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STUDENT CELL & POROUS CUP

CAT NO. PH0927-N8

Experiment Guide

VOLTAIC CELL WITH POROUS CUP
STUDENT VERSION

GENERAL BACK GROUND

A voltaic cell (sometimes referred to as galvanic cell) is a classic experiment to show that chemical reactions can generate a potential difference as electrons leave one metal and transfer to another metal. A battery consists of one or more voltaic cells. Traditionally a voltaic cell is used to help students understand redox (oxidation reduction) reactions. These reactions are defined in terms of the loss or gain of electrons. Voltaic cells use a spontaneous chemical reactions in order to generate a potential difference. In order for the reaction to continue a salt bridge is required to allow ions to move from one cup to the next. A voltaic cell uses two electrodes which are usually metals or another type of good conductor (carbon is included in this product for students to experiment with). These electrodes provide the surfaces on which oxidation and reduction occur. In a voltaic cell the cathode is positively charged. In electrolytic cells, where a current is used to force a reaction, the anode is positively charged.

A scientist named Luigi Galvani discovered that an amputated frog leg would move when two different metals (copper and zinc) were held on either side of the frog leg. Later in the 1800s Alessandro Volta constructed similar experiment to Luigi to create what was later to be known as the first battery. This is why the term Galvanic and Voltaic are interchangeable. Galvani thought that the electricity was in the leg of the frog, however Voltaic knew that the electron came from the copper wire, not the frog leg.

REQUIRED COMPONENTS (INCLUDED)

Object	*Quantity*
Plastic Jar w/ Lip	1
Electrode Brackets	2
Iron (Fe) Electrode	1
Tin (Sn) Electrode	1
Carbon (C) Rod	1
Nickel (Ni) Electrode	1
Zinc (Zn) Electrode	2
Aluminum (Al) Electrode	1
Copper (Cu) Electrode	1
Porous Cup (in place of salt bridge)	1

REQUIRED COMPONENTS (NOT INCLUDED)

Object	*Quantity*
An Electrolyte Solution (Ex: Acetic Acid, Dilute Sulfuric Acid, Dilute Hydrochloric Acid)	
Multimeter (Digital Recommended)	1
1 M Aqueous Solution of Copper Sulfate (CuSO4)	100 mL
1 M Aqueous Solution of Zinc Sulfate (ZnSO4)	200 mL

SAFETY & PRECAUTIONS

Caution - Diluting acids on your own can be hazardous, EISCO recommends purchasing factory diluted acid. Be sure students wear appropriate safety gear such as safety glasses, gloves and aprons.

Caution – Porous Cup will break easily, handle with care.

Maintenance – Porous cup should be rinsed thoroughly after each use.

Activity 1: Creating A Student Voltaic Cell

BACKGROUND:

If a piece of zinc is placed in a solution of copper sulfate a redox reaction occurs in which.

$$Zn_{(s)} + CuSO_{4\,(aq)} \rightarrow ZnSO_{4(aq)} + Cu_{(s)}$$

The zinc is replaced by copper on the zinc bar and electrons are transferred from the zinc to the copper in solution. LEO says GER is a pneumonic to help students remember that <u>L</u>ose Electrons <u>O</u>xidation, <u>G</u>ain <u>E</u>lectrons <u>R</u>eduction. Therefore the zinc is oxidized and copper is reduced.

Here are the half reactions:

$$\text{Oxidation: } Zn_{(s)} \rightarrow Zn^{2+}{}_{(aq)} + 2e-$$

standard reduction potential - 0.76 V

$$\text{Reduction: } Cu^{2+}{}_{(aq)} + 2e- \rightarrow Cu_{(s)}$$

standard reduction potential +0.34 V

Since the copper part of the reaction has a higher reduction potential, copper will be reduced while zinc will be oxidized. The oxidation potential is the reduction potential times -1.

If instead of the copper solution and zinc metal being in the same cup, the electrons are allowed to transfer only across a wire and each half reaction is placed in a separate cup, then a voltaic cell is made and one can measure the potential difference between the two cups with a voltmeter or digital multi-meter. Traditionally two cups are used and a salt bridge connects the two cups so ions may flow between the two cups. Salt bridges are messy and don't always work well, so in this apparatus a porous cup is used instead to make the experiment easier for the students.

Therefore: Cell potential (the amount of voltage produced) is equal to the sum of the oxidation reaction at the anode and the reduction reaction at the cathode. Or

$$E^{o}_{cell} = E^{o}_{ox} + E^{o}_{red}$$

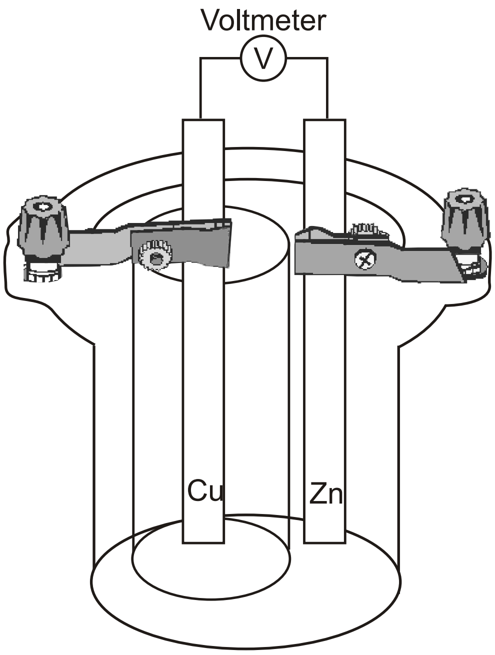
$$E^{o}_{cell} = 0.76\ V + 0.34\ V = 1.10\ V$$

This voltaic cell has relatively little error and a reading of about 1.0 V should be expected from this apparatus. There are a few assumptions made to get this voltage. The first is that the cell is operating under standard state conditions. This means using a 1 M solution, at 25°C and 1 atm of pressure. The cell potentials are relative so the reduction of hydrogen is typically set as the standard and has a value of 0.0 V.

Activity 1: Setting Up and Getting Familiar with a Voltaic Cell:

When students enter the classroom have them put on proper safety equipment and take a writing utensil, table of Standard Reduction Potentials and worksheet to their lab table. On the table the following equipment will be set up:

Have students work through the worksheet to apply what they have learned in class to the real voltaic cell in front of them.



STUDENT WORKSHEET

Name:______________________________Partners' Name(s):___________________

Date:_________________________Lab Section:______________________________

Observe the apparatus on your lab bench. The metal in the porous cup is copper and the solution in the porous cup is copper sulfate. The metal in the plastic cup is zinc and the solution in the plastic cup is zinc sulfate. Use your table of standard reduction potentials, your voltaic cell and your knowledge of chemistry and answer the following questions.

1. What is the standard reduction potential for zinc?

____

____

2. What is the standard reduction potential for copper?

____

____

3. Write both half reactions below:

____

____

4. Which metal is being reduced?

____

____

____

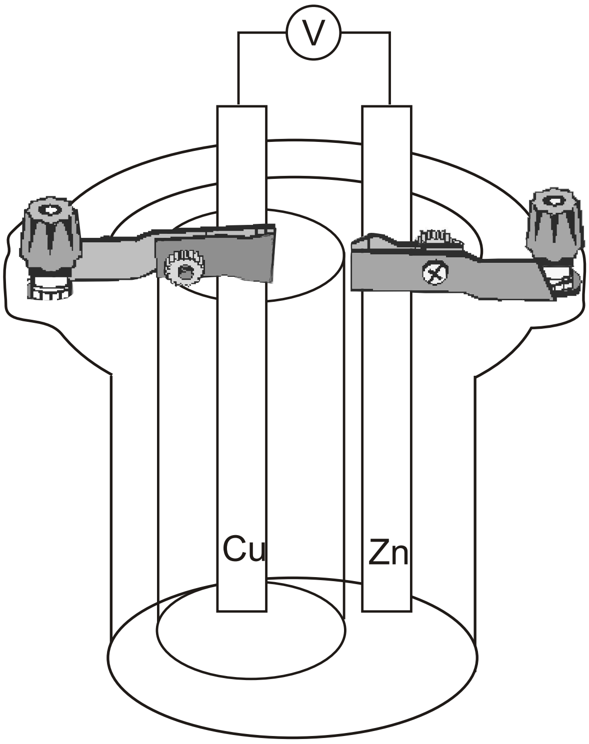
5. How do you know?

____

____

____

6. Label the zinc electrode, the copper electrode, the anode, the cathode, the reducing agent, the oxidizing agent, the voltmeter, the salt bridge, where oxidation occurs, where reduction occurs.



7. One of the leads to the voltmeter is not connected. Once your answers have been checked by your teacher, connect the lead and record your voltage below:

Voltage reading:___________________________

8. What should the cell potential be according to your calculations? Show your work.

____

____

____

9. What is the purpose of the porous cup? Would a voltage still be produced if a plastic cup was used instead of a porous cup?

____

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Activity 2:   Applying What you've learned to make your own Discoveries

For this part of the experiment you can use Acetic Acid (vinegar) as your electrolytic solution. Have students empty the solutions from the last experiment and dispose of them properly. Thoroughly rinse out the porous cup and fill both cups approximately two thirds full with acetic acid. Have students fill out the following table and share their thoughts with the class:

Observations about the apparatus	What can be changed about the apparatus?	What can you measure about the apparatus?
(Possible Responses) There is a larger white container There is acetic acid in the containers There is a bar of zinc extending into the vinegar in the plastic cup There is a bar of copper extending into the vinegar in the porous cup There is a reading of ________ on the voltmeter	(Possible Responses) • The amount of vinegar • The voltage measured • The type of metal used • The temperature of the room • The molarity of the solution • The air pressure of the apparatus • Time the reaction takes place	(Possible Responses) • Amount of vinegar used • The voltage • Temperature • Air pressure • Time reaction takes place

2. Next have the students come up with an investigation question.

   Possible questions:

   How does the type of metal used as an electrode affect the voltage (potential difference) between the two electrodes?

   How does the temperature of the acetic acid affect the voltage (potential difference) between the two electrodes?

   Will a voltage be generated if carbon is used instead of a metal in the voltaic cell?

   Does the amount of vinegar in each jar affect the voltage or potential difference between the two electrodes?

3. Have students make a hypothesis.

4. Have students design their own experimental procedure making sure that they are changing only one variable at a time. Remind them that anything in the last column of the chart they filled out is a variable. If it is not a dependent or independent variable then it must be controlled. Set up apparatus as shown in diagram.

Have students record and analyze data in a meaningful way such as a chart, a graph, a table.

Since this apparatus lends itself to several meaningful and investigable questions, each lab group may have a different question that they investigate. Have students answer their research question, back up their answer with their data and graphs or charts and then present their findings to the class.

Extensions or other ways to use this product:

For middle school level students where the idea is to demonstrate chemical energy converting into electrical energy, a 1 V light bulb can be placed between the two electrodes and will light when the switch is closed connecting the two electrodes.

Build a coulombmeter. Use the mass of copper deposited on one of the electrodes to determine Faraday's constant. (You will need and analytical balance for this demonstration.)

Hook the electrodes up to a current and produce a dry cell, then use your stored electrical energy to make a bell ring or light a light bulb.

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