An Experiment in Alchemy:
Copper to Silver to Gold

Write: Theory, purpose, prelab (answer the questions prior to the lab), summary of procedure, discussion in complete sentences.
Paste: Procedure, and Data
Read: Background Information

Theory: Zn + 2OH⁻ → ZnO₂²⁻ + H₂; alchemy, redox, electrochemistry, electroplating.

Background Information:
One of the goals of the ancient alchemist was to convert base metals into gold. Although this goal was never attained by chemical methods, the alchemists were able to perform many color changes to make metals resemble gold. In this experiment you will produce some color changes to a copper token and demonstrate diffusion in the solid state.

In this reaction, zinc dissolves in the hot concentrated sodium hydroxide solution to form sodium zincate, commonly written as Na₂ZnO₂ or, as obtained in solid form from concentrated solutions, NaZn(OH)₃. As an ionic equation this can be written:

Zn + 2 OH⁻ → ZnO₂²⁻ + H₂

When the copper token is added to the solution, an electrochemical couple formed by the copper-zinc contact causes the zincate ion to migrate to the copper surface where it is decomposed and reduced to metallic zinc, which forms a coating on the token, liberating hydrogen. When the token is heated, the zinc diffuses into the copper to form a layer of the alloy brass, which results in the gold color.

It should be noted that the reduction of the zincate ion to zinc will only take place if the copper metal is in direct contact with zinc metal. Also, no copper dissolves in the solution during the reaction.

Prior to the times of Lavoisier of the 1700’s, chemists—who were known as alchemists were generally preoccupied with finding the means to turn matter into gold. Alchemists spent years developing techniques and trickery that made their audiences believe that they had the ability of turning lead, and other substances into gold. One such trick involved filling a bored-out metal stirring rod with gold dust. The tip of the rod was then sealed with wax in order to contain the dust and to keep it from being seen by others. To prove himself as a master alchemist, the charlatan would stir a heated, empty crucible with this rod and (as the wax melted) the vessel would slowly fill with molten gold. Although alchemists were measured by the “success” of their trickery, their less-than- systematic research played an important contribution to laying the foundation for chemists like Lavoisier and others to build upon. It was the alchemists that discovered and developed the various techniques of chemical purification such as fractional distillation and sublimation.

When the penny is heated in a solution of sodium hydroxide and in the presence of zinc powder, atoms of zinc which have gone into solution migrate towards the penny and deposit a coating of zinc onto the copper. This process is known as we-chemical plating, as opposed to electrochemical plating. The coating of zinc gives the penny an appearance of silver. If the “silver” penny is heated gently, the zinc on the surface mixes with the outer layers of copper atoms of the penny producing an alloy which looks like gold. In making this alloy, the atoms must actually exchange places to facilitate mixing—this is accomplished by adding heat to cause the natural vibrational motion of the copper and zinc atoms to turn into a fluid motion.

Safety precautions:
Goggles or safety glasses must be worn at all times in the laboratory.
Acetic acid fumes may be irritating.
Do not allow the sodium hydroxide solution in this experiment to actively boil. Sodium hydroxide is caustic and may splatter causing severe damage to the skin or eyes. In case of contact, wash it off immediately with cold water until the skin no longer feels soapy. In the event that sodium hydroxide gets into your eye, wash the eye well with water for at least 10 minutes and get medical help immediately.

Disposal:
Disposal should be in accordance with local regulations.
The 5% acetic acid solution can be safely disposed of by diluting with water and pouring it down the drain.
The sodium hydroxide solution should be placed in the appropriate waste container.
The zinc metal can be reused. The zinc should be rinsed with water and placed in the appropriate container supplied in the laboratory. Do not pour any zinc metal down the drain.
Prelab:
1) What is wet-chemical plating? How does it compare with electrochemical plating?
2) Who is Lavoisier and what does he have to do with alchemy or this experiment?
3) Why do zinc electrons move toward the copper electrons?

Materials:
- 100-mL or 150-mL beaker
- Graduated cylinder, 25-mL or 50-mL
- Evaporating dish
- Crucible tongs
- 2 beakers: 250-mL or 400-mL
- Striker
- “copper tokens”
- Sodium chloride
- zinc granulated
- Bunsen burner or hot plate
- Ring stand with rings support
- 3M sodium hydroxide
- 5% acetic acid

Procedure:
1. Weigh out 3.0 grams of sodium chloride and place it in a clean 100-mL or 150-mL beaker. Add 15 mL of 5% acetic acid solution (or vinegar) and stir. Clean the copper tokens by placing them in the sodium chloride/acetic acid mixture and stir until they are shiny. Remove the tokens immediately after they are clean to prevent etching of the surface by extended contact with the acetic acid-sodium chloride solution. Wash the tokens well with water and dry them with a towel. Do not handle the tokens with your hands as oils from your skin will interfere with the reaction.

2. Weigh the tokens and record the mass of each token. You may use the date on the token to identify it. (If you have more than one token with the same date, you will have to determine a method of identify them.)

3. Weigh out 1.0 gram of zinc and place it in a clean evaporating dish. Add 25 mL of 3M sodium hydroxide solution. Set the evaporating dish and its contents on a ring support and heat gently with the burner until the solution is hot and starts to bubble. CAUTION: DO NOT ALLOW THE SOLUTION TO ACTIVELY BOIL, HOT SODIUM HYDROXIDE IS VERY CAUSTIC AND MAY SPATTER. Using the tongs, place two copper tokens into the hot solution and continue to heat gently. Almost immediately, the copper tokens should begin to turn silvery white and small bubbles of gas will fizz from the solution. Occasionally, using the tongs, rub the tokens into the zinc and turn the tokens over. When the tokens have become completely silver, remove them from the solution and immerse them in a beaker of distilled water. Wash the tokens well to remove any sodium hydroxide from them.

4. Weigh the silver tokens and record the mass of each token.

5. Using the tongs, hold one of the silver tokens by the edges and heat in in the outer cone of the Bunsen burner flame. Within a few seconds, the token will change color. Heat it for three more seconds and then immediately quench it in a beaker of distilled water. (Note: Heating a post-1983 token in the burner for too long may result in melting of the token.) The resulting gold token can be dried and polished with a towel.

6. Repeat this procedure with a second silver token.
7. Weigh the gold tokens and record the mass of each token.

8. If you wish to convert more tokens in the zinc/sodium hydroxide coloring bath, it may be necessary to add distilled water to the solution to replenish any liquid that has evaporated. It is NOT necessary to add any additional sodium hydroxide. The bath will be sufficient to color several additional tokens.

Data:
Initial appearance of tokens:

Step 1:
Step 3:
Step 5:

<table>
<thead>
<tr>
<th></th>
<th>Token 1</th>
<th>Token 2</th>
<th>Token 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of token</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of clean, dry token</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of clean, dry silver token</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mass of clean, dry, gold token (just 2 tokens weighed)</td>
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</tbody>
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Discussion:
1. What is being oxidized? What is being reduced?
2. Why is it necessary to quench the copper token in water after heating it to produce the color change? (Note: You may want to try heating a token and allowing it to cool in the air)
3. Compare the mass you measured, before and after the color change, for each of the tokens. How do the masses compare?
4. The densities of cooper, zinc, silver, and gold are given in the table. Based on this information, did you really change the copper token into gold. Explain.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Density in g/mL</th>
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<tbody>
<tr>
<td>Copper</td>
<td>8.92</td>
</tr>
<tr>
<td>Zinc</td>
<td>7.14</td>
</tr>
<tr>
<td>Silver</td>
<td>10.5</td>
</tr>
<tr>
<td>Gold</td>
<td>19.3</td>
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</tbody>
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5. There were 2 alloys produced in the experiment. What were the percentages of Zn and Cu in them? (Look up on the Internet)
6. What drives this reaction is entropy! How does it relate to the experiment?

Resources: Any URLs (including date accessed) or textbook pages cite here using a proper Bibliography MLA format.

Conclusion: