Lesson Title	Spectroscopy
Length of Lesson	1 class period (50 min)
Created By	Charles Vaughan
Subject	General Science
Grade Level	8
State Standards	1c, 1d, 2e, 4f
DOK Level	DOK 3
DOK Application	Compare, Differentiate, Explain Phenomena in Terms of Concepts
National Standards	5-8: A: Science as Inquiry; B: Physical Science
Graduate Research Element	Spectroscopy is a vital process used to identify molecules in comets and other extraterrestrial objects. Understanding spectroscopy requires an understanding of the electromagnetic (EM) spectrum.

Student Learning Goal:

MS 8th Grade:

Inquiry (1c): Summarize data to show the cause and effect relationship between qualitative and quantitative observations (using standard, metric, and non-standard units of measurement).

Inquiry (1d): Analyze evidence that is used to form explanations and draw conclusions.

Physical Science (2e): Contrast various components of the electromagnetic spectrum (e.g., infrared, visible light, ultraviolet).

Earth and Space Science (4f): Describe the hierarchical structure (stars, clusters, galaxies, galactic clusters) of the universe and examine the expanding universe to include its age and history and the modern techniques (e.g., radio, infrared, ultraviolet and X-ray astronomy) used to measure objects and distances in the universe.

National Standards for Grades 5-8:

(Inquiry - A) Use appropriate tools and techniques to gather, analyze, and interpret data. Think critically and logically to make the relationships between evidence and explanations.

(Physical Science - B) Transfer of energy.

Materials Needed (supplies, hand-outs, resources):

Spectral lamp, numerous gas bulbs (hydrogen, helium, etc.), incandescent light bulb (as a control), small diffraction gratings (one for each student), images of known spectra for each gas bulb (file name: INSPIRE_Vaughan_06_29_12_Spectrum.png)

Lesson Performance Task/Assessment:
After initial questions, students will be told that, in most cases, scientists cannot directly take samples of materials in space (comets, asteroids, stars, other planets). This means that scientists must identify and measure extraterrestrial chemicals by indirect means. Students will then be told that every atom or molecule has a distinct color pattern which acts as a "fingerprint" for that substance. Breaking light down into a spectrum by using a prism or other diffracting object will enable us to see this "fingerprint".

Students will view several illuminated gas bulbs through the diffraction grating. Students will be asked to describe what colors they see and how many lines are present from each bulb. They will then have to compare what they see to a given image of spectra that has the associated substances already listed. The teaching goal is to have students identify what substance is in the gas bulb based on the comparison to the given spectra.

For the last phase of the lesson, the instructor should discuss the EM spectrum as a whole, indicating that many other forms of light, not visible to humans, are emitted from substances. Scientists also use detectors capable of seeing UV rays, X-rays, gamma rays, etc., to identify substances. Spectroscopy is not limited to just the visible portion of the EM spectrum.

Lesson Relevance to Performance Task and Students:
Knowledge of spectroscopy will show how understanding the EM spectrum is useful for physics, astronomy, and chemistry. Students will also practice observation and comparison skills.

Anticipatory Set/Capture Interest:
The initial questions to be asked are, "How can we know what something is made of without touching it? What if it is really far away? Or what if something, such as the sun, is too hot for us to sample?" Teacher will lead short class discussion.

Guided Practice:

- Begin with anticipatory questions and description of the spectrum. Describe how each atom/molecule has its own unique "fingerprint" when light emitted from the chemical is viewed through a prism or other diffracting object.
- Show students the sample images (handout) of various chemicals and their associated spectra. Ask students to describe or make comparisons with each spectrum shown.
- Turn off classroom lights, and turn on an ordinary incandescent bulb. Make sure any other light sources (windows, hallway lights, etc.) are covered as much as possible. The students should be able to see a full continuous spectrum (i.e., a

complete rainbow) of colors when they view the incandescent bulb through the diffraction grating. Students will need to look to the left or right of the bulb while looking through the diffraction grating to see the full spectrum. Make sure every student can see the spectrum before continuing.

- Once students are familiar with looking through the diffraction grating, the instructor should turn off the incandescent bulb and turn on a gas bulb in the spectral lamp. The students should view the bulb through the diffraction grating as before, but they should be able to see individual colored lines, instead of a full rainbow of colors. These lines represent the "fingerprint" for that substance. Once everyone gets a good view of the spectrum, the students should be asked to identify what substance is being illuminated. The students will need to compare the viewed spectrum to the ones on their handout (classroom lights may need to be turned on temporarily for them to identify on the handout).
- Change the gas bulb, and repeat the above process for every unique gas bulb available, or until class time is running low.
- Discuss the EM spectrum as a whole. Indicate that many atoms or molecules can emit light that we cannot see (X-rays, infrared rays, etc.). Scientists can still use spectroscopy to identify these substances using special detectors that are sensitive to these invisible forms or radiation.

Independent Practice:
Students will individually attempt to identify the chemicals in the spectral lamp. For each bulb viewed, they should write down their answers or discuss aloud what substance they think is being illuminated.

Remediation and/or Enrichment:
Remediation – IEP

Enrichment - Using molecules (instead of pure elements) presents an additional challenge since the spectrum for a molecule includes the spectra for its constituent atoms, plus additional color bands based on molecular vibrations and rotations.

Check(s) for Understanding:
The instructor should ask questions regarding the colors or number of lines present to ensure that the students can see the spectra correctly. Additionally, when viewing the gas bulb for the first time, a gas with a simple spectrum should be used (e.g., hydrogen or helium), and the instructor can tell the students what gas is present, ensuring that they understand the comparison process.

Closure:
A scientist claims that a comet contains much more hydrogen than oxygen. How could he know this?

Using the spectra for hydrogen and oxygen, what do you think a spectrum for water vapor would look like?
Assume that a fire is burning at a chemical plant or laboratory. The workers need to extinguish the flames, but they do not know exactly what is burning. How could a scientist possibly identify what is being burned, while staying at a safe distance?

It is worth mentioning to students that helium, the second most abundant element in the universe, was discovered in space using spectroscopy before it was detected on the Earth.

Spectroscopy is an essential technique for studying many objects in space, such as comets.

Possible Alternate Subject Integrations:
Chemistry, Physical Science, Astronomy

Teacher Notes:
These materials (diffraction gratings, spectral lamp, and bulbs) were borrowed from the physics department at a partner university. The handouts with the spectra and substances listed should be color images. Alternatively, if a projector or other viewing screen is available in the classroom, the handout can be viewed this way, but the screen will need to be shut off every time a gas bulb is viewed.