From Corrosion to Conservation

Objectives: Students will: learn about corrosion, conduct an experiment, make a solution, create a electro-chemical reaction, observe oxidizing and reduction, and discover relationships between ions, electrons, and currents.

Materials: Handouts in this lesson (p.2-4) as appropriate for grade level/abilities. See experiment on p. 4 for materials list.

Procedure: Introduce background information to students. Have upper grade level students read hand outs (p.2-3); assist middle grade level students in understanding the hand outs. Lead a class discussion (for upper and lower grade level students) about those two handouts and big-picture concepts. Distribute hand (p.4) and materials for experiment. Allow students to conduct the experiment. Lead a classroom discussion about the results and the scientific rationale behind the results. Discuss how the experiment and molecular results would have differed depending on what was used at the cathode (i.e. instead of a penny, iron or instead of a penny, nothing – as in the electrolysis of water).

Georgia Performance Standards:

Science
- S5P2c
- S5P3b, c
- SP8P1e
- SCSh9a(technical),c
- SPS6a,b,e
- SPS7a,d

Reading Standards for Literacy in History/Social Studies
- L6-8RST3
- L9-10RST3

Writing Standards for Literacy in History/Social Studies, Science
- L11-12RST3

Benchmarks for Science Literary Concepts
- The Structure of Matter

Aligns with Next Generation Science Standards (NGSS):

MS. Chemical Reactions. MS-PS1-2, MS-PS1-6

HS. Chemical Reactions. HS-PS1-2

HS. Energy. HS-PS3-2

Background

The CSS *Georgia* was an ironclad vessel constructed in Georgia by the Confederacy in 1862. Ironclads were sheathed in iron in an attempt to protect them from enemy vessels firing upon them. Ladies from across the state and the south raised money to fund its construction. The vessel was built of wood and iron railroad rails. This made it too heavy to be propelled by its engine , so the CSS *Georgia* sat in the Savannah River defending the city until December 1864 when Union Major General William T. Sherman took the town on his March to the Sea. Confederate troops sunk the vessel so Union troops would not get it. Several years after the Civil War, and several times during the 20th century, attempts were made to salvage parts of the wreck. During this time, the U.S. Army Corps of Engineers (USACE) dredged the river repeatedly to make the channel deeper. In 2015, the USACE hired underwater archaeologists to excavate the CSS *Georgia* wreck. This was done so that the Savannah River channel could be dredged five feet deeper to allow larger ships coming through the Panama Canal to enter Savannah's port.

Underwater archaeologists excavated thousands of artifacts weighing many thousands of pounds. Many of them are metal and require conservation or else they will rust away. Archaeologists at the conservation lab will perform electrolysis the iron artifacts so that they can be studied and exhibited. Large pieces like the iron cannons will take several years of electrolysis and conservation to stabilize and protect them.

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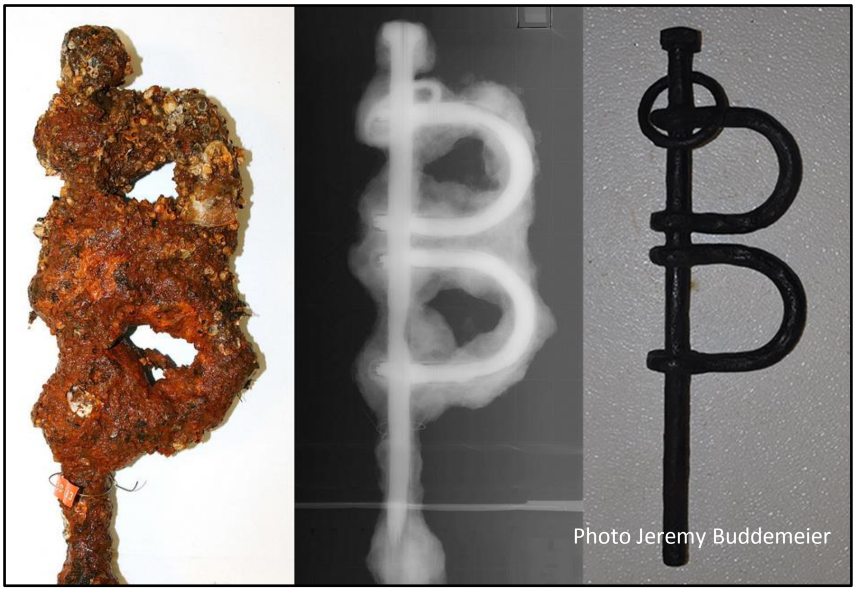

Shackles

Underwater archaeologists excavated these leg shackles from the CSS *Georgia* shipwreck. The wreck was in the Savannah River, in Savannah, Georgia. It is likely that the shackles were put on the legs of sailors who tried to desert, forcing them to stay on the miserably hot, leaky, noisy vessel.

The image on the far left shows what the shackles looked like when brought up from the river after being submerged since 1864. The image in the middle is an X-ray of the shackles, showing what the shape really looked like under all the rust. While it looks sturdy, only the outside shell of the shackles, remained. Most of the metal had rusted away. Archaeologists treated the hollow iron remains as a mold, and filled it with a synthetic material. They removed the rusty iron shell, revealing a cast of the mold. The image on the far right shows this cast, which is what the shackles would have looked like when they were used during the Civil War.

This cannon was one of several recovered by underwater archaeologists from the CSS *Georgia* wreck. Once removed from the water and exposed to air, metal artifacts like this corrode quickly. In order to stop the corrosion and see the artifacts in greater detail, iron objects like this were sent to a conservation lab. There conservators conducted electrolysis on the rusty metal.

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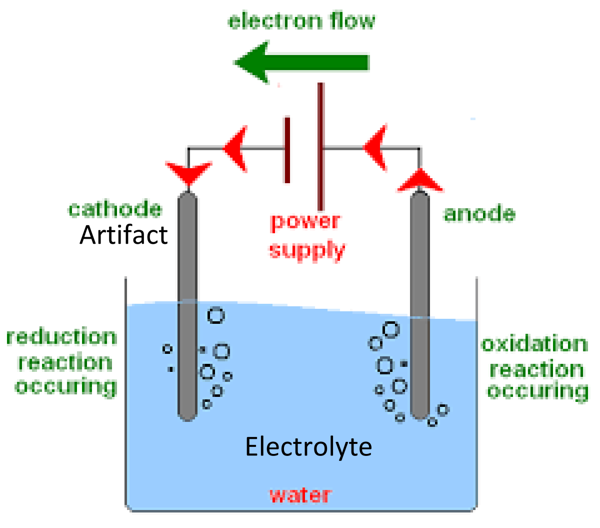
Electrolysis

If corroded artifacts still contain a large amount of their original metal, archaeologists often can clean and conserve them using a treatment called **electrolysis**. This is a method that uses an electro-chemical (electrical AND chemical) reaction to treat rust by turning it into iron. Electrolysis uses an electric current to drive a non-spontaneous chemical reaction.

Electrolysis creates a closed electric circuit. A container is filled with a solution made by mixing sodium bicarbonate (baking soda) and water. This makes a slightly basic solution (rather than an acidic solution) that works well on rusted iron and also helps conduct electricity through water. (Water alone has a high resistance to electric current. Dry baking soda is sodium bicarbonate, NaHCO3, and does not conduct electricity UNTIL it is dissolved in water.) The solution works because when the baking soda dissolves in water, it makes positive and negatively charged irons. These ions move through the solution making an electrical current (the same way electrons make a current when they move through a wire). This solution is called the electrolyte and produces these gasses: hydrogen (H_2), oxygen (O_2), and carbon dioxide (CO_2).



http://en.openei.org/wiki/Electrolysis

After the solution is made, the corroded artifact is suspended in the solution and connected to the negative end of a battery . This electrode is called a cathode. A piece of scrap iron/nail is suspended in the same liquid across from the artifact. The scrap iron is connected to the positive port of the battery. This electrode is called the anode. You have made an electrolytic cell, in which positive and negative electrodes are in a solution containing positively and negatively charged ions. This arrangement creates an electric current (electrons) that passes through the liquid and results in chemical changes to the metals. This happens when the negatively charged ions (electrons)travel in the current to the anode (positive battery terminal). Meanwhile, positively charged ions travel to the cathode (the negative terminal).

The electrolysis process works because of oxidation and reduction. Oxidation is a chemical reaction that happens when something GIVES Up or LOSES electrons, or oxidizes. When iron metal oxidizes it loses two electrons and becomes ferrous iron, Fe++. If it loses three electrons it becomes ferric iron, Fe+++. Reduction is the opposite of oxidation. Reduction is a chemical reaction in which something ACCEPTS electrons. For instance if that ferrous iron, Fe++ was reduced by accepting two electrons, it would become iron metal, or Fe++++. Oxygen likes to accept electrons and be reduced, making it oxide or O--.When oxygen mixes with iron metal, the iron gives electrons to the oxygen and the oxygen accepts the electrons lost from the iron. So the iron is oxidized and the oxygen is reduced. This results in one kind of rust known as ferric oxide, or Fe203. Whenever something is oxidized, something else must be reduced because electrons have to come from somewhere to go somewhere.

In the electrolysis process, the anode is connected to the positive terminal and accepts electrons. So who is giving up the electrons? The water is oxidizing at the anode surface, giving up electrons and producing oxygen. The bubbles coming from the scrap iron/nail are oxygen. Meanwhile, the cathode is on the negative battery terminal. The negative terminal supplies electrons and the water and the rusty artifact accept them. When they do this, the reduction produces hydrogen. The bubbles coming from the cathode are hydrogen gas. This process turns the orange rust to black iron metal. When the process is complete, conservators immediately dry the artifact and coat it with micro-crystalline wax or other surface coating to keep the rust from coming back. Conservators use electrolysis on other metals in addition to iron.

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Materials: Corroded objects (penny used here), scrap steel (non-galvanized nail used here), 1 9-volt battery, low-voltage plastic wrapped wire, wire stripper (correct size for wire), needle-nose pliers, clear plastic cup, teaspoon, water, baking soda (1 teaspoon per cupful of water), plastic spoons (1 per cup), eye protection, rubber or vinyl gloves (1 set per student). **Procedure:**

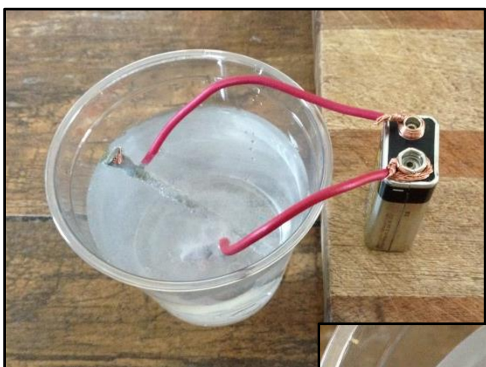
1. Gather supplies. Work in well ventilated area. For one plastic cup, a student will:
2. Cut two wires the same length, long enough to reach from the battery over and into the cup, while wrapped around the battery terminal and the penny. Using the wire strippers, cut and then pull the plastic wrapping off of each end. Make sure to bare enough wire so that the end can be wrapped around the penny.

3. Securely wrap the end of each wire to one of the battery terminals. Tighten with needle nose pliers if necessary. Securely wrap the other end of the wire coming from the negative terminal (-) to the object to be cleaned. Securely wrap the other end of the wire coming from the positive terminal (+) to the nail.

4. Write a description of the penny, noting the color and location of any corrosion.

5. Fill cup ¾ with water.

6. Place nail and penny (connected by wire) in water **but not touching each other** and keeping battery outside cup. (Prop up battery if necessary so objects can stay submersed). Why is there no reaction?



7. Remove nail, penny, and wires from water, being careful to keep wires securely wrapped. Add one teaspoon of baking soda to water and stir until dissolved. Repeat Step 6. What do you observe? What is happening?

8. After 15 minutes and again after 30 minutes pull wire out with penny on it. Make written observations about changes you see. When you think all the corrosion is gone, rinse off the penny and write down what happened. Try to explain it on a physical, chemical, electrical, and molecular level.

Resources

Museum of Underwater Archaeology
CSS *Georgia*
http://www.themua.org/cssgeorgia launched April 5, 2016 with new additions to follow.

Rick's Woodshop Creations
"Electrolysis"
http://www.rickswoodshopcreations.com/miscellaneous/rust_removal.htm, accessed November 12, 2015.

Texas A&M, Center for Maritime Archaeology and Conservation
"Iron Conservation: Part I – Introduction and Equipment"
http://nautarch.tamu.edu/CRL/conservationmanual/File10a.htm, accessed March 29, 2016.