Lesson: Observing Properties of Those Marvelous Metals

FOR THE TEACHER

Summary
In this lesson, students will see how metals, both pure metals and alloys, may have different physical and chemical properties. They will investigate how these properties contribute to their usefulness in manufacturing and construction.

Grade Level
High School

NGSS Alignment
This lesson will help prepare your students to meet the performance expectations in the following standards:

- **HS-PS1-3**: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- **HS-PS2-6**: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
- **Scientific and Engineering Practices**:
  - Developing and Using Models
  - Analyzing and Interpreting Data
  - Planning and Carrying Out Investigations

Objectives
By the end of this lesson, students should be able to

- Classify samples of matter.
- Explain the difference between a pure metal and alloy.
- Represent a pure substance and an alloy at the particle level through drawings and models.
- Distinguish between chemical and physical properties of metals.
- Relate the properties of metals to their real-world uses.

Chemistry Topics
This lesson supports students’ understanding of

- Matter
- Physical Properties
- Chemical Properties
- Elements
- Compounds
- Mixtures
- Metals
- Alloy

Time
**Teacher Preparation**: 30 minutes
**Lesson**: 60-120 minutes

Materials (Per Group)
**Station 1**:
- Tongs or Forceps
- 400 ml beaker containing ~200 ml tap water
- Bunsen Burner
- Striker
- 4 Bobby pins
- 4 steel paper clips

**Station 2:**
- 3 birthday candles (cut in half for a total of six pieces of wax)
- Sheet of aluminum foil (~12” x 18”)
- Bunsen Burner
- Striker
- 1-2 Thermal Conductometers with different metal spokes ([Flinn Scientific AP9212](https://www.flinnsci.com/products/thermal-conductometers))

**Station 3:**
- Bunsen burner
- Striker
- 1-2 Ball and Ring Apparatus ([Flinn Scientific AP9031](https://www.flinnsci.com/products/ball-and-ring-apparatus))
  - 1-2 Bimetallic Strips ([Flinn Scientific AP5650](https://www.flinnsci.com/products/bimetallic-strips))

**Station 4:**
- 1 small iron nail (not galvanized) or other small sample of iron
- 1 small steel nail or other small sample of steel
- 50 ml of **1M Hydrochloric Acid** solution in a dropper bottle
- 24-well plate
- Small piece of sandpaper

**Safety**
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
- When working with acids, if any solution gets on students’ skin, they should immediately alert you and thoroughly flush their skin with water.
- Always use caution around open flames. Keep flames away from flammable substances.
- Always be aware of an open flame. Do not reach over it, tie back hair, and secure loose clothing.
- Open flames can cause burns. Liquid wax is hot and can burn the skin.
- An operational fire extinguisher should be in the classroom.
- Students will need a waste container to place all used chemicals and metals at each lab station for proper disposal after the lab.

**Teacher Notes**

**Introductory Activity:**
- To begin this lesson, the teacher needs to have a collection of samples of elements, compounds and mixtures for students to investigate. Some suggestions include: a pre-1982 penny, a piece of aluminum foil, a piece of carbon, a box of baking soda, a bottle of water, a sugar packet, a fossil, a jar of peanut butter, a bottle of 70% isopropyl alcohol, etc. It would be helpful to have enough samples available for every student to have one.
- The teacher should place 3 large signs around the room that are labeled as: “Element”, “Compound” and “Mixture”.
- Before the beginning of the class, the teacher should place all of the items on a cart and as students enter the room ask each of them to select a piece of matter from the cart. Remind them that they should not to eat their chosen sample of matter (even if it is edible!!)
• Students should be directed to stand by the sign that represents their chosen sample of matter.
• The teacher should then ask all of the students standing in the “Mixtures” category to subdivide into two groups: homogeneous and heterogeneous. Students are then asked to defend their choice and may have to alter their position to the correct category if they are incorrectly classified.
• As the students are defending their classification, ask the students to describe their piece of matter using physical properties.
• Create a flow chart with the students that visualizes the separate categories of matter into four classification groups: elements, compounds, homogeneous mixtures (solutions) and heterogeneous mixtures.
• Draw associated particle level models of elements, compounds, and mixtures to help students conceptualize how they are each different.
• Ask the students to select one of the elements that were observed in the lesson. Create a list with the students of physical and chemical properties of element. If technology is accessible, research the element’s quantitative physical properties such as density or melting point and its chemical properties. Alternatively, have copies of the SDS for the element and show the students Section 9 which lists properties of the element.
• Have students define the terms element, compound, homogeneous and heterogeneous mixtures and give an example of each. This could be completed using an exit slip depending on the length of the class.

Lab Activity:
• After the class discussion on classification of matter and chemical and physical properties of matter, students are given the opportunity to observe these properties as they proceed through four lab stations. Students can then be tasked with researching alloys used in medical devices, sports equipment, jewelry, musical instruments, etc. that would align with their interests or career choice.
  o The author of this lesson works in a high school with a Career and Technical Education Program (CTE), so the students are tasked with applying the properties of metals to their CTE classwork to help them understand why different metals are used for applications in manufacturing and construction.
• Prior student knowledge should include the difference between an alloy (a homogeneous mixture of a metal and other metals or nonmetals) and a pure metal. Common alloys include:
  o 14 karat gold: mixture of gold, copper, and silver
  o Steel: mixture of iron and carbon
  o Brass: mixture of copper and zinc
• Most students have experience with all alloys. Ask students to share examples such as jewelry, musical instruments, sports equipment, and medical/dental devices.
  o In our CTE classes, students mostly use high carbon steel, low carbon steel, brass, iron, aluminum, and copper; therefore, those are the samples I use in class to help make chemistry more relevant.
  o I get samples of these metals from the CTE teachers to use in this lab. Other metal samples from the hardware store or from the chemistry stockroom may be used if access to CTE is not available.
• In my classroom, I have eight lab tables so I set up two sets of the four stations. I organize students in groups of 4 (smaller groups or partners would work as well) and have them rotate through all four stations in a class period spending about 10-12 minutes at each station.
• **Lab Station #1: Observing Steel**
  o At this station, set up a Bunsen burner, striker, 4 bobby pins, 4 paper clips, tongs/forceps, and a 400 ml beaker half-filled with ice water.
  o Students will be heating and cooling the pins and paperclips in different ways to see how the properties of high carbon and low carbon steel are affected.
  o The bobby pins represent high carbon steel while the paper clips are low carbon steel.
This lab station is adapted from one developed by the ASM Materials Education Association, which describes the properties of the types of steel and how heating and cooling affects the properties of the steel.

- A waste container will be needed to collect the metals after each group completes the station. The used bobby pins and paperclips may be disposed of in the trash.
- This station can be split into two different stations or completed all in one depending on the amount of time allotted or the level of the student.

**Lab Station #2: Comparing the Thermal Conductivity of Metals**
- At this station, set up a Bunsen burner, a striker, three birthday candles cut in half for a total of six pieces, a sheet of aluminum foil, and a thermal conductivity apparatus with different metal spokes (some have five spokes while others have six).
- The birthday candles must be pushed onto each of the spokes.
- The aluminum foil is placed under the burner to catch the melting wax.
- The center of the apparatus is heated over the burner, and the students record the order that the wax pieces melt from the different samples of metals.
- Prior to lab, the teacher should model how to put the wax on the ends. I also have the students predict the order that the wax will melt.
- Most students see the value of the thermal conductivity and predict the correct order; others disregard the values and make predictions from personal experience or by just guessing.
- If a second apparatus is available, have it ready to go for the next group and allow the first one to cool. Otherwise, the first one will be too hot to test again so cooling in water will be necessary.
- A waste container will be needed to collect the wax pieces after each group completes the station.

**Lab Station #3: Observing the Thermal Expansion of Metals**
- At this station, set up a Bunsen burner, a striker, the ball and hoop apparatus and the bimetal strip apparatus.
- The students should observe that the ball fits through the hoop prior to heating but the ball will expand after heating and will no longer fit through the hoop.
- The students should observe the varying expansion rate of the two metals (copper and steel) which causes the metal strip to bend upon heating.
- If a second set of apparatuses is available, have them ready to go for the next group and allow the first ones to cool. Otherwise, the first set will be too hot to test again so cooling in water will be necessary.
- This station may also be split into separate stations or done all in one depending on time allotted or level of student.

**Lab Station #4: Observing the Reactivity of Iron and Steel with Acid**
- At this station, set up a plastic well plate, dropper bottle of 1M hydrochloric acid, a sample of iron and a sample of steel.
- Students will place the samples in separate wells and add ~20 drops of acid to each.
- After five minutes, the students will observe the reaction with each metal sample.
- I use the same spot plate for all the groups, but I instruct the students to use a different location on the well plate for their tests.
- A waste container will be needed to collect the metals after each group completes the station. Metals may be reused after the oxidized layer is removed.
- Acid will need to be collected and neutralized prior to disposal.

- For students with attention or reading difficulties, I split up some of the. This allows the student fewer steps to follow. I also provide pictures of how to perform the lab at each station.