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Formation of a Brass Penny and X-Ray Analysis

Teacher Lesson Plan

Overview:	**Classroom time:**
In this lesson, students will make a brass penny by first coating the penny in zinc metal and heating it up to promote diffusion of the metals and create the brass alloy. They will explore phase diagrams and x-ray analysis data to determine the phases of brass present in a similar brass penny.	100 minutes

Objectives:
- Describe what an alloy is and how it differs from the contributing metals.
- Create and alloy and compare its properties to other materials.
- Analyze provided XRD data to determine brass alloy phases.

Related Next Generation Science Standards (NGSS):	**Materials:**
• HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.	• Copper pennies circa 1982 • Steel wool • Mossy zinc • 1 M NaOH • Tongs • Evaporating dish • Hot plate • Sink to rinse pennies • Student Handouts

Related North Carolina Standards:	**Safety:**
• Chm.1.3: Understand the physical and chemical properties of atoms based on their position in the Periodic Table. • Chm.3.2: Understand solutions and the solution process.	Safety glasses must be worn throughout this investigation. NaOH is caustic and care should be taken not to come in contact. The pennies will be hot when removed from the hot plate and should be cooled before touching.

Lesson Preparation:

You will need to prepare 1M NaOH ahead of time. It is safer for the teacher to add it to the evaporating dishes to limit direct students' interaction.

Lab stations will need to be set up with an evaporating dish on a hot plate. The evaporating dish will be filled with NaOH and mossy zinc inside.

You will need at least 3 stations with steel wool in aluminum dishes where students can clean the pennies and remove oxidation to ensure proper plating with the zinc. You should have one penny per student to ensure that each student is able to keep a brass penny at the end of the lab.

Teacher Instructions:

Brass Penny Lab

1. **Students will read handout for homework and do Pre-Lab questions and #8.**
2. **The next day they will conduct the lab**

Assessment:

The assessment for this activity is the lab handout attached.

Extensions:

The extension activity for this lab is using the XRD data to determine which phase or phases of brass are present in the penny alloy.

Resources:

Speakman, Scott. Introduction to X-Ray Powder Diffraction Analysis. Retrieved from http://prism.mit.edu/xray/introduction%20to%20xrpd%20data%20analysis.pdf

Banerjee, Debjani. X-Ray Diffraction (XRD). Retrieved from https://www.iitk.ac.in/che/pdf/resources/XRD-reading-material.pdf

Copper Development Association. The Balance. Retrieved from https://www.thebalance.com/brass-types-3959219

Total Materia. (2003) Copper-Zinc Alloys: The Brasses. Retrieved from https://www.totalmateria.com/page.aspx?ID=CheckArticle&site=ktn&NM=69

Name:______________

Alchemy: Can you turn a penny into gold?

In this lab, you will be converting a regular penny into a “gold” penny. In doing so, you are following a tradition that dates back to the earliest days of chemistry.

The modern practice of chemistry started with the study of alchemy in medieval Europe and the Middle East. Alchemists convinced people that by doing certain chemical reactions, you could turn cheap metals into gold. The alchemist would sell them the secret and by the time anyone realized that the “secret” didn’t work, they’d be long gone with the money.

In this lab, you will be making an alloy. Just like the alchemist, you will mix zinc with copper and make brass; it will appear to be gold. Since gold is an element on the periodic table we cannot really make gold, but we can combine elements into compounds through chemical reactions or combine elements physically into mixtures.

The zinc will dissolve in the sodium hydroxide and attaches to the penny. It forms a thin layer over the outside of the penny, this process if referred to as plating. You may be familiar with silver plated jewelry, which is usually stainless steel with a thin outer coating of silver. In other words it is not solid silver. When the zinc plated penny is heated on the hot plate, the silvery zinc atoms mix with the copper atoms forming a metal alloy, brass that appears “gold” in color. Brass is a metal alloy that has frequently been confused for gold, especially by people who don’t see gold often. Brass is a substitutional alloy where some of the zinc atoms take the place of copper atoms on the crystal lattice.

Pre-lab questions

Would an alloy be considered a compound or a mixture? Why?

____

What are different properties of a metal that could be tested to compare and identify materials?

____

______.

Safety:

- Hot pennies look the same as cold pennies. Make sure your penny is cool before touching it.

- Tie back your hair & roll up your sleeves
- Wear closed toed shoes
- Wear goggles, gloves & aprons at all time (using corrosive chemicals)

Procedure:

Step 1: Clean pennies using steel wool, rinse with water and dry completely.

Step 2: Mix chemicals:

- Place 2 grams of Zinc (dust or Mossy) in evaporating dish; distribute to cover the bottom of dish.
- Add 3 pipettes of 1M NaOH to evaporating dish and stir with the wooden splint.

Step 3: Place the evaporating dish on the hot plate and heat the NaOH and zinc mixture.

Never allow the mixture to boil, it should remain at a simmer.

Caution: Never allow your chemicals to boil, raise your hand to ask for assistance if your chemicals are boiling. Do not allow the evaporation dish to go dry, add 1 pipet of NaOH when necessary before adding your pennies.

Step 4:

Using tongs take two pennies and submerge them into the sodium hydroxide so they sit on top of the zinc mixture.

- Allow the pennies to "plate" for about two minutes. Then using the tongs turn the pennies over until both pennies are completely plated with the Zn. It will appear silver in color.
- Remove pennies one at a time using the tongs and run under water until the slimy coating is removed. Blot dry with a paper towel.

Step 5:

Using the tongs, one penny at a time, hold the penny at its edge and place it on a hot plate at medium heat for about 20 seconds and cool with water. Your penny should appear gold in color.

Chemical disposal – DO NOT handle hot chemicals. Turn off and unplug your hot plates, and leave the evaporating dishes on the hot plate to cool. The instructor will dispose of them properly after class.

Follow-up questions and analysis:

1. Why did the penny turn a silver color?

2. What does the term metal plating refer to?

3. At what point was an alloy formed?

4. Is the alloy formation a physical or chemical change? Support your answer.

5. What alloy did you create?

6. Why was the penny heated to form the alloy?

7. How does an alloy form, and why are alloys made?

8. Research three alloys, what metals do they contain, and what properties make them useful:

Name of Alloy:	***Contains:***	***Useful properties:***

9. Is it possible to really turn any metals into the element gold through a chemical reaction? Why or why not?

10. Describe a procedure to prove that the “gold” penny is not really gold.

Extension activity: Using X-Ray Diffraction (XRD) to Analyze the Brass Alloy

Brass is a substitutional alloy where some zinc atoms replace copper atoms on copper's crystal structure. There are many different brass alloys depending on the ratio of zinc to copper (see Figure 1). Three important copper alloys include alpha brasses (<37% zinc), alpha-beta brasses (37-45% zinc), and beta brasses (>45% zinc). Between 50-60% zinc, a combination of beta and gamma brass exists. At more than 60% zinc, a gamma brass phase exists.

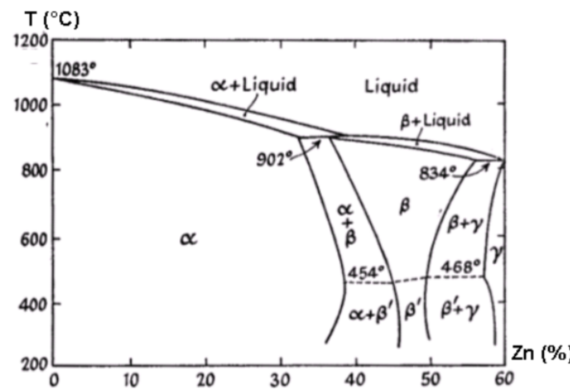
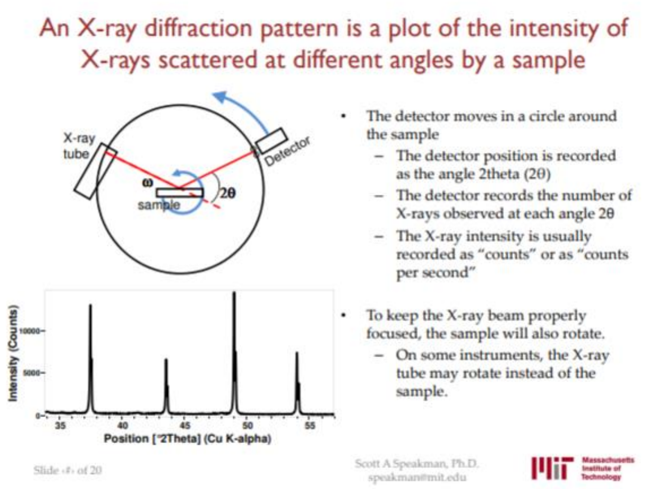
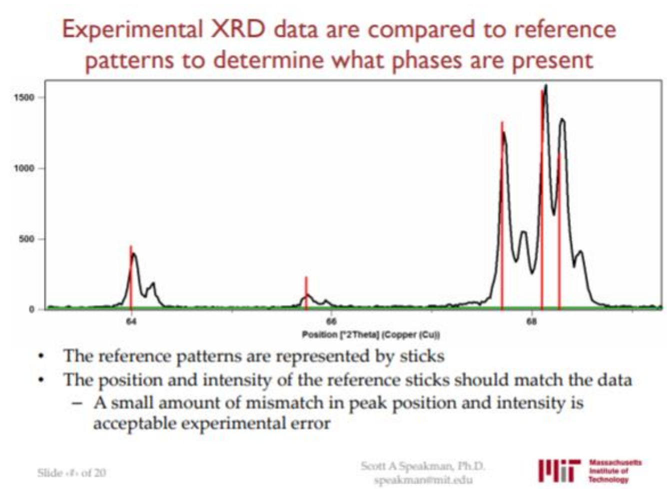


Figure 1. Constitutional Diagram of the Copper-Zinc Alloys

X-Ray diffraction is a technique where a sample is bombarded with x-rays and the diffracted waves are analyzed to determine the crystal structure. Different materials (and alloys) have different X-ray diffraction results. It is similar to how a finger print can identify a person. The X-ray diffraction results can be analyzed to determine the crystal structure of the sample, and it can be compared to known samples to confirm crystallographic geometries of materials.

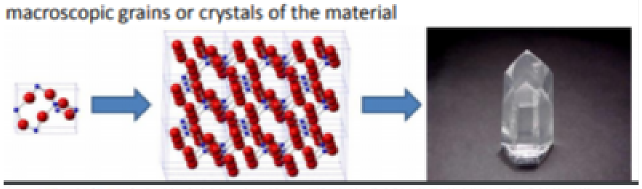




Crystalline materials are characterized by the long-range orderly periodic arrangements of atoms.

- The unit cell is the basic repeating unit that defines the crystal structure.
  - The unit cell contains the symmetry elements required to uniquely define the crystal structure.
  - The unit cell might contain more than one molecule:
    - for example, the quartz unit cell contains 3 complete molecules of SiO2.
  - The crystal system describes the shape of the unit cell
  - The lattice parameters describe the size of the unit cell

- The unit cell repeats in all dimensions to fill space and produce the macroscopic grains or crystals of the material



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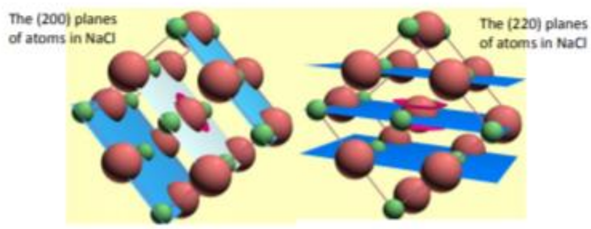
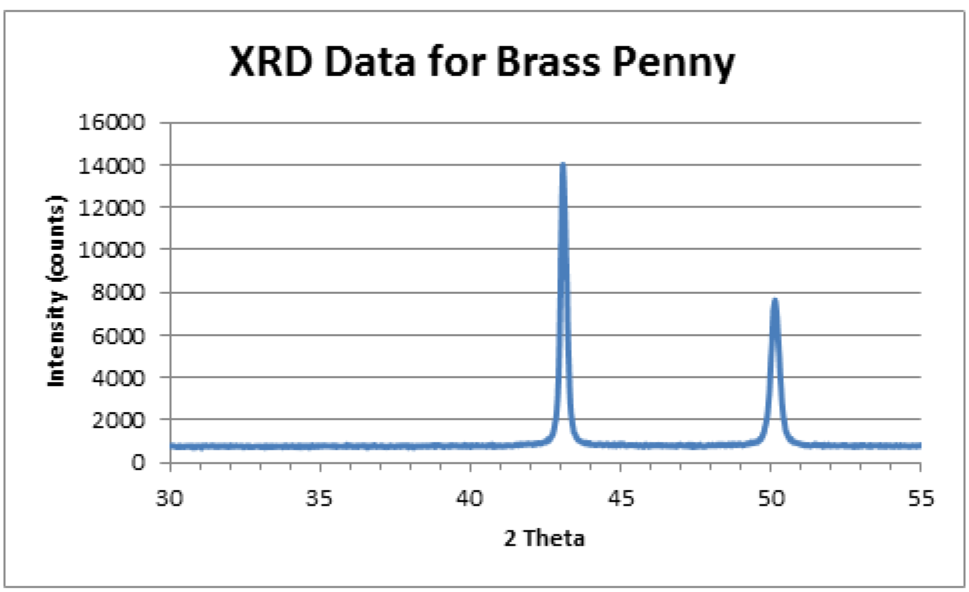
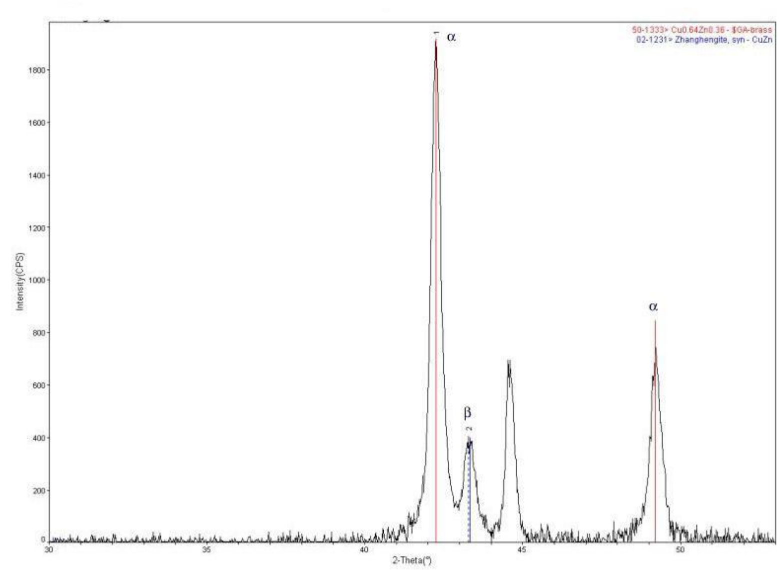


- The unit cell is the basic repeating unit that defines a crystal.
- Parallel planes of atoms intersecting the unit cell are used to define directions and distances in the crystal.
  - These crystallographic planes are identified by Miller indices.

Below is x-ray diffraction data for one of the brass pennies made in this lab. It was conducted at the RTNN facility at NC State University on the Rigaku X-ray diffractometer using Bragg-Brentano geometry.



Here are the x-ray diffractometer results for the various brass alloys. The red peaks represent alpha brass and the blue peak represents beta brass. Graph courtesy of Rigatu: (https://www.rigaku.com/en/products/xrd/miniflex/app009)



Based on this information, explain what phases of the brass alloy are present in the analyzed penny sample and how you determined that.