ElectroChemistry*

Name ____________________________ Section ______________

Instructions: You and your partner(s) will be working with a computer simulation that covers electrochemistry, please discuss each question with your partner(s) and write down your best answer.

Section I: Reactivity of Metals and Metal Ions PRELAB

Important Web Site address for the computer simulation:
http://intro.chem.okstate.edu/1515F01/Laboratory/ActivityofMetals/home.html

Activity 1

1) To start the animation click start and then select Activity One. You will see four ionic solutions. Pick one of the four metals and follow the instructions on the screen. Please write down your observations (e.g. evidence for reactions occurring or not occurring). Repeat this procedure for the other three metals and make sure to write all your observations /evidence for a reactions that occur or do not occur, down in the space below.

2) Do all four metals and all four solutions of metal ions have the same reactivity? What evidence do you have to support your answer.

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Electrochemistry SWH

Name ________________________________ Partner's Name(s) _____________

Lab Section _______ _____________

TA's Name ____________________________ _____________

Section I. Reactivity of Metals and Metal Ions LAB

1) Given three additional substances, Mg, Fe and HCl, how does the reactivity of these three substances compare to the four metals you investigated in the Pre-Laboratory Activity?
2) To answer the question above be sure all equipment and reagents you use are clean and ready for experimentation. If you use the 48-well culture plate be sure to clean and rinse the plate with distilled water before using. Shake any excess water out of the culture plate. Clean the metal strips using sandpaper before inserting the strips into any solutions. Sandpaper approximately one-half inch of the end of each metal strip you use. Half fill a well in the 48-well culture plate with any solutions that you need to use. Metal strips should be submerged for approximately 5 minutes. Record your observations before, during and at the end of each combination of metal and solution. Note changes that occur on the metal strip inserted into the solution and of the solution itself.

   Before starting plan a strategy for the an efficient procedure to determine the reactivity of the three new substances as compared to the four metals tested in the simulation and discuss your strategy with your teaching assistant.

   Space to write your strategy/procedure

Use this space to record your observations (evidence):

3) Summarize your results.

4) How do your ideas compare to the textbook’s or to other group’s.?

5) Write your results in the format used in your textbook.

6) Give at least one example of a complete, balanced, net ionic chemical equation to symbolically represent a chemical reaction from your experiments.

7) Give at least one example of a chemical equation to symbolically represent an example of a chemical reaction that did not occur in your experiments. Write the reactants and indicate ‘NR’ after the arrow.

Section II: Making a Battery PRELAB

Instructions: You and your partner(s) will be working with a computer simulation that covers electrochemistry, please discuss each question with your partner(s) and write down your best answer.

Important Web Site address for the computer simulation:
http://www.chem.iastate.edu/ChemEdGroup/GREENBOWE/sections/projectfolder/flashfiles/electroChem/volticCell.html

1. Follow the instructions as provided in the simulation and build an electrochemical cell by selecting two metals and solutions that contain each ion of the metal.

2. In the space below sketch the electrochemical cell that you make in the simulation and label the metal used for each electrode and the ion(s) in each solution. Also indicate the direction of flow of the electrons, the direction of migration of ions and the voltage of your cell.

3. Write the balanced chemical equation that represents the reaction that occurs at the electrode in each compartment of your electrochemical cell. Label each reaction as an oxidation or a reduction, and identify the anode and cathode.

4. Write the complete, balanced, net ionic chemical equation for the reaction that occurred in your electrochemical cell.

Section II: Making a Battery LAB

Batteries are example of chemical reactions that can be used to take advantage of a spontaneous chemical reaction. The chemical reactions that occur in batteries are examples of oxidation-reduction reactions. In this section we will investigate how to construct a battery and organize our observations about the nature of the chemical reactions.

1. Cut a piece of filter paper into a strip about 3-5 mm wide and 2 cm long. Repeat this procedure until you have six to eight strips of paper.

2. Using a clean culture plate, select two adjacent wells and fill one half full with 1.0 M $CuSO_4$. Fill the second well half-full with 1.0 M $ZnSO_4$. Obtain a strip of copper metal and a strip of zinc metal. Use a piece of sandpaper to clean the bottom half of each metal surface.

3. Place the copper metal in the 1.0 M $CuSO_4$ solution. Place the zinc metal in the $ZnSO_4$ solution. Wet the 2 cm length of filter paper with 1.0 M $NaNO_3$ solution. Place this strip with one end diped in the $ZnSO_4$ solution and the other end diped in the $CuSO_4$ solution.

4. Check the voltmeter. Make sure the red wire is plugged into the socket marked V (volts) and the black wire is plugged into the socket marked COM (common). Make sure the meter is set to read DC volts. Connect one of the wires to the copper electrode, the other wire to the zinc electrode. Connect the meter long enough to take a stable reading . Fill in your information in table 2. Reverse the connections to the metals. Connect the meter long enough to take a stable reading. Fill in your information in table 2.

5. Remove the metal strips and rinse them with distilled water. Return them to their original containers.

6. Repeat the procedure followed for the zinc-copper system and assemble each of the possible six cells from the four metal ion solutions. In your notebook record your observations using a table similar to table 2. Your instructor will guide you if you are uncertain about what to do.

7. In your notebook draw a diagram of at least one cell (that is not the zinc-copper system), using the wire connection that gave a positive voltage reading.

Table 2

	Voltage Readings					
	First set of wire connections			Inverse wire connection		
	Black	Voltage	Red	Black	Voltage	Red
Zinc-copper cell	Zn		Cu	Cu		Zn
Zinc-lead cell						
Zinc-tin cell						
Tin-lead cell						
Tin-copper cell						
Copper-lead cell						
Copper-lead cell						

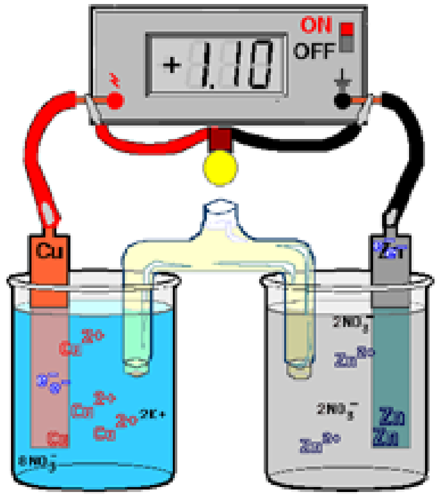
8. Is it relevant which way the black wire and the red wire are connected to the metal strips? Explain your answer.

9. What does it mean to have a negative value for the voltage measured?

10. For one of your cells write the oxidation half reaction, the reduction half reaction.

11. In the cell diagram below indicate the following parts:

- The oxidation half reaction
- The reduction half reaction
- The cathode
- The anode
- Apparent direction of electron flow
- Ion migration in the salt bridge



12. How does your cell produce electricity?

Section III. Electrode Potential LAB

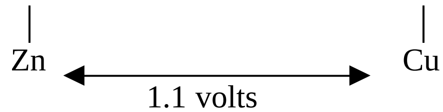
Before we discuss EMF scales, we need to discuss scales in general. The temperature scales are most familiar to you. There are three that are most commonly used; Celsius, Fahrenheit and Kelvin scales. The Celsius scale was originally based on the assignment of 0 ˚C to the freezing point of water and 100 ˚C to its boiling point at sea level. The Fahrenheit scale, more commonly used in the USA, has water freezing at 32 ˚F and boiling at 212 ˚F. The last temperature scale, uses units of Kelvins, and is based on the properties of gases. Water freezes at 273.15 K and boils at 373.15 K. When using the Kelvin scale, or absolute scale, there are no negative temperatures. The lowest temperature possible in Kelvins is 0. Each of these temperature scales has a different 0 value. When comparing the meaning of 0 Kelvins, 0 ˚C and 0 ˚F each is different.

Temperature measures the degree of hotness of coldness of an object. In truth we do not really know what the temperature water freezes at so we assign a scale so that we can assign a value for the freezing point, or the boiling point of a substance. Once we define our reference points we can determine the freezing point, boiling point, or any temperature based on the definition.

The idea of selecting a zero point is also used when discussing standard reduction potentials. In this case the EMF of the half-reaction for the standard hydrogen electrode was selected to be 'the zero' in the scale. We will never really know what the EMGF for the standard hydrogen electrode really is, but scientists have agreed to designate voltage as 0.00 volts.

1. Using a reference electrode. In a chemistry laboratory, usually a standard hydrogen electrode is used as a reference electrode. We will not use a standard hydrogen electrode due to the danger of having excess hydrogen gas in the laboratory. Select the zinc electrode. Prepare a cell for measurement by filling one well half-full with the 1.0 M solution of this metal cation. Fill an adjacent well half-full with a 1.0 M $NaNO_3$ solution. Cut a 2cm length of filter paper and wet this with the $NaNO_3$ solution. Place the filter paper so the ends make contact with the solutions in the two wells. Your instructor will show you how to connect a commercial silver/silver chloride reference electrode to the voltmeter. Measure the voltage and decide which substance is being reduced and which is being oxidized. Write this data in your laboratory notebook

2. Prepare the following graph in your notebook. Draw a horizontal line on your notebook. Use a scale of one square = 0.05 volts. Take copper and zinc and put them in your graph, as shown in the example below. We will always put the substance that was reduced to the right of the substance that was oxidized. Make sure the distance between them is the voltage obtained from your reading in section II.



3. Plot all the other five voltaic cells you tested in Section II on your graph.

4. Using the graph predict the cell voltage for Ag/AgCl and the other five half cell used in Section II. In your notebook, using a table similar to the one below, write a balanced equation for the cell and the predicted voltage.

Cell	**Voltage predicted**

5. Can the voltage for a single electrode system be measured by itself? Explain your answer.

6. Is the voltage at any point on the graph relative to other points on the graph? Explain your answer.

7. Could any electrode be chosen as a reference? Explain your answer.

8. Usually, the hydrogen electrode is used as the reference point. The reference voltage assigned to it is 0.0 volts. It is known that hydrogen reduces silver chloride to silver. The voltage observed for the cell containing the hydrogen electrode and the silver/silver chloride electrode is 0.22 volts. Using this information find the location of the standard hydrogen electrode in your graph.

9. In your graph label all the points to the right of the standard hydrogen electrode as positive numbers and all the points to the left of hydrogen as negative numbers.

10. Make a table in your notebook consisting of three columns. In the first column write the reduction reaction of the metal cation being reduced to the metal. In the second column, write the cell potential of this metal relative to the standard hydrogen electrode. In the third column calculate $\in^{o}_{rxn}$. Start your table with the largest positive number and work in order to the most negative number.

11. Is there any pattern between the reactivity of metals and the reduction values and/or $\in^{o}$ values in your table?

Section I: Reactivity of Metals and Metal Ions

The goal of this pre-laboratory simulation is for the students to end up with a rank list of the metals Zn, Cu Pb and Sn.

In the first question students are asked to write their observations of what happens when they add each metal strip to solutions of other metal ions. In the simulation the student will see a change in the metal strip when there is a reaction and there may be a change in the solution.

It may or may not be immediately clear to the students that the change on the metal strip is the plating out of another metal. They should realize that a metal is plating out when they look at the submicroscopic/atomic level view of the reaction.

Students will use different ways to organize their observation. Some will set up a 4 x 4 array with the metals on the horizontal or the vertical and the metal ions opposite. Then they can complete the corresponding cell with their observations. Some make simply indicate which combination produced a reaction.

The students must understand their observations are the evidence they need to establish that a reaction occurred or did not occur. That a reaction did not occur is an observation and the combination of metals and ions that did not react is just as important as the combinations that do react.

Independent of the approach the student uses to summarize their observations you should look to see that the student has indicated what happened on the strip and what happened in the solution. The change in the solution should be expressed as a change over the time of the reaction. For example, the solution was clear and colorless initially (before adding the metal strip) and it was clear, and colorless when the strip was removed; or the solution changed from colorless before the metal strip was added, to light green when the strip was removed.

Question 2 was written in such a way so as not to tell the student what is going to happen. As the student will discover the four metals all react differently. Therefore, they can be ranked from most reactive to least. Since our ultimate goal in this experiment is a series of reduction half-reactions, the best ranking will have the metals ordered (as a vertical list) from least reactive metal to most reactive metal.

The second part of this question is critical. Students must support any organization/ranking by citing the evidence they generated from their observations in 1). So if the student says Zn is the most reactive metal, they must cite the evidence they have found to support that statement. For example, Zn is the most reactive metal because it reacted with each of the other metal ions (Pb^{2+}, Cu^{2+} and Sn^{2+}).

Question 2 also asks the students if the metal ions have the same reactivity. The student should rank the metal ions also. They should realize that the reactivity of the metal ions is exactly opposite of the reactivity of the metals. The student might write their reactivity in the following way

Reactivity of metals
Cu
Pb
Sn
Zn

Reactivity of Metal Ions
Zn^{2+}
Sn^{2+}
Pb^{2+}
Cu^{2+}

What is preferred is an organization that places the metal and its ion in a way that the student might see the beginning of a half reaction;

Reactivity of metals and metal ions

most reactive metal ion least reactive metal ion	$Cu^{2+} \rightarrow Cu$ $Pb^{2+} \rightarrow Pb$ $Sn^{2+} \rightarrow Sn$ $Zn^{2+} \rightarrow Zn$	least reactive metal most reactive metal

Then it would be best to balance the equations. The student should realize the equation is mass balanced but not charge balanced. Balancing the equations leads to

Reactivity of metals and metal ions

most reactive metal ion least reactive metal ion	$2e^- + Cu^{2+} \rightarrow Cu$ $2e^- + Pb^{2+} \rightarrow Pb$ $2e^- + Sn^{2+} \rightarrow Sn$ $2e^- + Zn^{2+} \rightarrow Zn$	least reactive metal most reactive metal

In the laboratory part of Section I students will study the reactivity of two additional metals and HCl. Students will be expected to use the same approach they used in the simulation to test the reactivity of the new metals and HCl. The goal is to do enough reactions that they are comfortable with placing Mg, Fe and H^+ into their activity series.

The student should take a few minutes to plan their strategy.

Students should be thinking in the following way: Mg, Fe and H^+ must fit somewhere in my activity series because after testing the four metals in the simulation they each had a different reactivity so I have to conclude that it is entirely likely that all substances will have a different reactivity. To test the reactivity of the new substances I'll simply add the metals to solutions of the other metal ions. In the case of the HCl I'll add metals and I might also test solutions of the metal ions.

Students might think they have to test every solution of metal ion with each metal, but if they plan their strategy correctly they may be able to test only a few of the solutions. The important idea to have gotten from the simulation is there is a ranking of reactivity. If they are able to determine an adjacent set of metal ions that react and do not react they do not have to do any further tests. Some students may want to do additional tests to verify their conclusion and that is perfectly acceptable.

Following the experiments the students are asked a series of questions. They are first asked to summarize their results. This simply consists of providing a new activity series with all seven species. Again they should justify their series by citing evidence from their experiments.

Next they are asked to compare their ideas, that is the activity series they have generated, to the textbook's and/or another group in the laboratory. This comparison is designed to demonstrate to the student that they need to establish that they have reached the same conclusions as other scientists. It is always necessary/desirable to compare our own experimental results to others to verify that the experiments are repeatable. That is what we call scientific facts. They are not right or wrong, they are reproducible.

Next the student should see that their activity series looks like the book's. They should also notice that the activity series in their textbook is more extensive than theirs. Do they believe that the other substances are positioned correctly? Are they prepared on the basis of the subset of substances they tested to accept the book's more comprehensive list?

In the last two questions students are expected to practice writing symbolic representations of the reactions they observed in their experiments. So look for complete net ionic equation in those cases where a reaction occurs and look for the reactants going to NR (no reaction) for those combinations of metals and solution that do not produce a reaction.

Chemicals and Equipment for Activity I:

Chemicals:

Metals: Mg, Zn, Cu, Ag, Fe, Sn
Metal Ion Solutions (0.1 M): $Mg(NO_3)_2$, $Zn(NO_3)_2$, $Cu(NO_3)_2$, $AgNO_3$, $Fe(NO_3)_2$, $Sn(NO_3)_2$, HCl
Distilled water

Materials/Equipment:

48-well culture plate
Sand paper
Droppers (if the solutions are not in dropper bottles)
Goggles