

Electrochemistry!

Electricity and Chemical Reactions



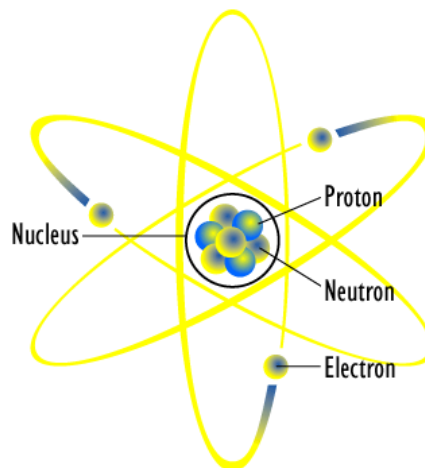
Mad Duck Science Friday Laboratory Notebook

Name:

Team:

Everything is made of atoms.

- Atoms are made of three parts; Protons, Neutrons, and Electrons. Protons and Neutrons sit together at the center of the atom (a region called the nucleus) while electrons occupy the rest of the area.
- Protons and Electrons have charge and are therefore “charged”
- Protons are positive (+)
- Electrons are Negative (-)
- Neutrons have no charge and are therefore “neutral”
- The charge of an atom is the total number of protons, which cannot be changed, minus the total number of electrons, which can be changed.
- Normally atoms have the same number of protons and electrons and therefore no charge.
- When they can, electrons will move from high energy atoms to low energy atoms. This can result in atoms that have a different number of electrons and protons. Such atoms are called ions and are charged.



Exercise: What is the charge of the following atoms?

Iron

26 Protons

26 Electrons

Iron Ion

26 Protons

24 Electrons

Sodium Ion

11 Protons

10 Electrons

Sometimes two ions with opposite charges come together to form a material these are called ionic compounds. Table salt (sodium chloride) is a common example. Ionic compounds dissolve easily in water. For example copper sulfate and iron sulfate dissolve in water though neither copper nor iron will dissolve by itself. Solutions with ions in them conduct electricity. Solutions without ions do not conduct electricity.

In chemical reactions sometimes electrons move between atoms thereby changing the charge of the atoms. We can also harness the power of these moving electrons. That's how batteries work.

When an atom's charge is lowered we call that REDUCTION. When an atom's charge is raised we call that OXIDATION. Chemical reactions in which one atom is oxidized and another is reduced are called REDOX reactions

Safety

In chemistry research sometimes we deal with dangerous things. While nothing that you will be using today is deadly there are some toxic things that could make you very sick. Here are some rules to follow when doing chemistry:

- Obey instructions from the graduate students
- Wear gloves and eye protection
- Do not put anything that we are using in the chemical area in your mouth
- Do not touch your mouth, eyes, or face while in the chemical area
- Be sure to wash your hands with soap and water when you are done with experiments
- Before you try something new check with the graduate student to make sure it is safe

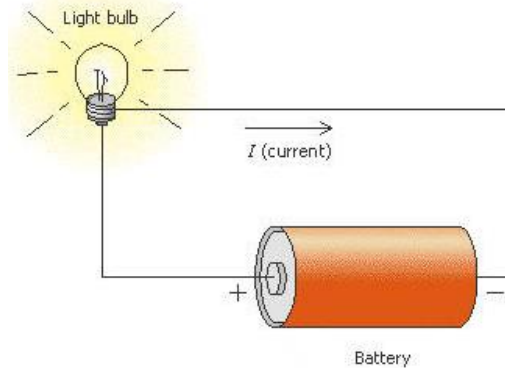
Experiment 1: Fruit and Vegetable Batteries

Background: The energy produced by a battery comes from chemical reactions inside the battery. Because the energy generated is in the form of electricity, a battery is known as an *electrochemical* cell. When wires are used to make a complete circuit, the battery's energy can be used to light bulbs, start cars, operate remotes, ect.

When we use electrical energy, we often refer to using *power*. A battery will produce current at a certain voltage. To calculate the power, we can simply multiply the current and the voltage:

$$P = V \cdot I$$

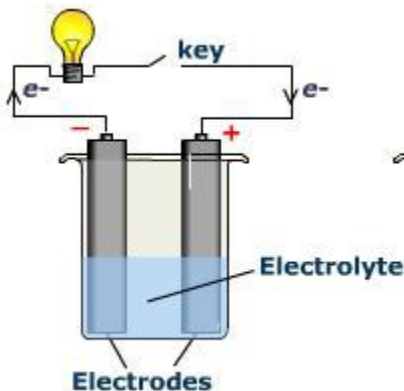
In this experiment, you will construct a battery from common materials. Two different metals will be used as well as a fruit or vegetable. The two pieces of metal are known as *electrodes*. Electrochemical differences in the two metals provide the energy to move electrons through the circuit. In order to complete the circuit without touching the metals together, an *electrolyte* is used. In this case the juice in a fruit (or vegetable) will be the electrolyte. After measuring the voltage and current, you will be able calculate the power of your battery!



Procedure:

Part 1: Deionized Water Cell

- Fill the small cup about halfway with D.I. H₂O.
- Place one strip of zinc (Zn) and one strip of copper (Cu) in the cup. Make sure they don't touch.
- Connect the red lead to the copper electrode and the black lead to the zinc electrode.
- Turn the multimeter to the 2 volt setting. Record the voltage below.
- Now turn the multimeter to the 2 miliamp setting. Record the current below.
- Calculate the power of your battery using the above equation!



Battery Voltage: _____

Battery Current : _____

_____ X _____ = _____
Voltage X Current = Battery Power

Part 2: Salt Water Cell

- Add 1 scoop of salt (sodium chloride, NaCl) to the D.I. H₂O.
- Make sure the two electrodes don't touch.
- Connect the red lead to the copper electrode and the black lead to the zinc electrode.
- Turn the multimeter to the 2 volt setting. Record the voltage below.
- Now turn the multimeter to the 2 miliamp setting. Record the current below.
- Calculate the power of your battery!



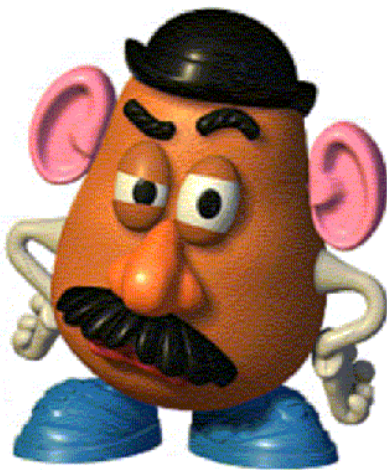
Battery Voltage: _____

Battery Current : _____

$$\begin{array}{ccccccc} \text{_____} & \times & \text{_____} & = & \text{_____} \\ \text{Voltage} & \times & \text{Current} & = & \text{Battery Power} \end{array}$$

Part 3: Potato Battery

- Remove the electrodes from the salt water cell and rinse clean.
- Carefully place the electrodes into the potato. Space them about an inch apart.
- Connect the red lead to the copper electrode and the black lead to the zinc electrode.
- Turn the multimeter to the 2 volt setting. Record the voltage below.
- Now turn the multimeter to the 2 miliamp setting. Record the current below.
- Calculate the power of your battery!



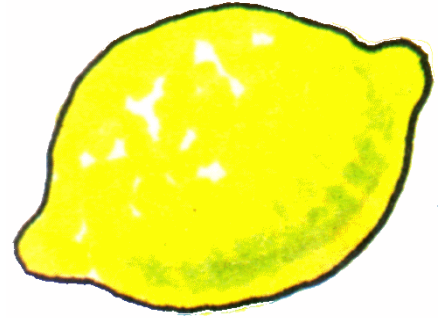
Battery Voltage: _____

Battery Current : _____

$$\begin{array}{ccccccc} \text{_____} & \times & \text{_____} & = & \text{_____} \\ \text{Voltage} & \times & \text{Current} & = & \text{Battery Power} \end{array}$$

Part 4: Lemon Battery

- Remove the electrodes from the potato and rinse clean.
- Carefully place the electrodes into the lemon. Space them about an inch apart.
- Connect the red lead to the copper electrode and the black lead to the zinc electrode.
- Turn the multimeter to the 2 volt setting. Record the voltage below.
- Now turn the multimeter to the 2 miliamp setting. Record the current below.
- Calculate the power of your battery!



Battery Voltage: _____

Battery Current : _____

$$\begin{array}{ccccccc} \text{_____} & \times & \text{_____} & = & \text{_____} \\ \text{Voltage} & & \text{Current} & & \text{= Battery Power} \end{array}$$

Part 5: Pickle Battery:

Now it's time to make a hypothesis! From what you observed, do you think the pickle will be a good battery (powerful)? Why?

Now test your hypothesis!

- Remove the electrodes from the lemon and rinse clean.
- Carefully place the electrodes into the pickle. Space them about an inch apart.
- Connect the red lead to the copper electrode and the black lead to the zinc electrode.
- Turn the multimeter to the 2 volt setting. Record the voltage below.
- Now turn the multimeter to the 2 miliamp setting. Record the current below.
- Calculate the power of your battery!



Battery Voltage: _____

Battery Current : _____

$$\begin{array}{ccccccc} \text{_____} & \times & \text{_____} & = & \text{_____} \\ \text{Voltage} & & \text{Current} & & \text{= Battery Power} \end{array}$$

Design Challenge:

Design the most powerful battery you can!

- Calculate the power of your battery!

Battery Voltage: _____

Battery Current : _____

$$\frac{\text{Voltage}}{\text{X}} \times \frac{\text{X}}{\text{Current}} = \text{Battery Power}$$

- Calculate the power of your battery!

Battery Voltage: _____

Battery Current : _____

$$\frac{\text{Voltage}}{\text{X}} \times \frac{\text{X}}{\text{Current}} = \text{Battery Power}$$

- Calculate the power of your battery!

Battery Voltage: _____

Battery Current : _____

$$\frac{\text{Voltage}}{\text{X}} \times \frac{\text{X}}{\text{Current}} = \text{Battery Power}$$

Experiment 2: Depositing Metals

Background: This experiment is slightly more dangerous than the previous experiments you have done. We will be using copper sulfate solutions. Try not to let them touch your skin. If the solution does touch your skin go to the bathroom and wash it off thoroughly with water. Be extra sure to wash your hands when you're done with the experiment.

We are going to perform a redox reaction. Remember in redox reactions something is reduced meaning it gains a negative charge and something else is oxidized meaning it gains a positive charge. An element's charge is the total number of protons it has taken away the total number of electrons. Ionic compounds have two parts one with a positive charge and one with a negative charge. The charges in an ionic compound are equal and opposite.

Questions:

What are nails made of? What is the primary element?

What is the charge of the atoms in the nail?

Copper sulfate is an ionic compound. Sulfate has a charge of (-2) and there is one copper for every sulfate. What is the charge of the copper ions?

Procedure

Part 1: Nail

- When your instructor tells you to do so put on your safety equipment. Goggles and gloves.
- Your instructor will give your group a glass vial with a copper sulfate solution in it. Copper sulfate is toxic do not let the copper sulfate touch your skin.
- With the cap on gently swirl the solution
- Slowly open the vial.
- While holding the vial such that it does not fall over place a nail into the vial and let it sit for 60 seconds
- Observe what happens

What did you observe?

Why do you think that happened? What is being reduced? What is being oxidized? Ask the grad student if you don't know.

What do you think will happen if you place aluminum or copper into the vial? Why?

Part 2: Other metals

- Remove the nail from the copper sulfate solution and set it aside
- Place a strip of aluminum foil in the solution and observe for 60 seconds.
- Remove the aluminum foil and add copper, what happens now?

Write down your observations for aluminum

Write down your observations for copper.

Why do you think the metals are different?

What do you think would happen if we use iron sulfate instead of copper sulfate? Make predictions.

Part 3: Iron Sulfate

- Your graduate student will now give you a vial of iron sulfate solution. Again this is toxic so use caution.
- Place a nail in the solution and observe for 60 seconds.
- Place a strip of aluminum foil in the solution and observe for 60 seconds.
- Remove the aluminum foil and add copper, what happens now?

What happened with iron?

What happened with Aluminum?

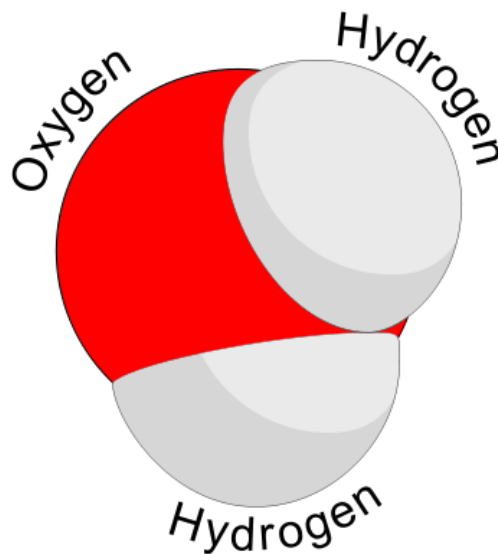
What happened with copper?

Based on what you have observed can you decide which element (copper or iron) has a lower energy for electrons to go to? That is given the choice do electrons want to be around iron or around copper more?

Experiment 3: Making hydrogen

Background: In this experiment we are going to split water (H_2O) into H^+ and OH^- ions. Then we will reduce the H^+ ions to form hydrogen. We will do this with different materials to observe different redox reactions take place.

Remember in each reaction something is being oxidized and something else is being reduced. It won't always be what you expect!



Procedure

Part 1: Completing the circuit

- Fill the small cup about halfway with H_2O (water).
- Place two pieces of copper into the cup
- Take two alligator clips and connect them to your battery. Do not let the negative and positive alligator clips touch.
- Connect one alligator clip to each of the copper pieces in your cup.
- Observe what happens.
- Disconnect and remove your electrodes
- Add a teaspoon of salt to your cup
- Now put the electrodes back in and hook them up again
- Observe and compare

Questions:

What happened without the salt? Why?

What happened with the salt? Why?

Part 2: Redox reactions

- Continuing directly from part one keep the electrodes hooked up for 30 seconds
- Observe what happens and write it down.
- Now switch the leads on your battery, watch closely to observe what happens
- Repeat this experiment a few times until you are confident in your observations
- Disconnect your electrodes from the battery terminal and write down your observations

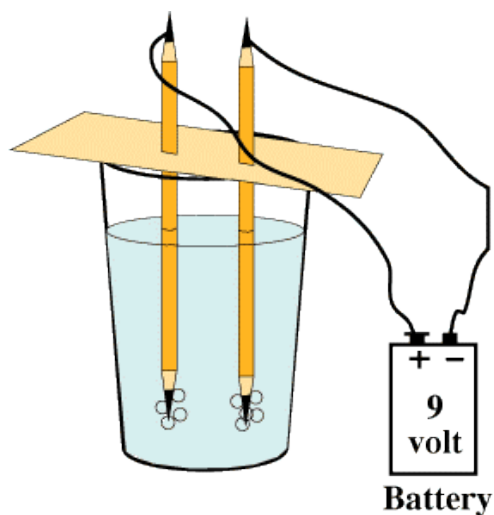
Questions

What happens to the copper connected to the positive terminal?

What happens to the copper connected to the negative terminal?

What happens when you switch the terminals?

Hydrogen gas is bubbling therefore hydrogen is being reduced. What is being oxidized?



Part 3: Different electrodes?

- Suppose we don't like copper oxide, can we oxidize something else?
- Replace one of your copper electrodes with aluminium.
- Connect the black (negative) lead to the copper and the red (positive) lead to the aluminium
- Observe what happens
- Try switching the leads again and see what happens.
- Repeat this using iron and with graphite (pencil lead).

What happens with iron electrodes?

What happens with aluminum electrodes?

What happens with graphite electrodes?

Why are these electrodes different? Ask your graduate student.

Experiment 4: A Penny Battery

Background: In this experiment we are going to build a battery. No fruit, this time it's pennies. Remember for the fruit battery experiment we used two metals and an electrolyte (fruit). Pennies are made of two metals zinc on the inside and copper on the outside. Our electrolyte will be vinegar. Unfortunately we don't have enough pennies for you to take any home so please leave the pennies for other kids to use in the future when you are done.

Procedure

Part 1: The first cell

- Cut up four penny sized cardboard squares and place them in a cup with a small amount of vinegar.
- Rub the zinc side (the silver colored side) of your pennies with sandpaper to make sure they are clean and free of copper.
- Place a penny on your aluminum foil
- put a vinegar soaked cardboard piece on top of the penny
- Connect the leads to your battery.
- Turn the multimeter to the 2 volt setting. Record the voltage below.
- Now turn the multimeter to the 2 miliamp setting. Record the current below.
- Calculate the power of your battery!



Battery Voltage: _____

Battery Current : _____

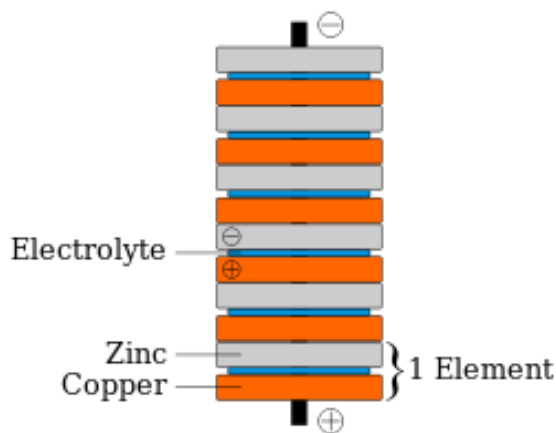
_____ X _____ =

Voltage X Current = Battery Power

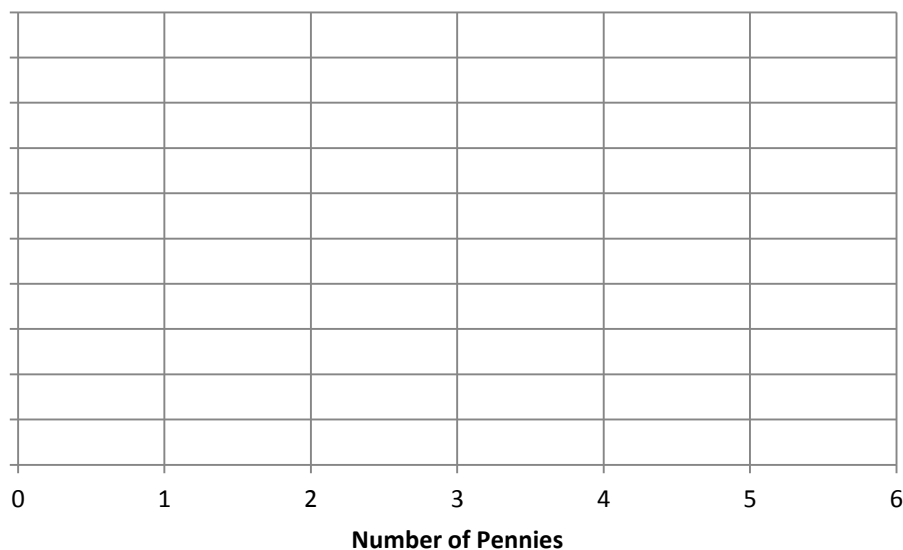
Does it matter which side is up on the pennies? Do they both need to have the same side up or does opposite sides up work as well?

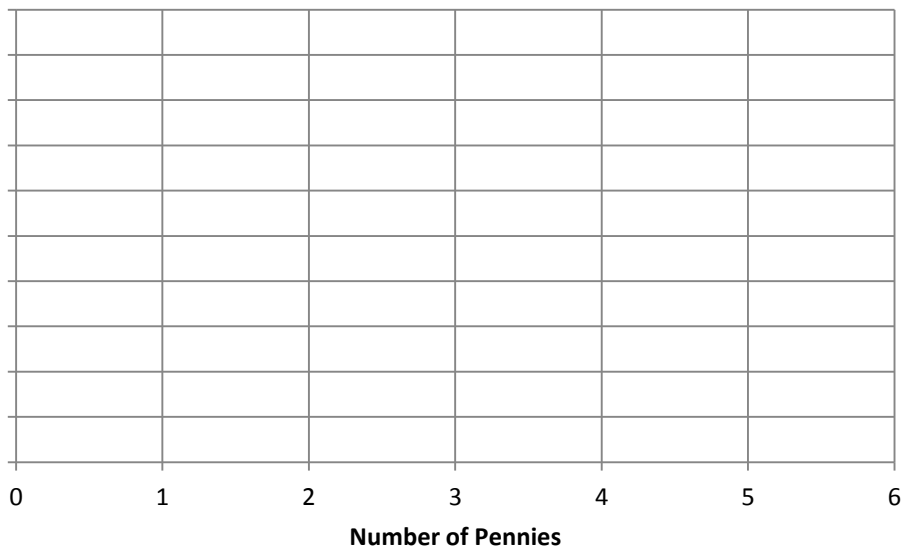
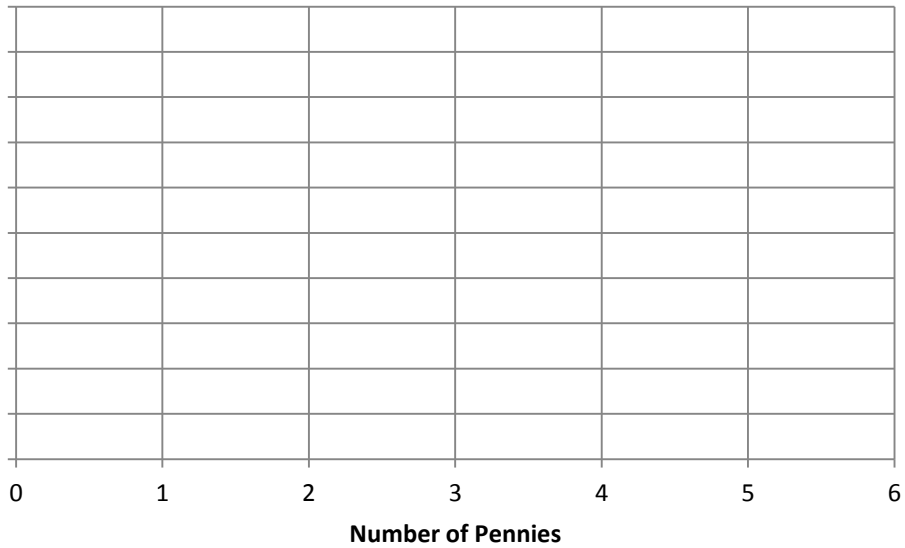
Part 2: Building a multi-cell battery

- Now add another vinegar soaked cardboard piece and another penny.
- Connect the leads to your battery.
- Turn the multimeter to the 2 volt setting. Record the voltage in the table below.
- Now turn the multimeter to the 2 miliamp setting. Record the current in the table below.
- Repeat this until you have a battery five pennies high
- Plot your data on the graphs provided. You will need to label the Y (up-down) axis yourself. It's best to measure all the data before you start plotting it.
- You should end up with three graphs, one for voltage, one for current, one for power.



# of Pennies	Voltage	Current	Power
1			
2			
3			
4			
5			





Does the power of the battery increase at a constant rate? Why do you think this happens? Feel free to check with your graduate student to see if your hypothesis is correct.

How many pennies would you need to have a 9 volt battery? What about a 12 volt battery? Car batteries have about 500 amps. How many pennies would you need for that?