Electrochemistry Practice Problems **Name** _____
AP Chemistry **Date** _____ **Block** ____

MULTIPLE CHOICE – NO CALCULATOR IS ALLOWED

$$2\ MnO_4^- + 5\ C_2O_4^{2-} + 16\ H^+ \rightarrow 2\ Mn^{2+} + 10\ CO_2 + 8\ H_2O$$

1. Which of the following statements is true concerning the reaction shown above?
   (A) Carbon is oxidized and manganese is reduced.
   (B) Manganese is oxidized and carbon is reduced.
   (C) Oxygen is oxidized and hydrogen is reduced.
   (D) Hydrogen is oxidized and oxygen is reduced.

I. $3\ Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$
II. $3\ F_2(g) + N_2(g) \rightarrow 2\ NF_3(g)$
III. $3\ H_2(g) + N_2(g) \rightarrow 2\ NH_3(g)$

2. In which of the reactions shown above does nitrogen gas get reduced?
   (A) I. only
   (B) I. and II. only
   (C) I. and III. only
   (D) II. and III. only

Half-Reaction	E^o (V)
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$	+0.34
$Ni^{2+}(aq) + 2\ e^- \rightarrow Ni(s)$	–0.28
$Zn^{2+}(aq) + 2\ e^- \rightarrow Zn(s)$	–0.76

3. A standard voltaic cell is to be constructed using two different metals. Based on the standard reduction potentials listed in the table above, which combination will produce the largest cell potential?
   (A) silver and copper
   (B) silver and zinc
   (C) nickel and copper
   (D) nickel and zinc

Half-Reaction	E^o (V)
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$	+1.06
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–0.14

4. Based on the information in the table above, which of the following reactions occurs spontaneously under standard conditions?
   (A) $Cl_2(g) + Fe(s) \rightarrow 2Cl^-(aq) + Fe^{2+}(aq)$
   (B) $Fe^{2+}(aq) + 2Br^-(aq) \rightarrow Fe(s) + Br_2(g)$
   (C) $Br_2(l) + 2Cl^-(aq) \rightarrow 2Br^-(aq) + Cl_2(g)$
   (D) $Fe^{2+}(aq) + Sn(s) \rightarrow Fe(s) + Sn^{2+}(aq)$

$$Cu(s) + 2Ag^+(aq) \rightleftharpoons Cu^{2+}(aq) + 2Ag(s)$$

5. If the equilibrium constant for the reaction above is 4×10^{15}, which of the following correctly describes the standard voltage (E^o) and the standard free energy change (ΔG^o) for this reaction?
   (A) $\Delta G^o > 0$ and $E^o < 0$
   (B) $\Delta G^o > 0$ and $E^o > 0$
   (C) $\Delta G^o < 0$ and $E^o < 0$
   (D) $\Delta G^o < 0$ and $E^o > 0$

6. In a certain experiment, molten $CaCl_2$ undergoes electrolysis, and the electrical current is 12.0 coulombs per second. Which of the following calculations is set up correctly to determine the time (in seconds) required to produce 1.00 gram of calcium?

   (A) $\frac{(2)(96485)(12.0)}{(40.08)}$

   (B) $\frac{(2)(96485)}{(40.08)(12.0)}$

   (C) $\frac{(96485)(12.0)}{(40.08)(2)}$

   (D) $\frac{(96485)}{(2)(40.08)(12.0)}$

FREE RESPONSE – CALCULATOR IS ALLOWED

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.

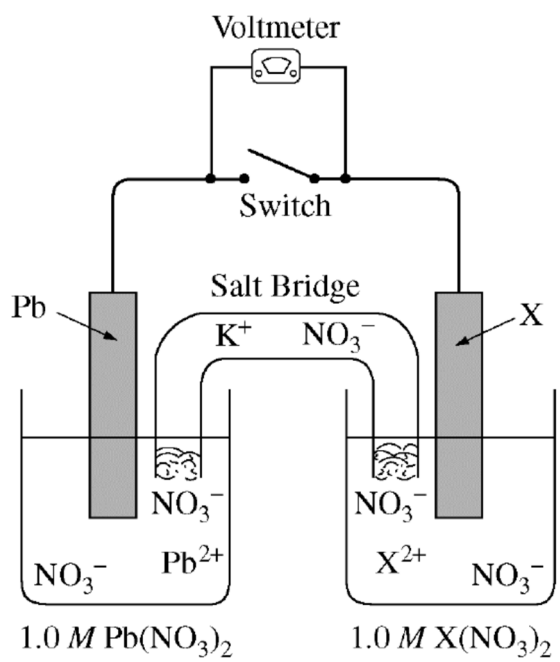
Observation 1: $Pb(s) + X^{2+}(aq) \rightarrow Pb^{2+}(aq) + X(s)$
Observation 2: $Q(s) + X^{2+}(aq) \rightarrow$ no reaction
Observation 3: $Pb(s) + Q^{2+}(aq) \rightarrow Pb^{2+}(aq) + Q(s)$

(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 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) Identify the metal that serves as the anode and the metal that serves as the cathode.

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

(d) Write the net ionic equation for the overall reaction that occurs in the cell.

(e) The value of the standard potential for the cell, E^o, is 0.47 V. Determine the standard reduction potential for the half-reaction that occurs at the cathode, and determine the identity of metal X.

Half-reaction	E^o (V)
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$	+0.34
$Pb^{2+}(aq) + 2\,e^- \rightarrow Pb(s)$	–0.13
$Sn^{2+}(aq) + 2\,e^- \rightarrow Sn(s)$	–0.14
$Cd^{2+}(aq) + 2\,e^- \rightarrow Cd(s)$	–0.40

(f) Calculate the value of ΔG^o for this cell.

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

(h) 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 the voltage equal to 0.47 or is the voltage equal to zero? 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 the voltage less than 0.47 or greater than 0.47? Justify your choice.

(iii) A student leaves the switch closed and allows the cell to run for several hours. Then the student opens the switch and checks the voltmeter. Is the voltage less than 0.47 or greater than 0.47? Justify your choice.