



Performing Well Under Pressure

Lesson Overview

GRADE LEVEL: 9-11

TIME ALLOTMENT: Two to three 45-minute class periods

OVERVIEW: The rarity and unique physical properties of diamonds have earned them an important and valuable place in our society. The NATURE episode “Diamonds” investigates the origins of this brilliant gemstone, as well as how it is mined and sold.

In this lesson, students will explore the characteristics of diamonds, and begin building an understanding of their formative environment, the resulting crystal structures and the physical properties of earth materials. Students will also be introduced to the silica tetrahedron and the silicate minerals, build physical models of silicate structures, and determine the physical properties of several common silicate mineral samples.

Prior to commencing this lesson, students should have already been introduced to the concepts of minerals and the physical properties used to identify them (i.e. luster, hardness, and cleavage/fracture).

SUBJECT MATTER: Earth Science, Mineralogy, Crystallography, Science and Society

LEARNING OBJECTIVES:

Students will be able to:

- Determine some physical properties of minerals;
- State and illustrate, with examples, that the physical properties of minerals are a function of their crystal structures;
- Connect the scientific significance of diamonds to its cultural and historical significance;
- Construct simple models of olivine, pyroxenes, amphiboles, and micas using 3 dimensional silicate tetrahedron models.

STANDARDS and CURRICULUM ALIGNMENT:

National Science Education Standards

<http://www.nsta.org/publications/nses.aspx>

CONTENT STANDARD A: As a result of activities in grades 9-12, all students should develop

Abilities necessary to do scientific inquiry
Understandings about scientific inquiry

USE TECHNOLOGY AND MATHEMATICS TO IMPROVE INVESTIGATIONS AND COMMUNICATIONS.



A variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard. Mathematics plays an essential role in all aspects of an inquiry. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results.

CONTENT STANDARD B: As a result of their activities in grades 9-12, all students should develop an understanding of STRUCTURE AND PROPERTIES OF MATTER.

- Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically.
- The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.
- Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.

New York State Regents Core Curriculum Alignments:

Physical Setting: Earth Science Core Curriculum

<http://www.emsc.nysed.gov/ciai/mst/pub/earthsci.pdf>

Standard 1: Analysis, Inquiry, and Design

Students will use mathematical analysis, scientific inquiry, and engineering design in order to pose questions, seek answers, and develop solutions.

Key Idea 3. The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.

Standard 2: Information Systems

Students will access, generate, process, and transfer information, using appropriate technologies.

Key Idea 1. Information technology is used to retrieve, process, and communicate information as a tool to enhance learning

Standard 4

Students will understand and apply scientific concepts, principles, and theories



pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Key Idea 3. Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Performance Indicators 3.1

Commencement. Students explain the properties of materials in terms of the arrangement and properties of the atoms that compose them

MEDIA COMPONENTS:

Video

NATURE: *Diamonds*, selected segments:

Clip 1: “Diamonds Everywhere”

A brief introduction the socio-economic value of diamonds

Clip 2: “Diamond Formation”

An expert describes the carbon composition of diamonds, as well as the conditions necessary for diamond formation.

Clip 3: “Aging Diamonds?”

Geological detectives use the ancient diamonds to learn more about the earth’s inner layers.

Clip 4: “Inclusion Conclusions”

Inclusions trapped within diamonds help geologists determine the age of diamonds and other information about where diamonds originate.

Access the streaming and downloadable video segments for this lesson at the Video Segments Page (<http://www.pbs.org/wnet/nature/lessons/performing-well-under-pressure/video-segments/1456/>).

WEB SITES

The Virtual Museum of Minerals and Molecules:

Graphite crystal visualization (<http://virtual-museum.soils.wisc.edu/graphite/index.html>)

Diamond crystal visualization (<http://virtual-museum.soils.wisc.edu/diamond/index.html>)



Learn more at www.pbs.org/nature.



This site features 3-D crystal models for graphite and diamonds.

Please Note: These images require a plug-in download. See instructions under Prep for Teachers.

Silicate Structures

From the University of Wisconsin-Madison Web site:

Silica Tetrahedron (<http://www.soils.wisc.edu/courses/SS325/silicon.gif>)

From the University of Arkansas Web site:

Olivine (<http://comp.uark.edu/~sboss/study1b.jpg>)

Augite (Single Chain) (<http://comp.uark.edu/~sboss/study1c.jpg>)

Hornblende (Double Chain) (<http://comp.uark.edu/~sboss/study1d.jpg>)

Muscovite (Sheets) (<http://comp.uark.edu/~sboss/study1e.jpg>)

From McGraw-Hill Higher Education Online Learning Center Web site:

Animations of Silicate Structures (http://highered.mcgraw-hill.com/sites/0072402466/student_view0/chapter2/animations_and_movies.html)

MATERIALS:

For each student:

- Tetrahedron Cutouts (<http://www-tc.pbs.org/wnet/wp-content/blogs.dir/3/files/2008/08/tetrahedron-cutouts.pdf>)
- Envelopes or plastic zip-top bags for student tetrahedron cutouts
- NY Earth Science Reference Tables (ESRT) or a copy of pages 8-9 of the ESRT (<http://emsc32.nysed.gov/osa/reftable/esp8-9.pdf>)
- Diamond Discussion Worksheet
- Tetrahedron Worksheet

For each group of 3-4 students:

- A mineral testing kit consisting of one sample each of olivine, augite, hornblende, and muscovite mica, one streak plate, and one glass hardness testing plate
- Envelopes or zip-top plastic sandwich bags to hold mineral testing kits
- Glue sticks or paste
- Paper and pens
- One computer with broadband internet access and updated browser installed

For the Classroom

- One computer for the teacher with a digital projection system
- Diamond Discussion worksheet Answer Key
- Tetrahedron worksheet Answer Key



PREP FOR TEACHERS:

Prior to teaching this lesson, you will need to:

Preview all of the video clips and Web sites used in the lessonload the video clips used in the lesson to your classroom computer, or prepare to watch them using your classroom's Internet connection.

Bookmark the Web sites used in the lesson on each computer in your classroom. Using a social bookmarking tool such as del.icio.us or diigo.com (or an online bookmarking utility such as portaportal.com) will allow you to organize all the links in a central location.

The ideal setup for this lesson would be a workstation or laptop at a small lab table or station for each group of 3 or 4 students. If that setup is not possible, read through this lesson and decide how best to make it work in your classroom situation.

Test student workstations for compatibility with jmol scripts by logging on to the Virtual Museum Web pages (newer computers and updated browsers should support jmol). If yours does not, ask your technical staff to make the proper adjustments and test the computers yourself before attempting this lesson.

Make copies of all print materials as outlined in the materials section.

Copy, cut-out and assemble a few tetrahedron models yourself, noting best practices for assembly to share with your students.

Prepare a mineral kit for each group of 3 or 4 students containing a sample each of olivine, augite (pyroxene), hornblende (amphibole), biotite or muscovite (mica), a streak plate, and a glass hardness testing plate.

PREP FOR STUDENTS:

Two days before the intended date of the lesson, hand out the Tetrahedron Cutouts and an envelope/plastic bag. Have students write their names on the envelope or bag. Instruct them to cut out their tetrahedrons at home, and bring the cutouts to class in the envelope/plastic bag the next day. Collect the envelopes/bags, and give students who forgot one more day to get them done. You may also hand out more sheets to students who are interested in cutting out a few more.

INTRODUCTORY ACTIVITY

1) Begin by asking students write down the first thing that comes to mind when they think about diamonds. Then ask the students to write down any other information they know about diamonds. Lead a discussion that allows students to share their answers with each other. Record some of the answers and reactions to diamonds on the board.

2) Provide students with a FOCUS FOR MEDIA INTERACTION, asking students to record some of the different things a diamond can evoke and symbolize, according to the video segment. PLAY Clip 1, "Diamonds Everywhere." (Access the video segments for this lesson at the Video Segments Page,



<http://www.pbs.org/wnet/nature/lessons/performing-well-under-pressure/video-segments/1456/>.) Lead a discussion that allows students to share their answers and compare them with their previous answers. Be sure to address the cultural and monetary value of diamonds.

LEARNING ACTIVITY

- 1) Tell students that in this lesson, they are going to learn a little about where and how diamonds are formed, and what makes them both rare and valuable. Distribute the “Diamond Discussion” worksheet to your students.
- 2) Provide students with a FOCUS FOR MEDIA INTERACTION, asking students to use their Diamond Discussion worksheet to record the conditions necessary for the formation of diamonds, as well as the composition of diamonds. (Students should complete Questions #1-2 on the organizer.) PLAY Clip 2, “Diamond Formation.” (Access the video segments for this lesson at the Video Segments Page, <http://www.pbs.org/wnet/nature/lessons/performing-well-under-pressure/video-segments/1456/>.) Lead a discussion about the extreme heat and pressure required for the formation of diamonds and their carbon composition. Emphasize that carbon is one of the most abundant elements in the universe. Carbon is a major component of graphite, limestone, marble, coal, petroleum and natural gas. Carbon occurs in all organic life and is important to many organic compounds.
- 3) Explain to students that graphite and diamonds are both examples of pure carbon atoms, but that they each have a different crystalline arrangement. Direct students to visit the following Web pages from the Virtual Museum of Minerals and Molecules:

Graphite crystal visualization (<http://virtual-museum.soils.wisc.edu/graphite/index.html>)
Diamond crystal visualization (<http://virtual-museum.soils.wisc.edu/diamond/index.html>)

Provide for the students a FOCUS FOR MEDIA INTERACTION, instructing students to manipulate the 3-D crystal structures, and read through the description of each mineral. Ask students to record a description of each structure on their Diamond Discussion worksheet, and provide information as to why the diamonds structure is so strong? (Students should complete Questions # 3-5 on the organizer.) See the Diamond Discussion worksheet Answer Key for suggested student responses. Lead a discussion with students about their answers, and how the arrangements of the atoms determine the physical properties of the mineral.

- 4) Provide students with a FOCUS FOR MEDIA INTERACTION, asking them to determine where diamonds are formed. What kind of information can diamonds provide to geologists studying this location? (Students should complete Questions #6-7 on the organizer.) Play Clip 3, “Aging Diamonds.” (Access the video segments for this lesson at the Video Segments Page, <http://www.pbs.org/wnet/nature/lessons/performing-well-under-pressure/video-segments/1456/>.) Lead a discussion with students about their answers. Be sure to point out that while diamonds are formed deep beneath the surface of the earth, most other rocks are formed in the earth’s crust. This is what makes



diamonds so important for geologists interested in learning about the deep interior of the earth.

5) Distribute pages 8-9 of the NY Earth Science Reference Tables (ESRT) (<http://emsc32.nysed.gov/osa/reftable/esp8-9.pdf>). Ask students read through the chart and be prepared to discuss what information is presented on the chart in pages 8-9. Direct students to the timeline along the left column of the page, and briefly allow students to share different elements of the chart. Ask students to mark a guess on the timeline as to the age of diamonds.

6) Provide students with a FOCUS FOR MEDIA INTERACTION, asking students to determine what allows geologists to identify the age of a diamond, how old diamonds are, and what other information this resource offers, and record their answers on the Diamond Discussion worksheet. (Students should complete Questions #8-10 on the organizer.) Play Clip 4, "Inclusion Conclusions." (Access the video segments for this lesson at the Video Segments Page, <http://www.pbs.org/wnet/nature/lessons/performing-well-under-pressure/video-segments/1456/>.) Lead a discussion with the students about their answers. Define "inclusions" with your students: "inclusions" are bits of surrounding minerals that are captured within diamonds. Discuss how inclusions allow geologists to determine the age of the diamond. Inclusions also offer geologists the opportunity to study materials that can only be formed deep within the inner core of the earth.

7) Ask students to look back at page 8 of the ESRT and indicate, using a different marking, the actual age of diamonds. (*Diamonds are 2-3 billion years old!*). Lead a discussion with your students about the inaccuracy or accuracy of their guesses, and what led them to make their decisions.

CULMINATING ACTIVITY

1) Remind students of the arrangement of atoms within a diamond and how this arrangement determines the physical properties of the mineral. Tell students that the arrangement of atoms within many other minerals also determines their physical properties.

2) Project the image of the silica tetrahedron (<http://www.soils.wisc.edu/courses/SS325/silicon.gif>), and explain that this arrangement of four oxygen atoms surrounding a silicon atom is the basic building block of many common minerals. Provide students with a FOCUS FOR MEDIA INTERACTION, asking students to describe the shape of each side of the silica structure, and count the sides (*each side is an equilateral triangle, and there are 4 sides*). Explain that a four-sided regular solid is called a **tetrahedron** (tetra = 4 and hedron = sides), that the oxide of silicon forms a **silica tetrahedron**, and they are arranged in very specific patterns in different silicate minerals.

3) Project the animation of silicate structures (http://highered.mcgraw-hill.com/sites/0072402466/student_view0/chapter2/animations_and_movies.html). Provide students with a FOCUS FOR MEDIA INTERACTION, asking students to



describe the various patterns illustrated in the animation. Lead a discussion with the students about their answers (*the atoms of the silicone oxygen tetrahedron bond with each other in single chains, double chains, sheets, and framework arrangements*).

4) Distribute the envelopes/bags of previously prepared tetrahedron cut-outs and a glue stick to every group of 3 or 4 students. Demonstrate for the class how to fold the tetrahedron cut-out into a 3-dimensional tetrahedron and glue it together. Explain that these paper models illustrate the basic atomic structure of the elements that compose many common minerals. Using these models, students will construct examples of the crystalline structure for four different types of minerals. Instruct students to make as many 3-dimensional tetrahedrons as they can with the cutouts they have prepared.

5) Distribute the mineral kits of olivine, augite, hornblende, and muscovite to each group of students. Direct them to the following Web pages:

Olivine (<http://comp.uark.edu/~sboss/study1b.jpg>)

Augite (Single Chain) (<http://comp.uark.edu/~sboss/study1c.jpg>)

Hornblende (Double Chain) (<http://comp.uark.edu/~sboss/study1d.jpg>)

Muscovite (Sheets) (<http://comp.uark.edu/~sboss/study1e.jpg>)

Provide students with a FOCUS FOR MEDIA INTERACTION, instructing students to construct models of each structure as seen on the website. After constructing the model of each mineral and matching it with the sample rock, ask students to sketch it on the Tetrahedron worksheet. Then, using the sample minerals, they should determine the physical properties of the sample and record that information on the Tetrahedron worksheet as well.

6) Lead a discussion with students about the different minerals they have just constructed and the various properties they possess. Allow students to share their drawings and models with each other.

7) Collect the Tetrahedron Worksheets as an assessment of student work. An Answer Key is provided.

CROSS-CURRICULAR EXTENSIONS

Direct students to visit the Web sites about diamonds listed below. Provide students with a FOCUS FOR MEDIA INTERACTION, asking students to look for two examples of diamonds in folklore and superstitions, as well as examples of the role of diamonds in art. Students should record this information on their Diamond Discussion worksheet. Lead a discussion between students so they can share their answers (see Answer Key for possible answers). Remind students of what was discussed in the introductory activity and how the cultural significance of diamonds is as valuable and extensive as the scientific.

Diamonds: Historical Diamond Reference Section

<http://www.farlang.com/diamonds-references>



Everything from diamond mining to diamond lore, this site offers fascinating look into the many facets of the world of diamonds.

Diamonds at the Paris Natural History Museum

<http://www.mnhn.fr/expo/diamants/index/english/ukinfo.htm#museum>

This site explores the history of the diamond, the craft of diamond cutting, and the gem's role in the art world.

COMMUNITY CONNECTIONS

Help students build a display of their models and drawings in the classroom. Invite a local jeweler or gemologist to your classroom to discuss their career path and understanding of diamonds.



NAME: _____

DATE: _____

See Web site for Tetrahedron Cutouts

<http://www-tc.pbs.org/wnet/wp-content/blogs.dir/3/files/2008/08/tetrahedron-cutouts.pdf>



NAME: _____

DATE: _____

**Diamonds and Crystalline Structure
Diamond Discussion Worksheet**

After watching Clip 2, "Diamond Formation," answer the following questions:

1. What conditions are essential to the formation of a diamond? _____

2. What common and plentiful element are diamonds made of? _____

After viewing the 3D graphite and diamond structures:

3. Describe the crystalline structure of graphite:

4. Describe the crystalline structure of diamonds:

5. Why is the diamond structure so strong?

After watching Clip 3, Diamond Formation:

6. Where are diamonds formed? Why is this special? _____

7. What kind of information can diamonds provide for geologists studying this location? _____



NAME: _____

DATE: _____

After watching Clip 4, "Inclusion Conclusions," answer the following questions:

8. How do geologists determine the age of a diamond? _____

9. How old are diamonds? _____

10. Beyond the diamonds themselves, what information can inclusions provide to geologists?

After exploring the "Diamonds: Historical Diamond Reference Section" and the "Diamonds at the Paris Natural History Museum" Web sites, answer the following question:

11. How have diamonds been represented in folk lore, superstitions, and art? Add any other points of interest you discover about these gems.



NAME: _____

DATE: _____

Diamonds and Crystalline Structure Tetrahedron Worksheet

Using the diagrams listed below:

<http://comp.uark.edu/~sboss/study1b.jpg> Olivine
<http://comp.uark.edu/~sboss/study1c.jpg> Single Chain
<http://comp.uark.edu/~sboss/study1d.jpg> Double Chain.
<http://comp.uark.edu/~sboss/study1e.jpg> Sheets

Complete the following:

A. On your desk, build a 3 D model of the mineral Olivine using at least 10 tetrahedron models.

Sketch what you have drawn here:

Mineral name _____

Describe what you have drawn here: _____

Determine the physical properties of Olivine and record them below:

The luster of this mineral is: *Metallic* *Non Metallic* (circle one)

This mineral *Cleaves* *Fractures* (circle one)

The streak of this mineral is *Clear or White* *Colored* (circle one)

This mineral is *Harder* *Softer* than a copper penny (circle one)



NAME: _____

DATE: _____

B. On your desk, build a 3 D model of the mineral Augite using at least 10 tetrahedron models.

Sketch what you have drawn here:

Mineral name _____

Describe what you have drawn here: _____

Determine the physical properties of Augite and record them below:

The luster of this mineral is: *Metallic* *Non Metallic* (circle one)

This mineral *Cleaves* *Fractures* (circle one)

The streak of this mineral is *Clear or White* *Colored* (circle one)

This mineral is *Harder* *Softer* than a copper penny (circle one)

C. On your desk, build a 3 D model of the mineral Hornblende using at least 10 tetrahedron models.

Sketch what you have drawn here:

Mineral name _____

Describe what you have drawn here: _____

Determine the physical properties of Hornblende and record them below:

The luster of this mineral is: *Metallic* *Non Metallic* (circle one)

This mineral *Cleaves* *Fractures* (circle one)

The streak of this mineral is *Clear or White* *Colored* (circle one)

This mineral is *Harder* *Softer* than a copper penny (circle one)



NAME: _____

DATE: _____

D. On your desk, build a 3 D model of the mineral Muscovite using at least 10 tetrahedron models.

Sketch what you have drawn here:

Mineral name _____

Describe what you have drawn here: _____

Determine the physical properties of Muscovite and record them below:

The luster of this mineral is: *Metallic* *Non Metallic* (circle one)

This mineral *Cleaves* *Fractures* (circle one)

The streak of this mineral is *Clear or White* *Colored* (circle one)

This mineral is *Harder* *Softer* than a copper penny (circle one)



NAME: _____

DATE: _____

Diamonds and Crystalline Structure

Diamond Discussion Worksheet ANSWER KEY

After watching Clip 2, "Diamond Formation," answer the following questions:

1. What conditions are essential to the formation of a diamond?

Extreme heat and pressure

2. What common and plentiful element are diamonds made of?

Carbon

After viewing the 3D graphite and diamond structures:

3. Describe the crystalline structure of graphite:

Responses may include: each carbon atom is surrounded by three other carbon atoms, the atoms bond into separate sheets

4. Describe the crystalline structure of diamonds:

Responses may include: each carbon atom is surrounded by four other carbon atoms, the atoms bond into eight sided figures,

5. Why is the diamond structure so strong?

Because of the arrangement of bonds/internal structure

After watching Clip 3, "Diamond Formation," answer the following questions:

6. Where are diamonds formed? Why is this special?

Deep within the earth, most other minerals are formed in the earth's crust

7. What kind of information do diamonds offer geologists?

Information about the inner earth

After watching Clip 4, "Inclusion Conclusions," answer the following questions:

8. How do geologists determine the age of a diamond?

By dating the material found within inclusions



NAME: _____

DATE: _____

9. How old are diamonds?

2 – 3 billion years old

10. Beyond the diamonds themselves, what information can inclusions provide for geologists?

Information about the composition and conditions of the inner earth

After exploring the “Diamonds: Historical Diamond Reference Section” and the “Diamonds at the Paris Natural History Museum” Web sites, answer the following question:

11. How have diamonds been represented in folk lore, superstitions, and art? Add any other points of interest you discover about these gems.

Potential answers may include: In the 1500's it was believed in India that Diamond dust was a poison whereas in Europe it was believed Diamonds protected against the plague; the diamond was called the stone of God in manuscripts from the Middle Ages. The diamond is therefore the stone of kings and has often been seen as an affirmation of power and an instrument of seduction.



NAME: _____

DATE: _____

Performing Well Under Pressure
Diamonds and Crystalline Structure

Tetrahedron Worksheet ANSWER KEY

Using the diagrams listed below:

- <http://comp.uark.edu/~sboss/study1b.jpg> Olivine
<http://comp.uark.edu/~sboss/study1c.jpg> Single Chain
<http://comp.uark.edu/~sboss/study1d.jpg> Double Chain.
<http://comp.uark.edu/~sboss/study1e.jpg> Sheets

Complete the following:

A. On your desk, build a 3 D model of the mineral Olivine using at least 10 tetrahedron models.

Sketch what you have drawn here:

Mineral name _____

Describe what you have drawn here: _____

Determine the physical properties of Olivine and record them below:

The luster of this mineral is: *Metallic* **Non Metallic** (circle one)

This mineral *Cleaves* **Fractures** (circle one)

The streak of this mineral is **Clear or White** *Colored* (circle one)

This mineral is **Harder** *Softer* than a copper penny (circle one)

B. On your desk, build a 3 D model of the mineral Augite using at least 10 tetrahedron models.

Sketch what you have drawn here:

Mineral name _____



NAME: _____

DATE: _____

Describe what you have drawn here: _____

Determine the physical properties of Augite and record them below:

The luster of this mineral is: *Metallic* **Non Metallic** (circle one)

This mineral **Cleaves** *Fractures* (circle one)

The streak of this mineral is **Clear or White** *Colored* (circle one)

This mineral is **Harder** *Softer* than a copper penny (circle one)

C. On your desk, build a 3 D model of the mineral Hornblende using at least 10 tetrahedron models.

Sketch what you have drawn here:

Mineral name _____

Describe what you have drawn here: _____

Determine the physical properties of Hornblende and record them below:

The luster of this mineral is: *Metallic* **Non Metallic** (circle one)

This mineral **Cleaves** *Fractures* (circle one)

The streak of this mineral is **Clear or White** *Colored* (circle one)

This mineral is **Harder** *Softer* than a copper penny (circle one)

D. On your desk, build a 3 D model of the mineral Muscovite using at least 10 tetrahedron models.

Sketch what you have drawn here:

Mineral name _____



NAME: _____

DATE: _____

Describe what you have drawn here: _____

Determine the physical properties of Muscovite and record them below:

The luster of this mineral is: *Metallic* **Non Metallic** (circle one)

This mineral **Cleaves** *Fractures* (circle one)

The streak of this mineral is **Clear or White** *Colored* (circle one)

This mineral is *Harder* **Softer** than a copper penny (circle one)