver metal is placed in aqueous thallium(I) fluoride, TlF, no reaction occurs. When the switch is closed in the cell represented above, the voltage reading is +1.14 V.

(a) Write the reduction half-reaction that occurs in the cell.

$Ag^+ + e^- \rightarrow Ag$	One point is earned for the correct equation.

(b) Write the equation for the overall reaction that occurs in the cell.

$Tl + Ag^+ \rightarrow Tl^+ + Ag$	One point is earned for the correct equation.

(c) Identify the anode in the cell. Justify your answer.

The anode is where oxidation occurs. In the overall reaction Tl is oxidized to Tl^+, so the anode is the Tl electrode in the left cell.	One point is earned for the correct answer with justification.

(d) On the diagram above, use an arrow to clearly indicate the direction of electron flow as the cell operates.

The arrow should show electron flow in the direction from the Tl electrode through the wire to the Ag electrode.	One point is earned for a correct arrow.

Question 6 (continued)

(e) Calculate the value of the standard reduction potential for the Tl^+/Tl half-reaction.

$E^\circ_{cell} = E^\circ_{red} - E^\circ_{ox}$ $+1.14\text{ V} = +0.80\text{V} - E^\circ_{ox}$ $E^\circ_{ox} =$ **–0.34 V**	One point is earned for the correct setup. One point is earned for the correct answer.

The standard reduction potential, $E°$, of the reaction $Pt^{2+} + 2\,e^- \rightarrow Pt$ is 1.20 V.

(f) Assume that electrodes of pure Pt, Ag, and Ni are available as well as 1.00 *M* solutions of their salts. Three different electrochemical cells can be constructed using these materials. Identify the two metals that when used to make an electrochemical cell would produce the cell with the largest voltage. Explain how you arrived at your answer.

$E°$(V) $Ni^{2+} + 2\,e^- \rightarrow Ni$ –0.25 $Ag^+ + e^- \rightarrow Ag$ 0.80 $Pt^{2+} + 2\,e^- \rightarrow Pt$ 1.20 $E^\circ_{cell} = E^\circ_{red} - E^\circ_{ox}$ The two metals that yield the largest E°_{cell} are those with the biggest difference in $E°$, namely, Pt and Ni (see E°_{cell} calculation below). $E^\circ_{cell} = +1.20 - (-0.25) = +1.45$ V	One point is earned for the correct answer with justification.

(g) Predict whether Pt metal will react when it is placed in 1.00 *M* $AgNO_3(aq)$. Justify your answer.

When Pt metal is added to 1.00 *M* $AgNO_3$, the only redox reaction that could occur would be for Pt to become oxidized as Ag^+ is reduced. $E^\circ_{cell} = E^\circ_{red} - E^\circ_{ox} = +0.80\text{ V} - (+1.20\text{ V}) = -0.40$ V Because E°_{cell} for that reaction is negative, no reaction will occur.	One point is earned for comparing $E°$ values. One point is earned for the correct interpretation.

6A,

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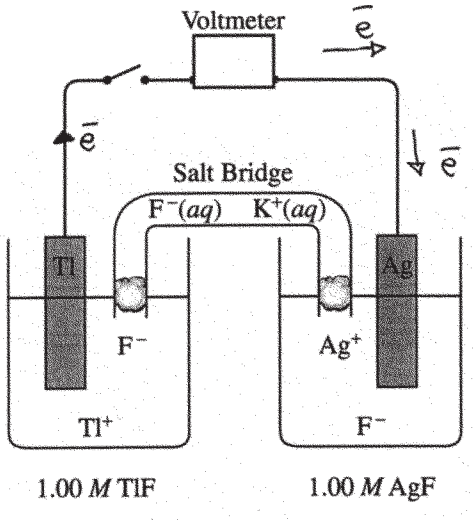
6. Answer the following questions about electrochemical cells.



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(b) Write the equation for the overall reaction that occurs in the cell.

(c) Identify the anode in the cell. Justify your answer.

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(g) Predict whether Pt metal will react when it is placed in 1.00 *M* $AgNO_3(aq)$. Justify your answer.

a) $Ag^+ + 1\bar{e} \rightarrow Ag$ $E=0.8V$ but $Ag_{(s)}$ is in Tl^+ solution, no reaction occur. so Ag is not going to be oxidized. so it's already reduced. → reduction

so. $Ag^+_{(aq)} + 1\bar{e} \rightarrow Ag_{(s)}$.

b). $Tl_{(s)} \rightarrow Tl^+_{(aq)} + 1\bar{e}$ ① ∴ ①+② $Tl_{(s)} + Ag^+_{(aq)} \rightarrow Tl^+_{(aq)} + Ag_{(s)}$.

$Ag^+_{(aq)} + 1\bar{e} \rightarrow Ag_{(s)}$ ②

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6A2

B B B B B B B B B B B B B

ADDITIONAL PAGE FOR ANSWERING QUESTION 6

c). Anode → oxidation taken place, so. Tl electrode b/c Tl → Tl^+ the charge NO. ↑ algebraically → oxidized.

d). electrons flows frum anode to cathode.

e) $Tl \rightarrow Tl^+ + 1\bar{e}$ $\mathcal{E}^\circ = \mathcal{E}v$ $\mathcal{E} + 0.8 = 1.14$

$Ag^+ + 1\bar{e} \rightarrow Ag$ $\mathcal{E}^\circ = 0.8V$. $\mathcal{E} = 1.14 - 0.8 = 0.34V$. 1.14 − 0.8 = 0.34

∴ $\mathcal{E}_{red} = -0.34V$. $Tl^+ + 1\bar{e} \rightarrow Tl$

f). Pt & Ag Ag & Ni Pt & Ni.

$Ag^+ + 1\bar{e} \rightarrow Ag$ $\mathcal{E} = 0.8V$ $Ni^{2+} + 2\bar{e} \rightarrow Ni$ $\mathcal{E} - 0.25V$. $Ni^{2+} + 2\bar{e} \rightarrow Ni$ $\mathcal{E} = -0.25$

$Pt^{2+} + 2\bar{e} \rightarrow Pt$ $\mathcal{E} = 1.2V$. ∴ $Ag^+ + 1\bar{e} \rightarrow Ag$ $\mathcal{E} = 0.8V$ $Pt^{2+} + 2\bar{e} \rightarrow Pt$ $\mathcal{E} = 1.2$

so Ag is anode. Ni is anode Ni is anode

$Ag \rightarrow Ag^+ + 1\bar{e}$ $\mathcal{E} = -0.8V$ $Ni \rightarrow 2\bar{e} + Ni^{2+}$

∴ $\Sigma\mathcal{E} = 1.2 - 0.8 = 0.4V$. $\Sigma\mathcal{E} = 0.25 + 0.8$ $\Sigma\mathcal{E} = 0.25 + 1.2$

$= 1.15V$. $= 1.45V$.

0.25 + 0.8 = 1.15

so the voltaic cell with.

Pt & Ni electrode & their solutions.

g). $Pt + 2Ag^+ \rightarrow Pt^{2+} + 2Ag$ $\mathcal{E} = -1.2 + 0.8 = -0.4V$.

the $\mathcal{E} < 0$ → nonspontaneous. → no reaction.

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6B1

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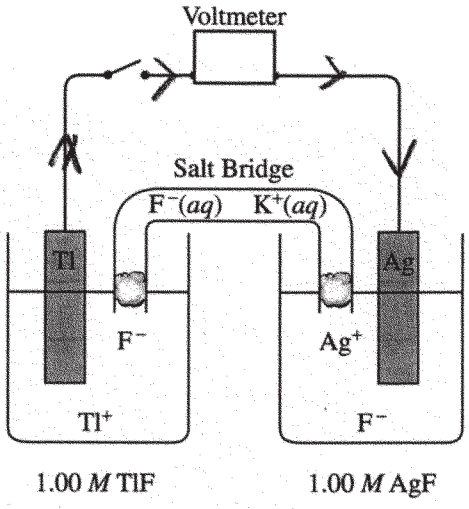
6. Answer the following questions about electrochemical cells.



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(g) Predict whether Pt metal will react when it is placed in 1.00 *M* $AgNO_3(aq)$. Justify your answer.

a. $Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$

b. $Tl_{(s)} + Ag^+_{(aq)} \rightarrow Ag_{(s)} + Tl^+_{(aq)}$

c. The Ag metal B the anode because it is attracting the positively charged silver cations. That means there

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ADDITIONAL PAGE FOR ANSWERING QUESTION 6

has to be a surplus of electrons on the piece of metal, making it negatively charged, and also the anion

e. $Ag^+ + e^- \Rightarrow Ag$ 0.80 V

$Ag + Tl = E^\circ$ $E^\circ = 1.14$

$1.14 = 0.80 + Tl$

$Tl = 0.34$ V,

1.14
−.80
0.34

however, because the reaction runs in reverse of the Ag reaction:

$Tl \rightleftharpoons Tl + e^-$

therefore, the reaction above has a value of -0.34 V

for Ni and Pt because the difference in their voltages is very high. Pt contains a V of 1.20 and Ni has one of −0.25, however in this reaction it will be 0.25 as it is the reverse of that. This gives us a voltage of 1.45V.

g. Yes, because it is higher up on the reduction Potential scale, giving it more energy, at least more than Ag. This allows Pt to remove the Ag from the NO_3 and react with the NO_3.

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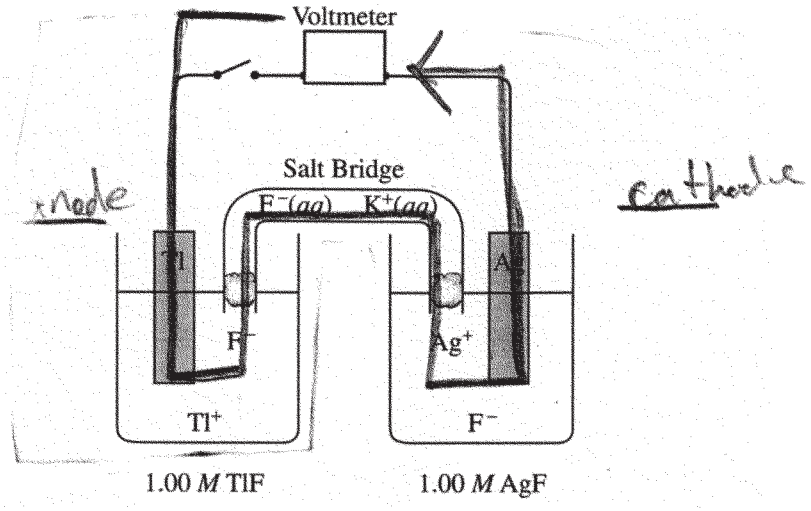

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(g) Predict whether Pt metal will react when it is placed in 1.00 *M* $AgNO_3(aq)$. Justify your answer.

a. $Ag^+ + e^- \rightarrow Ag_{(s)}$

b. $Ag^+ + Tl \rightarrow Tl^+ + Ag$

c. the anode is the thallium side, because the anode is where oxidation occurs.

d.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 6

	E°(V)
e. $Tl^+ + e^- \rightarrow Tl$	2.0
$Ag^+ + e^- \rightarrow Ag$	.80

$Ag \rightarrow Ag^+ + e^- = -.80$

$$\begin{array}{r} 1.20 \\ +\ .80 \\ \hline 2.0 \end{array}$$

g. No, nitrates are soluble, no reaction will occur because the product is soluble.

f. Pt, and Ni. They have negative E°(V) values

AP® CHEMISTRY
2009 SCORING COMMENTARY (Form B)

Question 6

Sample: 6A
Score: 9

This response earned all 9 points: 1 for part (a), 1 for part (b), 1 for part (c), 1 for part (d), 2 for part (e), 1 for part (f), and 2 for part (g).

Sample: 6B
Score: 6

This response earned 6 of the possible 9 points. In part (a) 1 point was earned for correctly writing the reduction half-reaction. In part (b) 1 point was earned for correctly writing the overall redox reaction. In part (c) the response incorrectly identifies the anode and consequently did not earn the point. In part (d) 1 point was earned for indication of the direction of electron flow consistent with the reactions given in parts (a) and (b). In part (e) 2 points were earned for the correct calculation of the reduction potential of thallium ion with the correct sign. In part (f) 1 point was earned for identifying the correct metal pair along with a reasonable justification. In part (g) neither point was earned because the response uses incorrect reasoning and makes the wrong prediction.

Sample: 6C
Score: 3

This response earned 3 of the possible 9 points. In part (a) 1 point was earned for correctly writing the reduction half-reaction. In part (b) 1 point was earned for correctly writing the overall redox reaction. In part (c) 1 point was earned for correctly identifying the anode with justification. In part (d) the point was not earned because the response shows an incorrect direction of electron flow on the diagram. In part (e) no points were earned because the calculation and answer are incorrect. In part (f) although the response identifies the correct metal pair, the justification is incorrect, and the point was not earned. In part (g) no points were earned because the explanation is incorrect.