SCIENCE AT HOME

ELECTROCHEMISTRY

GRADE: **12**

SCH4U, SCH4C
SUBJECT: CHEMISTRY
STRAND: ELECTROCHEMISTRY
TOPIC: ELECTROLYTIC CELLS (ELECTRO-ETCHING AND ELECTROPLATING)
EXPECTATIONS: SCH4U: F2.1, F2.2, F2.5, F3.1, F3.5; SCH4C: D1.1, D2.1, D2.2, D2.3, D2.4, D3.1
VIDEO: youtu.be/lYqrfCZrCaM

INTRODUCTION:

Metals are part of our everyday lives — formed into kitchen utensils, moulded into building and vehicle parts and employed to store energy in batteries.

The physical, chemical and mechanical properties of a metal item can be changed through a process called "electroplating," where an electric current is used to create a new metal layer. This helps us create metal items that are resistant to abrasion and corrosion and have increased structural strength. The Royal Canadian Mint, for example, uses electroplating when making some of our coins.

The opposite of electroplating is "electro-etching" (sometimes called "electrochemical machining") which involves the removal of surface metal atoms. This process is used to manufacture parts with difficult shapes, such as turbine blades. Electro-etching is a technique that brings chemistry and art together.

ACTIVITY: Electro-etching

TIME: 60 minutes

SAFETY:

When you are electro-etching, make sure you're in a well-ventilated area — outside, or near an exhaust fan.

Don't connect multiple 9V batteries together.

Don't submerge batteries in water.

Don't connect the positive and negative electrodes of a battery without a load — a bulb, for instance, or a speaker — between them.

Be careful when you connect wires.

Wear protective gloves when you're working with electrolyte solutions.

WHAT YOU NEED:

- Metal object (a steel water bottle, for instance, or a metal tool)
- Vinegar (¼ cup/60 mL)
- Salt (2 tsp/10 mL)
- Shallow container (for the vinegar-salt solution)
- Cotton swab (such as a Q-tip)
- 9V Battery
- Wire (from an electrical cord, for instance, or charging cables)
- Pliers
- Measuring spoon
- Measuring cup

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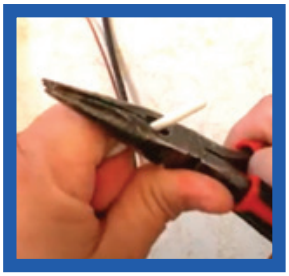
WHAT YOU NEED: (continued):

- Hobby knife (for instance, an X-acto knife)
- Water-resistant tape (such as electrical tape or duct tape)
- Clip (such as a clothes peg or a binder clip)
- Protective gloves (dish gloves, latex gloves or nitrile gloves)
- Sand paper (or steel wool or a nail file or an emery cloth or a whetstone)
- Cutting mat (or a cutting board or piece of wood)

WHAT YOU DO:

- Prepare your metal object. Lightly sand off any coating on the surface where you want to etch. Make sure it's clean.
- Create a stencil. Put down overlapping rows of water-resistant tape on a cutting mat, and then use your hobby knife to cut a shape. Transfer the stencil to your metal object.
- Prepare the electrolyte solution by mixing a quarter cup of vinegar with two teaspoons of salt in a shallow container.
- Using scissors or pliers with a cutting blade, strip the plastic insulation from both ends of two repurposed electrical wires. Be careful not to damage the wire.




- Connect one wire to the battery's positive terminal. Connect the other wire to the negative terminal. Cover the terminals with electrical tape.

  Note: Never connect wires without a load between them, as this will create a short circuit that can burn you or make the battery explode.


- Connect the wire from the positive terminal to the metal object and secure the wire with electrical tape.
- Connect the wire from the negative terminal to the end of a cotton swab

  Note: Work in a well-ventilated area. Wear protective gloves.

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WHAT YOU DO (continued):

- Dip the cotton swab in the vinegar-salt electrolyte solution. Press the swab to your metal object, in the stencil cut-out area. Notice the bubbling. Continue pressing until you have the amount of etching you want.
- When you're done, let your work sit and dry. Then peel the stencil off your object to reveal your work of art.

ACTIVITY: Electroplating

TIME: 30 to 60 minutes

SAFETY:

Do not dump your electroplating solution down the drain! Add some water to dilute it, and then feed it to your plants.

Wear protective gloves.

WHAT YOU NEED:

- 9V Battery
- Copper metal (for instance, scrap from a pipe or a stripped wire).
- Metal plate or object
- 6 tbsp all-purpose fertilizer containing a copper salt compound (such as Miracle-Gro)
- 1 cup vinegar
- Measuring spoon (but not a spoon you ever use for food)
- Measuring cup
- Large plastic container (for the vinegar-fertilizer solution)
- Wire (paperclip, electrical cord or charging cord with plastic coating)
- Protective gloves (dish gloves, latex gloves or nitrile gloves)

WHAT YOU DO:

- Put on your protective gloves.
- Prepare the electrolyte solution by mixing six tablespoons of copper-containing plant fertilizer with one cup of vinegar.
- Clean and sand your metal object. This will help you get a better metal coating.

  Note: Never connect wires without a load between them, as this will create a short circuit that can burn you or make the battery explode.
- Using scissors or pliers with a cutting blade, strip the plastic from the ends of two wires. Be careful not to damage the wires.
- Connect one wire to the positive terminal of the battery, and the other to the negative terminal of the battery.
- Connect the wire from the positive terminal to your piece of scrap copper.
- Connect the wire from the negative terminal to the metal object you want to plate.

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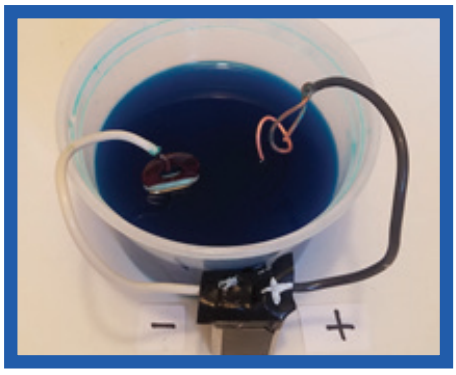
WHAT YOU DO (continued):

- Wearing protective gloves, dip your two metals into the electrolyte solution, but make sure they don't touch.
- Let the reaction proceed for 30 minutes to two hours, depending on the amount of plating you want.
- Wearing protective gloves, remove your metal object from the solution. Disconnect the battery. Rinse and wipe your object.
- Dilute the fertilizer-vinegar solution according to the package instructions, and then water the acid-loving plants in your home, balcony or yard.



WHY THIS MATTERS:

We use electroplating all the time to keep metals like iron from rusting. In the machine and automotive parts industries, for example, chromium or cadmium plating is used for waterproofing.

Electroplating a thin coating of an active metal — one that undergoes an oxidation reaction similar to what you saw in the etching experiment — is another method of protection. The thin outer layer of active metal is sacrificial. An example of this is zinc on iron: the zinc will go through the oxidation reaction more quickly than the iron, keeping the iron safe from oxidation. Galvanized nails, water heaters, water tanks and the hulls of ships all use this process.

Electroplating has other purposes as well. What if you want conductivity in a plastic part? Companies coat plastics with graphite powder or even plate them with copper to create conductivity on plastic surfaces.

TAKING IT FURTHER:

Make an art piece with materials you have at home. Try plating, etching or both. Some things to consider before creating your metal masterpiece:

What metals can be etched with acid?

What happens if you use different concentrations of electrolyte?

Check the fertilizer ingredients. Besides copper, what other metals could you plate onto an object?

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TAKING IT FURTHER (continued):

What if you connected a load instead of a battery? In the electroplating experiment above, you created electrolytic cells, and used electric energy to cause chemical reactions in the metals. But you can also create galvanic cells, which convert chemical potential energy into electric energy. Test different combinations of metals and electrolytes and measure the output of energy using an LED bulb, an old motor or a speaker from an old toy.

For more inspiration, see "More Online" below.

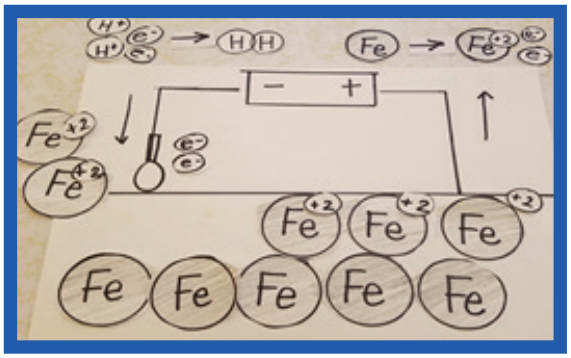
UNPACKING WHAT HAPPENED:

Metals left outside can degrade and get rusty. That's because of "redox" reactions — chemical reactions that involve the exchange of electrons between different atoms or ions. The term redox or “oxidation-reduction" reaction, refers to a set of paired reactions: reduction, in which electrons are gained by a substance — an atom or ion — and oxidation, in which electrons are lost by a different substance.

It is through this reaction that we can remove or add metals on electrically conductive surfaces, through metal etching and electroplating respectively.

In the electro-etching experiment, you created an electrolytic cell, where the electric energy from the battery was used to force the redox reaction. The positive terminal on the battery pulls electrons from the surface metal atoms, oxidizing them into positive metal ions. The negative terminal pushes electrons into the electrolyte on the swab, attracting the metal ions and dissolving them in the electrolyte solution. These excess electrons in the solution also reduce hydrogen ions from the vinegar into hydrogen gas, seen as bubbles. The ions in the vinegar-salt electrolyte solution conduct electricity as electrons are removed from the metal.

Oxidation: $Fe + energy \rightarrow Fe^{2+} + 2e^-$
Reduction: $2\ e^- + 2H^+ \rightarrow H_{2(g)}$



MORE ONLINE:

Copper Electroplating
https://youtu.be/T3qhqTVssoo

Electrochemistry - Direct Redox Reactions
https://courses.lumenlearning.com/cheminter/chapter/electrochemistry/

Spacecraft Materials and the Chemistry of Space Exploration
https://www.jpl.nasa.gov/edu/teach/activity/spacecraft-materials-and-the-chemistry-of-space-exploration/

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