Name: _____ Date: _____ Period: ___ Seat #: _____

AP Chemistry **Electrochem FRQs**

WORKSHEET #9

2000

2. Answer the following questions that relate to electrochemical reactions.

(a) Under standard conditions at 25°C, $Zn(s)$ reacts with $Co^{2+}(aq)$ to produce $Co(s)$.

(i) Write the balanced equation for the oxidation half reaction.

(ii) Write the balanced net-ionic equation for the overall reaction.

(iii) Calculate the standard potential, $E°$, for the overall reaction at 25°C.

(b) At 25°C, H_2O_2 decomposes according to the following equation.

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g) \qquad E° = 0.55\ V$$

(i) Determine the value of the standard free energy change, $\Delta G°$, for the reaction at 25°C.

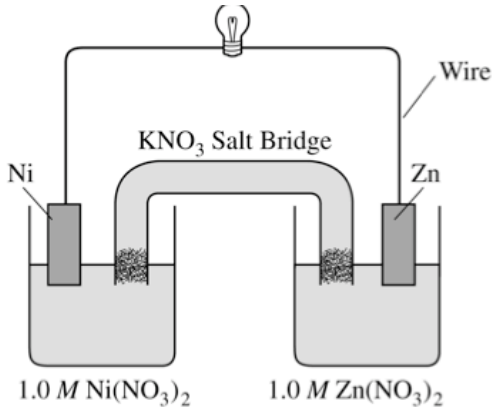
(ii) Determine the value of the equilibrium constant, K_{eq}, for the reaction at 25°C.

(iii) The standard reduction potential, $E°$, for the half reaction $O_2(g) + 4\ H^+(aq) + 4\ e^- \rightarrow 2\ H_2O(l)$ has a value of 1.23 V. Using this information in addition to the information given above, determine the value of the standard reduction potential, $E°$, for the half reaction below.

$$O_2(g) + 2\ H^+(aq) + 2\ e^- \rightarrow H_2O_2(aq)$$

(c) In an electrolytic cell, $Cu(s)$ is produced by the electrolysis of $CuSO_4(aq)$. Calculate the maximum mass of $Cu(s)$ that can be deposited by a direct current of 100. amperes passed through 5.00 L of 2.00 M $CuSO_4(aq)$ for a period of 1.00 hour.

2001



7. Answer the following questions that refer to the galvanic cell shown in the diagram above. (A table of standard reduction potentials is printed on the green insert and on page 4 of the booklet with the pink cover.)

(a) Identify the anode of the cell and write the half-reaction that occurs there.

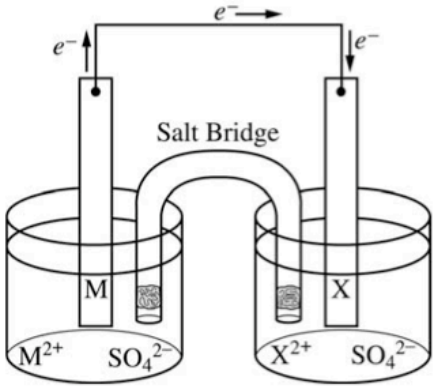
(b) Write the net ionic equation for the overall reaction that occurs as the cell operates and calculate the value of the standard cell potential, $E°_{cell}$.

(c) Indicate how the value of E_{cell} would be affected if the concentration of $Ni(NO_3)_2(aq)$ was changed from 1.0 M to 0.10 M and the concentration of $Zn(NO_3)_2(aq)$ remained at 1.0 M. Justify your answer.

(d) Specify whether the value of K_{eq} for the cell reaction is less than 1, greater than 1, or equal to 1. Justify your answer.

2002B 7. The diagram below shows the experimental setup for a typical electrochemical cell that contains two standard half-cells. The cell operates according to the reaction represented by the following equation.

$$Zn(s) + Ni^{2+}(aq) \rightarrow Ni(s) + Zn^{2+}(aq)$$



(a) Identify M and M^{2+} in the diagram and specify the initial concentration for M^{2+} in solution.

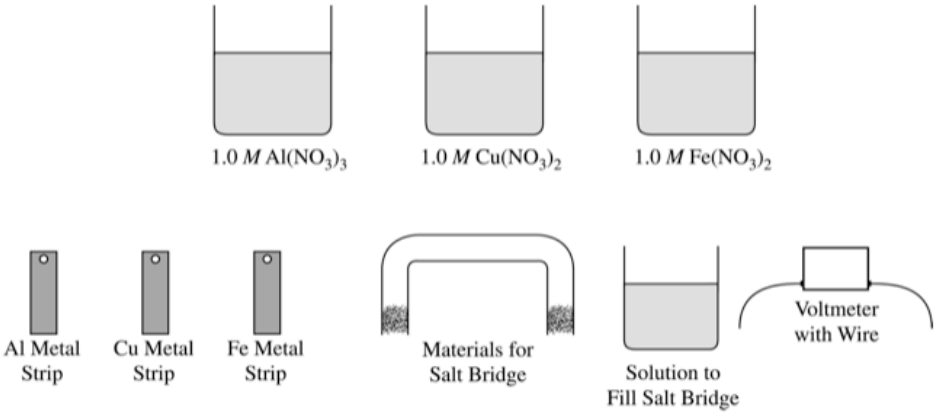
(b) Indicate which of the metal electrodes is the cathode. Write the balanced equation for the reaction that occurs in the half-cell containing the cathode.

(c) What would be the effect on the cell voltage if the concentration of Zn^{2+} was reduced to 0.100 *M* in the half-cell containing the Zn electrode?

(d) Describe what would happen to the cell voltage if the salt bridge was removed. Explain.

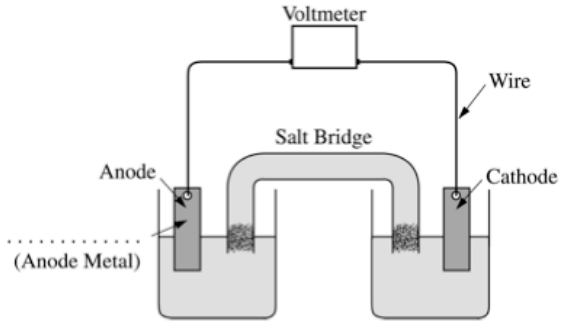
2003B 6. Answer the following questions about electrochemistry.

(a) Several different electrochemical cells can be constructed using the materials shown below. Write the balanced net-ionic equation for the reaction that occurs in the cell that would have the greatest positive value of E°_{cell}.



(b) Calculate the standard cell potential, E°_{cell}, for the reaction written in part (a).

(c) A cell is constructed based on the reaction in part (a) above. Label the metal used for the anode on the cell shown in the figure below.



2003B (cont)

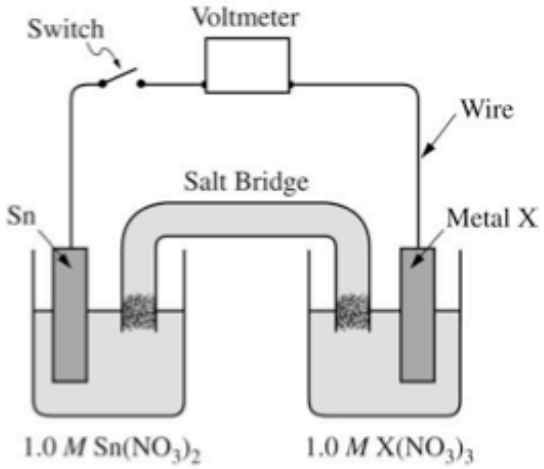
(d) Of the compounds NaOH, CuS, and $NaNO_3$, which one is appropriate to use in a salt bridge? Briefly explain your answer, and for each of the other compounds, include a reason why it is not appropriate.

(e) Another standard cell is based on the following reaction.

$$Zn + Pb^{2+} \rightarrow Zn^{2+} + Pb$$

If the concentration of Zn^{2+} is decreased from 1.0 *M* to 0.25 *M*, what effect does this have on the cell potential? Justify your answer.

2004



6. An electrochemical cell is constructed with an open switch, as shown in the diagram above. A strip of Sn and a strip of an unknown metal, X, are used as electrodes. When the switch is closed, the mass of the Sn electrode increases. The half-reactions are shown below.

$$Sn^{2+}(aq) + 2\,e^- \rightarrow Sn(s) \qquad E^\circ = -0.14\ V$$

$$X^{3+}(aq) + 3\,e^- \rightarrow X(s) \qquad E^\circ = ?$$

(a) In the diagram above, label the electrode that is the cathode. Justify your answer.

(b) In the diagram above, draw an arrow indicating the direction of the electron flow in the external circuit when the switch is closed.

(c) If the standard cell potential, E°_{cell}, is +0.60 V, what is the standard reduction potential, in volts, for the X^{3+}/X electrode?

(d) Identify metal X.

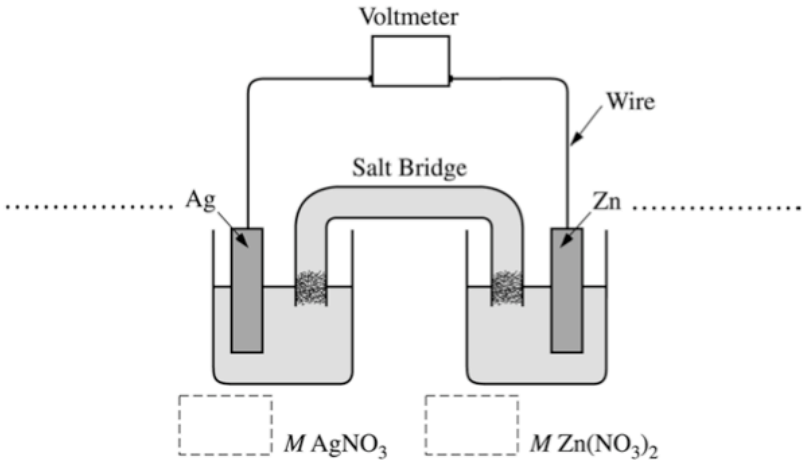
(e) Write a balanced net-ionic equation for the overall chemical reaction occurring in the cell.

(f) In the cell, the concentration of Sn^{2+} is changed from 1.0 *M* to 0.50 *M*, and the concentration of X^{3+} is changed from 1.0 *M* to 0.10 *M*.

(i) Substitute all the appropriate values for determining the cell potential, E_{cell}, into the Nernst equation. (Do not do any calculations.)

(ii) On the basis of your response in part (f) (i), will the cell potential, E_{cell}, be greater than, less than, or equal to the original E°_{cell}? Justify your answer.

2004B



6. The following questions refer to the electrochemical cell shown in the diagram above.

(a) Write a balanced net ionic equation for the spontaneous reaction that takes place in the cell.

(b) Calculate the standard cell potential, $E°$, for the reaction in part (a).

(c) In the diagram above,

(i) label the anode and the cathode on the dotted lines provided, and

(ii) indicate, in the boxes below the half-cells, the concentration of $AgNO_3$ and the concentration of $Zn(NO_3)_2$ that are needed to generate $E°$.

(d) How will the cell potential be affected if KI is added to the silver half-cell? Justify your answer.

2005

$$AgNO_3(s) \rightarrow Ag^+(aq) + NO_3^-(aq)$$

8. The dissolving of $AgNO_3(s)$ in pure water is represented by the equation above.

(a) Is ΔG for the dissolving of $AgNO_3(s)$ positive, negative, or zero? Justify your answer.

(b) Is ΔS for the dissolving of $AgNO_3(s)$ positive, negative, or zero? Justify your answer.

(c) The solubility of $AgNO_3(s)$ increases with increasing temperature.

(i) What is the sign of ΔH for the dissolving process? Justify your answer.

(ii) Is the answer you gave in part (a) consistent with your answers to parts (b) and (c) (i) ? Explain.

The compound NaI dissolves in pure water according to the equation $NaI(s) \rightarrow Na^+(aq) + I^-(aq)$. Some of the information in the table of standard reduction potentials given below may be useful in answering the questions that follow.

Half-reaction	$E°$ (V)
$O_2(g) + 4\,H^+ + 4\,e^- \rightarrow 2\,H_2O(l)$	1.23
$I_2(s) + 2\,e^- \rightarrow 2\,I^-$	0.53
$2\,H_2O(l) + 2\,e^- \rightarrow H_2(g) + 2\,OH^-$	−0.83
$Na^+ + e^- \rightarrow Na(s)$	−2.71

(d) An electric current is applied to a 1.0 M NaI solution.

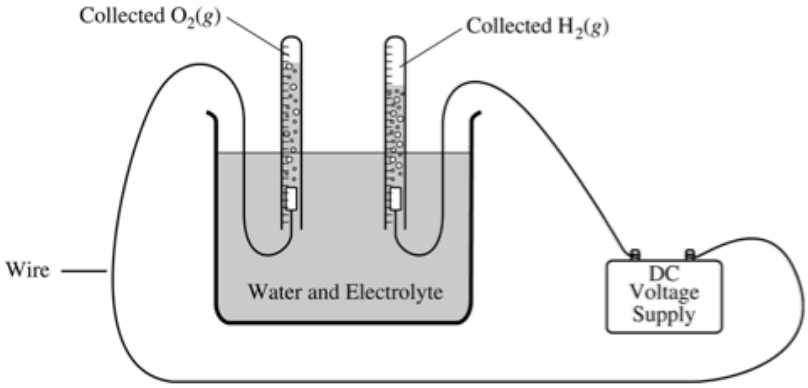
(i) Write the balanced oxidation half-reaction for the reaction that takes place.

(ii) Write the balanced reduction half-reaction for the reaction that takes place.

(iii) Which reaction takes place at the anode, the oxidation reaction or the reduction reaction?

(iv) All electrolysis reactions have the same sign for $\Delta G°$. Is the sign positive or negative? Justify your answer.

2005B



2. Water was electrolyzed, as shown in the diagram above, for 5.61 minutes using a constant current of 0.513 ampere. A small amount of nonreactive electrolyte was added to the container before the electrolysis began. The temperature was 298 K and the atmospheric pressure was 1.00 atm.

   (a) Write the balanced equation for the half reaction that took place at the anode.

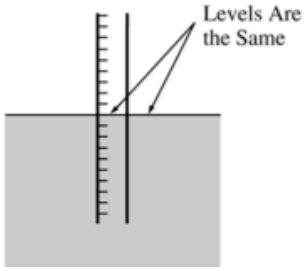
   (b) Calculate the amount of electric charge, in coulombs, that passed through the solution.

   (c) Why is the volume of $O_2(g)$ collected different from the volume of $H_2(g)$ collected, as shown in the diagram?

   (d) Calculate the number of moles of $H_2(g)$ produced during the electrolysis.

   (e) Calculate the volume, in liters, at 298 K and 1.00 atm of dry $H_2(g)$ produced during the electrolysis.

   (f) After the hydrolysis reaction was over, the vertical position of the tube containing the collected $H_2(g)$ was adjusted until the water levels inside and outside the tube were the same, as shown in the diagram below. The volume of gas in the tube was measured under these conditions of 298 K and 1.00 atm, and its volume was greater than the volume calculated in part (e). Explain.



2006B

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.

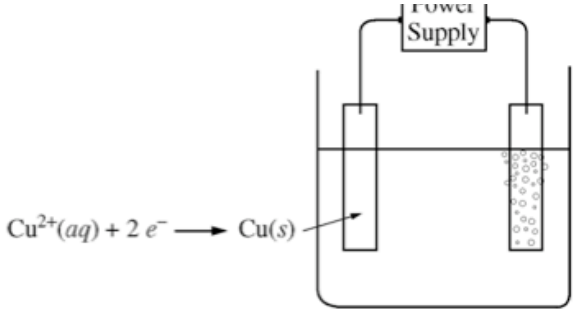
      (ii) Determine the value, in volts, of the standard potential, $E°$, for the spontaneous cell reaction.

      (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.

2007



3. An external direct-current power supply is connected to two platinum electrodes immersed in a beaker containing 1.0 M $CuSO_4(aq)$ at 25°C, as shown in the diagram above. As the cell operates, copper metal is deposited onto one electrode and $O_2(g)$ is produced at the other electrode. The two reduction half-reactions for the overall reaction that occurs in the cell are shown in the table below.

Half-Reaction	$E°$(V)
$O_2(g) + 4\,H^+(aq) + 4\,e^- \rightarrow 2\,H_2O(l)$	+1.23
$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$	+0.34

(a) On the diagram, indicate the direction of electron flow in the wire.

(b) Write a balanced net ionic equation for the electrolysis reaction that occurs in the cell.

(c) Predict the algebraic sign of $\Delta G°$ for the reaction. Justify your prediction.

(d) Calculate the value of $\Delta G°$ for the reaction.

An electric current of 1.50 amps passes through the cell for 40.0 minutes.

(e) Calculate the mass, in grams, of the $Cu(s)$ that is deposited on the electrode.

(f) Calculate the dry volume, in liters measured at 25°C and 1.16 atm, of the $O_2(g)$ that is produced.

2007B

$$2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(l)$$

. In a hydrogen-oxygen fuel cell, energy is produced by the overall reaction represented above.

(a) When the fuel cell operates at 25°C and 1.00 atm for 78.0 minutes, 0.0746 mol of $O_2(g)$ is consumed. Calculate the volume of $H_2(g)$ consumed during the same time period. Express your answer in liters measured at 25°C and 1.00 atm.

(b) Given that the fuel cell reaction takes place in an acidic medium,

(i) write the two half reactions that occur as the cell operates,

(ii) identify the half reaction that takes place at the cathode, and

(iii) determine the value of the standard potential, $E°$, of the cell.

(c) Calculate the charge, in coulombs, that passes through the cell during the 78.0 minutes of operation as described in part (a).

2008

3. Answer the following questions related to chemical reactions involving nitrogen monoxide, $NO(g)$.

The reaction between solid copper and nitric acid to form copper(II) ion, nitrogen monoxide gas, and water is represented by the following equation.

$$3\ Cu(s) + 2\ NO_3^-(aq) + 8\ H^+(aq) \rightarrow 3\ Cu^{2+}(aq) + 2\ NO(g) + 4\ H_2O(l) \qquad E^\circ = +0.62\ V$$

(a) Using the information above and in the table below, calculate the standard reduction potential, E°, for the reduction of NO_3^- in acidic solution.

Half-Reaction	Standard Reduction Potential, E°
$Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$	+0.34 V
$NO_3^-(aq) + 4\ H^+(aq) + 3\ e^- \rightarrow NO(g) + 2\ H_2O(l)$	?

(b) Calculate the value of the standard free energy change, ΔG°, for the overall reaction between solid copper and nitric acid.

(c) Predict whether the value of the standard entropy change, ΔS°, for the overall reaction is greater than 0, less than 0, or equal to 0. Justify your prediction.

Nitrogen monoxide gas, a product of the reaction above, can react with oxygen to produce nitrogen dioxide gas, as represented below.

$$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$$

A rate study of the reaction yielded the data recorded in the table below.

Experiment	Initial Concentration of NO (mol L^{-1})	Initial Concentration of O_2 (mol L^{-1})	Initial Rate of Formation of NO_2 (mol L^{-1} s^{-1})
1	0.0200	0.0300	8.52×10^{-2}
2	0.0200	0.0900	2.56×10^{-1}
3	0.0600	0.0300	7.67×10^{-1}

(d) Determine the order of the reaction with respect to each of the following reactants. Give details of your reasoning, clearly explaining or showing how you arrived at your answers.

(i) NO

(ii) O_2

(e) Write the expression for the rate law for the reaction as determined from the experimental data.

(f) Determine the value of the rate constant for the reaction, clearly indicating the units.