Title: Spectral Analysis with DVDs and CDs

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Date Created: Summer 2011

Subject: Physics/Chemistry/Earth Science

Grade Level: 9-12

Standards:
- Standard 1: Analysis, Inquiry, and Design
- Standard 2: Information Systems
- Standard 4: Science
- Standard 5: Technology
- Standard 6: Interconnectedness, Common Themes

Schedule: 2 - 45 minute periods

Description:

This lesson introduces students to the concept of line spectra and how they can be used as an analysis tool. Working in teams, students construct spectrometers out of DVDs and CDs and observe and analyze different light sources. They are then challenged to apply their knowledge to identify the composition of an unknown.

Objectives:

Students will:
- design a spectrometer to explore basic properties of light;
- use spectral analysis to identify elements; and
- understand the importance of examining different wavelengths of light

Vocabulary:

- Wavelength
- Diffraction Grating
- Bohr Model
- Ground State
- Excited State
- Spectral Lines
- Emission Spectrum

Materials:

- CDs and DVDs
- Colored Pencils
- Ruler
- Fluorescent Light Source
- Incandescent Light Source
- Several Different Spectrum Tubes
- Spectrum Tube Power Supply

Safety:

Always be careful with sharp objects and electricity.

Science Content for the Teacher:

ENGAGE (10 minutes)

1. Write ROY G BIV on the board. Ask the students to discuss what they think the letters represent. (They represent the colors of the rainbow in order – red, orange, yellow, green, blue, indigo, violet.)
2. Ask students to explain how a rainbow is formed. (Light is being refracted by small water droplets in the atmosphere.) Tell them you will demonstrate this with a prism.
3. Turn the lights off and shine a white light through a prism and ask the students to discuss what they observe. (Lead students to understand that white light is composed of all of the colors of the rainbow and that each color represents a specific wavelength of light. As the white light passes through a prism, the different wavelengths of light are refracted at different angles so the individual colors can be observed.)

EXPLORE (40 minutes)

In this activity, students will build a spectrometer and view spectrums of light.

1. Have students read the background information.
2. Ask students the difference between a continuous spectrum, an absorption spectrum, and an emissions spectrum. (A continuous spectrum contains all the colors of the rainbow as one continuous band and is produced when an object is heated. An absorption spectrum looks similar to a continuous spectrum except that there are black lines where elements absorb specific wavelengths of light. The pattern of black bands is different for every element. An emission spectrum looks like a negative image of an absorption spectrum. Elements in the gas state can release certain wavelengths of light when exposed to high energy.)
3. Divide the class into groups of two or three. Distribute the materials for the activity to each group.
4. Using spectrum glasses and different gas emission spectrum tubes allow students to see the spectra of different elements. Ask students to sketch what they observe and share their sketches with the class.

EXPLAIN (15 minutes)

1. While still in groups, ask students to answer the questions in the assessment section.
2. Ask students to share their answers with the class. Lead students to understand that an incandescent light and a fluorescent light produce light by different methods. Most fluorescent lights use mercury vapor and a phosphorescent coating to produce light whereas incandescent lights produce light by heating a filament.

EXTEND (15 minutes)

1. Have students brainstorm other uses for the spectroscope they have built. Have students design an activity that incorporates one of their ideas.

EVALUATE (20 minutes)

1. Use questions, discussions, and student handouts used throughout the lesson to assess students’ understanding.

Classroom Procedure:

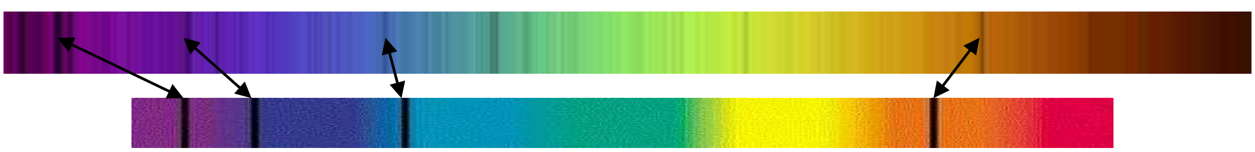
Background
Scientists can learn a great deal about a material by studying its spectrum. They can determine such things as the composition, temperature, and density of the material.

The study of the light and associated spectrum emitted from an object is called **spectroscopy**. **Spectrometers** are instruments which measure light by spreading it out to create its spectrum. Within this spectrum, scientists study emission and absorption lines.

There are three types of spectra which a substance can emit: continuous, emission and absorption. Continuous spectra, also called a thermal or blackbody spectra, are emitted by any substance that radiates heat. As shown in Figure 1, the light is spread out into a continuous band of colors with every **wavelength** having some amount of radiation. For example, when sunlight is passed through a prism, its light is spread out into its component colors.

Figure 1. A continuous visible light spectrum. Image credit: SIRTF Science Center.

If you use a more precise spectrometer to look at the Sun's spectrum, you will notice the presence of dark lines, as shown in Figure 2 below. These lines are caused by gaseous elements in the Sun's atmosphere absorbing light at these wavelengths, so this type of spectrum is called an **absorption spectrum**. The atoms and molecules in a gas will absorb only certain wavelengths of light. The pattern of absorption is unique to each element and tells us what elements make up the atmosphere of the Sun. Compare Figure 3, the absorption spectrum of hydrogen, with Figure 2. There are dark bands in the same part of both spectra, indicating the presence of hydrogen in the Sun.



Figures 2 and 3. The absorption spectrum of the sun and hydrogen. Image credit: SIRTF Science Center

An **emission spectrum** occurs when the atoms and molecules in a hot gas emit light at certain wavelengths, causing bright lines to appear in a spectrum. As with absorption spectra, the pattern of these lines is unique for each element.

Figure 4. The emission spectrum of hydrogen. Image credit: SIRTF Science center.

A compact disc (CD) contains a large amount of information encoded onto its surface. This information is stored in concentric rings that are read by a laser beam while the disc is spinning. If the light hits the concentric rings just right, the rings act as a **diffraction grating**, separating the light into the component colors that make it up. You will use this property to build a **spectroscope** with a CD. The spectroscope will allow you to observe the spectra produced by different light sources and compare them.

1. Your group should gather the following materials:
   - fluorescent light source
   - incandescent light source
   - compact disc or DVD
   - ruler
   - colored pencils
2. Position the compact disc at different angles under the fluorescent light source until a spectrum appears. Look at the surface of the CD to observe the spectrum. Record what you see in the space below the diagram.

Diagram of fluorescent light spectrum

3. Point the tube towards an **incandescent** light source. Record what you see in the space below.

Diagram of incandescent light spectrum

A. What differences did you see between the spectra observed from a fluorescent light versus an incandescent light?

B. Why do you think that the different lights had different spectra?

In Bohr's atomic model an atom's electrons are assigned to specific energy levels. The atom is in its **ground state** when the electrons occupy the lowest possible energy levels. When an electron absorbs sufficient energy it moves to a higher energy level to produce an **excited state**. When the electron releases the energy, it drops back to a lower energy level. The energy is released in the form of light. The wavelength of the emitted light indicates the difference in the energy of these two levels. Each wavelength of light corresponds to a specific color of light (which may or may not be visible). Consequently, atoms emit a characteristic set of discrete wavelengths - not a continuous spectrum.

Since each element has its own unique electron arrangement, the light that is emitted by the atoms produces an emission spectrum that can be used to identify the element. In other words, an atomic spectrum can be used as a "fingerprint" for an element because it is unique for each element and reflects the energy levels occupied by the electrons in an atom of the element.

4. Observe additional light sources and record what you see in the spaces below.

Diagram of gas spectrum #1:

Diagram of gas spectrum #2:

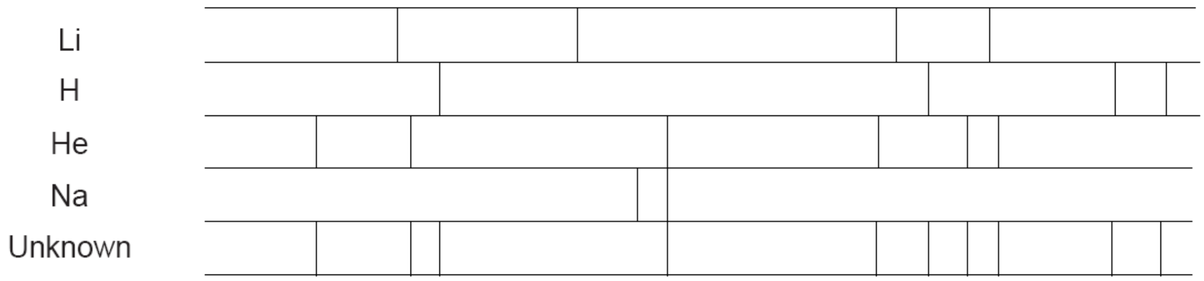
Diagram of gas spectrum #3

Diagram of gas spectrum #4

Assessment:

New York State Chemistry Regents questions #63 & 64 from the August 2003 Exam:

Base your answers to questions 63 and 64 on the diagram below, which shows bright-line spectra of selected elements.



63. Identify the two elements in the unknown spectrum.

64. Explain how a bright-line spectrum is produced, in terms of excited state, energy transitions, and ground state.

Acknowledgements:

Cornell Center for Materials Research
National Science Foundation
Kevin Dilley, Nevjinder Singhota, & Kaleigh Muller
CCMR Facility Managers