Electrochemistry:

Electrolysis of Water Lab

Introduction:

Electrochemistry is the study of the relationship between electrical forces and chemical reactions. There are two basic types of electrochemical processes. In a voltaic cell, commonly known as a battery, the chemical energy from a spontaneous oxidation-reduction reaction is converted into electrical energy. In an electrolytic cell, electricity from an external source is used to "force" a nonspontaneous chemical reaction to occur. What chemical reaction will take place when an electric current flows through water?

- In an oxidation half-reaction, an element *loses* electrons. This causes that element's oxidation number (charge) to *increase*. (Because electrons have a negative charge, removing some of those negatively charged electrons from an element makes the element more positive.)
- In a reduction half-reaction, an element *gains* electrons. This causes the element's oxidation number (charge) to *decrease*. (Because the electrons it gains have a negative charge.)
- The electrons *lost* by the **oxidized element** are transferred to the **reduced element**. The reduced element *gains* electrons from the oxidized element. This is how flow of electrical current is generated.

Purpose:

The purpose of this experiment is to investigate the electrolysis of water in an electrochemical cell. Two carbon pencil "leads" (graphite rods) will be inserted into the opposite ends of a Petri dish containing water, sodium sulfate, and bromthymol blue. An electric current will be passed through the solution by connecting the pencil-leads to the positive and negative terminals of a 9-volt battery. The pencil-leads (electrodes) act as external conductors and provide a surface for the chemical reaction. Sodium sulfate, an ionic compound, is conductive in aqueous solution and makes it possible to complete the circuit between the two pencil-leads. Bromthymol blue, an acid-base indicator, will help to identify the changes occurring in the solution as the electrolysis proceeds. Bromthymol blue is yellow in acidic solutions (at $pH < 6.0$) blue in basic solutions (a $pH > 7.6$), and various shades of green at intermediate pH values ($pH = 6.0-7.6$).

Low pH (acidic solution) is generated by an excess of hydrogen ions (H^+). High pH (basic solution) is generated by an excess of hydroxide ions (OH^-).

Safety Precautions:

To extend the life of the battery, avoid connecting the positive and negative terminals to each other. Wear chemical splash goggles. Wear chemical-resistant gloves and a chemical-resistant apron if available. Wash hands thoroughly with soap and water before leaving the lab.

Pre-Lab:

Complete the Pre-Lab Questions on your lab sheet before proceeding to the next section.

Preparation:

If alligator clamps are affixed to the wire leads of the battery clip, carefully clamp a pencil-lead in each clamp.

If no alligator clamps are available, strip ¼ inch of plastic coating from the end of each wire lead and wrap the bare wire around the pencil-lead starting at the very top, on an angle. Gently tape over the connection to secure the pencil-lead without breaking it. Repeat for the remaining wire.

Procedure:

1. Attach the battery cap with the carbon leads to the 9-V battery. The battery may be placed in a support clamp, if needed, to prevent tension when the carbon pencil-leads are placed into the solution (step 4).

2. Obtain about 40 mL of 0.5 M sodium sulfate solution in a small beaker. Using a Beral-type pipet, add about 3 mL of bromthymol blue indicator and swirl the solution to evenly distribute the indicator color. Observe and record the initial indicator color of the solution.

3. Carefully pour this electrolysis solution into the Petri dish until the liquid level fills about two-thirds of the dish.

4. Place the pencil-lead-electrodes at opposite sides of the Petri dish. Be sure the electrodes extend into the solution but do not touch each other directly.

5. Observe and record all changes as the current flows through the electrolysis solution. Be specific—compare the changes at the pencil-lead-electrodes attached to the positive (+) and negative (-) terminals of the battery. Note the comparative rates at which changes take place.

6. Allow the current to flow through the solution for about 5 minutes, taking care to keep the ends of the electrodes in the electrolyte solution throughout.

7. Remove the pencil-lead-electrodes from the solution.

8. Disconnect the battery cap from the battery. Gently rinse off the pencil-leads with water. If using alligator clamps, remove the pencil-leads from the clamps.

9. Return battery, battery clip, and pencil-leads to the appropriate locations.

10. Pour the solution from the Petri dish into a small beaker, then swirl the solution to mix. Observe and record the final indicator color of the mixed solution.

11. Dispose of the final solution as directed by the instructor.

Name:
Period:

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Recall that any oxidation-reduction reaction may be written as the sum of two half-reactions: an oxidation half-reaction and a reduction half-reaction. Electrons flow from the substance that is oxidized (which loses electrons), to the substance that is reduced (which gains electrons). If the half-reaction are separated, the electrons will flow through an external conductor rather than through the solution. This is the basis of electrochemistry. In electrolysis, the electron flow is not spontaneous, but rather is "forced" by a battery.

Pre-Lab Questions:

1. A *decomposition reaction* may be defined as any reaction in which a reactant which is a compound breaks down to give two of more products. Write the balanced chemical equation for the decomposition of water to its elements. (Remember diatomics!)

2. In a diatomic oxygen molecule (O_2), the oxidation number (charge) of the oxygen atom is zero. *(When an element is in its elemental state (not part of a compound, not acting as an ion), it always has an oxidation number of zero.) In a compound, the element has an oxidation number (charge) that can be predicted by its location on the periodic table.)*

   Balance the reaction below, including the number of electrons that must be produced to account for the charge difference between the two types of oxygen. (Hint: the total **charge** on the left and right of the arrow must be equal as well as the number of each atom.)

   $$\_\_\_\_ O^{2-} \rightarrow \underline{\ 1\ } O_2 + \_\_\_\_ e^-$$

3. Electrochemical reactions always involve both an oxidation component—in which an element's charge increases—and a reduction component—in which a (different) element's charge decreases. Is the reaction in the previous question an oxidation or a reduction?

If you need help on the two following questions, refer back to the explanation in #2.

4. In a water molecule (H_2O), what is the oxidation number (charge) of the hydrogen atoms?

5. In a water molecule (H_2O), what is the oxidation number (charge) of the oxygen atom?

6. Balance and label the following redox half-reactions for the decomposition of water.

   a. $\_\_\_ H_2O \rightarrow \_\_\_ O_2 + \_\_\_ H^+ + \_\_\_ e^-$ oxidation or reduction?

   b. $\_\_\_ H_2O + \_\_\_ e^- \rightarrow \_\_\_ H_2 + \_\_\_ OH^-$ oxidation or reduction?

Data Table:

	Color	Bubbles (rate)	Other
Initial Indicator-Electrolysis Solution		X	
Changes Occurring at the Positive (+) Electrode			
Changes Occurring at the Negative (-) Electrode			
Final Mixed Indicator-Electrolysis Solution		X	

Post-Lab Questions:

1. Suggest an explanation for the *initial* indicator color of the electrolysis solution.

2. Describe *at least three* observations that indicate a chemical reaction has occurred during the electrolysis of water.

3. What are the **two** functions of the pencil-lead-electrodes?

4. Compare the color changes observed at the positive (+) and negative (-) electrodes.
    a. What ions (H^+ or OH^-) were produced at the positive electrode, based on the color change there? (Refer back to the Introduction and Purpose sections if needed.)

    b. What ions (H^+ or OH^-) were produced at the negative electrode, based on the color change there? (Refer back to the Introduction and Purpose sections if needed.)

5. Write out the oxidation and reduction half-reactions for the decomposition of water and **identify which reaction occurred at each electrode**, based on the indicator color changes. (Refer back to your Pre-Lab Questions if needed.)
   Oxidation: + or – electrode?

   Reduction: + or – electrode?

6. Compare the rates of gas evolution at the positive and negative electrodes. What gas was produced at each electrode? Explain the rates observed based on the balanced chemical equation for the decomposition of water. (See Pre-Lab Question #1.)

7. Suggest an explanation for the *final* color of the mixed electrolysis solution (Step 10 in the Procedure).

8. Think about the flow of electrons and current in the electrolysis of water. What do the positive and negative signs on a battery signify? (Use your answers from #5 above and what you learned in the introduction.)