Directions: Answer each of the following problems. Record your responses on the **Team Answer Sheet.** Each problem or part thereof is worth 3 points unless otherwise noted.

You are provided with the following materials:

- Lemon in a petri dish with two slices in its peel
- A pencil, sharpened on both ends, exposing its carbon (graphite) core
- An iron nail (or other sample of iron metal)
- A magnesium strip
- A zinc strip
- Voltmeter (or equivalent instrument for measuring voltage)
- Alligator clips to connect the voltmeter probes to electrodes
- Optional - piece of steel wool or sandpaper to clean the metal electrodes

1. Place a combination of pencil, iron, magnesium, and zinc electrodes in different combinations into the slits in the lemon and use the voltmeter to measure the voltage of each combination. Organize your data in a table on your answer sheet.

   Use your data to answer the following questions:

2. When C is paired with Fe, write the half reaction that occurs at the cathode.
3. When C is paired with Fe, write the half reaction that occurs at the anode.
4. When Zn is paired with Fe, write the half reaction that occurs at the cathode.
5. When Zn is paired with Fe, write the half reaction that occurs at the anode.
6. Rank the 3 metals according to chemical activity from highest to lowest. (A high voltage when paired with the carbon electrode indicates high chemical activity)
7. Using zinc and copper electrodes of high purity in an especially ripe lemon at room temperature produces 0.9 V and 0.3 mA (milliamperes). Considering that the power of a voltaic cell is measured in Watts, which is calculated by multiplying volts x amps, what is the power of this voltaic cell?
8. A low power LED (Light Emitting Diode) requires 80 mW to properly work. How many lemon zinc-copper lemon cells described in problem #7 would be needed to be connected in series to power this LED? (Round your answer off to the nearest whole number)

For problems 9 - 11 , complete and balance each half reaction. In each case, indicate whether oxidation or reduction occurs.

9. $Co^{2+}_{(aq)} \rightarrow Co^{3+}_{(aq)}$

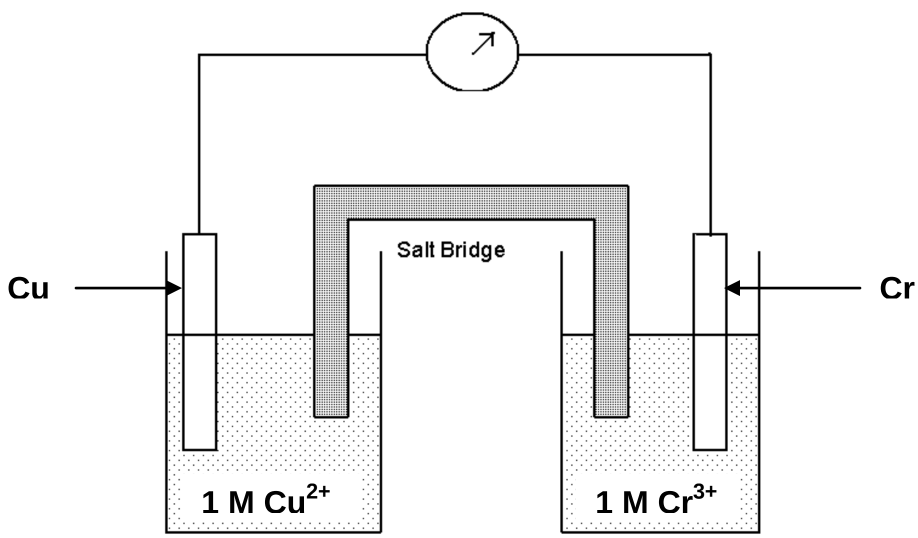
10. $ClO_3^-{}_{(aq)} \rightarrow Cl^-{}_{(aq)}$ (acidic solution)

11. $SO_3^{2-}{}_{(aq)} \rightarrow SO_4^{2-}{}_{(aq)}$ (basic solution)

For problem #12, complete and balance the redox reaction.

12. $Pb(OH)_4^{2-}{}_{(aq)} + ClO^-{}_{(aq)} \rightarrow PbO_{2(s)} + Cl^-{}_{(aq)}$ (basic solution)

Use the table of Standard Electrode Potentials to answer the following questions on the Galvanic Cell (Problems 13-22 are worth 2 pts. each):



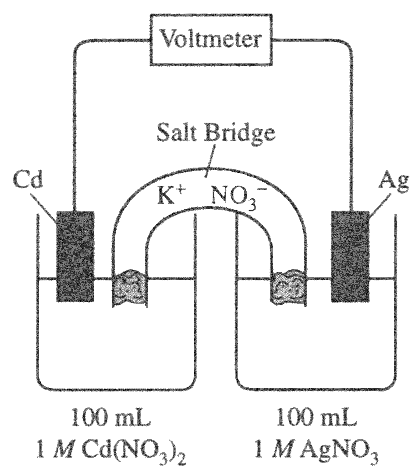
13. Write the oxidation half reaction for this cell.
14. Write the reduction half reaction for this cell.
15. Write the net ionic reaction for this cell.
16. Identify the substance being oxidized
17. Identify the substance being reduced.
18. Identify the oxidizing agent.
19. Identify the reducing agent.
20. On your answer sheet, place an arrow over the voltmeter to indicate the direction of electron flow.
21. Which electrode is gaining in mass?
22. What is the E^o for this cell?

23. A battery consists of one or more voltaic cells. One of the most common and useful batteries is the lead storage battery, also known as a car battery. It consists of six cells, each producing 2 V. The electrode reactions that occur during discharge are as follows:

Cathode: $PbO_{2(s)} + SO_4^{2-}{}_{(aq)} + 4H^+{}_{(aq)} + 2\ e^- \rightarrow PbSO_{4(s)} + 2\ H_2O_{(l)}$
Anode: $Pb_{(s)} + SO_4^{2-}{}_{(aq)} \rightarrow PbSO_{4(s)} + 2\ e^-$

(a) Write a complete, balanced equation for the reaction that occurs within a lead storage battery.
(b) Write the balanced oxidation half reaction.
(c) Write the balanced reduction half reaction.
(d) Based upon the oxidation and reduction half reactions, write the balanced redox reaction.
(e) What is the total voltage of a lead storage battery?
(f) One advantage of a lead storage battery is that it can be recharged. Write the complete, balanced equation for the reaction that occurs while a lead storage battery is being recharged.
(g) Old or defective car batteries may leak fluid which is very dangerous to touch. Identify this liquid.

For problem 24, answer the following questions regarding the electrochemical cell shown.



(a) Write the balanced net-ionic equation for the spontaneous reaction that occurs as the cell operates.
(b) If the cell voltage is +1.20 V, what is the E° for the oxidation of Cd?
(c) In which direction do anions flow in the salt bridge as the cell operates?
(d) If 10.0 mL of 3.0-molar $AgNO_3$ solution is added to the half-cell on the right, what will happen to the cell voltage?
(e) If 1.0 gram of solid NaCl is added to each half-cell, what will happen to the cell voltage?

<u>Station 1 Multiple Choice</u>: Record the letter of the best answer on your answer sheet.

25. How many moles of electrons are required to reduce 1.0 mole of BrO^- in this reaction?

$$BrO^- + H_2O \rightarrow Br^- + 2OH^-$$

(A) 1
(B) 2
(C) 3
(D) 4
(E) 0

26. What is the oxidation number of chromium in $Cr_2O_7^{2-}$?

(A) +3
(B) +4
(C) +5
(D) +6
(E) +7

27. Which half–cell reaction correctly represents reduction?

(A) $Sn^{4+} \rightarrow Sn^{2+} + 2e^-$
(B) $Sn^{2+} \rightarrow Sn^{4+} + 2e^-$
(C) $Sn^{4+} + 2e^- \rightarrow Sn^{2+}$
(D) $Sn^{2+} + 2e^- \rightarrow Sn^{4+}$
(E) $Sn^{4+} + Sn^{2+} \rightarrow Sn^{6+} + 2e^-$

28. The function of the salt bridge in an electrochemical cell is to

(A) increase the cell voltage
(B) maintain electrical neutrality
(C) increase the oxidation–reduction rate
(D) supply a travel pathway for electrons
(E) increase the rate of attainment of equilibrium

29. What are the anode and cathode reactions during the electrolysis of fused KBr?

(A) Anode: $2\,H_2O \rightarrow O_2 + 4\,H^+ + 4e^-$
Cathode: $4\,K^+ + 4e^- \rightarrow 4\,K$
(B) Anode: $2\,Br^- \rightarrow Br_2 + 2e^-$
Cathode: $2\,H_2O + 2e^- \rightarrow H_2 + 2\,OH^-$
(C) Anode: $Br_2 + 2e^- \rightarrow 2\,Br^-$
Cathode: $2\,K \rightarrow 2\,K^+ + 2e^-$
(D) Anode: $2\,H_2O \rightarrow O_2 + 4\,H^+ + 4e^-$
Cathode: $4\,H_2O + 4e^- \rightarrow 2\,H_2 + 4\,OH^-$
(E) Anode: $2\,Br^- \rightarrow Br_2 + 2e^-$
Cathode: $2\,K^+ + 2e^- \rightarrow 2\,K$

30. Base your answer on the table below.

STANDARD ELECTRODE POTENTIALS
Ion Concentrations 1.0 M H_2O at 298 K, 1 atm

Half–Reaction	$E°$, volts
$Fe^{3+} + 3e- \rightarrow Fe(s)$	–0.036
$Cd^{2+} + 2e- \rightarrow Cd(s)$	–0.40

According to these data, which reaction takes place?

(A) $2\,Fe^{3+} + 3\,Cd \rightarrow 2\,Fe + 3\,Cd^{2+}$
(B) $2\,Fe + 3\,Cd^{2+} \rightarrow 2\,Fe^{3+} + 3\,Cd$
(C) $2\,Fe + 3\,Cd \rightarrow 2\,Fe^{3+} + 3\,Cd^{2+}$
(D) $2\,Fe^{3+} + 3\,Cd^{2+} \rightarrow 2\,Fe + 3\,Cd$
(E) $2\,Fe^{3+} + 3\,Cd^{2+} \rightarrow Fe_2Cd_3 + 12e^-$

31. Which is correctly balanced?

(A) $Ag + 2\,HNO_3 \rightarrow AgNO_3 + NO + H_2O$
(B) $Ag + 4\,HNO_3 \rightarrow AgNO_3 + 7\,NO + 2H_2O$
(C) $3\,Ag + 4\,HNO_3 \rightarrow 3\,AgNO_3 + NO + 2\,H_2O$
(D) $Ag + 2\,HNO_3 \rightarrow AgNO_3 + NO + 2\,H_2O$
(E) $3\,Ag + 4\,HNO_3 \rightarrow 3\,AgNO_3 + NO + 2\,H_2O + 3e^-$

32. Which is true?

I. Aluminum is a better reducing agent than copper.
II. Potassium is a reducing agent, iodine is an oxidizing agent.
III. Copper (II) ion is a better oxidizing agent than hydrogen ion.

(A) I, II, and III
(B) I and II only
(C) I and III only
(D) II and III only
(E) III only