The Periodic Table of the Elements
Metalloids
Teacher's Guide

Grade Level: 6–8	**Curriculum Focus:** Physical Science	**Lesson Duration:** Two class periods

Program Description

Introduce students to these elements, which sometimes act like metals and other times like non-metals. See how boron and other elements provide their distinctive colors to fireworks displays. Examine the semiconductor properties of silicon to see how it ushered in the era of information. Investigate the story told by metalloid traces found in the mummified remains of a 5,000-year-old man. And explore the inner workings of computers and the elements that make them possible.

- Exploring Metalloids (5 min.)
- Boron: Pyrotechnic Paintbrush (5 min.)
- Silicon: Computing Champion (6 min.)
- Arsenic: Mummified Mystery (6 min.)
- Understanding Computers and Computing (21 min.)

Onscreen Questions

- What property makes the metalloids unique among other elements?
- Describe how a semiconductor works.
- What is the function of metalloids in computers?
- What other elements are used in computers?

Lesson Plan

Student Objectives

- Talk about metalloids, their use as semiconductors, and their impact on the computer industry.
- Work in groups to create a visual timeline showing the evolution of the computer.
- Consider how today's computers have evolved and might continue to change in the future.

Materials

- *Metalloids* program
- Periodic table
- Print and online resources about the history of the computer
- Computer with Internet access
- Color copier or printer

Procedures

1. After watching the program, remind students that every element can be classified as a metal, nonmetal, or metalloid. Show students where these elements are found on the periodic table, pointing out that metalloids fall between the metals and nonmetals.
2. Explain that metalloids share some properties with metals and some with nonmetals. For example, one of the most important distinctions is that metals are good conductors of heat and electricity but nonmetals are not. In other words, metals allow electricity to flow through them, while nonmetals block electric currents. Ask students: How can metalloids share both the properties of metals and nonmetals when it comes to their ability to conduct electricity? *(Metalloids are semiconductors: At high temperatures, they conduct electricity as if they were metals, but at lower temperatures, they act as insulators, stopping electric currents from flowing.)*
3. Review how our knowledge of semiconductors has changed the computer industry: Early computers used mechanical on-off switches, then vacuum tubes, to conduct and stop electric currents, creating the ones and zeroes used in the computer's binary code. Then semiconductors were used to create silicon transistors without moving parts—switches were turned on or off depending on temperature. Silicon transistors allowed computers to be smaller, faster, and more reliable.
4. Have students work in small groups to create a visual timeline that shows the evolution from the earliest computers to the first popular personal computers. Each group should select five computers that they think best reflect the most important advancements from the 1940s to the 1980s. On the timeline, they should include an image of the computer, the date it was released, and one to two sentences describing its significance. Some of the computers they may wish to highlight include (but are certainly not limited to) the following:
    - ENIAC (1946)
    - UNIVAC (1951)
    - IBM 1401 (1961)
    - Nova (1958)
    - Kenbak-1 (1971)
    - MITS Altair 8800 (1975)

- Apple II (1977)
- IBM PC (IBM PC 5150) (1981)
- Osborne I (1981)
- Apple Lisa (1983)
- Macintosh (1984)
- PC Convertible (IBM 5140 PC Convertible) (1986)

5. Provide any appropriate print resources about early computers and point students to the following Web sites:
    - The Obsolete Technology Web site (click "Show Images" under timeline)
      http://oldcomputers.net/
    - Computer History Museum: Timeline (Computers)
      http://www.computerhistory.org/timeline/timeline.php?timeline_category=cmptr
    - Computer Closet Collection: Classic Microcomputers
      http://www.computercloset.org/compindex.htm
6. After the groups share their timelines with the class, ask students: What were some of the most common choices? How did these computers change the face of the computer industry? How have computers changed since the 1980s?
7. Challenge students to think of everyday products that include computer chips made with semiconductors, such as PDAs (personal digital assistants), cars, camera phones, coffee makers, even children's toys. Ask students: In the future, what other products might use computer chips?

Assessment

Use the following three-point rubric to evaluate students' work during this lesson.

- 3 points: Students were active in class discussions; showed a strong understanding of metalloids and their use as semiconductors; created a complete, engaging visual timeline of the evolution of computers that included a clear, compelling description of the significance of each computer.
- 2 points: Students participated in class discussions; showed a satisfactory understanding of metalloids and their use as semiconductors; created a complete visual timeline of the evolution of computers that included a simple description of the significance of each computer.
- 1 point: Students did not participate in class discussions; showed a weak understanding of metalloids and their use as semiconductors; created an incomplete or confusing visual timeline of the evolution of computers that included unclear or incomplete descriptions of the significance of each computer.

Vocabulary

abacus

Definition: A manual computing device consisting of a frame holding parallel rods strung with movable beads that represent numbers

Context: The abacus, a five-thousand year-old computing system, is considered the earliest version of the digital computer.

central processing unit (CPU)

Definition: The part of a computer that interprets and executes instructions; often referred to as the brains of the computer

Context: More complex operations like adding, subtracting, and comparing data are also a function of the CPU.

conductor

Definition: A substance or body that allows electricity, heat, or sound to pass through it

Context: Silicon acts as an electrical conductor when heated.

electronegative

Definition: Having the tendency to attract valence electrons from other elements during chemical reactions

Context: If an element has more than four valence electrons, as nonmetals do, it is electronegative.

electropositive

Definition: Having the tendency to release valence electrons to other elements during chemical reactions

Context: If an element has less than four valence electrons in its outermost shell, as most metals do, it is electropositive.

metalloid

Definition: An element that has some properties of metals and nonmetals; metalloids include boron, silicon, germanium, arsenic, antimony, tellurium, and polonium

Context: Most metalloids are brittle, somewhat shiny solids that exhibit properties of metals and nonmetals.

microchip

Definition: A tiny complex of electronic components and their connections that is produced in or on a small slice of material (like silicon)

Context: Very pure silicon is used to make semiconductors and microchips for electronic devices.

semiconductor

Definition: An element (like germanium or silicon) that behaves as an insulator at room temperature, but as an electrical conductor when heated

Context: Semiconductors are used in everything from calculators to computer chips.

transistors

Definition: A solid-state electronic device that is used to control the flow of electricity in electronic equipment and consists of a small block of a semiconductor (like germanium) with at least three electrodes

Context: The invention of silicon transistors revolutionized and miniaturized the world of computers.

valence electrons

Definition: The electrons in an atom's outermost electron shell that dictate how elements interact

Context: Boron has three valence electrons and tends to act as a metal by shedding its valence electrons during chemical reactions.

Academic Standards

Mid-continent Research for Education and Learning (McREL)

McREL's Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education addresses 14 content areas. To view the standards and benchmarks, visit http://www.mcrel.org/compendium/browse.asp.

This lesson plan addresses the following national standards:

- Science: Physical Sciences—Understands the structure and properties of matter
- Technology—Knows the characteristics and uses of computer hardware and operating systems

National Academy of Sciences

The National Academy of Sciences provides guidelines for teaching science in grades K–12 to promote scientific literacy. To view the standards, visit this Web site: http://books.nap.edu/html/nses/html/overview.html#content.

This lesson plan addresses the following science standards:

- Physical Science
- Science and Technology
- Science in Personal and Social Perspectives

Support Materials

Develop custom worksheets, educational puzzles, online quizzes, and more with the free teaching tools offered on the Discoveryschool.com Web site. Create and print support materials, or save them to a Custom Classroom account for future use. To learn more, visit

- http://school.discovery.com/teachingtools/teachingtools.html

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DVD Content

This program is available in an interactive DVD format. The following information and activities are specific to the DVD version.

How to Use the DVD

The DVD starting screen has the following options:

Play Video—This plays the video from start to finish. There are no programmed stops, except by using a remote control. With a computer, depending on the particular software player, a pause button is included with the other video controls.

Video Index—Here the video is divided into five segments (see below), indicated by video thumbnail icons. Watching all parts in sequence is similar to watching the video from start to finish. Brief descriptions and total running times are noted for each part. To play a particular segment, press Enter on the remote for TV playback; on a computer, click once to highlight a thumbnail and read the accompanying text description and click again to start the video.

Curriculum Units—These are specially edited video segments pulled from different sections of the video (see below). These nonlinear segments align with key ideas in the unit of instruction. They include onscreen pre- and post-viewing questions, reproduced below in this Teacher's Guide. Total running times for these segments are noted. To play a particular segment, press Enter on the TV remote or click once on the Curriculum Unit title on a computer.

Standards Link—Selecting this option displays a single screen that lists the national academic standards the video addresses.

Teacher Resources—This screen gives the technical support number and Web site address.

Video Index

I. Exploring Metalloids (5 min.)

Sometimes acting as metals and sometimes as nonmetals, the metalloids may be the strangest and perhaps most useful group of elements on the periodic table.

II. Boron: Pyrotechnic Paintbrush (5 min.)

Element number five on the periodic table, boron is a key ingredient in some fireworks and other flammable devices. Learn about the properties and uses of this metalloid.

III. Silicon: Computing Champion (6 min.)

The discovery that the metalloid silicon works as a semiconductor revolutionized the world of computers. Examine the atomic structure, properties, and most common uses of this abundant element.

IV. Arsenic: Mummified Mystery (6 min.)

Arsenic is a deadly poison that can also cause cancer. Learn more about this element and see how evidence of arsenic residue helped scientists learn about a 5,000-year-old mummy.

V. Understanding Computers and Computing (21 min.)

Explore the evolution of the modern computer and see how the modern information age has changed the way people do business and interact on a global scale.

Curriculum Units

1. All About Metalloids

Pre-viewing question
Q: What elements make up the metalloid group?
A: Boron, silicon, arsenic, antimony, germanium, tellurium, and polonium

Post-viewing question
Q: Describe the atomic structures of the metalloids and their placement on the periodic table.
A: The metalloids span groups 13 through 16, between the metals and the nonmetals, on the periodic table. Metalloids have between three and six valence electrons; their atomic structures lie squarely between those of the metals and the nonmetals. Boron has three valence electrons and usually acts as a metal by shedding its valence electrons through chemical reactions. Arsenic, antimony, tellurium, and polonium have more than four valence electrons, and they typically act as nonmetals by gaining electrons from other elements. Silicon and germanium have exactly four valence electrons and sometimes act as metals and sometimes as nonmetals.

2. Boron: Properties and Uses

Pre-viewing question
Q: What do you know about the element boron?
A: Answers will vary.

Post-viewing question
Q: What happens to boron when it is placed in a hydrogen flame?
A: When boron enters the hydrogen flame, it produces a brilliant green glow. That glow is the reason it is often used in fireworks, flares, and other flammable devices. The high melting point of boron is more than 4,000°F, so while the element colors a flame, it does not actually melt.

3. Fireworks: A Display of Elements

Pre-viewing question
Q: Describe an interesting fireworks display you have seen.
A: Answers will vary.

Post-viewing question
Q: What elements and chemical compounds are used to produce specific colors in fireworks?
A: Chemists know that, when heated, every known element in the world gives off its own color. A strontium or lithium compound added to fireworks will produce a brilliant red color. A copper compound results in a blue color. Boron and barium will produce a striking green. Yellow fireworks contain sodium. Calcium salts give off an orange glow. Aluminum, magnesium, and titanium produce the color white.

4. Silicon: Properties and Uses

Pre-viewing question
Q: What household products typically contain silicon?
A: Possible answers include soaps, adhesives, lotions, cosmetics, hair products, furniture polish, and aluminum foil.

Post-viewing question
Q: What are common uses of silicon compounds?
A: Silicon is the second most abundant element on the planet, and its compounds are used to manufacture glass and to make soaps, adhesives, preservatives, lubricants, polishes, electrical insulators, cement, and solar cells. Pure silicon is used to make semiconductors and microchips for calculators, computers, and other electronic devices.

5. Transforming Computer Technology

Pre-viewing question
Q: What would your life be like without computers?
A: Answers will vary.

Post-viewing question
Q: How did silicon transform the computer industry?
A: Thanks to the unique property of silicon, researchers could create silicon transistors without moving parts that allow an electrical current to pass through, depending on temperature. This enabled binary switches to become microscopic, faster, and more reliable. This revolutionized the

computer industry because computers could be made smaller and lighter and could handle multiple and more-complex tasks.

6. Arsenic: Properties and Uses

Pre-viewing question
Q: What do you know about arsenic?
A: Answers will vary.

Post-viewing question
Q: What are common uses of arsenic?
A: Arsenic, a deadly poison, is primarily used to make insecticides and animal poisons. Small amounts can be added to metal alloys to help make them stronger. Arsenic is also used in the manufacturing of mirrors, glass, LED lights, and semiconductors.

7. Ötzi the Ice Man and Copper Tools

Pre-viewing question
Q: What artifacts from life today would archeologists find interesting in the future?
A: Answers will vary.

Post-viewing question
Q: How did scientists determine that Ötzi had made copper tools and objects?
A: Scientific evidence showed that the copper and arsenic found in Ötzi's hair must have been absorbed during his lifetime. This would have happened if Ötzi had made copper objects, such as his axe. Copper can be extracted from malachite, but much of the malachite where Ötzi lived also contains arsenic. Early toolmakers who smelted malachite to produce copper would have been exposed to high levels of arsenic, which appears to have been the case with Ötzi.

8. Computers Share Information

Pre-viewing question
Q: How does computer technology help you with your schoolwork?
A: Answers will vary.

Post-viewing question
Q: What are the pros and cons of global dependence on computers?
A: Answers will vary.

9. Early Computation and Binary Code

Pre-viewing question
Q: What tools can help people count or compute numbers?
A: Possible answers include computer, calculator, adding machine, and the abacus.

Post-viewing question
Q: What is the binary number system and why is it used in computers?
A: The binary number system, or binary code, uses zeros and ones. In binary counting, you shift one place every time you get to a multiple of two. One is one, but two is one-zero. Three is one-one, but four is another multiple of two, so it shifts one place to the left for one-zero-zero. Binary code was selected because it was simple for computers to interpret information because you can make it look like a switch—either on or off.

10. Switches and Silicon Transistors

Pre-viewing question
Q: How have computers changed in your lifetime?
A: Answers will vary.

Post-viewing question
Q: What is the role of a transistor?
A: Transistors are a fundamental component of the active electrical circuits used in computers and other electronic products. Microscopic semiconductor devices work together to transport electrically coded currents inside a computer. Transistors have built-in error-correcting codes.

11. Microchips, Circuit Boards, and Memory

Pre-viewing question
Q: How are the functions of a computer and the human body similar?
A: Answers will vary.

Post-viewing question
Q: Describe the making of a microchip.
A: Most computer chips begin life as silica, which is heated with carbon and treated with hydrochloric acid and hydrogen to create extremely pure silicon wafers. Workers use ultraprecise machinery to etch microscopic circuits on the them. Then phosphorous and boron and thin layers of copper and gold are added.

12. Evolution of Modern Computers

Pre-viewing question
Q: What things in the real world remind you of science fiction?
A: Answers will vary.

Post-viewing question
Q: How do you imagine computers and computing will evolve in the future?
A: Answers will vary.