Galvanized Nails

Prelab Assignment:

Read the entire experiment. Submit your completed prelab questions on Labflow before you begin the lab, according to the deadline set in the syllabus.

Experimental Overview: The task this week is to determine whether the nails from a given factory comply with the industry standard. This will be accomplished by studying the reaction that occurs when a galvanized nail is placed in contact with hydrochloric acid. The zinc layer will dissolve in an acidic solution:

$$Zn(s) + 2\ HCl\ (aq) \rightarrow ZnCl_2\ (aq) + H_2\ (g) \qquad (1)$$

By measuring the mass of a galvanized nail before and after its reaction with hydrochloric acid, you will be able to determine the mass of zinc coated on the nail. The iron in the nails will also react with acid, but only after all of the zinc has reacted. By stopping the reaction at the appropriate time, you will avoid dissolving the iron.

Green Chemistry Note

Every chemistry experiment generates "waste" of some form, and this lab is no exception. An experimentalist must always determine if the waste is hazardous and how it should be handled. For example, in this laboratory procedure, you will generate an acidic waste solution containing zinc and chloride ions. The chloride ions don't present a problem, but according to regulations, neither the zinc ions nor the acidic solution are permitted to go down the drain. Without any treatment, the entire volume of waste generated would require disposal at a hazardous waste facility. The second portion of this lab requires that you process the waste in a manner that minimizes the volume and works to meet the green chemistry goals.

NOTE: Unless specifically instructed otherwise, always assume that water is the only substance that can be safely poured down the drain. Even after treating the waste for this experiment, it will be collected for correct disposal.

Application

Coatings are used to protect varied materials from paintings to ship hulls. The concerns of a shipowner include buildup of mollusks, corrosion in seawater and deterioration due to collisions.[1] Some of these concerns carry over to the art world. Some of the greatest concerns for the longevity of artwork are temperature, humidity and pollution. Many artists store their works in dark rooms in order to protect them from UV exposure. When artworks are on display, care is taken to reduce light, both by reducing the light in the room as well as by using coated glasses around the works.

However, the protection is only as good as the coating. If the coating is thin, it will not protect the art as well.[2] If the coating is not applied uniformly, the piece of art may bleach inconsistently, leaving a splotchy pattern. Therefore, the consistency of the coating is important.

This experiment addresses the question of uniformity within a given set of galvanized nails. These are iron nails that have been coated with a layer of zinc, *galvanized*, to prevent the iron from rusting. When an iron nail rusts, it undergoes an oxidation reaction with water to form iron oxide, which is commonly called rust. If a layer of zinc is present, the zinc becomes oxidized instead of the iron, thus protecting the nail. The protectiveness of the zinc coating does not last forever, however. Eventually, a galvanized nail will rust, but the process takes quite a bit longer than rusting of uncoated nails.

The process of coating iron with zinc is known as *galvanization*. The two most common methods of galvanization are electrolysis and "hot dipping". Hot dipped nails have a thicker zinc coating than electrolyzed nails, though the coating is less uniform. The highest industry standard (ASTM A-153) for galvanized nails is an average of 1 oz. of coating per square foot.[3] A slightly lower standard (NER 272) within the industry is 0.28 oz./ft^2. Poor quality nails may not comply with either of these standards. Because of the lack of uniformity in hot dipped nails, a large number of nails must be analyzed and the average coating determined in order to know whether a particular brand of nails complies with a particular standard. Nails that do not meet these standards will begin to rust earlier than higher quality galvanized nails.

References:

1. Furer, J. A. The Care and Protection against corrosion of ships' hulls and fittings. Naval Engineers Journal (1926) 38:825-855.
2. Boye, C. Preusser, F and T. Schaeffer. UV-Blocking window films for use in museums - Revisited. WAAC Newsletter (2010) 32: 13-18. http://cool.conservation-us.org/waac/wn/wn32/wn32-1/wn32-104.pdf
3. ASTM Adopts New Standard for Hot-Dip Galvanizing of Fasteners http://www.astm.org/SNEWS/JULY_2006/brahimi_jul06.html accessed 08/09/2016

Procedure

Part A – Remove the Coating

All data should be neatly recorded in tabular form, in your lab notebook. A data table for this laboratory might look like this:

Trial #:	1	2	3	4	5
length of nail					
start time					
stop time					
initial mass of nail (g)					
final mass of nail (g)					
Observations					

1. Obtain 5 nails. Use a ruler to measure the length of each nail in millimeters. Record the diameter of the nails.

2. Using the analytical balance, determine the mass of one of the nails. Note which balance you used and be sure to use the same balance for all subsequent weighings.
3. Place the nail in the bottom of a small (12 *x* 75 mm) test tube and place the test tube in a test tube rack or small beaker.
4. When you are ready to begin, add sufficient 6M hydrochloric acid (HCl) to cover the nail, but no more. Record the time and any observations, including heat, bubbles, color, and time elapsed.

   If we were unsure of the gaseous product from this reaction, the presence of hydrogen gas can be confirmed by holding a match just above the test tube while gas bubbles are coming out of solution. A characteristic of hydrogen gas is that it reacts explosively with the oxygen in air. None of the other substances that you could imagine being formed in this reaction have this property. However, we will NOT be doing this confirmation.
5. After the nail has been in acid for 5 minutes, pour the contents into a "waste beaker". Use forceps to remove the nail from the beaker, rinse the nail with water, wipe dry, and reweigh.
6. In the meantime, repeat steps 2-5 with the other four nails. Use the same waste beaker for all test tubes.
7. Place used nails in the Solid waste container.

Part B – Waste Management

One of the twelve principles of green chemistry states that it is better to prevent waste than to treat or clean up waste afterwards. By extension, this principle indicates that if waste is produced, the quantity should be minimized whenever possible. The first step in determining whether a procedure complies with this principle is to assess what substances remain after the procedure has been completed. We will assume that the reaction in equation (1) has gone to completion and that the reaction products are hydrogen gas, which bubbled off, and zinc ions in aqueous solution. Because an excess of hydrochloric acid was added, the first step is to test the solution's acidity to see if it is still acidic. This can be done using blue litmus paper. A pH below 7 indicates the presence of an acid, pH of 7 is neutral, and a pH greater than 7 indicates a basic solution. Blue litmus paper turns red below pH 7 (acidic solutions).

The standard method for dealing with aqueous acidic waste is to add base (OH^-) to neutralize the solution:

$$H^+ (aq) + OH^- (aq) \rightarrow H_2O (l) \qquad (2)$$

If the base used is sodium hydroxide (NaOH), the zinc ions will react with hydroxide ions to form insoluble zinc hydroxide:

$$Zn^{2+} (aq) + 2\ OH^- (aq) \rightarrow Zn(OH)_2 (s) \qquad (3)$$

Maximum removal of zinc from solution by this method occurs at pH 8.6. At this pH, the level of dissolved zinc is reduced to approximately 0.3 mg/L,[1] well below the legal limit in discharged wastewater of 1 mg/ L. The zinc now exists in a different physical state, as small solid particles of zinc hydroxide. The zinc removal process is not complete until these metal solids are removed from the wastewater. Because these solids are finely divided, removal is generally accomplished by sedimentation over time, followed by filtration. The solids produced are referred to as sludge and must be disposed of as hazardous waste.

1. Obtain approximately 75 mL of 2M NaOH from a dispensing container. Gradually add about 20 mL of the base to your waste beaker. Record any observations.
2. Using a pH meter, test the pH of the solution. If the pH is 5.5 or greater, the acid has been effectively neutralized. (Normal surface water has a pH of about 5.5, so a slightly acidic solution is normal and safe to pour down the drain.) Add more NaOH dropwise until you have reached a pH of 8-9. (Avoid going beyond pH 9 because the zinc hydroxide will begin to redissolve.)
3. After recording observations, take the solution containing the zinc hydroxide precipitate to the aqueous waste for disposal. Make sure to also dispose of your first rinse into the aqueous waste, as it commonly contains a significant amount of small precipitates.
4. At the end of the week's labs, the aqueous waste will be tested to verify that zinc levels have been reduced to legal disposal levels and the zinc hydroxide sludge will be disposed of according to environmental regulations.

Calculations

Enter your data into the class database for later analysis.

Calculations are to be done using MS Excel or another spreadsheet program. Once you have the data entered into a spreadsheet, you can use the calculation abilities of the program (Excel) to do all of the calculations.

If you are using Excel, detailed instructions are provided at the end of the lab.

Calculate the following averages: length, mass loss, percentage mass lost, mass lost per mm^2, and standard deviations.

Copy the spreadsheet into your lab report as part of the appendix.

Convert the industry standards of 1.0 oz / $ft.^2$ and 0.28 oz / $ft.^2$ to the units used in this experiment, g / mm^2. Be sure to square values as well as units when doing this conversion.

Data Analysis

Replicate measurements with five different nails will probably not result in identical measurements. Recall, the question that you must try to answer is whether a particular brand of nails, on average, complies with one of the industry standards. Interpretation of such a small data set makes it difficult to come up with a definitive answer. To provide a larger, more statistically significant data set, you will enter your values into the class data bank and analyze the results obtained by the entire class.

Possible Discussion Topics

- Report N (the number of nails analyzed), the mean and the standard deviation of the mass of zinc lost, and the percentage mass lost for the nails you used as well as for the entire class. (Be sure the standard deviations are rounded correctly.) Report the average mass of zinc per inch for your nails and your class.

- Use this information to address the question of whether galvanized nails are coated uniformly with zinc and whether the batch we used in lab complies with any of the national standards given in the introduction. How does your confidence in your ability to answer these questions change as N is increased?
- What does the magnitude of the standard deviations tell you about the uncertainty in the results?
- What are the major sources of determinate and indeterminate error in this laboratory experiment and how do they impact the results?
- What is "green chemistry" and how were the principles of green chemistry incorporated? Imagine that you are employed in the galvanizing industry and are regularly faced with quality control questions regarding assessment of the quantity of zinc on the nails. Can you propose any methods to make this investigation greener?
- Does the zinc hydroxide waste need to be disposed of, or can it be used for another purpose? Find and report any uses for $Zn(OH)_2$ that could possibly keep this by-product out of the hazardous waste landfill.

Adapted from: Ayres, David M., Davis, Allen P., Gietka, Paul M.; *Removing Heavy Metals from Wastewater,* University of Maryland Engineering Research Center Report, 1994.
http://www.erc.umd.edu/TES/techtips/ PMG metal precip man.pdf

Title:

Introduction:

Methods:

Results:

Discussion and Conclusion:

Literature Cited:

Refer to the posted **Mini-Report** guidelines as you write your report. The questions throughout the lab are intended to guide you in developing your report. Include molecular-level explanations where appropriate. References are required for all reports.

This report will be turned in via Labflow.