Name________________________________ Section_________________

Partner(s)_____________________________ Date___________________

AN INVESTIGATION OF ELECTROCHEMICAL REACTIONS

PRE-LAB QUERIES

1. How does electricity or electrical current get from the power plant to your house?

   Can you get electrical current from any source other than an electrical outlet? If so, what?

2. Dissociate the following soluble salts into ions:

   $NaCl \rightarrow$

   $MgSO_4 \rightarrow$

   $Fe(NO_3)_3 \rightarrow$

3. If the following gases were produced during a reaction, how would you identify them? Consider chemical tests and any physical properties to aid in identification.

   hydrogen

   oxygen

   chlorine

   sulfur dioxide

4. For the spontaneous reactions below, predict the products and list evidence that would indicate reaction occurred.

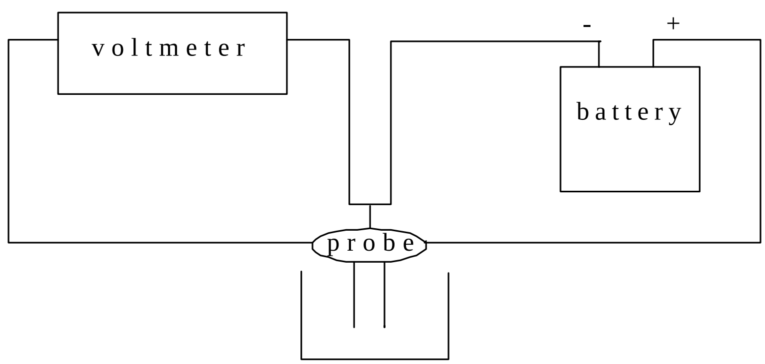
   $Mg(s) + HCl(aq) \rightarrow$

   $Fe(s) + CuSO_4(aq) \rightarrow$

PROBING THE CURRENT SITUATION

In this activity we will explore some electrochemical properties of solutions and reactions. Careful observation is critical in this activity. You may want to review *An Investigation of Chemical Reactions* from your CHM 101 manual.

The **conductivity** of a solution is a measure of its ability to carry electrical current. Obtain a conductivity probe, battery, and voltmeter and set them up as shown in the illustration. Your instructor will help with the wiring. The conductivity probe functions by measuring the relative ability of a solution to conduct electricity. A voltage is read on the voltmeter that is mathematically related to conductivity. (They are NOT directly proportional.).



Do **NOT** change the spacing of the electrodes after you start making measurements with the probe.

1. To show that voltage on the voltmeter is related to the conductivity of the solution, hold a piece of pencil lead (graphite with a clay binder, a good conductor) across the two metal electrodes (paper clips) on the probe using plastic forceps. What happens?

2. What type of particles, ions or molecules, are required for a solution to be conductive? Explain your answer.

Predict whether each of the solutions in the table below will be conductive.

Dip the probe into distilled water and then into each of the 0.01 M solutions listed below and record each reading on the voltmeter. Do **NOT** leave the probe sitting in any solutions. Rinse the probe in distilled water after each solution. Classify each of the solutes as non-electrolyte, weak electrolyte, or strong electrolyte.

Solution	Will Conduct? (Y or N)	Voltmeter Reading	Type of Electrolyte
distilled water			
sugar			
NaCl			
CH_3COOH			
HCl			
tap water			

3. Now let's see what factors influence the conductivity of a solution. Dip the probe into the solutions of strong electrolytes listed in the table that follows and record the readings on the voltmeter. Remember to rinse the probe with distilled water after testing each solution.

   Look for trends or patterns in the readings.

Possible Factor	Solution	Reading
Concentration	0.001 M NaCl	
	0.01 M NaCl	
	0.1 M NaCl	
Type of Salt	0.01 M NaCl	
	0.01 M $CaCl_2$	
Cation	0.01 M HCl	
	0.01 M NaCl	
	0.01 M KCl	
Anion	0.01 M NaCl	
	0.01 M NaOH	
	0.01 M $NaNO_3$	
Temperature	0.01 M NaCl @ 25^{o}C	
	0.01 M NaCl @ 60^{o}C	

Summarize your results for each factor and explain how each factor influences conductivity.

Does any one ion seem to have an unusually high conductivity? Explain.

4. Conductivity measurements can be used to quickly determine total dissolved solids (TDS) in stream water, since the proportion of ions are fairly constant. TDS is usually measured by massing the residue remaining after evaporating a quantity of filtered stream water (suspended solids removed).

   Using the handheld meter, measure the TDS content of the stream water provided and tap water. **Multiply the scale reading by 10** to get TDS in mg solids/L water.

Solution	TDS
stream water	
tap water	

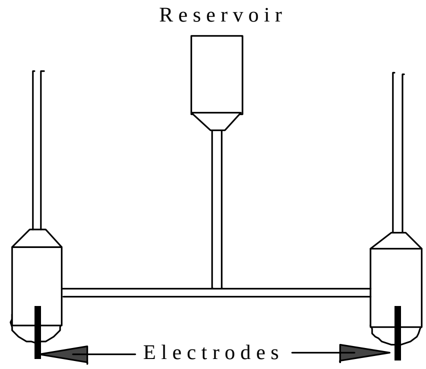
Here are some typical TDS levels for various water sources.

Source	TDS
Rainwater	< 10 mg/L
municipal water systems	< 500 mg/L
rivers and streams	100-2000 mg/L
seawater	35,000 mg/L

How do the stream water and tap water you measured above compare to the sources in the table?

5. Next we will pass an electrical current through a solution and observe if any chemical reaction occurs. What types of evidence would indicate that a chemical reaction is occurring?

Obtain the small-scale Hoffman apparatus, illustrated below, and a battery. The electrodes in this version are made of pencil lead. Be careful they are fragile!



Place distilled water into the reservoir, making sure the electrodes are submerged, and apply a current by connecting the battery to the electrodes. What happens and why?

Empty the apparatus and place an aqueous solution of sulfuric acid into the apparatus. Apply the current. What happens and why?

Empty the apparatus, rinse with distilled water, and place an aqueous solution of $NaNO_3$ in the apparatus. Apply the current. What happen and why?

Rinse the small-scale Hoffman apparatus with distilled water when finished.

Observe the reaction again using the large Hoffman apparatus containing aqueous sulfuric acid. Do **NOT** change the solution in this apparatus! Test the products and record your results. What type of chemical reaction is occurring? Write an overall chemical reaction. This is called the electrolysis of water.

What is the purpose of the sulfuric acid or $NaNO_3$ in the apparatus?

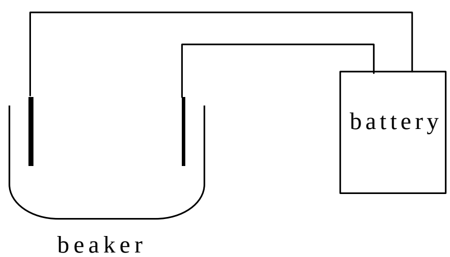
6. In any electrochemical reaction, both oxidation (loss of electrons) and reduction (gain in electrons) occur simultaneously. The two electrodes, or half cells, are given names depending on which process occurs. Oxidation occurs at the **anode** and reduction occurs at the **cathode**.

Here is an example of a half-cell reaction which occurs at the positive electrode of the conductivity probe.

$$Fe(s) \rightarrow Fe^{+2}(aq) + 2e^{-}$$

This is the anode (Why?) and the process slowly corrodes the paper clip. You may have noticed a rusty appearance of some of the solution after testing them with the conductivity probe.

Set up the electrolysis cell for aqueous copper (II) chloride. Obtain a 50-mL beaker, two 3-cm pieces of pencil lead, and wires with a battery as shown below. Fill the beaker with copper (II) chloride.



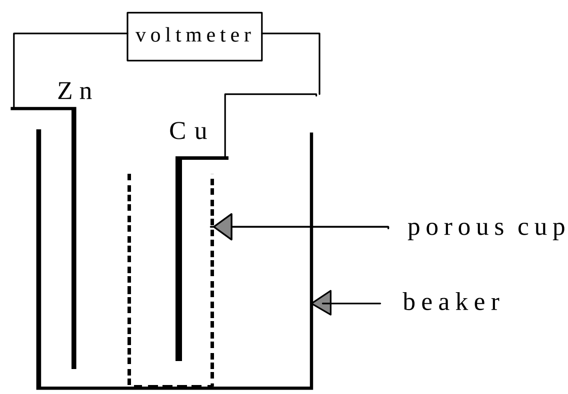
Apply the electrical current using a battery and **observe both electrodes**. Do NOT allow this cell to operate more than 2 minutes. Note the polarity (sign) of each electrode.

Identify the anode and cathode and write the half-cell reactions occurring at each.

7. In the reactions above, we supplied the electrical current by means of a battery. Can a chemical reaction generate electrical current on its own? Explain.

Obtain a voltmeter, galvanized nail, and thick piece of copper wire. Attach the nail to the negative lead on the voltmeter and the copper wire to the positive lead. Push the nail and wire into an apple or orange. Record what happens.

8. Now let's construct another voltaic or galvanic cell. We will consider some single displacement reactions using a metal and another metal salt. Obtain a strip of copper and zinc, a porous cup and a 250-mL beaker. Set up the arrangement shown below:



The porous cup (made of fragile porcelain) allows electrical contact between the two solutions without allowing mixing.

Place 25 mL of 1.0 M $ZnSO_4$ into the beaker and 25 mL of 1.0 M $CuSO_4$ in the porous cup. Be sure the metal electrodes are dipping into the solutions.

The following overall reaction **or** the reverse of it will occur in this cell.

$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$

Observe the electrodes for evidence of reaction and determine the anode and cathode half-cell reactions. Record any voltage. Be aware, metals in a finely powdered state will look <u>black</u>!

In galvanic cells, the source of electrons is the anode, which is negative in polarity. The cathode is the positive electrode.

Allow the reaction to run for a period of time. Does the voltage change? Explain.

Clean the cell up.

9. Describe and attach an **illustration** of how to construct a cell using Mg and Zn and their 1.0 M sulfate solutions. Set the cell up and measure the voltage, identify the anode and cathode, and determine the half-cell reactions and polarity.

POST-LAB QUESTIONS

1. Based on *your laboratory observations*, rank the three metals (copper, magnesium, zinc) in order of reactivity and explain.

__________ > __________ > __________
MOST LEAST

2. Lead storage batteries (a collection of galvanic cells) in automobiles commonly fail (do not produce enough voltage to start car) in very cold weather. Why might this be the case?

3. How would the "total dissolved solids" measurement by conductivity be influenced if the following materials were dumped into a stream?

road salt, $CaCl_2$

urea, $CO(NH_2)_2$-a fertilizer and non-electrolyte

4. If you made a cell of magnesium metal in 1.0 M $MgSO_4$ and copper metal in 1.0 M $CuSO_4$, what would the anode and cathode half-cell reactions be? Which metal electrode is negative?