Unit 5 – Chapter 16 Electrochemistry FRQ problems

Name _____

Period _____

1. In a laboratory experiment, Pb and an unknown metal Q were immersed in solutions containing aqueous ions of unknown metals Q and X. The following reactions summarize the observations.

Observation 1: $Pb_{(s)} + X^{2+}_{(aq)} \rightarrow Pb^{2+}_{(aq)} + X_{(s)}$

Observation 2: $Q_{(s)} + X^{2+}_{(aq)} \rightarrow$ no reaction

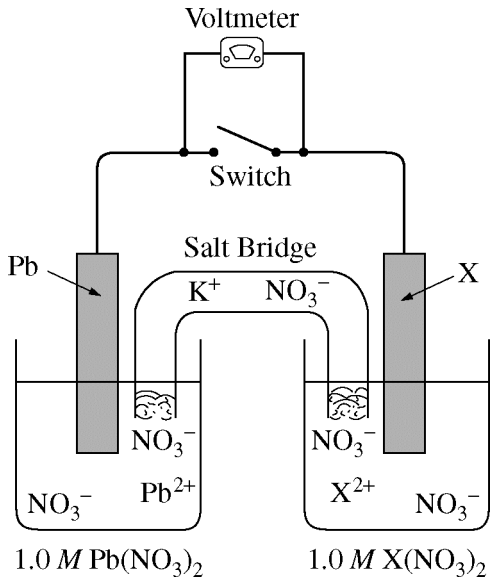
Observation 3: $Pb_{(s)} + Q^{2+}_{(aq)} \rightarrow Pb^{2+}_{(aq)} + Q_{(s)}$

(a) On the basis of the reactions indicated above, arrange the three metals, Pb, Q, and X, in order from least reactive to most reactive on the lines provided below.

_____ , _____ , _____

least reactive metal most reactive metal

The diagram below shows an electrochemical cell that is constructed with a Pb electrode immersed in 100. mL of 1.0 *M* $Pb(NO_3)_{2(aq)}$ and an electrode made of metal X immersed in 100. mL of 1.0 *M* $X(NO_3)_{2(aq)}$. A salt bridge containing saturated aqueous KNO_3 connects the anode compartment to the cathode compartment. The electrodes are connected to an external circuit containing a switch, which is open. When a voltmeter is connected to the circuit as shown, the reading on the voltmeter is 0.47 V. When the switch is closed, electrons flow through the switch from the Pb electrode toward the X electrode.



(b) Write the equation for the half-reaction that occurs at the anode.

(c) The value of the standard potential for the cell, E^0, is 0.47 V.

(i) Determine the standard reduction potential for the half-reaction that occurs at the cathode.

(ii) Determine the identity of metal X.

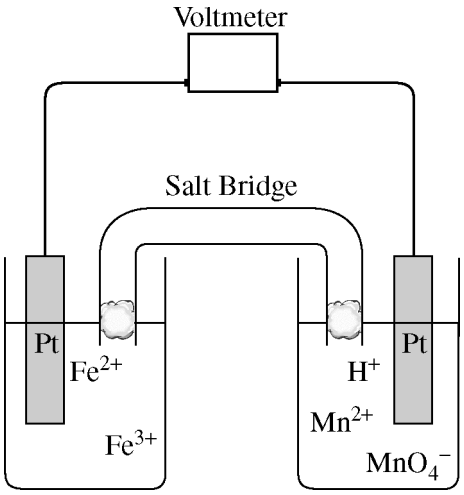
(d) Describe what happens to the mass of each electrode as the cell operates.

(e) During a laboratory session, students set up the electrochemical cell shown above. For each of the following three scenarios, choose the correct value of the cell voltage and justify your choice.

(i) A student bumps the cell setup, resulting in the salt bridge losing contact with the solution in the cathode compartment. Is V equal to 0.47 or is V equal to 0? Justify your choice.

(ii) A student spills a small amount of 0.5 *M* $Na_2SO_{4(aq)}$ into the compartment with the Pb electrode, resulting in the formation of a precipitate. Is V less than 0.47 or is V greater than 0.47? Justify your choice.

(iii) After the laboratory session is over, the student leaves the switch closed. The next day, the student opens the switch and reads the voltmeter. Is V less than 0.47 or is V equal to 0.47? Justify your choice.



$$5\ Fe^{2+}_{(aq)} + MnO_4^{-}{}_{(aq)} + 8\ H^{+}_{(aq)} \rightarrow 5\ Fe^{3+}_{(aq)} + Mn^{2+}_{(aq)} + 4\ H_2O_{(l)}$$

2. 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^0 (V) at 298 K
$Fe^{3+}_{(aq)} + e^{-} \rightarrow Fe^{2+}_{(aq)}$	+0.77
$MnO_4^{-}{}_{(aq)} + 8\ H^{+}_{(aq)} \rightarrow Mn^{2+}_{(aq)} + 4\ H_2O_{(l)}$	+1.49

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

(b) Calculate the value of the standard potential, E^0, for the spontaneous cell reaction.

(c) How many moles of electrons are transferred when 1.0 mol of $MnO_{4(aq)}^{-}$ is consumed in the overall cell reaction?

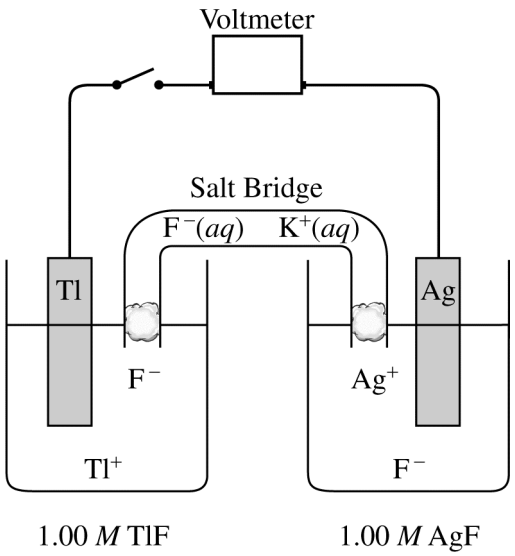
(d) Calculate the value of the equilibrium constant, K_{eq}, for the cell reaction at 25^{0}C. Explain what the magnitude of K_{eq} tells you about the extent of the reaction.

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.

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

3. 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.

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

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

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

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

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.

(g) Predict whether Pt metal will react when it is placed in 1.00 *M* $AgNO_{3(aq)}$. Justify your answer.

4. A voltaic cell consists of two half-cells. One of the half-cells contains a platinum electrode surrounded by chromium (III) and dichromate ions. The other half-cell contains a platinum electrode surrounded by bromate ions and liquid bromine. Assume that the cell reaction, which produces a positive voltage, involves both chromium (III) and bromate ions. The cell is at 25^0C. Information for the bromate reduction half reaction is as follows:

$$2\ BrO_3^-{}_{(aq)} + 12\ H^+{}_{(aq)} + 10\ e^- \rightarrow Br_{2(l)} + 6\ H_2O \qquad E^0_{red} = 1.478\ V$$

a) Write the anode half-reaction, the cathode half-reaction, and the overall equation for the cell.

b) Write the cell description in abbreviated notation.

c) Calculate E^0 for the cell.

d) For the redox reaction in a, calculate K and ΔG^0

e) Calculate the voltage of the cell when all ionic species except H+ are at 0.1500 *M* and the pH is at -0.301.

An electrolytic cell contains an aqueous solution of chromium (III) nitrate at 25^0C. Assume that chromium plates out at one electrode and oxygen gas is evolved at the other electrode.

f) Write the anode half-reaction, the cathode half-reaction, and the overall equation for the electrolysis.

g) How many hours will it take to deposit 22.00 g of chromium metal, using a current of 5.4 A?

h) A current of 3.75 A is passed through the cell for 45 minutes. Starting out with 1.25 L of 0.787 *M* $Cr(NO_3)_3$, what is the $[Cr^{3+}]$ after electrolysis? What is the pH of the solution, neglecting the H^+ originally present? Assume 100% efficiency and no change in volume during electrolysis.