

Corrosion Activities

C12-1-12

Note: This activity is intended to follow the Corrosion Investigation & Presentation activity where students investigate and summarize factors affecting corrosion and corrosion prevention. However, it can be done on its own if students have been introduced to the concept of corrosion.

Introduction:

What does corrosion look like? Compare samples of corroded and un-corroded metals such as iron, aluminum, copper, zinc, silver and magnesium. Do all corroded samples look the same? What is corrosion a result of? What are some common objects that are subject to corrosion? Do all metals corrode at the same rate? What are some methods used to prevent corrosion?

Corrosion is a major destructive process that results in costly and unsightly gaping holes or cracks in aircraft, automobiles, boats, gutters, screens, plumbing, and many other items constructed of every metal except gold.

Corrosion results from the overwhelming tendency of metals to react electrochemically with oxygen, water, and other substances in the aqueous environment. Fortunately, most useful metals react with the environment to form protective films of corrosion reaction products that prevent the metals from going into solution as ions. For example, aluminum forms a protective coating of aluminum oxide on its surface that prevents further corrosion. This is because many metals are not stable in their elemental state; they prefer to combine with elements such as oxygen to form metal oxides that are lower in energy and thus more stable.

Corrosion occurs via two opposing electrochemical reactions. The first is the anodic reaction, in which a metal is oxidized, releasing electrons into the metal. The other is the cathodic reaction, in which a solution species (often O_2 or H^+) is reduced, removing electrons from the metal. The two reactions can take place on one metal or on two dissimilar metals (or metal sites) that are electrically connected.

There are several different reactions that describe the process of corrosion and most are fairly complex, depending on the type of corrosion and the conditions. Visit the following website to view some typical anode and cathode reactions involved in corrosion: http://www.arvanitakis.com/en/cl/corrosion_reactions.htm

In this activity you and your group will be responsible for setting up a prescribed corrosion experiment. You will then visit the various stations providing examples of corrosion. You will record details of the experiment and take initial (end of class) and 24-hour observations and attempt to explain these observations based on your knowledge of corrosion.

Stations

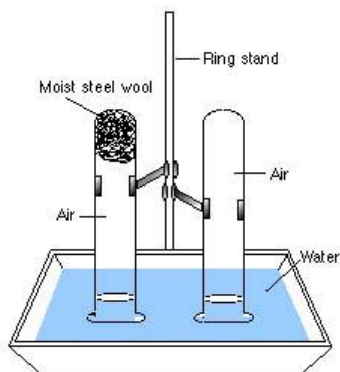
Station #1: Steel Wool Corrosion

Materials:

2 test tubes
Ring stand
Steel wool

Procedure:

1. Place enough **moist** steel wool into the to fill about 1/4 of the tube.
2. Set up the apparatus as shown above. The moist steel wool and an empty (control) test into a pan of water about 1/2 inch or more. Set aside undisturbed.
3. Observe the two test tubes at the end of class and also 24 hours later. What has happened to the steel wool? What have you noticed about the water level in each of the test tubes?
4. Using your knowledge of corrosion, attempt to explain your observations.



2 utility clamps
Shallow pan
Water

bottom of a test tube
test tube with the
tube are lowered

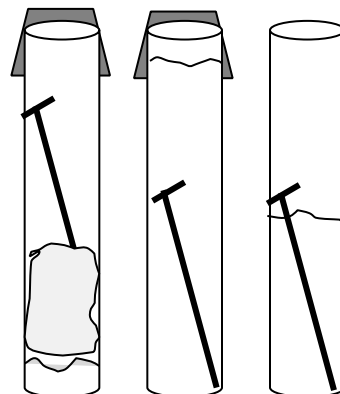
Station #2: Iron Nail Corrosion

Materials:

3 test tubes
2 corks
Test tube holder
3 clean iron nails (clean with steel wool if necessary)
Cotton ball
 CaCl_2 (absorbs water from the air)
Cooled, boiled water (boiling removes oxygen from the water)
Distilled water

Procedure:

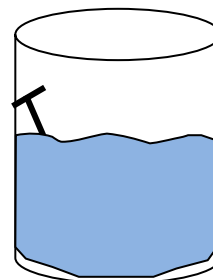
1. In the first test tube, place a scoop of CaCl_2 in the test tube, followed by a cotton ball and then the nail. Cork the test tube.
2. In the second test tube fill completely with boiled water and add the nail. Cork the test tube.
3. In the third test tube, half-fill with distilled water and add the nail. Do not cork this test tube.
4. Record observations for each of the three test tubes at the end of class and also 24 hours later.
5. Using your knowledge of corrosion, attempt to explain your observations.



Station #3: Corrosion Prevention: Copper Plating of an Iron Nail

Materials:

Root killer (copper(II)sulfate pentahydrate)
250 mL beaker
Distilled water
Clean iron nail (clean with steel wool if necessary)



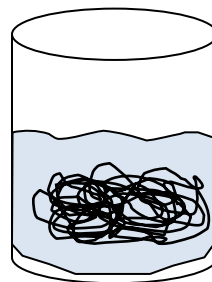
Procedure:

1. Purchase a bag of root killer that contains copper(II)sulfate pentahydrate (or use reagent grade $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ from a chemical supply company). Place a scoop of these crystals into a 250 mL beaker, add 150 mL of water and stir until the crystals are completely dissolved.
2. Place the nail into the 250 mL beaker.
3. Observe the nail at the end of the class as well as 24 hours later.
4. What is the metal that has plated onto the nail?
5. Explain how this process might prevent corrosion of the iron nail.

Station #4: Steel Wool Corrosion

Materials:

Steel wool
Bleach (non-detergent)
1000 mL beaker



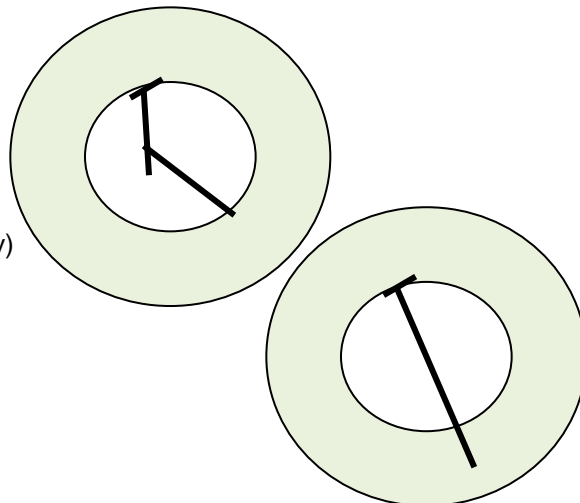
Procedure:

1. Place a bunch of steel wool into the 1000 mL beaker. Add enough bleach to cover the steel wool.
Caution: The reaction may become very hot. For safety, place the 1000 mL beaker into a sink to sit overnight.
2. Observe the reaction at the end of class and also 24 hours later. What has happened to the steel wool?
3. Using your knowledge of corrosion, attempt to explain your results.

Station #5: Iron Nail Corrosion

Materials:

2 Petri Dishes
Clean iron nail (clean with steel wool if necessary)
Clean bent iron nail (clean with steel wool if necessary)
Agar
Potassium chloride, KCl
Potassium ferricyanide ($\text{K}_3\text{Fe}(\text{CN})_6$)
Phenolphthalein Indicator



Distilled water
Electronic balance

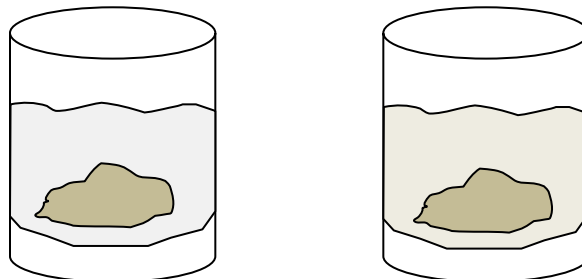
Procedure:

1. Prepare the agar solution by adding 0.6 g of agar, 1.3 g KCl, 2-3 mL of $K_3Fe(CN)_6$ and 20 drops phenolphthalein to 60 mL distilled water. Heat until all solids are dissolved and then pour into 2 Petri dishes (half-full), cover, and allow the solution to cool. (This recipe makes enough for two Petri dishes and can be prepared ahead of time).
2. Push the straight nail into the agar solution in one Petri dish and push the bent nail into the agar solution in the other Petri dish.
3. Make observations at the end of class and then observe again 24 hours later.
4. What colors are observed on the nail? Do the straight nail and the bent nail produce the same colors? What are the colors a result of?
5. Use your knowledge of corrosion to explain your results.

Station #6: Aluminum Foil Corrosion

Materials:

2-250 mL beakers
Distilled water
2 crumpled pieces of aluminum foil
NaCl (table salt)



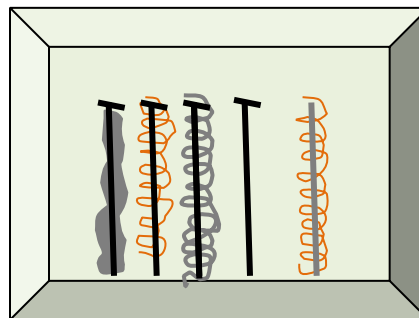
Procedure:

1. Fill each 250 mL beaker with around 100 mL of distilled water. Add two scoops of salt to the first beaker only. Stir to dissolve.
2. Add similar sized pieces of crumpled aluminum foil to each of the two beakers and allow them to sink to the bottom.
3. Observe the aluminum foil at the end of class and also 24 hours later. What color is the corrosion that you see? Which piece of aluminum corroded more quickly?

Station #7: Iron Nail Corrosion with Aluminum, Copper and Solder

Materials:

Large glass dish
4 iron nails
Aluminum foil
2 pieces of copper wire (4 inches long)
2 pieces silver solder (4 inches long)
Steel wool
Distilled water (warmed)
1 teaspoon of salt

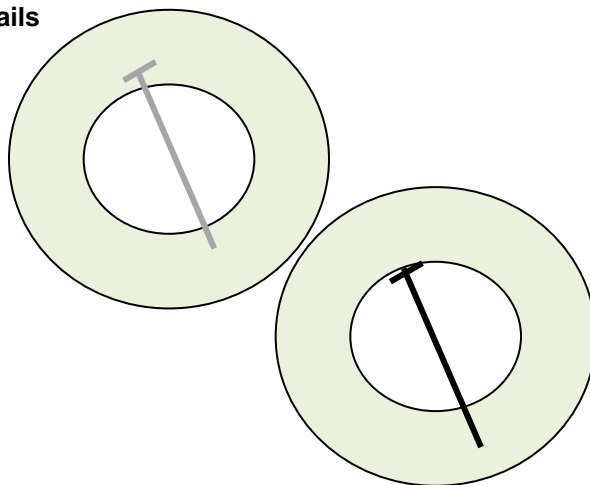


Procedure:

1. Use the steel wool to clean the nails, copper and solder.
2. Tightly wrap the aluminum foil around the first nail, the copper wire around the second nail and the silver solder around the third nail. Do not add any metal to the fourth nail.
3. Wrap the second piece of copper wire around the second piece of silver solder.
4. Add warm water (enough to cover the nails) and salt to the glass dish and stir the mixture until the salt has dissolved.
5. Add the four nails and the silver solder with copper wire around it to the glass dish (making sure that they do not touch).
6. Leave the experiment to sit for 24 hours and then observe any changes.
7. Has corrosion taken place on any of the metals? If so, which metals show the greatest amount of corrosion? The least? Also state the color of any corrosion observed.
8. Use the Standard Reduction Potential Chart provided to explain your results.

Station #8: Corrosion of Pure Iron / Galvanized Iron Nails**Materials:**

2 Petri Dishes
Clean iron nail
(clean with steel wool if necessary)
Clean galvanized iron nail
(clean with steel wool if necessary)
Distilled water
Salt



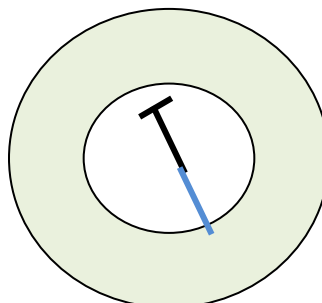
Procedure:

1. Place the pure iron nail into the salt solution in one Petri dish and put the galvanized iron nail into the salt solution in the other Petri dish.
2. Make observations at the end of class and then observe again 24 hours later.
3. What is the difference between the pure iron nail and the galvanized iron nail?
4. Use your knowledge of corrosion to explain your results.

Station #9: Corrosion of an Iron Nail Half-Coated with Paint

Materials:

1 Petri Dish
Clean iron nail (half-coated with paint)
Distilled water
Salt



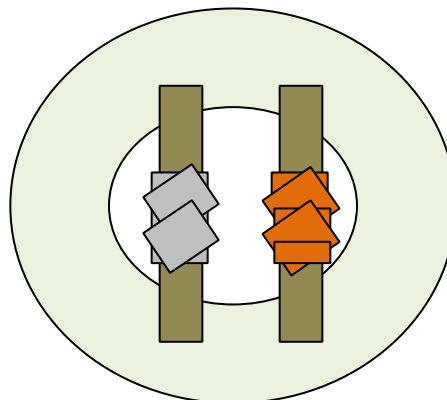
Procedure:

5. Place the iron nail into the salt solution in a Petri dish.
6. Make observations at the end of class and then observe again 24 hours later.
7. What is the difference between the coated and un-coated portion of the iron nail?
8. Use your knowledge of corrosion to explain your results.
9. Explain how paint might be used in industry to prevent corrosion.

Station #10: Iron Coated with Zinc and Copper. Which Piece of Iron Corrodes?

Materials:

2 clean strips of iron (clean with steel wool if necessary)
Petri dishes
Agar
Phenolphthalein indicator
Flexible strip of zinc metal
Flexible strip of copper metal
Distilled water
Electronic balance



Procedure:

1. Prepare the agar solution by adding 0.3 g of agar and 10 drops phenolphthalein to 30 mL distilled water. Heat the mixture until the agar is dissolved and then pour into a Petri dish

(half-full), cover, and allow the solution to cool. (This solution can be prepared ahead of time).

2. Wrap the zinc metal tightly around one iron strip and wrap the copper metal tightly around the other iron strip.
3. Push both pieces of iron into the agar in a large Petri dish.
4. Make observations at the end of class and then observe again 24 hours later.
5. Which piece of iron corroded? Why did one piece of iron corrode and not the other?
6. What is the significance of the pink color of the phenolphthalein?
7. Explain your results using the Standard Reduction Potential Table provided.

Data Table:

Station #	Initial (end of class) Observations	24-hour Observations	Explanation of Results
Station #1			
Station #2			
Station #3			

Station #4			
Station #5			
Station #6			
Station #7			
Station #8			
Station #9			
Station #10			

Extension Activities:

Research answers/explanations for the following:

1. Is corrosion reversible?
2. Explain what is meant by the term “anodizing” and describe where it is used.
3. Explain why aluminum doesn’t corrode as quickly as many other metals despite its high reactivity.
4. Describe the process of sacrificial protection. What is it and why is it used?
5. Even though salt catalyzes corrosion, explain why shipwrecks deep under water rust more slowly than beached wrecks.
6. Corrosion has many serious economic, health, safety, technological, and cultural consequences to our society. Explain.

7. Why do gold, platinum and other precious metals not corrode?

STANDARD REDUCTION POTENTIALS IN AQUEOUS SOLUTION AT 25°C

Half-reaction	E^0 (V)
$F_2(g) + 2e^- \rightarrow 2F^-$	2.87
$Co^{3+} + e^- \rightarrow Co^{2+}$	1.82
$Au^{3+} + 3e^- \rightarrow Au(s)$	1.50
$Cl_2(g) + 2e^- \rightarrow 2Cl^-$	1.36
$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O(l)$	1.23
$Br_2(l) + 2e^- \rightarrow 2Br^-$	1.07
$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	0.92
$Hg^{2+} + 2e^- \rightarrow Hg(l)$	0.85
$Ag^+ + e^- \rightarrow Ag(s)$	0.80
$Hg_2^{2+} + 2e^- \rightarrow 2Hg(l)$	0.79
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.77
$I_2(s) + 2e^- \rightarrow 2I^-$	0.53
$Cu^+ + e^- \rightarrow Cu(s)$	0.52
$Cu^{2+} + 2e^- \rightarrow Cu(s)$	0.34
$Cu^{2+} + e^- \rightarrow Cu^+$	0.15
$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$	0.15
$S(s) + 2H^+ + 2e^- \rightarrow H_2S(g)$	0.14
$2H^+ + 2e^- \rightarrow H_2(g)$	0.00
$Pb^{2+} + 2e^- \rightarrow Pb(s)$	-0.13
$Sn^{2+} + 2e^- \rightarrow Sn(s)$	-0.14
$Ni^{2+} + 2e^- \rightarrow Ni(s)$	-0.25
$Co^{2+} + 2e^- \rightarrow Co(s)$	-0.28
$Tl^+ + e^- \rightarrow Tl(s)$	-0.34
$Cd^{2+} + 2e^- \rightarrow Cd(s)$	-0.40
$Cr^{3+} + e^- \rightarrow Cr^{2+}$	-0.41
$Fe^{2+} + 2e^- \rightarrow Fe(s)$	-0.44
$Cr^{3+} + 3e^- \rightarrow Cr(s)$	-0.74
$Zn^{2+} + 2e^- \rightarrow Zn(s)$	-0.76
$Mn^{2+} + 2e^- \rightarrow Mn(s)$	-1.18
$Al^{3+} + 3e^- \rightarrow Al(s)$	-1.66
$Be^{2+} + 2e^- \rightarrow Be(s)$	-1.70
$Mg^{2+} + 2e^- \rightarrow Mg(s)$	-2.37
$Na^+ + e^- \rightarrow Na(s)$	-2.71
$Ca^{2+} + 2e^- \rightarrow Ca(s)$	-2.87
$Sr^{2+} + 2e^- \rightarrow Sr(s)$	-2.89
$Ba^{2+} + 2e^- \rightarrow Ba(s)$	-2.90
$Rb^+ + e^- \rightarrow Rb(s)$	-2.92
$K^+ + e^- \rightarrow K(s)$	-2.92
$Cs^+ + e^- \rightarrow Cs(s)$	-2.92
$Li^+ + e^- \rightarrow Li(s)$	-3.05