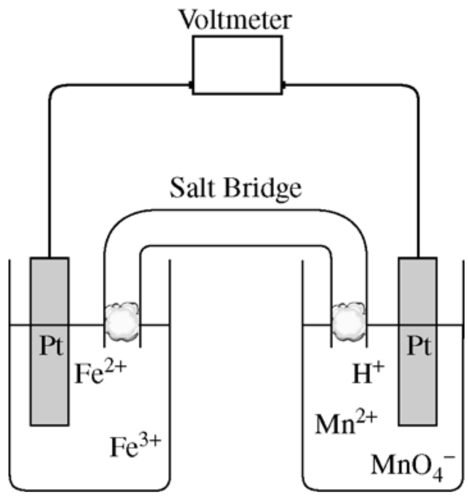
AP® CHEMISTRY
2010 SCORING GUIDELINES (Form B)

Question 2
(10 points)



$$5\ Fe^{2+}(aq) + MnO_4^{-}(aq) + 8\ H^{+}(aq) \rightarrow 5\ Fe^{3+}(aq) + Mn^{2+}(aq) + 4\ H_2O(l)$$

A galvanic cell and the balanced equation for the spontaneous cell reaction are shown above. The two reduction half-reactions for the overall reaction that occurs in the cell are shown in the table below.

Half-Reaction	$E°$ (V) at 298 K
$Fe^{3+}(aq) + e^{-} \rightarrow Fe^{2+}(aq)$	+0.77
$MnO_4^{-}(aq) + 8\ H^{+}(aq) + 5\ e^{-} \rightarrow Mn^{2+}(aq) + 4\ H_2O(l)$	+1.49

(a) On the diagram, clearly label the cathode.

The electrode in the beaker on the right should be labeled.	One point is earned for correct identification of the cathode.

(b) Calculate the value of the standard potential, $E°$, for the spontaneous cell reaction.

$E_{cell} = 1.49 - 0.77 = 0.72$ V	One point is earned for the correct numerical answer.

(c) How many moles of electrons are transferred when 1.0 mol of $MnO_4^{-}(aq)$ is consumed in the overall cell reaction?

5.0 moles of electrons are transferred.	One point is earned for the correct numerical answer.

Question 2 (continued)

(d) Calculate the value of the equilibrium constant, K_{eq} , for the cell reaction at 25°C. Explain what the magnitude of K_{eq} tells you about the extent of the reaction.

$\log K_{eq} = \frac{nE}{0.0592} = \frac{5 \times 0.72}{0.0592} = 61$ $K_{eq} = 6.5 \times 10^{60}$ Because the magnitude of K_{eq} is very large, the extent of the cell reaction is also very large and the reaction goes essentially to completion.	One point is earned for the correct substitution. One point is earned for the correct numerical answer. One point is earned for an explanation.

Three solutions, one containing $Fe^{2+}(aq)$, one containing $MnO_4^-(aq)$, and one containing $H^+(aq)$, are mixed in a beaker and allowed to react. The initial concentrations of the species in the mixture are 0.60 M $Fe^{2+}(aq)$, 0.10 M $MnO_4^-(aq)$, and 1.0 M $H^+(aq)$.

(e) When the reaction mixture has come to equilibrium, which species has the higher concentration, $Mn^{2+}(aq)$ or $MnO_4^-(aq)$? Explain.

$[Mn^{2+}(aq)]$ will be greater than $[MnO_4^-(aq)]$ because: (1) as indicated in part (d), the reaction essentially goes to completion, and (2) there is more than sufficient Fe^{2+} and H^+ to react completely with the MnO_4^-. $[MnO_4^-(aq)]$ at equilibrium is essentially zero.	One point is earned for the choice of Mn^{2+} with the explanation including only item (1). One point is earned for including item (2) in the explanation.

(f) When the reaction mixture has come to equilibrium, what are the molar concentrations of $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$?

At equilibrium, $[Fe^{2+}(aq)] = [Fe^{2+}(aq)]_{initial} - 5[MnO_4^-(aq)]_{reacted}$ $= 0.60 - 5(0.10) = 0.10\ M$ $[Fe^{3+}(aq)] = 5 \times [MnO_4^-(aq)]_{reacted}$ $= 5\,(0.10) = 0.50\ M$	One point is earned for a correct setup (including a correct setup for an equilibrium calculation). One point is earned for correct numerical answers.