# Properties of Metals and Non-Metals

## Objectives

Students will:

1. Understand that every element is classified as a metal, nonmetal or semimetal (metalloid) based on its individual properties.
2. Be able to classify an element as a metal, nonmetal or semimetal based on experimental observations of physical and chemical properties.

## Materials

Each student group should have the following:

- Eight labels
- Seven vials with caps, filled with the following:
  - Iron filings
  - Sulfur rolls
  - Mossy zinc
  - Graphite (replacement leads for mechanical pencils work well)
  - Silicon
  - Mossy tin
  - Carbon

  (If the above materials are not available, some substitutes are: paper clips, beebees, nails, fishing weights, charcoal)
- One dropper bottle
- 6M hydrochloric acid
- One hammer
- Eight pieces of paper each measuring approximately 3.5 × 5 inches
- A conductivity apparatus such as 9-volt battery, a small appliance light bulb, and three pieces of insulated copper wire to make an open circuit (the circuit will be closed with each of the seven samples)
- One test tube holder
- Seven test tubes

• Every student should have the following:
  - Safety goggles
  - A copy of the Properties Data Sheet handout

## Procedures

1. Before beginning this activity, students should already have a basic understanding of the differences in the physical properties of luster, malleability, and conductivity between metals and nonmetals. Students should understand that metalloids have characteristics of both metals and nonmetals and that acids will react with most metals and not nonmetals. Students should always be reminded to follow proper safety procedures and guidelines when working with any chemicals.

2. Break the class into groups of two or three, depending on class size. Use labels to number a set of vials from 1 through 7. Each group should receive a set of seven vials. Fill and label the complete set of vials as follows:
   Vial 1—iron filings
   Vial 2—sulfur
   Vial 3—mossy zinc
   Vial 4—graphite
   Vial 5—silicon
   Vial 6—mossy tin
   Vial 7—carbon

3. Make a 6M solution of hydrochloric acid. Label a set of dropper bottles and fill with the acid solution. There should be one dropper bottle of acid per group. At each group's lab station place a hammer, eight pieces of white paper, a set of vials containing samples 1-7, a dropper bottle of 6M hydrochloric acid, a conductivity apparatus, a test tube holder, and seven test tubes.

4. Give each student a copy of the Properties Data Sheet

5. Before students begin their experiment, make sure they are all wearing their safety goggles. Instruct a student in each group to take a piece of white paper, fold it in half, open it, and place it on the lab top. Another member of the group should then open vial 1 and shake about a pea-sized portion of the sample onto the white paper. Each student should observe the appearance of the sample and record his or her observations in the "color" and "luster" columns of the data sheet.

6. Next, have one student in each group place a second piece of paper over the top of the sample and crush the sample with the hammer. The student should then remove the top piece of paper and each student in the group should observe the sample and record his or her observations in the "malleability" column of the data sheet.

7. Have one student within each group test the conductivity of the sample with the conductivity apparatus by placing the ends of the wires not attached to the power source or light bulb into the sample vial. DO NOT LET THE WIRES TOUCH EACH OTHER. Each student should observe the light bulb and record his or her

observations in the “conductivity” column of the data sheet.

8. Have one student place a test tube in the test tube rack. The student should then pour sample 1 from the paper into the test tube and add 10 to 20 drops of 6M hydrochloric acid. Each student should then wait at least three minutes before observing and then record his or her observations in the “reaction with acid” column of the data sheet.

9. Each group should then repeat steps 3 through 7 above for the remaining six vial samples.

10. Each student, based on his or her group’s experimental observations and the knowledge he or she has about the properties of metals and nonmetals, should then classify each of the samples as a metal, nonmetal, or semimetal. He or she should record the answer in the “classification” column of the data sheet. Each student should then submit his or her data sheet.

11. After submission of the data sheets, discuss with the class their conclusions for each of the seven vials. What conclusions did they draw and why?

## Adaptations

Adaptation for younger students:
Define the concepts of color, luster, malleability, and conductivity with your students. Next, review the properties of metals, nonmetals, and semimetals. Divide the class into small groups and give each group a few samples of everyday objects, including paper clips, beebees, nails, fishing weights, and charcoal. Ask each group to observe these objects and complete the Properties Data Sheet. The teacher should perform the electricity and acid tests in front of the class while students record their observations.

## Discussion Questions

1. What accounts for the observed differences between samples? Describe how these samples might be arranged with respect to other elements in the periodic table. What other tests could be performed to help identify materials as metals, nonmetals, and semimetals? What are some useful applications of such tests?

2. Our society is rapidly consuming raw materials that are nonrenewable. Discuss whether we should rely on materials scientists to develop new materials to replace older ones that are no longer available or consume and discard currently available materials more wisely. Is every material replaceable?

3. Discuss what types of materials are most important to recycle. Debate whether recycling should be made the law nationwide. Is the expense of enforcing such a law justified or is the money better spent on other social or scientific programs?

4. Given the high quality and ready availability of substitutes, debate whether rare materials such as gold or diamonds should be used for jewelry and art or saved solely for technology and industry.

5. Discuss how our global society would change if the technology to change one element into a different element were developed. Is this a technology that, if developed, should be made public?

6. One area of great advancement in materials science is the area of medicine. Artificial joints are available, and scientists are currently developing artificial skin and blood. Discuss whether there should be limits placed on the development of physiological substitutes. Can you think of any reasons why advances in this area should be controlled?

7. Many of the greatest advances in materials science have been made accidentally. In light of this, discuss the value of following the scientific method versus chance. Is there ever room for chance when strictly adhering to the scientific method?

## Evaluation

The data sheet for this activity can be used as the evaluation. Each of the observations in the color, luster, malleability and conductivity columns can be assigned a value of one point. Each classification can be assigned a value of three points. The total points for this activity are then 49, which can be rounded to 50. The column for reaction with acid is not graded because the bubbles of gas are sometimes very difficult to observe. Evaluation of the classification should be done based on the student observations, not necessarily on what the sample actually is. The reason is that the students are to classify based on their own experimental data, which may or may not be correct.

## Extensions

**Evaluating Electrolytes**
Metals are not the only substances that conduct electricity. Electrolytes also conduct electricity and are essential to the proper functioning of our bodies. Discuss with students what an electrolyte is. Have students use a conductivity apparatus to investigate the following solutions and determine if they are a strong electrolyte, weak electrolyte, or nonelectrolyte. The solutions are salt water, sugar water, rubbing alcohol, tap water, and distilled water. Have them make a prediction based on the chemical formula of the solution and then check their hypothesis. Once they

have checked these solutions, they may want to test bottled spring water or a few sports drinks to see if they are strong electrolytes, weak electrolytes, or nonelectrolytes.

NOTE: Make all solutions with bottled distilled water since tap water and even some deionized water can test as weak electrolytes.

## Suggested Readings

**Materials**
Sally and Adrian Morgan. Facts On File, 1994.
This book describes the many natural and synthetic materials used in everyday life, including fibers and plastics, building materials, rubber, and glue. Photographs and drawings illustrate the great variety of their composition, characteristics of growth or method of manufacture, and their industrial and personal uses.

**Stuff: The Materials the World is Made Of**
Ivan Amato. Basic Books, 1997.
Writing in an engaging, down-to-earth style, the author tells the story of the development and utilization of the materials humans have used to take us from the Stone Age to the present high-tech world. Early improvements in pottery, paper, and metals are touched on, but the book concentrates on the more recent discoveries in the synthesis of totally new materials - from steel to plastics to the development of nanotechnologies and “smart” materials.

## Links

**WHAT IS MATERIALS SCIENCE & ENGINEERING ?**
What is "material science" and what do material scientists and engineers do? In a matter of fact way, the subject is introduced here by the University of Wales Swansea.

**Challenge of Materials**
Exploring the hidden world of materials, find out what materials have changed the world with multimedia games and quizes that will challenge your understanding of the science of materials.

**Materials Science and Technology Teachers Workshop**
The University of Illinois provides seven teaching modules with background information, lesson plans, and materials lab activities suitable for middle school and up, on metals, ceramics, semiconductors, composites, concrete, energy and polymers.

**Exploring Materials Engineering**
Very few people know of the field called Materials Engineering. On this web page, you are invited to explore some industrial sites on the Internet that will give you a sense of what materials engineering is all about.

**The Periodic Table**
This website provides a multimedia crash course on the chemistry behind all materials, and includes the ever popular and very interactive "David's Whizzy Periodic Table."

## Vocabulary

Click on any of the vocabulary words below to hear them pronounced and used in a sentence.

**brittle**

**Definition:** Easily broken or shattered.
**Context:** The brittle piece of chalk shattered when the student accidentally stepped on it.

**ductile**

**Definition:** Able to be drawn into a wire.
**Context:** Two properties of copper metal that make it suitable for electrical wiring are that it conducts electricity and it is ductile.

**electrolyte**

**Definition:** Any substance that conducts electricity when molten or in solution.
**Context:** In order to stay healthy, the body must have salts to help maintain its balance of electrolytes.

**insulator**

**Definition:** Any substance that does not conduct electricity.
**Context:** In order to prevent short circuits, electrical wires are coated with nonconducting insulators.

**luster**

**Definition:** The quality, fact, or condition of shining by reflecting light.
**Context:** All metals, when polished, have very high luster.

**malleable**

**Definition:** Can be hammered or pressed without breaking.
**Context:** Blacksmiths are able to shape iron by hitting it with hammers because metals are malleable.

## Standards

This lesson plan may be used to address the academic standards listed below. These standards are drawn from Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education: 2nd Edition and have been provided courtesy of the Mid-continent Research for Education and Learning in Aurora, Colorado.

**Grade level:** 9-12
**Subject area:** Physical Science
**Standard:**
Understands basic concepts about the structure and properties of matter.
**Benchmarks:**
Understands how elements are arranged in the periodic table and how this arrangement shows repeating patterns among elements with similar properties (e.g., numbers of protons, neutrons, and electrons; relation between atomic number and atomic mass).

**Grade level:** 9-12
**Subject area:** Physical Science
**Standard:**
Knows the kinds of forces that exist between objects and within atoms.
**Benchmarks:**
Knows how different kinds of materials respond to electric forces (e.g., as insulators, semiconductors, conductors, and superconductors).

**Grade level:** 9-12
**Subject area:** Science and Technology
**Standard:**
Understands the nature of scientific inquiry.
**Benchmarks:**
Uses technology (e.g., hand tools, measuring instruments, calculators, computers) and mathematics (e.g., measurement, formulas, charts, graphs) to perform accurate scientific investigations and communications.