# Technical Problem Solving

# Test Booklet

April 5th, 2014

State Tournament

University of Wisconsin - Stout

## Part 1: Electrochemistry

### EXPERIMENTAL

1. You will be electroplating zinc from a 0.1 M solution of zinc nitrate onto a copper electrode. Set up your plating cell as shown in **Figure 1** and operate it for 3 minutes (180 seconds).


**Figure 1: Electroplating Setup**

**Instructions:**

a. Start by opening **ScienceOlympaid.cmbl** on the desktop of the computer. Your data collection time should be automatically set to 180 seconds**.**
b. Pour approximately 20 mL of 0.1 M Zinc Nitrate solution into the 30 mL beaker (your plating cell)
c. Place your copper and zinc electrodes into the plating cell
d. Attach the positive (red) lead to the zinc electrode
e. Click the “Collect” button to begin collecting voltage and amperage
f. Attach the negative (black) lead to the copper electrode data.
g. Allow the plating reaction to proceed for 180 seconds and observe the changes that occur at the copper electrode surface.
h. After 180 seconds click the “Stop” button and disconnect the leads from the electroplating cell.
**i. Record the amperage that you observed during your plating experiment on your answer sheet.**
**j. Calculate the number of Coulombs of charge that passed through the cell and record on your answer sheet.**
**k. Calculate the theoretical number of moles of zinc atoms that should have plated onto the copper strip and record on your answer sheet.**
**l. Calculate the theoretical mass of the zinc that plated onto the copper strip and record on your answer sheet.**
**m. Write the oxidation and reduction half reactions on your answer sheet.**
**n. Record which electrode is the anode and which one is the cathode (copper or zinc).**
**o.** After recording your data, close the program and **DO NOT save** the file.
p. Disassemble the plating cell, place your used solutions and electrodes into the appropriate beakers.
q. Rinse your plating cell, dry and replace in the same configuration you found it.

<u>NOTE: Up to a 10% deduction will be taken off your points for this station if you do not clean up in the time allowed!</u>

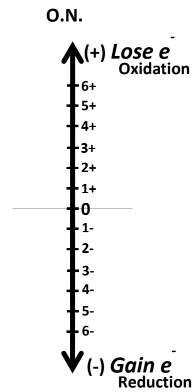
## QUESTIONS

2. A plating cell similar to the one you used is operated at **1.5 volts and 0.5 amps**. The copper and zinc electrodes are 1 cm wide, have negligible thickness, and are submerged to a depth of 3 cm. Assuming that the total submerged area (front and back) plates evenly, **how long would it take to deposit a 0.1 mm thick film of zinc under these conditions?** The density of zinc is **7.14 g/cm$^3$**. **Record the submerged electrode area, mass of zinc plated, and the deposition time on your answer sheet.**

3. Iron ore is smelted to produce Iron metal according to the following reaction. **What is the oxidation number (O.N.) of each atom present, which atom is oxidized, which atom is reduced, and what are the half reactions?** Record the answer on your answer sheet.

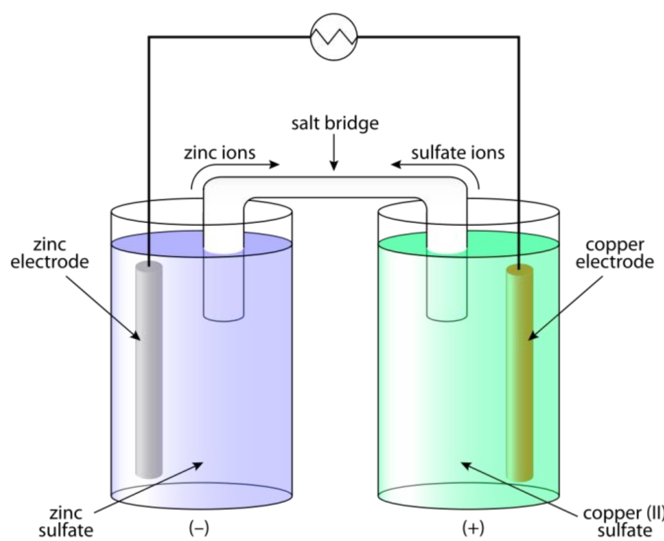
$$Fe_2O_3(s) + 3\,CO(g) \rightarrow 2\,Fe(\ell) + 3\,CO_2(g)$$

| Reactants | | Products | |
|---|---|---|---|
| Atom | O.N. | Atom | O.N. |
| Fe in $Fe_2O_3(s)$ | | Fe in $Fe(\ell)$ | |
| O in $Fe_2O_3(s)$ | | O in $CO_2(g)$ | |
| C in $CO(g)$ | | C in $CO_2(g)$ | |
| O in $CO(g)$ | | O in $CO_2(g)$ | |




DO NOT WRITE ON THIS FORM, PLACE ALL ANSWERS ON ANSWER SHEET!

4. A Daniel cell is a type of Galvanic cell constructed from a zinc electrode, zinc sulfate solution, salt bridge, copper sulfate solution and copper electrode as shown in the figure to the right:



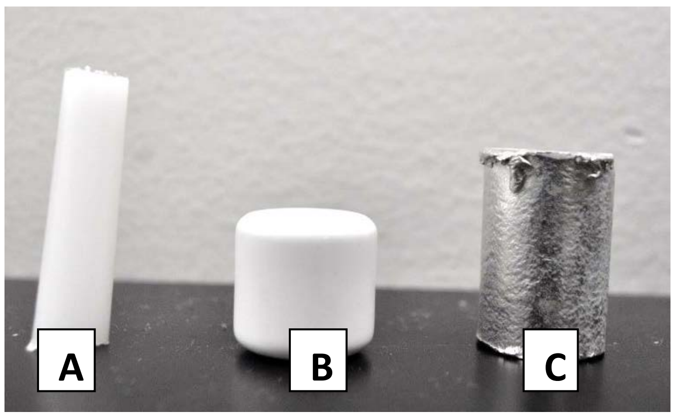

**What is the standard voltage of the cell, which electrode is the anode and which electrode is the cathode, and what direction are the electrons flowing (zinc to copper OR copper to zinc)?**

5. Calculate the nonstandard voltage of the Daniel cell using the Nernst equation under the following conditions: 1.00 x $10^{-4}$ M zinc sulfate and 1.00 M copper sulfate at 25°C (298 K). **Record answer on your answer sheet.**

**Part 2: Heat and Thermodynamics**

**EXPERIMENTAL**

The goal is to measure the specific heat capacity of three samples and determine the chemical identity of the sample. The samples are pictured below.




6. **SAMPLE A**: The specific heat of water is 4.184 J/(g · °C). Assume that no heat is lost in the calorimeter or during the process of transferring the sample to the calorimeter.
Measure the heat capacity of the unknown samples and identify them based on the attached data table at the end of this packet.

   **Make sure you don't let your water bath boil dry! If it gets low, add more water and wait for the temperature to stabilize again.**

**Instructions:**

a. Record the mass of each sample.
b. Place samples in boiling water and wait long enough for sample temperature to equilibrate with the water bath.
c. Place temperature probe in the hot water bath.
d. Add 50.0 mL of water to the nested Styrofoam calorimeter.
e. Place cardboard cover on top and place second temperature probe in the calorimeter.
f. Set the data collection time to 500 seconds
g. Start collecting data by pressing the "Start" button
h. Remove one of the samples from the hot water bath and place into the calorimeter

i. Replace the cardboard lid and thermocouple and gently stir the contents of the calorimeter with the temperature probe.
j. Wait for the temperature inside to equilibrate
k. Stop the data collection, and record the initial sample temperature (hot water bath temperature just before addition), the initial calorimeter temperature, and the final calorimeter temperature.
**l. Calculate the change in temperature for the sample and the calorimeter and record on your answer sheet.**
**m. Calculate the heat gained by the calorimeter (the calorimeter constant is 247.3 J/°C) and the heat lost by the sample and record on your answer sheet.**
**n. Calculate the specific heat capacity of the sample and record on your answer sheet**
**o. Use the attached table to identify your unknown and record on your answer sheet.**
p. Empty and dry your calorimeter cups, return samples to their original position, clean up lab station.

<u>NOTE: Up to a 10% deduction will be taken off your points for this station if you do not clean up in the time allowed!</u>

7. Repeat the above process for **SAMPLE B**

8. Repeat the above process for **SAMPLE C**

**QUESTIONS**

9. A 20.0 g sample initially at 100°C is placed into a Styrofoam cup containing 50.0 g of water initially at 20 °C. The final temperature of the sample and water is 26.3°C. For this calculation, assume that heat transfer to the cup and thermometer is negligible and all heat released from the sample is absorbed by the water only. **What is the heat capacity of the sample and what is it's likely identity based on the attached data table?** Record answer on your answer sheet.

10. A 1000 g sample of water is placed into liquid nitrogen (at -196°C ) and flash frozen. The ice sample is removed and placed into a calorimeter pressure chamber. **How much heat must be absorbed by the sample to produce 1000 g of steam at 300 °C?** Record answer on your answer sheet.

| Properties of Water | |
|---|---|
| $C_{H_2O(g)}$ | 1.841 J/(g·K) |
| $\Delta_{vap}H°_{H_2O}$ | 2258 J/g |
| $C_{H_2O(\ell)}$ | 4.184 J/(g·K) |
| $\Delta_{fus}H°_{H_2O}$ | 333.5 J/g |
| $C_{H_2O(s)}$ | 2.092 J/(g·K) |

11. A private investigator needs to know approximately how long a car has been sitting in front of a residence. It is **2:00 AM** on an October night in Madison, WI and the temperature is 50 °F with no wind. The thermostat of a car engine keeps the engine block between 180 and 210 degrees Fahrenheit during operation. Using and infrared thermometer, the temperature of the engine block was measured and found to be **150.00°F**. Ten minutes later the temperature was measured again and found to be **138.35°F**. **Calculate the cooling constant and record on your answer sheet.** Assuming that the engine block temperature of the car started at the center of the normal operating range (195°F), **how long before the first measurement was the car presumably turned off, and what was the time the car was turned off?** Record answers on your answer sheet.

12. An iron cube with a mass of 50.0 g has an initial temperature of 20°C, which is the room temperature for the lab. 5000 J of heat energy is added to the cube with a Bunsen burner and then the heat is removed. **Record the temperature of the cube after heating on your answer sheet.** After 10 minutes, the temperature of the block is measured and found to be 200°C. **How long will it take for the temperature of the iron cube to decrease to 100°C?** Record answers on your answer sheet.

| Properties of Iron | |
|---|---|
| Melting Point | 1538 °C |
| Heat of Fusion | 267 J/g |
| Specific Heat Capacity of Fe(s) | 0.449 J/(g·K) |
| Specific Heat Capacity of Fe(ℓ) | 0.611 J/(g·K) |

13. Match each of the four situations below with the letter of the *most significant* form of heat transfer. Record all answers on the answer sheet.
    A. Convection
    B. Radiation
    C. Conduction

    Using a microwave oven to warm up leftovers: _________
    Cooling a house with central air conditioning: _________
    Frying a fish in a skillet: _________

14. Of these heat transfer methods, which does not require a medium to transfer energy?

15. Match the situation below with the *most suitable* type of system
    A. Closed (energy transfer)
    B. Open (mass and energy transfer)
    C. Isolated (no mass or energy transfer)

    An ocean : _________
    A coffee thermos : _________
    A greenhouse : _________

**DO NOT MARK ON THIS QUESTION BOOKLET**

**CONSTANTS**

F=96,500 C/mol= 96,500 J/(V·mol)

R = 8.314 J/(K·mol)

**EQUATIONS AND TABLES**

$$\text{Mass deposited at an electrode} = \frac{I \times t \times (MM)}{96{,}500 \times \text{n}}$$

$$\text{aA} + \text{bB} \rightarrow \text{cC} + \text{dD}$$

$$\text{E} = \text{E}^\circ - \frac{\text{R}\cdot\text{T}}{\text{n}\cdot\text{F}} \cdot \ln\left(\frac{[\text{C}]^\text{c} \cdot [\text{D}]^\text{d}}{[\text{A}]^\text{a} \cdot [\text{B}]^\text{b}}\right)$$

$$\text{E} = \text{E}^\circ - \frac{0.0592}{\text{n}} \cdot \log\left(\frac{[\text{C}]^\text{c} \cdot [\text{D}]^\text{d}}{[\text{A}]^\text{a} \cdot [\text{B}]^\text{b}}\right)$$

$q = C \cdot m \cdot \Delta T$

$q_{trs} = \Delta H \cdot m$

$$T(^\circ C) = \left[T(^\circ F) - 32^\circ F\right] \times \frac{5(^\circ C)}{9(^\circ F)}$$

$$T(^\circ F) = \left[T(^\circ C) \times \frac{9(^\circ F)}{5(^\circ C)}\right] + 32^\circ F$$

$$T(K) = \left[T(^\circ C) + 273.15(^\circ C)\right] \times \frac{1(K)}{1(^\circ C)}$$

$$T(^\circ C) = \left[T(K) - 273.15(K)\right] \times \frac{1(^\circ C)}{1(K)}$$

$$Temp2 = Ambient + (Temp1 - Ambient)e^{-k(time2 - time1)}$$

$$k = \frac{-ln\left(\frac{Temp2 - Ambient}{Temp1 - Ambient}\right)}{(time2 - time1)}$$

$$InitialTime = -\frac{1}{k} ln\left(\frac{InitialTemp - Ambient}{FinalTemp - Ambient}\right)$$

| Material | Heat Capacity |
|---|---|
| | J/(g·K) |
| | |
| Uranium | 0.116 |
| Bismuth | 0.123 |
| Gold | 0.129 |
| Lead | 0.129 |
| Tungsten | 0.134 |
| Mercury | 0.140 |
| Antimony | 0.207 |
| Tin | 0.227 |
| Cadmium | 0.231 |
| Silver | 0.233 |
| Arsenic | 0.328 |
| Copper | 0.385 |
| Zinc | 0.387 |
| Chromium | 0.449 |
| Iron | 0.450 |
| Steel | 0.466 |
| Glass, flint | 0.503 |
| Diamond | 0.509 |
| Titanium | 0.523 |
| Glass, crown | 0.670 |
| Silica (fused) | 0.703 |
| Graphite | 0.710 |
| Glass, pyrex | 0.753 |
| Granite | 0.790 |
| Sand | 0.835 |
| Brick | 0.840 |
| Glass, silica | 0.840 |
| Concrete | 0.880 |
| Marble | 0.880 |
| Aluminium | 0.897 |
| Asphalt | 0.920 |
| Magnesium | 1.020 |
| Gypsum | 1.090 |
| Polyester (PET) | 1.172 |
| Sodium | 1.230 |
| Plexiglas (PMMA) | 1.376 |
| Beryllium | 1.820 |
| Polyethylene (PE) | 2.303 |
| Lithium | 3.580 |

**DO NOT MARK ON THIS QUESTION BOOKLET**

## Standard Electrode Potentials in Aqueous Solution at 25°C

| **Cathode (Reduction) Half-Reaction** | **Standard Potential $E^{\circ}$ (volts)** |
|---|---|
| $Li^{+}(aq) + e^{-} \leftrightarrow Li(s)$ | -3.04 |
| $K^{+}(aq) + e^{-} \leftrightarrow K(s)$ | -2.92 |
| $Ca^{2+}(aq) + 2e^{-} \leftrightarrow Ca(s)$ | -2.76 |
| $Na^{+}(aq) + e^{-} \leftrightarrow Na(s)$ | -2.71 |
| $Mg^{2+}(aq) + 2e^{-} \leftrightarrow Mg(s)$ | -2.38 |
| $Al^{3+}(aq) + 3e^{-} \leftrightarrow Al(s)$ | -1.66 |
| $2H_2O(l) + 2e^{-} \leftrightarrow H_2(g) + 2OH^{-}(aq)$ | -0.828 |
| $Zn^{2+}(aq) + 2e^{-} \leftrightarrow Zn(s)$ | -0.763 |
| $Cr^{3+}(aq) + 3e^{-} \leftrightarrow Cr(s)$ | -0.744 |
| $Fe^{2+}(aq) + 2e^{-} \leftrightarrow Fe(s)$ | -0.440 |
| $Cd^{2+}(aq) + 2e^{-} \leftrightarrow Cd(s)$ | -0.403 |
| $Co^{2+}(aq) + 2e^{-} \leftrightarrow Co(s)$ | -0.277 |
| $Ni^{2+}(aq) + 2e^{-} \leftrightarrow Ni(s)$ | -0.250 |
| $Sn^{2+}(aq) + 2e^{-} \leftrightarrow Sn(s)$ | -0.136 |
| $Pb^{2+}(aq) + 2e^{-} \leftrightarrow Pb(s)$ | -0.126 |
| $Fe^{3+}(aq) + 3e^{-} \leftrightarrow Fe(s)$ | -0.04 |
| **$2H^{+}(aq) + 2e^{-} \leftrightarrow H_2(g)$** | **0.000** |
| $Sn^{4+}(aq) + 2e^{-} \leftrightarrow Sn^{2+}(aq)$ | 0.15 |
| $Cu^{2+}(aq) + e^{-} \leftrightarrow Cu^{+}(aq)$ | 0.16 |
| $ClO_4^{-}(aq) + H_2O(l) + 2e^{-} \leftrightarrow ClO_3^{-}(aq) + 2OH^{-}(aq)$ | 0.17 |
| $AgCl(s) + e^{-} \leftrightarrow Ag(s) + Cl^{-}(aq)$ | 0.22 |
| $Cu^{2+}(aq) + 2e^{-} \leftrightarrow Cu(s)$ | 0.337 |
| $ClO_3^{-}(aq) + H_2O(l) + 2e^{-} \leftrightarrow ClO_2^{-}(aq) + 2OH^{-}(aq)$ | 0.35 |
| $IO^{-}(aq) + H_2O(l) + 2e^{-} \leftrightarrow I^{-}(aq) + 2OH^{-}(aq)$ | 0.49 |
| $Cu^{+}(aq) + e^{-} \leftrightarrow Cu(s)$ | 0.521 |
| $I_2(s) + 2e^{-} \leftrightarrow 2I^{-}(aq)$ | 0.536 |
| $ClO_2^{-}(aq) + H_2O(l) + 2e^{-} \leftrightarrow ClO^{-}(aq) + 2OH^{-}(aq)$ | 0.59 |
| $Fe^{3+}(aq) + e^{-} \leftrightarrow Fe^{2+}(aq)$ | 0.771 |
| $Hg_2^{2+}(aq) + 2e^{-} \leftrightarrow 2Hg(l)$ | 0.799 |
| $Ag^{+}(aq) + e^{-} \leftrightarrow Ag(s)$ | 0.799 |
| $Hg^{2+}(aq) + 2e^{-} \leftrightarrow Hg(l)$ | 0.85 |
| $ClO^{-}(aq) + H_2O(l) + 2e^{-} \leftrightarrow Cl^{-}(aq) + 2OH^{-}(aq)$ | 0.90 |
| $2Hg^{2+}(aq) + 2e^{-} \leftrightarrow Hg_2^{2+}(aq)$ | 0.90 |
| $NO_3^{-}(aq) + 4H^{+}(aq) + 3e^{-} \leftrightarrow NO(g) + 2H_2O(l)$ | 0.96 |
| $Br_2(l) + 2e^{-} \leftrightarrow 2Br^{-}(aq)$ | 1.07 |
| $O_2(g) + 4H^{+}(aq) + 4e^{-} \leftrightarrow 2H_2O(l)$ | 1.23 |
| $Cr_2O_7^{2-}(aq) + 14H^{+}(aq) + 6e^{-} \leftrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$ | 1.33 |
| $Cl_2(g) + 2e^{-} \leftrightarrow 2Cl^{-}(aq)$ | 1.36 |
| $Ce^{4+}(aq) + e^{-} \leftrightarrow Ce^{3+}(aq)$ | 1.44 |
| $MnO_4^{-}(aq) + 8H^{+}(aq) + 5e^{-} \leftrightarrow Mn^{2+}(aq) + 4H_2O(l)$ | 1.49 |
| $H_2O_2(aq) + 2H^{+}(aq) + 2e^{-} \leftrightarrow 2H_2O(l)$ | 1.78 |