Name________________________

Hey Man, Let's Split – Water, That Is…
Pre-Lab Assignment

Pre-Lab Assignment

- This pre-lab assignment is worth 5 points.
- This part of the pre-lab assignment is due *at the beginning* of the lab period, and must be done individually *before you come to lab!*

I. Background Preparation

- **Read this experiment thoughtfully**

Mentally note any procedural questions and plan how you and your partner will complete all experiments efficiently during the three-hour lab period.

II. Safety Hazards/Precautions

1. Complete the following table. Use the PCC MSDSonline link on your lab web page. Be sure to select the location *Sylvania ST* and be sure the chemical name matches precisely.

Materials	GHS Pictograms (Circle all that apply)	Hazard Statements (Check and list all that apply)
sodium sulfate		☐ Corrosive ☐ Toxic ___________________ ☐ Flammable ☐ Reactive _________________ ☐ Irritant ☐ Other? __________________
Waste Disposal	Identify (briefly) how you will dispose of waste materials from this experiment.	

2. **Workplace/Personal Cleanup Notes** (indicate what you will do to clean up yourself and your lab space before you leave the lab):

III. Pre-Lab Questions

1. How is an electrolytic cell different than a voltaic cell?

2. How is a fuel cell different than a battery?

3. Balance the following equation, including adding in the states of matter:

$$H_2O \longrightarrow H_2 + O_2$$

4. Which product has been reduced? Which product has been oxidized?

5. How will you determine which tube captures the hydrogen and which tube captures the oxygen?

6. What is the purpose of the sodium sulfate?

NSF –DUE Award #1204279

Questions of the Day

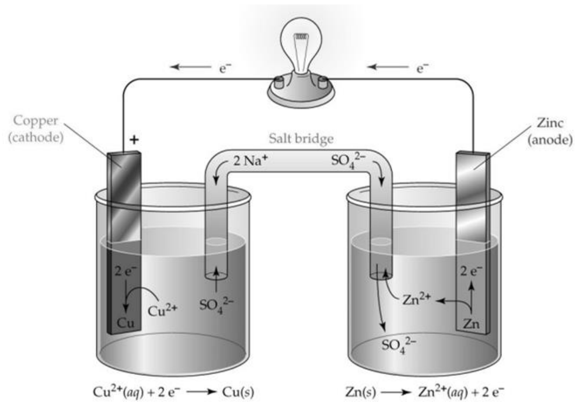
- What is electrolysis?
- What are the chemical reactions taking place during electrolysis of water?
- How can the stoichiometry of the electrolysis of water be experimentally measured/verified?
- How can electrolysis be used in fuel cell technology?

Introduction

Voltaic cells use a product-favored (spontaneous) chemical reaction to drive an electric current through an external circuit. These cells are an extremely important as this class of oxidation and reduction reactions are used to provide useful electrical energy as batteries. A simple electrochemical cell can be made from copper and zinc metals with solutions of their sulfates. You may have studied in detail such cells in previous experiments.

Electrochemical cells which generate an electric current are called voltaic cells or galvanic cells, and common batteries consist of one or more such cells.

Figure 1. A schematic of a common voltaic (a.k.a. galvanic) cell.



Electrolytic Cells

Voltaic cells in general do work on their surroundings (such as a turning on a light bulb or powering an electronic device) as a result of this ***driving force*** for electrons to move from the oxidation half reaction to the reduction half reaction solution. Voltaic cells are not the only kind of electrochemical cells, however. It is also possible to construct a cell that does work **on a chemical system** by driving an electric current through the system. These cells are called electrolytic cells. Electrolysis is used to drive an oxidation-reduction reaction in a direction in which it does not occur naturally.

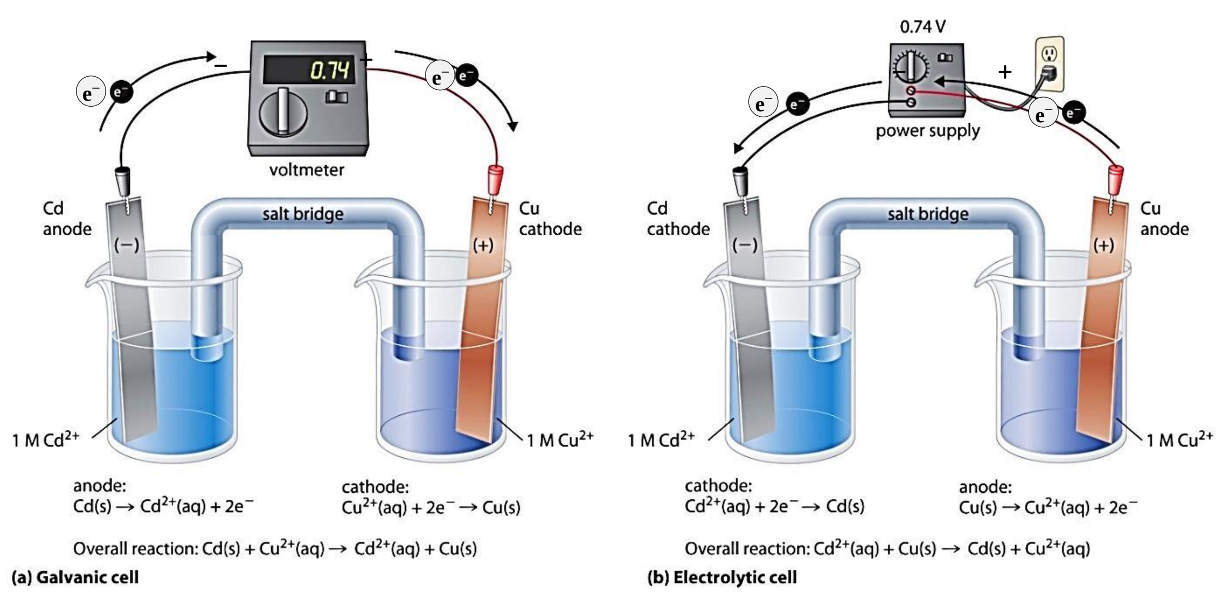
In the electrolytic cell, energy from an applied voltage (some external power source, such as a battery or a solar cell) is used to drive an otherwise *reactant-favored* (nonspontaneous) reaction. Such a cell could be produced by applying a reverse voltage to a voltaic cell. In other words, the use of an **external voltage supply** to cause electrons to travel in the reverse direction in which they would naturally move in such a cell. If a voltage greater than 1.10 volts is applied to the Zn|Cu cell under standard state conditions, then the following nonspontaneous reaction

$$Cu(s) + Zn^{2+}(aq) \leftrightarrows Zn(s) + Cu^{2+}(aq)\ E^{o}_{cell} = -1.10\ V$$

can be driven by removing Cu from the copper electrode ($Cu(s) \rightarrow Cu^{2+}(aq) + 2e^{-}$) and plating zinc on the zinc electrode (Zn^{+2} (aq) + 2 $e^{-} \rightarrow Zn(s)$) (this is the reaction of the electrochemical cell in reverse). Electrolytic processes are very important for the preparation of pure substances like aluminum and chlorine.

If the electrical work is stopped (remove the voltage source), the reaction stops. Such a process is *non-spontaneous* *as written*. The value of E^{o} is negative for the Cu/Zn reaction illustrated above (indicating a reactant-favored process).

Figure 2. Comparison between a galvanic (voltaic) cell (a) and an electrolytic cell (b).



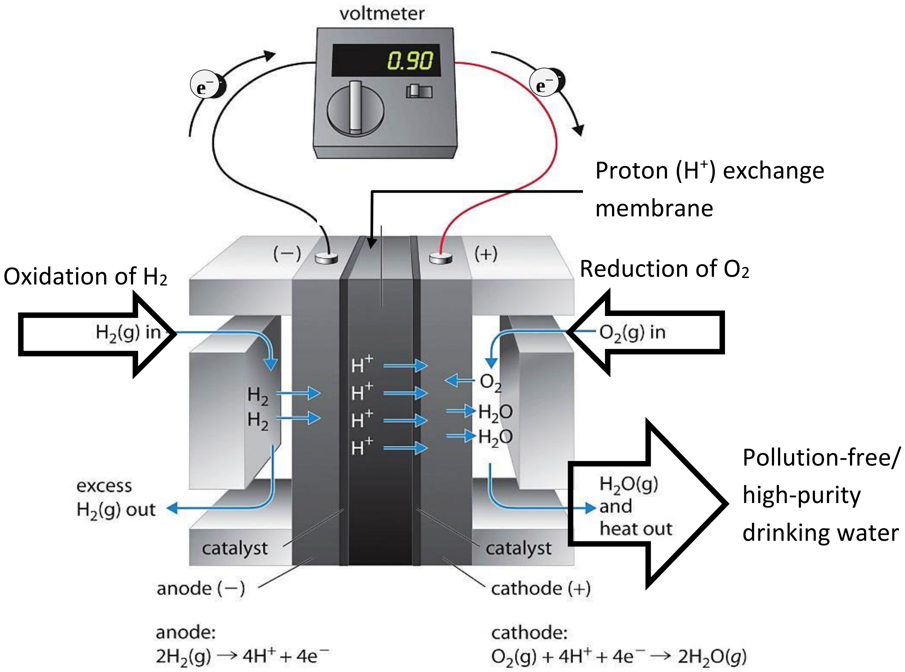
H_2/O_2 Fuel Cells

A fuel cell is a **galvanic** cell that requires a constant external supply of reactants as the products of the reaction are continuously removed. A fuel cell differs from a voltaic cell (battery) in that the chemicals in the reaction are easily recharged during the process, whereas in batteries, the chemicals are depleted with use leading to a "dead" battery. In the process, electrical energy is extracted. A fuel cell is simply a differently-designed "battery". In principle, this should be a more efficient process than, for example, burning the fuel to drive an internal combustion engine that turns a generator, which is typically less than 40% efficient, and in fact, the efficiency of a fuel cell is generally between 40% and 60%.

Advantages of using fuel cells vs. conventional batteries are that they can be connected to a source that constantly generates fuel for the cell to use, if possible by a clean, renewable process (solar cells, wind, etc.). As well, fuel cells can be constructed that use hydrogen and oxygen and produce only water as a byproduct.

Unfortunately, significant cost and reliability problems have hindered the wide-scale adoption of fuel cells. In practice, their use has been restricted to applications in which mass may be a significant cost factor, such as US manned space vehicles. These space vehicles use a hydrogen/oxygen fuel cell that requires a continuous input of $H_2(g)$ and $O_2(g)$, as illustrated in Figure 3.

Figure 3. A schematic of a H_2/O_2 fuel cell.



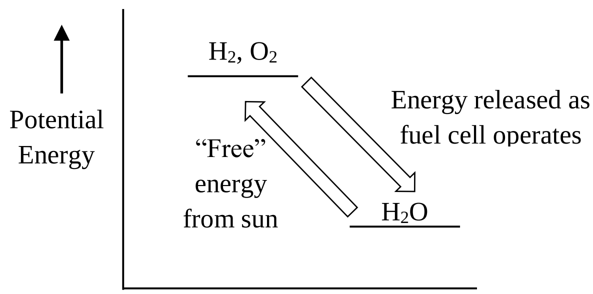
<u>The electrode reactions are as follows:</u>

cathode: $O_2(g) + 4\,H^+ + 4e^- \rightarrow 2\,H_2O(g)$
anode: $2\,H_2(g) \rightarrow 4\,H^+ + 4e^-$
overall: $2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(g)$

The overall reaction represents an essentially pollution-free conversion of hydrogen and oxygen into water, which in space vehicles is collected and used as drinking and other water. Although this type of fuel cell should produce 1.23 V under standard conditions, in practice the device achieves only about 0.9 V. One of the major barriers to achieving greater efficiency is the fact that the four-electron reduction of $O_2(g)$ at the cathode is intrinsically rather slow, which limits current that can be achieved. All major automobile manufacturers have major research programs involving fuel cells: one of the most important goals is the development of a better catalyst for the reduction of O_2.

Closing the Loop. Renewable and Sustainable Sources of Power

Interestingly, many fuel cells can be used as electrolytic cells. With a renewable (or other) supply of outside energy (such as from a solar cell, wind or water turbine, battery, etc.), a fuel cell can be run in reverse (as an *electrolytic cell*) and used to generate H_2 and O_2. Consider connecting a bank of solar cells to H_2/O_2 fuel cells. Free energy (apart from the materials used to construct and maintain the solar cells) is captured from sunlight and used to power a fuel cell in electrolytic (reverse) mode. The solar energy, through the solar cell, converts solar energy into electrical energy (the most efficient form of power we have). The electrical potential is then converted into stored chemical energy ($2\ H_2O \rightarrow 2\ H_2 + O_2$), through the use of a fuel cell. The chemical energy is "stored", not in the H_2 and O_2 bonds, but rather in the difference in potential energy (mostly bond enthalpy) of the products compared to the reactants. The following figure should make sense based on your previous knowledge of chemistry!



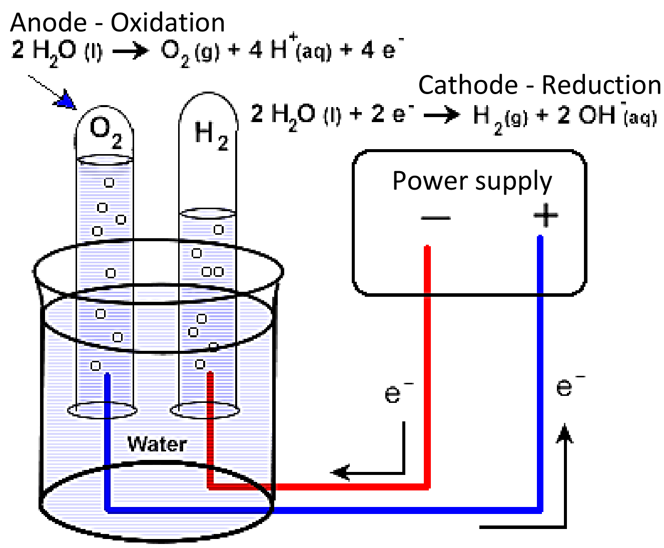
When power is necessary, we simply run the fuel cell in the forward direction, converting the stored chemical potential due to the difference in potential energy between H_2/O_2 and H_2O back into electrical energy, which we can use to drive whatever we want! Think about it, free solar energy which might otherwise be "wasted" can be converted through electrical and chemical means (which you can now understand!), into stored chemical potential, ready for us to harness at our whim, even if the sun isn't shining.

Consider the difference between this and the fossil fuel cycle currently used: free energy from the sun is captured by plants and stored as chemical potential energy (sugar and O_2 vs. CO_2 and water) through the process of photosynthesis (solar cells are an analog to chloroplasts in plants). The chemical potential energy stored in plants is over millions and millions of years transformed into fossil fuels (the analog of H_2/O_2 in our fuel cell system). Finally the chemical potential energy is obtained through combustion in an internal combustion engine, a highly inefficient and highly polluting process (the analog of using a fuel cell)! What a better potential technology the renewable fuel cell cycle is! Water is plentiful on planet earth (although most water is not fresh water). We know much of the background science necessary for the above process. The problem is now one of developing cost-effective technology to implement it. Perhaps you will be involved in the future development of these systems! Make it happen! Be the future!

This experiment

You won't be using a fuel cell in this experiment, but you will study the electrolysis reaction that "splits" water into its component elements, H_2 and O_2. This is the same reaction that must occur to obtain the raw fuel for H_2/O_2 fuel cells. Instead of using a solar cell to drive this reaction, you will use a commercial power supply to to drive the current through your electrolytic cell.

Figure 4. Water-splitting apparatus. The path of free elections and resulting reactions when a circuit is complete.



The last piece of the puzzle is the circuit through the water. Because pure water does not conduct electricity (no free charge carriers), there is no way for the electrons produced at the cathode to make it to the anode. An electrolyte (salt) must be added to the water solution in our experiment allow charge movement in the apparatus. You will use sodium sulfate, Na_2SO_4.

Safety Precautions

Wear gloves when handling nickel wire. All solutions should be collected in the waste beaker. Always be aware of your power source making sure it is turned off when connecting or disconnecting alligator clips.

Waste Management

Any excess sodium sulfate can be flushed down the drain with plenty of water, or disposed of according to your local disposal standards.

Seattle's Hub for Industry-driven
Nanotechnology Education – May 2016

NSF –DUE Award #1204279

Procedure

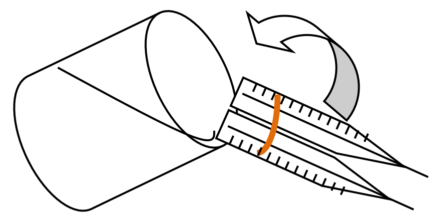
1. Fill a 500 mL beaker about 2/3 full with distilled water.

2. Weigh 1 g of sodium sulfate (Na_2SO_4). Add the sodium sulfate to the water and stir with a glass stir rod until dissolved.

3. Obtain a prepared electrode/tube assembly. Make sure both tubes in the electrode/tube assembly are labeled (tube 1 and tube 2). Completely fill both tubes with the water solution.

4. Hold the beaker and the electrode/tube assembly at a 45° angle, as shown in Figure 5.

Figure 5. 45° angle of the beaker and the electrode/tube assembly before quickly flipping tubes over into the beaker.

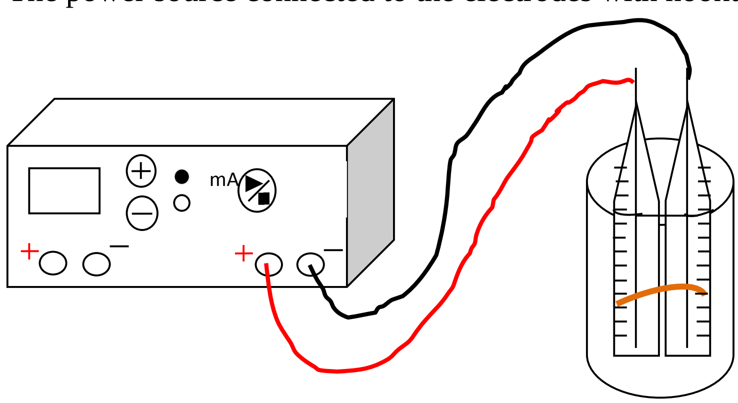


5. Quickly turn the tubes over into the beaker maintaining as much of the liquid as possible within the tubes. This can be difficult. If 10-14 mL of solution are not contained in the electrode/tube assembly after flipping, repeat steps 3 – 5.

6. Dry off the nickel wire at the top of the electrode/tube assembly.

7. Make sure the power source is turned off. Using alligator clips, hook up the power source to each nickel wire electrode, as shown in Figure 6.

Figure 6. The power source connected to the electrodes with hookup wires and alligator clips.



8. On the Report Sheet, record which tube (tube 1 or tube 2) you have connected to the positive electrode of the power source and which is connected to the negative electrode of the power source. Make sure you are consistent in how you connect the components throughout the experiment.

Time-dependent Electrolysis

1. In Table 1 on the Report Sheet, record the volume of H_2O solution inside the two tubes. (Note: the weight of the alligator clips added to the electrode/tube assembly may cause the tubes to lean against the beaker. Measurements of the water level might not be able be taken by properly reading the meniscus as one would in any other lab be in any other lab. Decide the best way to take measurements and remain consistent throughout the experiments.)

2. Turn on the power source, and set the current so that it reads 100 mA. Make note of the time. Hit the run button to start the flow of current. Record the volume of the two tubes every two minutes for 20 minutes in Table 1 on the Report Sheet.

3. As the reaction is running, make note of what you are observing.

4. After 20 minutes, turn off the current. Record the final volumes of the two tubes in Table 1 of the Report Sheet.

Current-dependent Electrolysis

1. Refill the wire/tube assembly as shown in steps 3-5 in the Experiment Setup procedure.

2. Dry off the nickel wire at the top of the electrode/tube assembly.

3. Make sure the power source is turned off. Using alligator clips, hook up the power source to each nickel wire electrode, as shown in Figure 6.

4. In Table 2 on the Report Sheet, record the volume of H_2O solution inside the two tubes. (Note: the weight of the alligator clips added to the electrode/tube assembly may cause the tubes to lean against the beaker. Measurements of the water level might not be able be taken by properly reading the meniscus as one would in any other lab be in any other lab. Decide the best way to take measurements and remain consistent throughout the experiments.)

5. Turn on the power source, and set the current so that it reads 50 mA. Make note of the time. Hit the run button to start the flow of current and let the reaction run for 5 minutes.

6. As the reaction is running, make note of what you are observing.

7. After 5 minutes, turn off the current. Record the volumes of the two tubes in Table 2 of the Report Sheet.

8. Repeat steps 1 through 7 above three times. Each time, change the value of the current – 100 mA, 150 mA, and 200 mA respectively. Record your beginning and ending volumes for each experiment on the Report Sheet. Make sure you refer to your notes on how you hooked up the positive and negative electrodes each time you repeat the experiment.

Optional Extensions

Other independent variables:

- salt levels – de-ionized water and no sodium/sulfate, dissolved sodium sulfate, over saturated sodium sulfate
- different metals
- surface area – different gauges of wire or by curling wire

Fuel Cell vehicle kits

References

- www.H2fromH2O.org

H2fromH2O. California Institute of Technology. Web. 01 Aug. 2011. <http://www.H2fromH2O.org>.

- http://www.fctec.com/fctec_basics.asp

"Artificial Leaf' Moves Closer to Reality - MIT News Office." *MIT - Massachusetts Institute of Technology*. Web. 01 Aug. 2011. <http://web.mit.edu/newsoffice/2011/water-splitting-0609.html>.

New/Research Articles

- http://www.sciencedaily.com/news/matter_energy/fuel_cells/

Ruhr-Universitaet-Bochum. "Extremely rapid water: Scientists decipher a protein-bound water chain." *ScienceDaily*, 11 Jul. 2011. Web. 1 Aug. 2011. <http://www.sciencedaily.com/news/matter_energy/fuel_cells/>.

- http://www.sciencedaily.com/releases/2011/07/110711131153.htm

"First Student Hydrogen Racing Car Revealed." *Science Daily: News & Articles in Science, Health, Environment & Technology*. 11 July 2011. Web. 01 Aug. 2011. <http://www.sciencedaily.com/releases/2011/07/110711131153.htm>.

- http://web.mit.edu/newsoffice/2011/water-splitting-0609.html

"'Artificial Leaf' Moves Closer to Reality - MIT News Office." *MIT - Massachusetts Institute of Technology*. Web. 01 Aug. 2011. <http://web.mit.edu/newsoffice/2011/water-splitting-0609.html>.

- http://opac.yale.edu/news/article.aspx?id=8399

"Novel Nanowires Boost Fuel Cell Efficiency." *Yale University News*. 31 Mar. 2011. Web. 01 Aug. 2011. <http://opac.yale.edu/news/article.aspx?id=8399>.

- http://www.greencarcongress.com/2011/04/yale-20110406.html

"Pt-BMG Nanowires Boost Fuel Cell Efficiency and Durability; Easy and Economical Fabrication." *Green Car Congress*. 6 Apr. 2011. Web. 01 Aug. 2011. <http://www.greencarcongress.com/2011/04/yale-20110406.html>.

- http://www.physorg.com/news156003211.html

"Nanowires May Lead to Better Fuel Cells." *PhysOrg.com - Science News, Technology, Physics, Nanotechnology, Space Science, Earth Science, Medicine*. 11 Mar. 2009. Web. 01 Aug. 2011. <http://www.physorg.com/news156003211.html>.

Name________________________

Hey Man, Let's Split – Water, That Is…

Report Sheet

Observations

Draw a schematic representation of your experimental setup. Be sure to include the following:

- Apparatus
- Direction of electron flow
- (+) and (−) electrodes (nickel wires)
- Gas produced in each tube
- Observations as experiment proceeds

Data

Record which tube you are connecting to the positive and negative electrodes of the power source.

Tube 1____________________________ Tube 2 ____________________________

Table 1 – Time-dependant Electrolysis

		Time (minutes)										
		0	2	4	6	8	10	12	14	16	18	20
Volume (mL)	H_2											
	O_2											

Table 2 – Current-dependent Electrolysis

		50 mA	**100 mA**	**150 mA**	**200 mA**
Beginning volume (t = 0 min)	H_2				
	O_2				
Ending volume (t = 5 min)	H_2				
	O_2				

NSF –DUE Award #1204279

Analysis

1. Graph the data from Table 1. Use whatever graphing method your instructor suggests. Use two colors: one color for hydrogen and a different color for oxygen. Time in minutes is on the x-axis and gas volume in milliliters (mL) is on the y-axis. **Attach the graph to this report sheet.**

   - Determine the best fit straight line for each curve. Report the equations below.

H_2 (reduction)	
O_2 (oxidation)	

   - The slope of each line will represent the rate of gas production.

Rate of H_2 production = ______ mL/min.

Rate of O_2 production = ______ mL/min.

2. Determine the ratio of H_2 production to O_2 production rates.

Ratio of $\frac{H_2}{O_2}$ production = ______

3. Report the best fit lines for your graph from Analysis Question 1. This time, do NOT use variables "x" and "y" but rather use the physical variables (gas volume and time) studied in this experiment as well as their UNITS.

Equation of Best-Fit Line (H_2)	

Equation of Best-Fit Line (O_2)	

4. Explain why the ratio of $\frac{H_2}{O_2}$ production rates is as you determined in this experiment.

5. Graph the data from Table 2. Use whatever graphing method your instructor suggests. Your graph should have 8 lines, one for each current value for each tube. Time in minutes is on the x-axis and gas volume in milliliters (mL) is on the y-axis. **Attach the graph to this report sheet.**

6. Determine the rate of production of each gas (slope of each line) and report below.

		50 mA	**100 mA**	**150 mA**	**200 mA**
Rate of Gas Production (slope of line) (mL/min)	H_2				
	O_2				

7. Examine the data from the current-dependent electrolysis. For each current setting, does the ratio of $\frac{H_2}{O_2}$ production rates match (within experimental error) that determined in Analysis Question 2? If they do, explain why this must be so. If they do not, explain why they should not be the same.

8. Examine the slopes of the current-dependent electrolysis data (Analysis Question 4). Create a third graph that plots the rate of gas production on the y-axis and the current on the x-axis. There should be two lines on this graph, one for H_2 and another for O_2. **Attach the graph to this report sheet.**

Seattle's Hub for Industry-driven
Nanotechnology Education – May 2016

NSF –DUE Award #1204279

9. Assume that the lines for H_2 and O_2 are linear. Determine the slope of the line for each tube and report below.

Slope of line (mL/min/mA)	H_2	
	O_2	

10. What you determined in Analysis Question 9 is the rate of a rate. It is the rate at which the rate of gas production changes with changing current. In Question 9 we assumed the slope of the line (this rate of a rate) is linear with increasing current.

    A. Within the limits of experimental error, are your rate of the rate lines from Analysis Question 8 linear? If they are not, describe why you think your graph shows them not to be.

    B. **Hypothesis:** Propose an hypothesis that explains why we should expect the rate of gas production to increase linearly with increasing current. (Note: you should consider what current is, and how it is related to how fast the chemical reaction will occur)

11. Describe at least two ways data collection could be made more accurate.

NSF –DUE Award #1204279

12. Hydrogen and oxygen are produced because of the redox reactions that occur on the surface of the nickel wires. How might nanotechnology be used to increase the efficiency of this reaction?

13. How would you be able to show that the energy used during this reaction (from the power supply) is stored in the reaction products, H_2 and O_2 gas?

Instructor's Guide

Pre-Lab Preparations

Before the lab, construct one electrode/tube assembly for each lab group.

Safety

Wear gloves when handling nickel wire. Use care when using sharp tools and wire cutters.

Pre-Lab Materials

- 2 15mL graduated plastic tubes (such as Falcon tubes)
- Nickel wire
- Rubber band
- Wire cutters
- Sharp, pointed instrument (such as a compass point or small awl)
- Labels (tape and marker)
- Gorilla glue
- Gloves

Pre- Lab Procedure

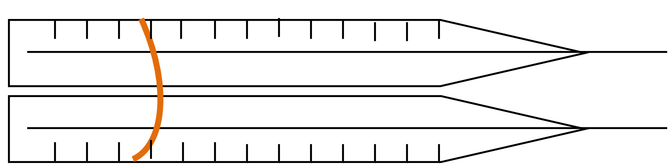
1. Using a sharp pointed instrument, poke a hole in the bottom of each graduated plastic tube.

2. While wearing gloves, use wire cutters to cut 2 pieces of nickel wire about one inch in length longer than the length of the plastic tubes.

3. Thread one nickel wire piece through the holes at the bottom of one of the plastic tubes leaving about an inch exposed through the hole of the tubes, as shown below.

4. Using gorilla glue, seal the hole surrounding the nickel wire so that the tubes are water and air tight. Allow sufficient time to dry.

5. Rubber band the two tubes together ensuring the ease of reading the water levels.



6. Determine the voltage range of your power source. The amount of sodium sulfate used will depend on the voltage of your power source. The lower the voltage, the more sodium sulfate will be needed. With a minimum voltage around 12 V, about 10 g of sodium sulfate is needed. With high voltages, only 1 g of sodium sulfate will be needed. Adjust the lab procedure as necessary to reflect this.

Report Sheet Answer Key

Learning Outcomes

- Understand the chemical reaction taking place during electrolysis
- Test the stoichiometry of the water splitting equation
- Understand how the electrolysis reaction can be used in fuel cell technology

Washington EALR Alignment

9-12 APPA Science affects society and cultures by influencing the way many people think about themselves, others, and the environment. Society also affects science by its prevailing views about what is important to study and by deciding what research will be funded.

9-11 PS2A Atoms are composed of protons, neutrons, and electrons. The nucleus of an atom takes up very little of the atom's volume but makes up almost all of the mass. The nucleus contains protons and neutrons, which are much more massive than the electrons surrounding the nucleus. Protons have a positive charge, electrons are negative in charge, and neutrons have no net charge.

9-11 PS2B Atoms of the same element have the same number of protons. The number of electrons determines how the atom interacts with other atoms to form molecules and ionic arrays.

9-11 PS2D Ions are produced when atoms or molecules lose or gain electrons, thereby gaining a positive or negative electrical charge. Ions of opposite charge are attracted to each other, forming ionic bonds. Chemical formulas for ionic compounds represent the proportion of ion of each element in the ionic array.

9-11 PS2E Molecular compounds are composed of two or more elements bonded together in a fixed proportion by sharing electrons between atoms, forming covalent bonds. Such compounds consist of well-defined molecules. Formulas of covalent compounds represent the types and number of atoms of each element in each molecule.

9-11 PS2G Chemical reactions change the arrangement of atoms in the molecules of substances. Chemical reactions release or acquire energy from their surroundings and result in the formation of new substances.

9-11 PS2I The rate of a physical or chemical change may be affected by factors such as temperature, surface area, and pressure.

9-11 PS3A Although energy can be transferred from one object to another and can be transformed from one form of energy to another form, the total energy in a closed system is constant and can neither be created nor destroyed. (Conservation of Energy)

9-11 ES2D The Earth does not have infinite resources; increasing human consumption impacts the natural processes that renew some resources and it depletes other resources including those that cannot be renewed.

9-11 LS2F The concept of sustainable development supports adoption of policies that enable people to obtain the resources they need today without limiting the ability of future generations to meet their own needs. Sustainable processes include substituting renewable for nonrenewable resources, recycling, and using fewer resources.

Oregon Content Standards Alignment

H.1 P.1 Describe how different types and strengths of bonds affect the physical and chemical properties of compounds.

H2. P.1 Explain how chemical reactions result from the making and breaking of bonds in a process that absorbs or releases energy. Explain how different factors can affect the rate of chemical reaction.

H.2 P.2 Explain how physical and chemical changes demonstrate the law of conservation of mass.

H.2 P.3 Describe the interactions of energy and matter including the law of conservation of energy.

H.2 E.1 Identify and predict the effect of energy sources, physical forces, and transfer processes that occur in the Earth system. Describe how matter and energy are cycled between system components over time.

H.2 E.4 Evaluate the impact of human activities on environmental quality and the sustainability of Earth systems. Describe how environmental factors influence resource management.

H.3 S.3 Analyze data and identify uncertainties. Draw a valid conclusion, explain how it is supported by the evidence, and communicate the findings of a scientific investigation.

Idaho Content Standards Alignment

8 – 9 Physical Science, 8 – 9 Earth Science, 9 – 10 Biology

1.2.1 Use observations and data as evidence on which to base scientific explanations.

1.2.3 Develop scientific explanations based on knowledge, logic and analysis.

1.3.3 Measure and calculate using the metric system.

5.2.1 Explain how science advances technology.

5.2.2 Explain how technology advances science.

5.2.3 Explain how science and technology are pursued for different purposes.

8 – 9 Physical Science, 8 – 9 Earth Science, 9 – 10 Biology

9-10.B.5.1.1 Analyze environmental issues such as water and air quality, hazardous waste, forest health, and agricultural production.

9-10.B.5.3.1 Describe the difference between renewable and nonrenewable resources.

8 – 9 Physical Science

8-9.PS.2.3.1* Explain that energy can be transformed but cannot be created nor destroyed.

8-9. PS.2.3.2* Classify energy as potential and/or kinetic and as energy contained in a field.

8-9 PS.2.4.2. Explain the processes of fission and fusion.

8-9.PS.2.4.4 State the basic electrical properties of matter.

8-9.PS.2.5.1 Explain how chemical reactions release or consume energy while the quantity of matter remains constant.

11 – 12 Chemistry

11-12.C.1.3.1 Identify, compare and contrast physical and chemical properties and changes and appropriate computations.

11-12.C.1.3.5 Analyze and solve reaction stoichiometry problems.

11-12.C.1.8.1 Correctly write symbols, formulas and names for common elements, ions and compounds.

11-12.C.1.8.2 Communicate scientific investigations and information clearly.

11-12.C.2.3.2 Demonstrate the conservation of matter by balancing chemical equations.

11-12.C.2.5.2 Classify, write and balance chemical equations for common types of chemical reactions and predict the products.

11-12.C.2.5.3 Describe the factors that influence the rates of chemical reactions.

11-12.C.5.1.1 Demonstrate the ability to work safely and effectively in a chemistry laboratory.

11-12.C.5.2.1 Assess the role of chemistry in enabling technological advances.

11-12.C.5.3.1 Evaluate the role of chemistry in energy and environmental issues.

Lab Prep Sheet per class of 24 students (12 pairs)

Splitting Water

CHEMICALS & SOLUTIONS

	Chemical	Concentration	Total Quantity	Distribution Notes	Amount used per student PAIR	Amount used per section
❑	Na_2SO_4 (solid)		15 g	divide into jars, 1 per group of 4	1 g	12 g +

Instructor Notes: -

Lab Tech Notes: Determine the voltage range of your power source. The amount of sodium sulfate used will depend on the voltage of your power source. The lower the voltage, the more sodium sulfate will be needed. With a minimum voltage around 12 V, about 10 g of sodium sulfate is needed. With high voltages, only 1 g of sodium sulfate will be needed. Adjust the lab procedure as necessary to reflect this

EQUIPMENT, GLASSWARE & MODELS

	Quantity	Equipment / Model	Distribution Notes
		Prepare 12 electrode assemblies as described below	
❑	24	15mL graduated plastic tubes (such as Falcon tubes)	
❑	12	nickel wire (see instructions below) (~12 ft total)	
❑	12	rubber bands	
❑	1	wire cutters	
❑	1	sharp pointed instrument	
❑	12	labels	
❑		Gorilla glue	
❑		gloves	

Lab Tech Notes:

Prepare electrode assemblies as follows:

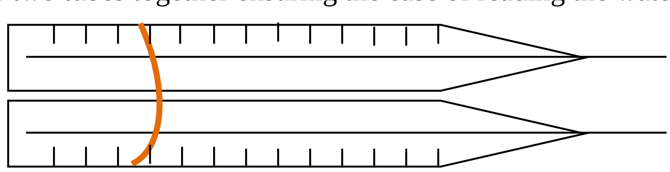
1. Using a sharp pointed instrument, poke a hole in the bottom of each graduated plastic tube.

2. While wearing gloves, use wire cutters to cut 2 pieces of nickel wire about one inch in length longer than the length of the plastic tubes.

3. Thread one nickel wire piece through the holes at the bottom of one of the plastic tubes leaving about an inch exposed through the hole of the tubes, as shown below.

4. Using gorilla glue, seal the hole surrounding the nickel wire so that the tubes are water and air tight. Allow sufficient time to dry.

5. Rubber band the two tubes together ensuring the ease of reading the water levels.



❑ **WASTE CONTAINER(S)**

Flush Na_2SO_4 down drain with plenty of water.
If local regulations require, set out waste collection jug.

Label: Na_2SO_4 (aq) - 12-15 grams
Capacity: approx 4 L