Metal Corrosion

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Abstract:
This is a long term corrosion experiment requiring a few minutes each day first for setup then for observation. Students will be able to observe the results of corrosion over several days, up to 2 weeks.

Rates of corrosion can be affected by many factors, including the environment, stress, oxygen availability, etc. When different metals are in electrical contact, the most active metal corrodes. Steel corrosion produces a variety of iron oxides, depending on conditions. In this experiment, students can observe several of these factors. The samples need to be kept in a safe location for this period, undisturbed but available for observation.

Objectives: The student will be able to
Explain the process of corrosion
Determine differences in corrosion rates as a function of salinity in the water and stress in the material
Compare corrosion effects when different materials are in contact

MatEd Core Competencies Addressed (most important in bold)
0B Prepare tests and analyze data
4A Demonstrate effective work with teams
5A Apply safe and environmentally appropriate methods of chemical handling
7A Illustrate the general nature of metals
8A Demonstrate the execution of materials experiments
16A Distinguish effects of processing and manufacturing variations on material properties

Key Words: Steel, corrosion, rusting, reactivity, oxidation

Type of Module: Class experiment with observation over time

Time Required
Up to 2 weeks for observation of the results
Initial 15 minutes setup
Initial 10 minutes discussion in class as an intro
10 minutes per subsequent class period for observation

Grade Levels
Grades 4 through college

Equipment and supplies needed
10 jars or beakers, 1 to 2 cup size (250 to 500 ml)
Fresh water
Salt water (add salt to fresh water, about 0.5 grams per cup of water)
2 each of steel nails, 2 to 3 inches long, as follows:

- Standard bright nails
- Standard bright nails, bent to a 90 degree angle (use a vise and hammer to bend these nails)
- Galvanized nails
- Galvanized nails with galvanizing removed in one area (use a file or sandpaper)

2 copper pennies
Aluminum foil

Instructor background and notes:
Corrosion occurs through the oxidation of metals in our environment. Most metals corrode, some more rapidly than others, depending on that environment. Students are familiar with rust, the iron oxide corrosion product of steel. The form and amount of corrosion that occurs depends on factors such as:

- Amount of water in the environment
- Presence of salt or other chemicals
- State of stress of the steel
- Presence of other metals in the environment

In these experiments we test each of these parameters to allow students to experience the variety of results possible. The question on the state of stress relates to the manufacturing process, since different parts of the same product may be produced in different states of stress. Corrosion will occur where the state of the material is at the highest energy. This is the case for deformed areas. Corrosion will occur at the bent portion of the nail and at the head and point of the nail (nails are formed from a wire by applying stress).

Another effect relates to different metals being present. A galvanized nail has a layer of zinc electrodeposited on it. The zinc is more active than iron, so the zinc will corrode first, protecting the nail from corrosion. Even if there is a break in the galvanized coating, the protection will still be present. Galvanizing is used on many steel products, such as garbage cans and light poles.

For the Aluminum/copper experiment, aluminum is more active than copper, so the aluminum corrodes. The cloudy solution results from the aluminum corrosion products.

Experimental process:

1. Fill 5 beakers part way with fresh water—label as fresh water
2. Fill 5 beakers part way with salt water—label as salt water
3. Introduce one set of each type of nails into 4 fresh water beakers
4. Introduce the second set of each type of nails into 4 salt water beakers

5. In the 5th fresh water beaker introduce a piece of aluminum foil, then place a penny on top of the aluminum foil.
6. Repeat #5 using a salt water beaker.

Have the students observe the process of corrosion in each beaker or jar over a period of 1 to 2 weeks. Have them make notes on what is happening in each beaker as a function of time. Then discuss the following:

a. What is the difference between corrosion in salt water as opposed to fresh water? Discuss why it occurs.
b. Why do the nails corrode at points of stress? Can you tell where the stress points are? What is the cause of the stress?
c. What does the galvanized coating do for the nails? Have them give examples of galvanizing used on other products.
d. What happened to the aluminum foil where it was in touch with the copper penny? Relate this to a metal activity chart.

Further Study

1. Experiment with other combinations of materials. Some nails are aluminum—how do they behave?
2. Carry out the introductory experiments described at http://www.terrific-scientific.co.uk/Topics/Corrosion/0-introduction.htm
3. Find a real example of corrosion in your environment. Research its causes and ways to prevent such corrosion

References

1. Basics on rust: http://science.howstuffworks.com/question445.htm
2. For other introductory corrosion experiments: http://corrosion-doctors.org/Experiments/Introduction.htm
2. For the corrosion process in iron http://en.wikipedia.org/wiki/Rust
3. For detailed information on corrosion and corrosion control: http://www.corrosion-doctors.org/

Evaluation:

Student evaluation questions (discussion or quiz):

1. What is the difference between corrosion in salt water as opposed to fresh water?
2. What does the galvanizing do?
3. Where do the nails corrode the most? Explain
4. What happened to the aluminum foil where it was in touch with the copper penny? Why?

Instructor evaluation questions:

1. At what grade level was this module used?
2. Was the level and rigor of the module what you expected? If not, how can it be improved?

3. Did the activity work as presented? Did they add to student learning? Please note any problems or suggestions.
4. Was the background material sufficient for your background? Sufficient for your discussion with the students? Comments?
5. Did the activity generate interest among the students? Explain.
6. Please provide your input on how this module can be improved, including comments or suggestions concerning the approach, focus and effectiveness of this activity in your context.

Course evaluation questions (for the students)

1. Was the activity clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions?
4. Was the instructor able to answer your questions?
5. Was the importance of materials testing made clear?
6. What was the most interesting thing that you learned?