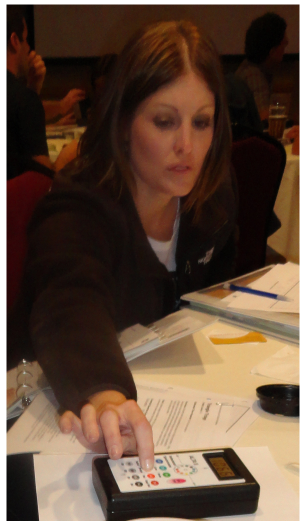
Mars Mystery Rock

Grades: 5-12 Prep Time: ~20 Minutes Lesson Time: ~90 Minutes



WHAT STUDENTS DO: Identify "Mars" Mystery Rocks using Reflectance Spectra

In this activity, students create a reflectance spectra using ALTA spectrometers to analyze mystery rock samples. These spectra can be compared to the limited spectral library provided in the lesson to identify specific rock samples in a process similar to how scientists identify material on and from other planets and celestial bodies.

NRC CORE & COMPONENT QUESTIONS

HOW ARE WAVES USED TO TRANSFER ENERGY AND INFORMATION?

NRC Core Question: PS4: Physical Science

What other forms of electromagnetic radiation are there?

NRC Component Question: PS4B: Electromagnetic Radiation

How are instruments that transmit and detect waves used to extend human senses?

NRC Component Question: PS4C: Information Technologies and Instrumentation

INSTRUCTIONAL OBJECTIVES

Students will be able

IO1: to predict the identity of a variety of "Mars" mystery rocks

On behalf of NASA's Mars Exploration Program, this lesson was prepared by The Lunar and Planetary Institute and adapted by Arizona State University's Mars Education Program, under contract to NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology.

1.0 About This Activity

Mars lessons leverage *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (see *Section 4* and *Teacher Guide* at the end of this document). This taxonomy provides a framework to help organize and align learning objectives, activities, and assessments. The taxonomy has two dimensions. The first dimension, cognitive process, provides categories for classifying lesson objectives along a continuum, at increasingly higher levels of thinking; these verbs allow educators to align their instructional objectives and assessments of learning outcomes to an appropriate level in the framework in order to build and support student cognitive processes. The second dimension, knowledge, allows educators to place objectives along a scale from concrete to abstract. By employing Anderson and Krathwohl's (2001) taxonomy, educators can better understand the construction of instructional objectives and learning outcomes in terms of the types of student knowledge and cognitive processes they intend to support. All activities provide a mapping to this taxonomy in the Teacher Guide (at the end of this lesson), which carries additional educator resources. Combined with the aforementioned taxonomy, the lesson design also draws upon Miller, Linn, and Gronlund's (2009) methods for (a) constructing a general, overarching, instructional objective with specific, supporting, and measurable learning outcomes that help assure the instructional objective is met, and (b) appropriately assessing student performance in the intended learning-outcome areas through rubrics and other measures. Construction of rubrics also draws upon Lanz's (2004) guidance, designed to measure science achievement.

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the Mars instructional series. The 5E stages can be cyclical and iterative.

2.0 Materials

Required Materials

Please supply:

• Inkpad	- 1 per group
• Hand wipes or access to a sink with soap	- 1 per student
• "Earth" Rock sample (can order from Wards)	- 1 per group
○ Basalt *(Item # 47 V 1044)*	
• White paper	- 2 per group
• Mystery "Mars" Rock Sample	- 1 sample per group
○ Specular Hematite	
○ Red Ochre Hematite	
○ Chalk (Limestone)	
○ Grey Rhyolite	
• Blank transparencies	- 2 per group
• ALTA reflectance spectrometer	- 1 per group
• 1 calculator	- 1 per group

Please Print:

From Student Guide:

(A) Fingerprint Chart	– 1 per group
(B) Reflectance Sheet	– 2 per student
(C) Spectrum Graph	– 1 per group
(D) ALTA Quick Tips	– 1 per group
(E) Spectral Fingerprint Graphs	– 1 per group
(F) Evaluation Sheet	– 1 per student

Optional Materials

From Teacher Guide:

(G) "Mars Mystery Rock" Assessment Rubrics
(H) Placement of Instructional Objectives and Learning Outcomes in Taxonomy

3.0 Vocabulary

IR	infrared light. A wavelength of light that occurs just outside of the visible spectrum of light.
LED	light-emitting diode. A semiconductor diode that emits light when a voltage is applied.
Mineral	solid, crystalline chemical element or compound that is inorganic and made naturally
Reflectance	the total amount of reflection of a wavelength from a surface
Rock	an aggregate of minerals
Spectrometer	an instrument used for measuring wavelengths of light
Spectrum	resembles a color spectrum consisting of an arrangement by a particular characteristic (such as wavelength)
Voltage	electrical potential
Wavelength	the measurement of a wave from crest to crest or trough to trough

4.0 Instructional Objectives, Learning Outcomes, Standards, & Rubrics

Instructional objectives, standards, and learning outcomes are aligned with the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which serves as a basis for upcoming "Next-generation Science Standards." Current National Science Education Standards (NSES) and other relevant standards are listed for now, but will be updated when the new standards are available.

The following chart provides details on alignment among the core and component NRC questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and education standards.

- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO)**.

- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics** (see Teacher Guide at the end of this lesson).

Quick View of Standards Alignment:

The Teacher Guide at the end of this lesson provides full details of standards alignment, rubrics, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were derived through, and align with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view follows:

HOW ARE WAVES USED TO TRANSFER ENERGY AND INFORMATION?

NRC Core Question: PS4: Physical Science

What other forms of electromagnetic radiation are there?

NRC Component Question: PS4B: Electromagnetic Radiation

How are instruments that transmit and detect waves used to extend human senses?

NRC Component Question: PS4C: Information Technologies and Instrumentation

Instructional Objective *Students will be able*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	
IO1: **to predict** the identity of a variety of "Mars" mystery rocks	**LO1a: to construct** a reflectance spectra of the "Mars" mystery rock **LO1b. to interpret** a reflectance spectra **LO1c. to explain** and defend the classification of the "Mars" mystery rock	**NSES (A): SCIENCE AS INQUIRY: Abilities Necessary to do Scientific Inquiry** **Grades 5-8:** A1c, A1d, A1e, A1f, A1g, A1h **Grades 9-12:** A1c, A1d, A1e, A1f **Understanding about Scientific Inquiry** **Grades 5-8:** A2c **Grades 9-12:** A2c **NSES (B): PHYSICAL SCIENCE: Transfer of Energy** **Grades 5-8:** B3c	***Rubrics in Teacher Guide***

This activity also aligns with:

PRACTICES:
4. Analyzing and Interpreting Data
5. Using Mathematics and Computational Thinking
6. Constructing Explanation and Designing Solutions
7. Engaging in Argument from Evidence
8. Obtaining, Evaluating, and Communicating Information

CROSSCUTTING CONCEPTS:
1. Patterns

21ST CENTURY SKILLS:
- Critical Thinking and Problem Solving
- Communication
- Collaboration
- Initiative and Self-Direction

5.0 Procedures

PREPARATION (~20 minutes)

Assemble and check materials:

A. All rocks need to be at least 2”x2” wide (hand specimens), with a flat surface; can be purchased at Wards (http://wardsci.com/default.asp):

(A) basalt rocks (item# 47 V 1044)
(B) hematite - specular (item# 46 V 3879)
(C) hematite – red ochre (item# 46 V 0949)
(D) limestone (chalk) – (item# 47 V 4664)
(E) rhyolite (gray) - (item# 47 V 6909)

B. The darker the classroom is, the better the measurements collected by the ALTAs will be. Consider the following options:

(A) Closing window blinds and turning off the overhead lights.
(B) Cover windows with black felt to reduce light bleed through.
(C) Choose a classroom without windows to work in.
(D) Cut a 1”x1” square out of the middle of the bottom of a shoebox. Flip it upside down and this will be used to create a “dark” room for the rock sample.

C. Plan to break your class into groups of 3-4 students each, with one ALTA spectrometer per group. If there are not enough ALTA spectrometers to share for the entire class, split the class in half. Half of the class will complete the Mars Mystery Rocks Lesson while the other half completes another lesson. Then switch. Other Mars lessons can be found at http://marsed.asu.edu/.

D. Check each ALTA reflectance spectrometer—make sure that it has a relatively new battery in it, and that numbers appear on the digital display when you turn it on.

Printing:

E. Please print handouts (A) – (E) in the Student Guide

STEP 1: ENGAGE (~10 minutes)

Fingerprinting

A. Ask your students to describe how they can identify a person. Hold a brief class discussion on ways we use to identify people. (Discussion may include appearance, photo identification cards like driver's licenses, their knowledge of personal information, and fingerprints.)

B. Pass out a fingerprint card to a group of 8 students, and pass around 1 inkpad per group. Ask the students to each use an inkpad to ink their thumbs and slowly press their thumb into one of the boxes on their fingerprint card.

C. Ask students to look for some of the similarities and differences of their fingerprints. Ask them to identify at least two different characteristics for fingerprints and to group the fingerprints by characteristics on *(A) Fingerprint Chart.*

D. Let your class know that minerals also have a type of fingerprint—each mineral has a characteristic reflectance spectrum. Scientists can use this information across the solar system to identify rocks and minerals.

a. Tell your students that they are going to simulate a mission to understand and map out the rocks at the surface of Mars. There are orbiters and rovers that have gathered spectroscopic data from Mars rocks. When these missions measure a spectrum, they send the information back to Earth and the scientists have to determine the rock type by matching the spectrum of a known rock or mineral on Earth to the spectrum collected at Mars.

Curiosity Connection Tip: For making a connection to NASA's Mars Rover "Curiosity," please show your students additional video and slideshow resources at:

http://mars.jpl.nasa.gov/participate/marsforeducators/soi/

STEP 2: EXPLORE (~30 minutes)
Exploring an Earth Rock with the ALTA spectrometer

A. Divide your class into groups, and give each group of 3-4 students an ALTA spectrometer and the *(D) ALTA Quick Tips Sheet*.

B. Ask the students to turn on the ALTA spectrometer. Some of the spectrometers may turn themselves off immediately; the students will need to play with the on/off button until it stays on. If there is no reading on the digital display, the spectrometer is off.

C. Point out that there is a circle of 11 little lights—LEDs—with another similar-looking object in the middle on the back of the spectrometer.

D. Ask the students to experiment with pushing the different buttons on the front, and observing the LEDs on the back. If they are having difficulty pushing the buttons hard enough or holding down the buttons, recommend that they use a pencil eraser to push the buttons.

   a. Students should notice that when they push the "blue" button after turning it on that the blue LED on the back lights up and remains lit while you hold the button down.

   b. When they push one of the "IR" buttons on the front, nothing noticeable happens—in fact, however, one of the infrared LEDs on the back "lights up," but at a wavelength our eyes cannot see!

E. Ask the students to observe the numbers on the front.

   a. Ask them what do the numbers do when you point the bottom of the ALTA towards your desk or a book? What do they do when you hold it up higher in the air? Students should find that the numbers change and increase with increased brightness, until they overload the detector—at which point the ALTA gives a "1".

   b. Now have them cover the back. What do the numbers do? Student should observe that the numbers go down.

F. Ask the students to place the ALTA down onto a surface (such as a dark piece of paper, a book, their coat…) and push two or three of the buttons (one at a time) and look at the numbers. Ask them to then place the ALTA onto a white piece of paper and repeat the same buttons and look at the numbers.

   a. How were the numbers different? Students should say that the numbers are much higher for the white piece of paper. If they were not, ask the students to repeat their observations, making sure to lay the ALTA onto the flat surface of the object they are measuring, and to hold the buttons down firmly until the numbers stop changing.

b. What could the reflectance spectrometer be measuring? Answers may include "color" or "brightness" or "light;" a better answer is the amount of light that is reflecting off of an object.

c. Which part of the ALTA could be taking the measurements? The object in the center of the LEDs on the back is a detector, measuring the amount of light that is entering it.

G. Share with the students that the light detector measures the amount of light it receives, and displays that amount as a number on the front of the ALTA, measured as voltage.

a. Explain that *"when we hold the ALTA up in the air, light from the room is entering the detector; therefore the numbers are higher. When no light is getting to the detector, the number on the front of the ALTA is called the "Dark Voltage". Each ALTA varies slightly, so we will need to record these numbers. When we press different buttons on the front, those buttons turn on LEDs that emit different wavelengths. We see these as different colors. These wavelengths will reflect off of a surface and into the detector so that we can measure how well an object reflects that particular wavelength of light. When we place the ALTA on a white sheet of paper, more light is reflected back to the detector, therefore we see a higher number on the ALTA than we do for a dark piece of paper, which is absorbing the light."*

H. Tell the students they are going to make a graph of the different intensities / amounts of energy for different wavelengths of light reflecting off of a rock. Give each group one of the samples of red hematite, a copy of the *(B) Reflectance Worksheet,* and a transparency sheet.

I. Give the students some instructions on taking reflectance measurements of rocks.

Teacher Tip: The rock should be large enough to cover the detector hole at the back of the ALTA. If using a shoebox, the rock will need to be close to the pre-cut hole at the top of the box. Students may need to elevate the rock beneath the shoebox to get it close to the hole. They should avoid trying to fit a pointed part of the rock into the hole—they should only take measurements from a flat surface. This is important because rocks are not perfectly flat—we are trying to cut down on the amount of outside light reaching the ALTA's detectors, and to position the rock at the optimum distance from the LEDs and detector.

J. As a group, the students should determine the maximum reflectance for their ALTA.

a. To do this, students will use their measurements of white paper to calculate the percentage of light reflected from an object. The students should place their ALTA flat down on a blank white sheet of paper and press the different wavelengths (colors) one at a time, and record the number for each of the 11 wavelength on the *(B) Reflectance Worksheets* in the White Paper Reading column. Students will now subtract the Dark Voltage Reading from the White Paper Reading.

K. Next, each student should place the ALTA directly onto a flat surface of the rock they are analyzing, and push the different wavelengths (colors) one at a time, and record the number for each of the 11 wavelengths on their *Reflectance Worksheets*.

L. Give each group of students a calculator. The students should determine what the percentage of reflectance is for their material for each of the 11 wavelengths, by following the calculations on their *Reflectance Worksheet*.

M. The students should fill out the *(C) Spectrum Graph* on transparencies, with the final numbers from their *(B) Reflectance Worksheet*.

Teacher Tip: Graphing is a skill that has not been mastered by even some high school students; you may wish to demonstrate how to fill out the graph by doing one as an example while projecting it for the class to view together.

a. *Where is the x-axis for this graph? What does it indicate?* [The horizontal x-axis indicates different wavelengths of light.]

b. *Where is the y-axis for this graph? What does it indicate?* [The vertical y-axis indicates the percentage of light reflected off of their object.]

c. *Does your graph have any peaks or high points? If so, at which wavelengths? What does that tell you about your object?* [Objects reflect more of the light at those wavelengths; red objects will reflect more red and orange light, for instance.]

d. *Does your graph have any valleys or low points? If so, what does that tell you about your object?* [The object absorbs most of the light at those wavelengths.]

STEP 3: EXPLAIN (~10 minutes)
Sharing Reflectance Spectral Graphs

A. Ask students to lay their transparencies on top of each other. As a group, they will decide the most common spectral signature for this rock and discuss the shape of the graph.

B. Hand out *(E) Spectral Fingerprint Graphs.*

C. Ask the class to identify which type of rock the Earth rock most closely resembles.

D. Explain that there are always slight variations between rocks because they form under different circumstances. There are variations in the quantities of the minerals that make up these rocks which vary the readings slightly. The reference spectra we use (such as the ones on *(E) Spectral Fingerprint Graphs*) represent an average.

STEP 4: ELABORATE (~20 minutes)
Identifying the "Mars" Mystery Rocks

A. Hand out 1 "Mars" Mystery Rock to each group. The remaining rock types should be equally distributed across the room with 2 or more groups attempting to identify the same rock.

B. Give each student a fresh copy of *(B) Reflectance Worksheet* and blank transparencies. The students will again, complete steps from the Explore phase to find the identity of the "Mars" Mystery Rock.

C. Once students have identified their "Mars" Mystery Rock, have groups with the same rock types meet. Ask groups with "sparkle-y" rocks to meet in one spot, white rocks in another, and so on. Have the students overlay the transparencies to better identify a spectral line and as a group, determine the identity of the rock.

STEP 5: EVALUATE (~20 minutes)
Presentation and Evaluation Sheet

A. Ask each group to present their rock, showing the rock and the transparency sheet on the overhead. Ask them to explain the rock's identity and why they chose that identity.

B. During the presentations, the class will make notes and write comments on their own *(F) Evaluation Sheet*.

C. After Presentations, ask students to complete their evaluation sheets.

6.0 Extensions

Students can participate in the "Rock Around the World" project. Students can submit a mystery rock to the "Rock Around the World" project and it will be analyzed to create a reflectance spectra and become part of the spectral library at Arizona State University. http://ratw.asu.edu/

As a homework activity, ask students to follow their curiosity about Mars. Ask them to go online (with the parents, if their age suggests it), and ask "Dr. C" at least 3 questions about Mars. Have them write down the following url: http://mars.jpl.nasa.gov/drc

7.0 Evaluation/Assessment

Use the *(G) "Mars" Mystery Rocks Rubric* as a formative and summative assessment, allowing students to improve their work and learn from mistakes during class. The rubric evaluates the activities using the National Science Education Standards.

8.0 References

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This lesson was adapted from the *ALTA Reflectance Spectrometer Activity: Mars Mystery Rocks* from the Lunar and Planetary Institute.

(A) Fingerprint Chart

Names of Scientists on Team

A ______________________________ B ______________________________

C ______________________________ D ______________________________

E ______________________________ F ______________________________

G ______________________________ H ______________________________

A	**B**	**C**	**D**
E	**F**	**G**	**H**

Descriptions of key characteristics of fingerprints:

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Group by characteristics:

1st group: ______________________________

2nd group: ______________________________

3rd group: ______________________________

4th group: ______________________________

(B) Reflectance Worksheet (1of 2)

NAME:______________________________

Use the procedure below to fill out the Reflectance Worksheet on the other side of this sheet.

1. Place the ALTA Spectrometer on a dark surface or a black sheet of paper. **Without pressing any buttons** on the ALTA, record this number in the Dark Voltage Constant in the table. This number will be the same for each wavelength of color and can be recorded for the entire column.

2. Place the ALTA spectrometer on a white surface or a white sheet of paper. Press the "Blue" button on the ALTA and record this number in the White Paper Reading column. Repeat this step for each wavelength color.

3. For each wavelength, subtract the Dark Voltage Constant from the White Paper Reading. Record this number in the column.

4. Repeat steps 1-3 using your Earth rock sample. Record the Sample Readings for each wavelength, the Dark Voltage Constant and subtract the Dark Voltage Reading from the Sample Reading.

5. For each wavelength, divide B by A. This will give you the % of Reflectance for the Earth rock sample. % of Reflectance means the amount of light that is reflected back to the ALTA. (Example: If the % of Reflectance is 75%, then 75% (or ¾) of the light that was emitted by the ALTA was reflected off of the rock and back to the detector.)

6. Place the blank transparency sheet over the top of the *(E) Spectrum Graph* paper and graph the Wavelength vs the % of Reflectance using a wet erase marker.

(B) Reflectance Worksheet (2 of 2)

Sample Description ______________________________

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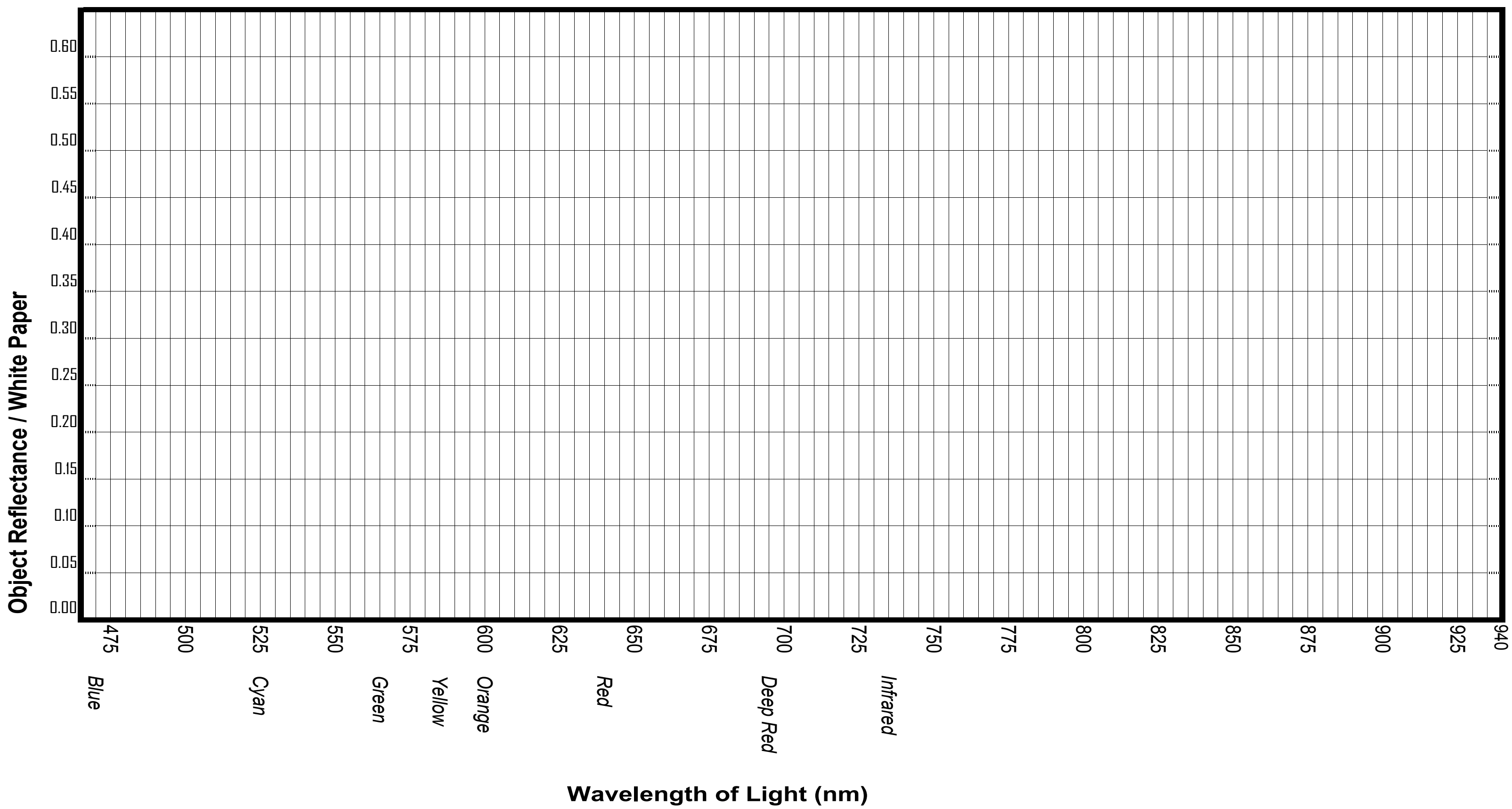
Wavelength in Nano-meters	White Paper Reading	Dark Voltage Constant	White Paper Reading - Dark Voltage (A)		Sample Reading	Dark Voltage Constant	Sample Reading -Dark Voltage (B)		B / A or (Sample – Dark V) / (White – Dark V)
470									
525									
560									
585									
600									
645									
700									
735									
810									
880									
940									

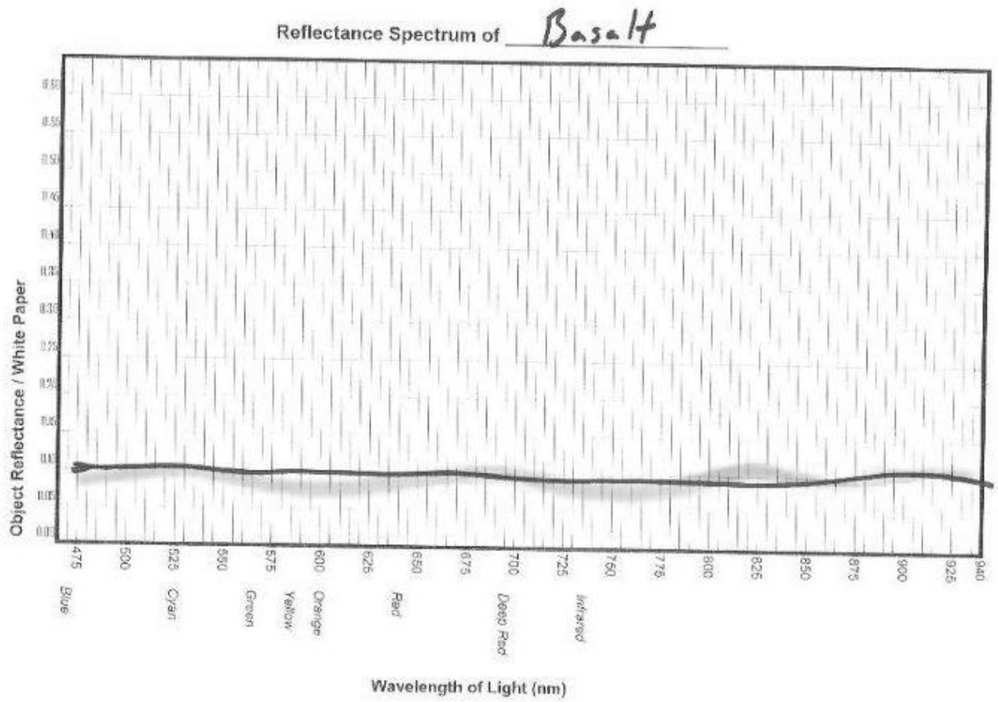
(C) Spectrum Graph

Reflectance Spectrum of ______________________



(E) Spectral Fingerprint Graphs – Basalt (1 of 5)

Pattern remains fairly low with few ups and downs



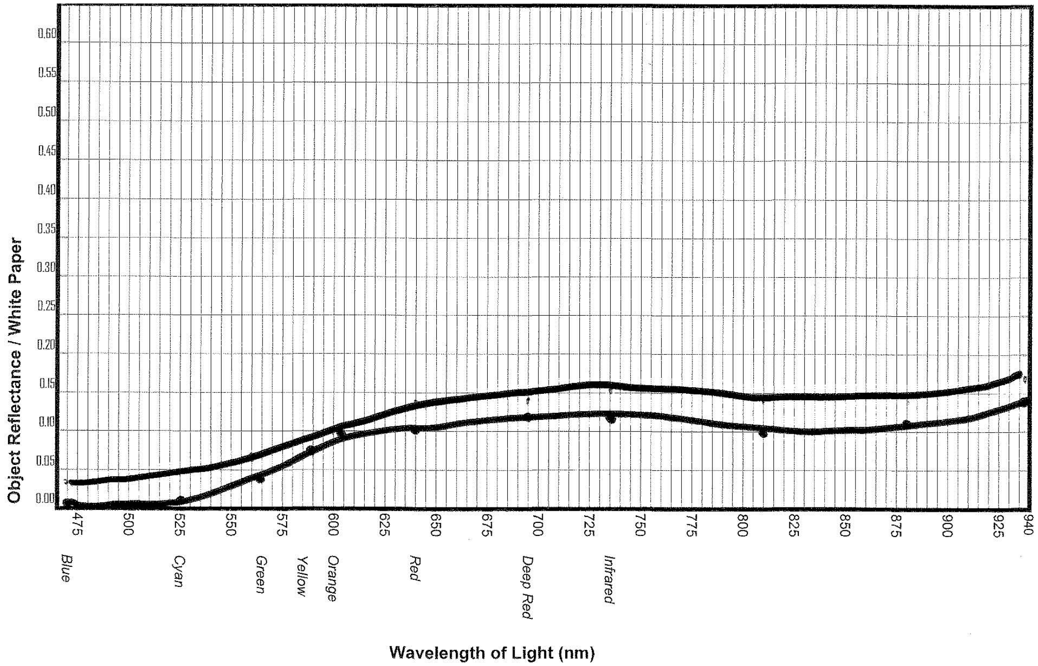
Description: Basalt is a dark grey volcanic rock with few or no visible crystals. It is heavier than most rocks. It has large amounts of the minerals plagioclase feldspar and pyroxene, and some olivine.

Locations on Earth: Basalt is found on the ocean floor and makes up the ocean crust. It is also found around shield volcanoes like the Hawaiian Islands, and it can form huge, stacked sheets on land, such as the Deccan Traps in India and the Columbia River area of the United States.

Formation: Basalt is formed when magma from the Earth’s mantle erupts onto the Earth’s surface and cools quickly.

(E) Spectral Fingerprint Graphs – Red Hematite (2 of 5)

Reflectance is low overall. Pattern begins extremely low for blue, then increases for orange through the near-infrared.



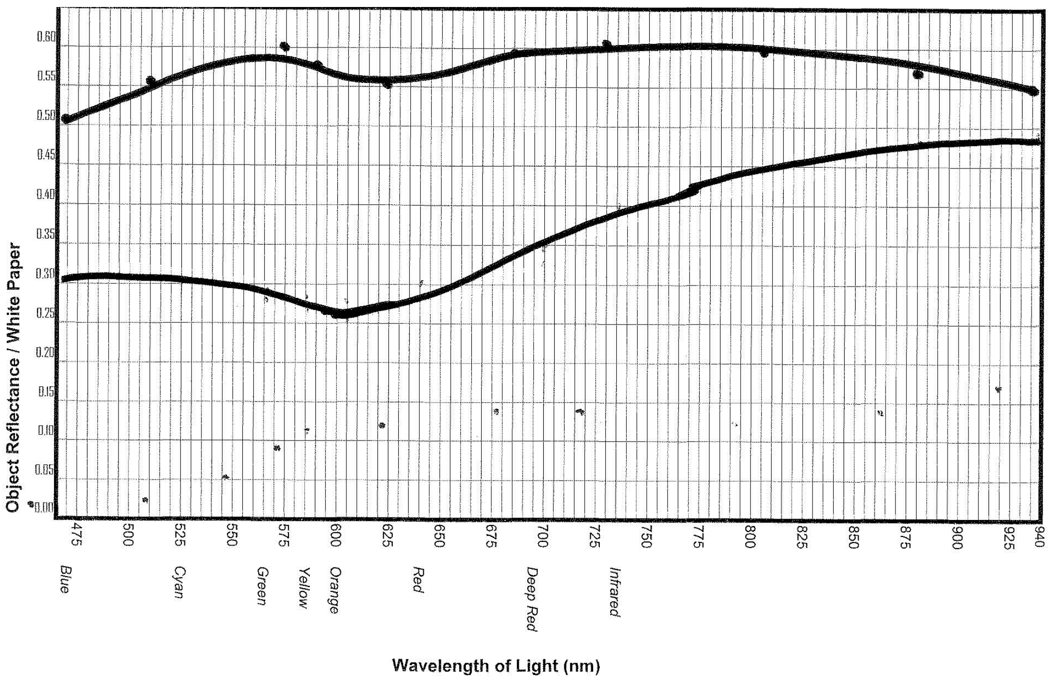
Description: Hematite is a mineral, colored black to steel or silver-gray, brown to reddish brown, or red. It is mined as the main ore of iron.

Location: Huge deposits of hematite are found in banded iron formations. Grey hematite is typically found in places where there has been standing water or mineral hot springs. Hematite is often the red cementing material in sandstones, and is found to a lesser extent in red clays and shales.

Formation: The mineral can precipitate out of water and collect in layers at the bottom of a lake, spring, or other standing water. Hematite can also occur without water, however, usually as the result of volcanic activity.

(E) Spectral Fingerprint Graphs – Limestone Chalk (3 of 5)

Overall reflectance is very high. Pattern dips for green, bottoming-out around yellow-orange, then climbs sharply to higher reflections for red and continues to climb in the infrared.



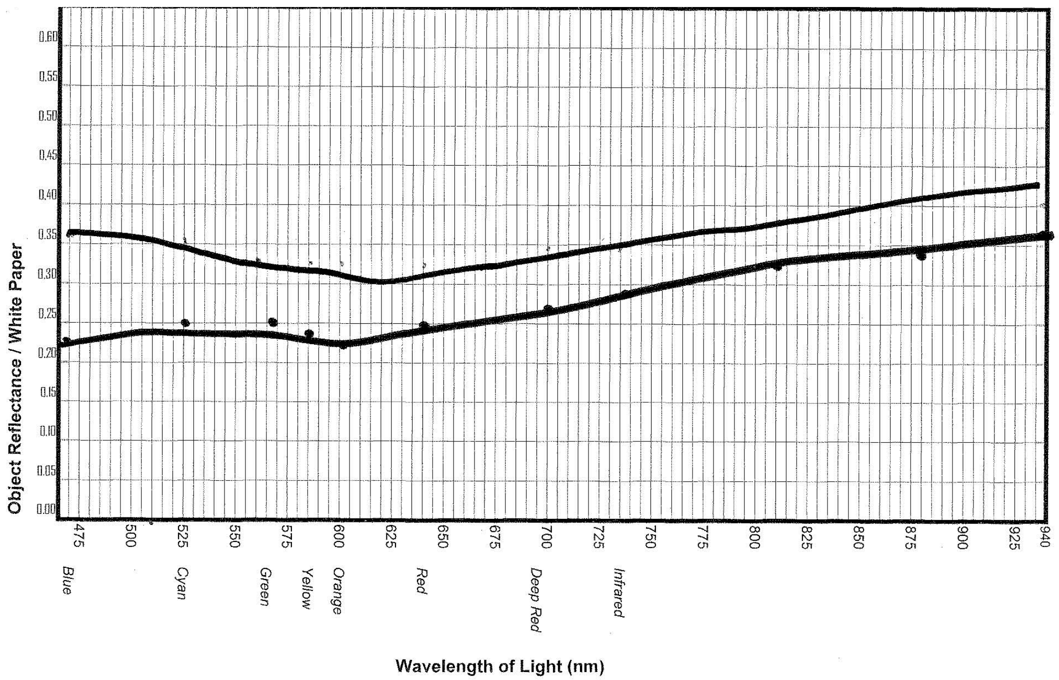
Description: Limestone chalk is white sedimentary rock. It is lighter than the average rock on Earth. It has large amounts of calcite, also known as calcium carbonate, which fizzes when an acid, like vinegar, is dropped on it.

Locations on Earth: Chalk is found in rock deposits on land and in water.

Formation: Chalk is formed in deep seas and oceans from the shells or outer coatings of micro-organisms.

(E) Spectral Fingerprint Graphs – Rhyolite (4 of 5)

Overall reflectance is fairly high. Pattern gently slopes down for yellow-orange, then climbs to higher reflections for red and continues to climb in the infrared.



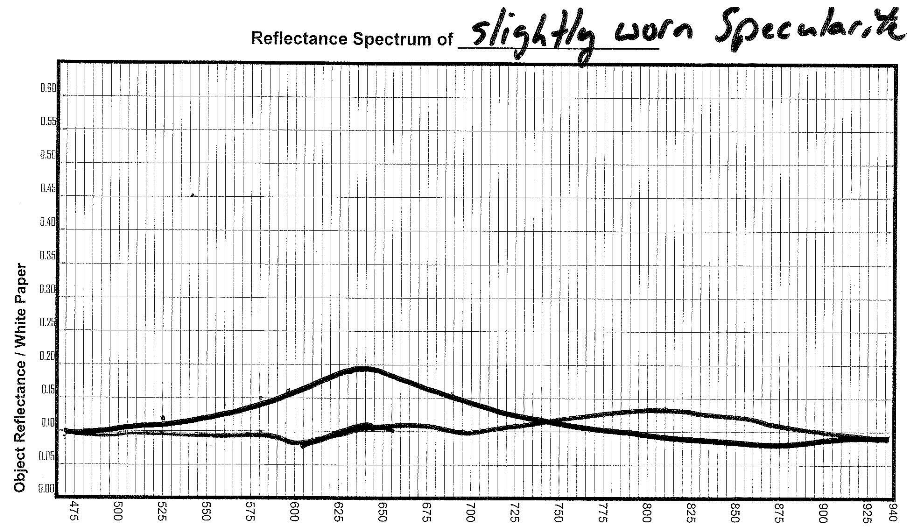
Description: Rhyolite is a volcanic rock with few or no visible crystals. Rhyolite ranges in color from light grey to pink. It feels lighter than many other volcanic rocks. It may have layers that mimic sedimentary rocks. It has large amounts of the minerals quartz and potassium feldspar; it has varying amounts of plagioclase feldspar.

Locations on Earth: Rhyolite is found in continental crust, near explosive composite volcanoes.

Formation: Rhyolite comes from lava formed by melting the Earth's crust, such as melted continental crust or a combination of melted ocean and continental crust. Rhyolite often forms when volcanic ash from an explosive eruption settles in layers.

(E) Spectral Fingerprint Graphs – Specular Hematite (5 of 5)

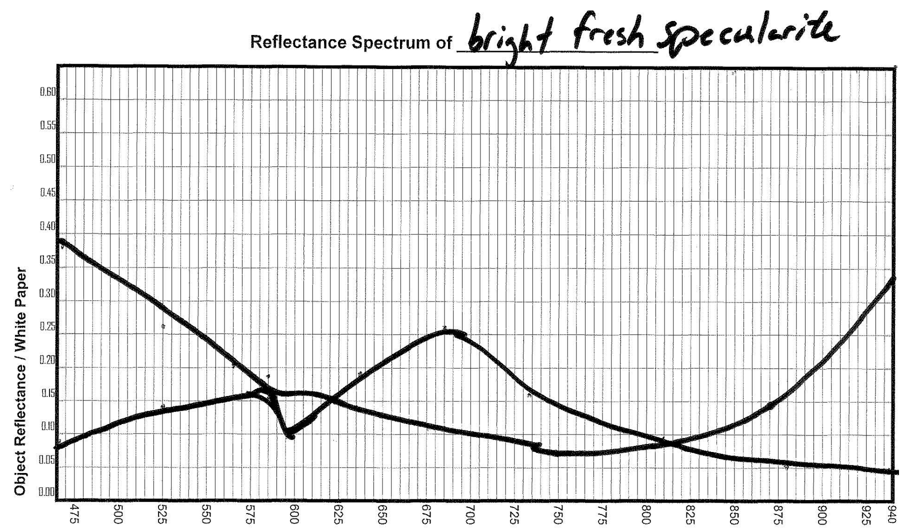
This spectrum is highly reflective and changes depending on the angle and the weathering of the crystals.



Specular Hematite (Specularite) is a form of hematite, a mineral, colored black to steel or silver-gray, brown to reddish brown, or red.

Location: Huge deposits of hematite are found in banded iron formations. Grey hematite is typically found in places where there has been standing water or mineral hot springs.

Formation: The mineral can precipitate out of water and collect in layers at the bottom of a lake, spring, or other standing water. Hematite can also occur without water, however, usually as the result of volcanic activity.



(F) Evaluation Sheet (1of 2)

NAME:________________________________

Complete the following table during presentations. Only record during group presentations of different rock types. An example has been done for you.

Group # Presenting	Group Identified the Rock as……?	Do you agree or disagree with the identification using ***their*** evidence. Why or why not?
Ex. 1	*Ex. Specular Hematite*	*Ex. Disagree. The graph line has very little change and is really low on the graph. I think it is basalt.*

(F) Evaluation Sheet (2 of 2)

Think about the activity and answer the following questions.

1. How confident are you with your identification of your "Mars" Mystery Rock?

   Why or why not?

   ____

   ____

   ____

2. What was the purpose of using the ALTA spectrometer?

   ____

   ____

   ____

3. Do you think scientists complete this rock identification process in a similar way?

   ______________ Explain the steps scientists will go through to identify mystery rocks, either through sample collection by a rover or through meteorites.

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

(G) Teacher Resource. "Mars" Mystery Rocks Rubric (1 of 3)

You will know the level to which your students have achieved the **Learning Outcomes**, and thus the **Instructional Objective(s)**, by using the suggested **Rubrics** below.

Instructional Objective 1: to predict the identity of a variety of "Mars" mystery rocks

Related Standard(s) (will be replaced when new NRC Framework-based science standards are released):

National Science Education Standards (NSES)
(A) Science as Inquiry: Abilities Necessary to do Scientific Inquiry

Use mathematics in all aspects of scientific inquiry. Mathematics is essential to asking and answering questions about the natural world. Mathematics can be used to ask questions; to gather, organize, and present data; and to structure convincing explanations. (Grades 5-8: A1h).

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. (Grades 9-12: A1c).

National Science Education Standards (NSES)
(A) Science as Inquiry: Understandings about Scientific Inquiry

Mathematics is important in all aspects of scientific inquiry. (Grades 5-8: A2c).

Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used. (Grades 9-12: A2c).

Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a: to construct a reflectance spectra of the "Mars" mystery rock	Reflectance graph contains all information	Reflectance graph contains most of the information	Reflectance graph contains some of the information	Reflectance graph contains little information

(G) Teacher Resource. "Mars" Mystery Rocks Rubric(2 of 3)

Related Standards (will be replaced when new NRC Framework-based science standards are released):

National Science Education Standards (NSES)
(A) Science as Inquiry: Abilities Necessary to do Scientific Inquiry

Use appropriate tools and techniques to gather, analyze, and interpret data. The use of tools and techniques, including mathematics, will be guided by the question asked and the investigations students design. The use of computers for the collection, summary, and display of evidence is part of this standard. Students should be able to access, gather, store, retrieve, and organize data, using hardware and software designed for these purposes. (Grades 5-8: A1c)

Formulate and revise scientific explanations and models using logic and evidence. Student inquiries should culminate in formulating an explanation or model. Models should be physical, conceptual, and mathematical. In the process of answering the questions, the students should engage in discussions and arguments that result in the revision of their explanations. These discussions should be based on scientific knowledge, the use of logic, and evidence from their investigation. (Grades 9-12: A1d).

Recognize and analyze alternative explanations and models. This aspect of the standard emphasizes the critical abilities of analyzing an argument by reviewing current scientific understanding, weighing the evidence, and examining the logic so as to decide which explanations and models are best. In other words, although there may be several plausible explanations, they do not all have equal weight. Students should be able to use scientific criteria to find the preferred explanations. (Grades 9-12: A1e).

National Science Education Standards (NSES)
(A) Science as Inquiry: Understandings about Scientific Inquiry

Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used. (Grades 9-12: A2c)

National Science Education Standards (NSES)
(D) Physical Science: Transfer of Energy

Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object—emitted by or scattered from it—must enter the eye. (Grades 5-8: B3c)

Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1b. to interpret a reflectance spectra	Very closely represents the sample from the spectral library.	Closely represents the sample from the spectral library	Is a relatively close match to the sample from the spectral library	Does not match the sample from the spectral library.

(G) Teacher Resource. "Mars" Mystery Rocks Rubric (3 of 3)

National Science Education Standards (NSES)
(A) Science as Inquiry: Abilities Necessary to do Scientific Inquiry

Develop description, explanations, predictions, and models using evidence. Students should base their explanation on what they observed, and as they develop cognitive skills, they should be able to differentiate explanation from description—providing causes for effects and establishing relationships based on evidence and logical argument. This standard requires a subject matter knowledge base so the students can effectively conduct investigations, because developing explanations establishes connections between the content of science and the contexts within which students develop new knowledge. (Grades 5-8: A1d).

Think critically and logically to make the relationships between evidence and explanations. Thinking critically about evidence includes deciding what evidence should be used and accounting for anomalous data. Specifically, students should be able to review data from a simple experiment, summarize the data, and form a logical argument about the cause-and-effect relationships in the experiment. Students should begin to state some explanations in terms of the relationship between two or more variables. (Grades 5-8: A1e).

Recognize and analyze alternative explanations and predictions. Students should develop the ability to listen to and respect the explanations proposed by other students. They should remain open to and acknowledge different ideas and explanations, be able to accept the skepticism of others, and consider alternative explanations. (Grades 5-8: A1f).

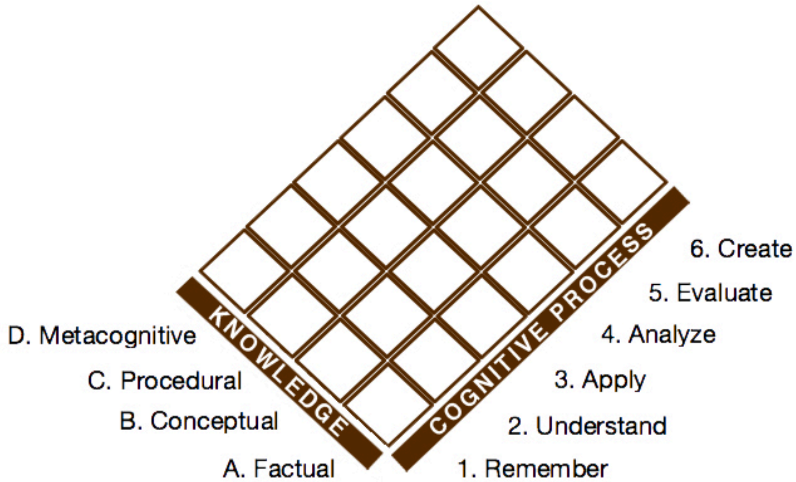
Communicate scientific procedures and explanations. With practice, students should become competent at communicating experimental methods, following instructions, describing observations, summarizing the results of other groups, and telling other students about investigations and explanations. (Grades 5-8: A1g).

Communicate and defend a scientific argument. Students in school science programs should develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments. (Grades 9-12: A1f).

Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1c. to explain and defend the classification of the "Mars" mystery rock	Explanation is complex and thoughtful at a high level of understanding.	Explanation is thoughtful and uses an understanding of light concepts.	Explanation is somewhat thoughtful and uses a basic understanding of light concepts.	Explanation is basic and has a lack of understanding of light concepts.

(H) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (1 of 3)



This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s). Activity procedures and assessments are designed to support the target knowledge/cognitive process.

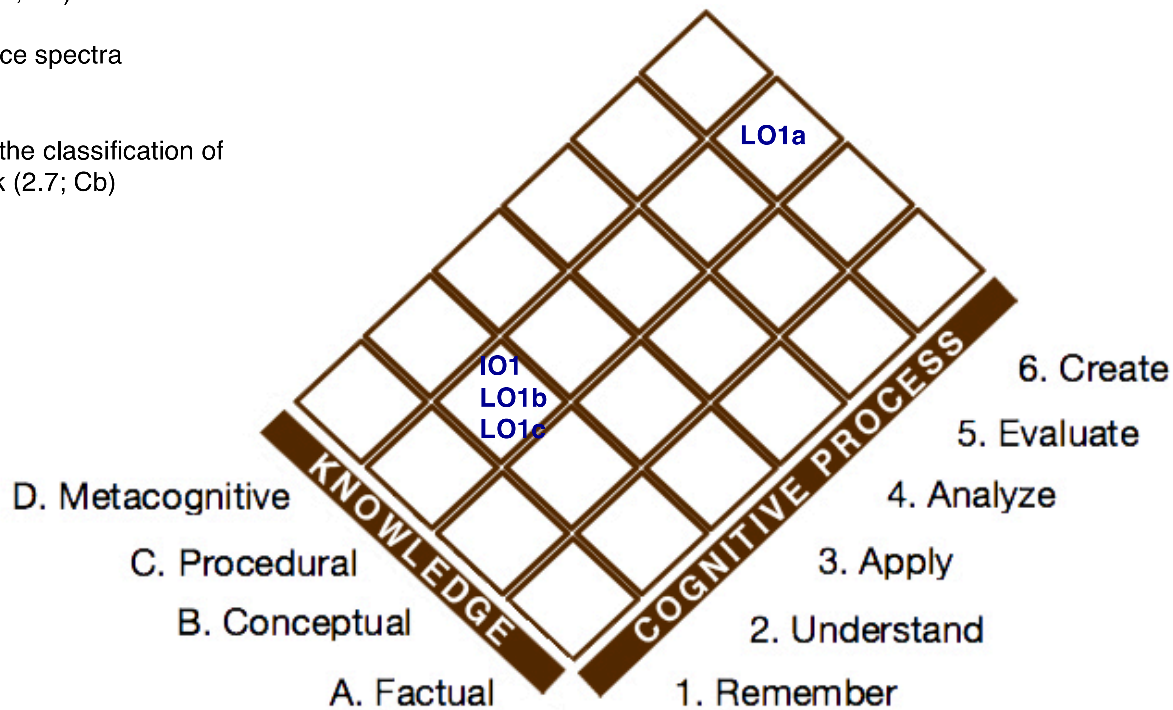
Knowledge	Cognitive Process
A. Factual **Aa:** Knowledge of Terminology **Ab:** Knowledge of Specific Details & Elements **B. Conceptual** **Ba:** Knowledge of classifications and categories **Bb:** Knowledge of principles and generalizations **Bc:** Knowledge of theories, models, and structures **C. Procedural** **Ca:** Knowledge of subject-specific skills and algorithms **Cb:** Knowledge of subject-specific techniques and methods **Cc:** Knowledge of criteria for determining when to use appropriate procedures **D. Metacognitive** **Da:** Strategic Knowledge **Db:** Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge **Dc:** Self-knowledge	**1. Remember** **1.1** Recognizing (Identifying) **1.2** Recalling (Retrieving) **2. Understand** **2.1** Interpreting (Clarifying, Paraphrasing, Representing, Translating) **2.2** Exemplifying (Illustrating, Instantiating) **2.3** Classifying (Categorizing, Subsuming) **2.4** Summarizing (Abstracting, Generalizing) **2.5** Inferring (Concluding, Extrapolating, Interpolating, Predicting) **2.6** Comparing (Contrasting, Mapping, Matching **2.7** Explaining (Constructing models) **3. Apply** **3.1** Executing (Carrying out) **3.2** Implementing (Using) **4. Analyze** **4.1** Differentiating (Discriminating, distinguishing, focusing, selecting) **4.2** Organizing (Finding coherence, integrating, outlining, parsing, structuring) **4.3** Attributing (Deconstructing) **5. Evaluate** **5.1** Checking (Coordinating, Detecting, Monitoring, Testing) **5.2** Critiquing (Judging) **6. Create** **6.1** Generating (Hypothesizing) **6.2** Planning (Designing) **6.3** Producing (Constructing)

(H) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (2 of 3)

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Pedagogically, it is important to ensure that objectives and outcomes are written to match the knowledge and cognitive process students are intended to acquire.

IO 1: **to predict** the identity of a variety of "Mars" mystery rocks (2.5; Cb)

- **LO1a:** **to construct** a reflectance spectra of the "Mars" mystery rock (6.3; Cb)
- **LO1b.** **to interpret** a reflectance spectra (2.1; Cb)
- **LO1c.** **to explain** and defend the classification of the "Mars" mystery rock (2.7; Cb)



(H) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (3 of 3)

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Below are the knowledge and cognitive process types students are intended to acquire per the instructional objective(s) and learning outcomes written for this lesson. The specific, scaffolded 5E steps in this lesson (see 5.0 Procedures) and the formative assessments (worksheets in the Student Guide and rubrics in the Teacher Guide) are written to support those objective(s) and learning outcomes. Refer to (H, 1 of 3) for the full list of categories in the taxonomy from which the following were selected. The prior page (H, 2 of 3) provides a visual description of the placement of learning outcomes that enable the overall instructional objective(s) to be met.

At the end of the lesson, students will be able

IO1: to predict the identity of a variety of "Mars" mystery rocks

2.5: to predict
Cb: Knowledge of subject-specific techniques and methods

To meet that instructional objective, students will demonstrate the abilities:

LO1a: to construct a reflectance spectra of the "Mars" mystery rock

6.3: to construct
Cb: Knowledge of subject-specific techniques and methods

LO1b: to interpret a reflectance spectra

2.1: to interpret
Cb: Knowledge of subject-specific techniques and methods

LO1c: to explain and defend the classification of the "Mars" mystery rock

2.7: to explain
Cb: Knowledge of subject-specific techniques and methods