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Michigan Technological University ~ Center for Science & Environmental Outreach

The Chemistry of Surface Corrosion

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Target Grade/Subject: Grades 6-8 Physical Science
Grade 9-12, Science/Chemistry
Time: 40 minutes

Lesson Overview

Student will place different metals in acidic conditions and observe the physical changes to the metals. Students will investigate how metal corrosion impacts pipe infrastructure and drinking water.

Sources Consulted

Science Bob https://sciencebob.com/clean-pennies-with-vinegar/
Bizfluent "Why do Paper Clips Rust?" https://bizfluent.com/facts-5730689-do-paper-clips-rust-.html

Learning Objectives

After this lesson, students will be able to:

1. Define corrosion.
2. Give examples of metals and items made with them.
3. Explain how metal corrosion occurs with pipe materials in municipal water infrastructure and drinking water supply.

For High School:

4. Determine oxidation states of metals and chemical reaction stoichiometry (High School)
5. Explain changes of metal color with oxidation state.

Michigan Science Standards Addressed

Middle School

MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
MS-PS1-6 Undertake a design project to construct, test, and modify a device

High School

HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
HS-PS1-6 Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*

Materials Needed & Quantities

PowerPoint slides
Per group (# of students) 2-4 students per group

- several old (not shiny) pennies (oxidized copper)
- copper wool (for cleaning pans and dishes)
- paper clips (galvanized steel – Zinc coated steel
- stainless steel (wood) nails (0.25-0.5 inches in length)

- 1/4 cup white vinegar per metal (total 1 cup needed)
- 1 teaspoon sea salt (other salts will cause an opaque solution) per metal (total 4 t. needed)
- 4 clear 9 oz. plastic cups
- Paper towels
- Plastic tweezers (to remove metals from solutions)
- Safety Goggles
- Nitrile or latex gloves
- camera – smart phone (optional)

Describe Room Arrangement or Special Needs: a lab or tables

PROCEDURE

Phenomenon / Focus Questions

- What happened to cause the Flint Water Crisis?
- Why do shiny metals become dull and dull metals become shiny?

Note: Prompt questions are animated in the power point slides as students go through the procedure.

Remind students of safety precautions—wear safety goggles and plastic gloves

Procedure

1. Observe dirty pennies, shiny paperclips, shiny stainless steel wire, and a zinc-coated stainless steel nail. Describe how they look in your science journal. Take "before" photo with a smartphone.

2. Dissolve 1 teaspoon of sea salt into ¼ cup (60 mL) of vinegar (acetic acid) in four plastic cups—a cup for each metal that you are testing (1 cup per metal). Swirl the solution to dissolve the salt into the vinegar. What is the formula for vinegar and salt (NaCl)?

3. Place each metal object into one of the cups. Observe what happens. Write down your observations in your science journal.

4. After 5-8 minutes take the four metals out of each solution using plastic tweezers and place on paper towel. Observe the changes and describe in your science journal. Take 'after' photos.

7. Compare 'before' and 'after' photos. Each group should discuss what they think happened to each of the metals. Write down your explanation in your science journal.

8. Ask student groups to share their explanations of what they think happened to each metal
    - *the copper oxide is removed to reveal clean metallic copper penny;*
    - *the copper wool will not change, as it was not oxidized before the experiment;*
    - *the zinc coating on paper clip will dissolve in the solution and the underlying steel will corrode sitting out in air; will look dull*
    - *the steel nail will corrode as it has iron in it* (reacts with O_2 to form iron oxide = rust

Assessment of Student Learning

1) **What are the metal materials made of?** *Copper pennies are made of copper coated zinc; for the purposes of this demo they are oxidized copper; the copper wire mesh is made of pure copper; the paper clip is zinc coated steel, the nail is made of uncoated steel (iron and carbide)*
2) **What is in the solution?** *acetic acid (vinegar) CH3COOH + NaCl (salt) = Na(acetate) that forms HCl (hydrochloric acid)*

3) **What happens in the solution?** *When the sea salt is dissolved in acetic acid, primarily HCl and sodium acetate are formed; there are other impurities in sea salt, but for this demo it produces a clear solution instead of a cloudy one from pure NaCl or NaI.*
4) **Why are the metals changing?** *The H+ ions remove the oxide from the copper (Cu^{1+}) on the copper pennies forming Cu^0, thus cleaning them. The H+ ions do not affect the copper wool, as it is already cleaned. The HCl dissolves the Zn on the paper clip, forming soluble $ZnCl_2$. The underlying steel paper clip begins to rust in air, forming Fe^{2+}. The steel nail will form Fe^{2+} immediately, as there is no Zn coating – called galvanization.*
5) **What is the definition of corrosion?**
   Corrosion. Is the breaking down or destruction of a material, especially a metal, as a result of chemical reactions between it and the surrounding environment. The most common form of **corrosion** is rusting, which occurs when iron combines with oxygen and water. Both the type of metal and the environmental conditions, particularly gasses that are in contact with the metal, determine the form and rate of deterioration.

Summary - reinforce key concepts with students

- Some metal corrode in acidic solutions releasing metal ions into the water supply.
- Power point slides contain the balanced reactions and real world examples of corrosion and why copper was cleaned, zinc dissolved and the steel corroded (rusted).
- Putting chemical mixtures into pipes used to provide a community's drinking water supply will cause corrosion, if there is no pipe protection.
- Chemicals in our water supply need to be cleaned/filtered and removed.
- Pipe protection is necessary to prevent metal corrosion. Certain chemicals are added to the water supply to provide a protective coating on the pipes.

Cleanup: Students should discard the corroded metals. Plastic cups and tweezers can be rinsed and reused.

Safety Considerations: Students should wear safety goggles to prevent vinegar (acetic acid) and HCl (from mixing acetic acid with NaCl) from splashing. Students should wear gloves and use plastic tweezers to pick metals out of acidic solution, as some of the metals could dissolve into solution.