LESSON 10

Examining Spectra

Inquiries 1
Periods 1–2

CONCEPTS

Different light sources produce different spectra.

The spectrum produced by a luminous object is determined by the wavelengths of light emitted by the object.

Spectroscopy can be used as an analytical tool.

STUDENT OBJECTIVES

Build a spectroscope and use it to examine light from different sources.

Observe and draw spectra produced by different light sources.

Discuss how spectroscopy is used.

OVERVIEW

In this lesson, students continue their investigation of spectra. Each student constructs a simple spectroscope and then uses it to observe and draw spectra from different light sources. Students discuss the appearance of these spectra in terms of the presence or absence of different colors and wavelengths of light. They read about and discuss the use of spectroscopy as an analytical tool in chemistry and astronomy. They will use their assembled spectroscopes again in Lesson 11 to examine the effect of filters on white light.

BACKGROUND

The spectroscope students construct in this lesson uses the same type of diffraction grating as the “special glasses” students encountered in Inquiry 1.2. The diffraction grating consists of a sheet of transparent plastic that has thousands of tiny parallel plastic grooves carved into its surface (usually on the order of hundreds to thousands per mm). Each groove deflects light that strikes it over a wide range of angles. This deflecting effect is called **diffraction.** (Diffraction occurs—in its most basic form—when a wave meets the edge of an obstacle or edge of an aperture. While modeling light in Lesson 7, students may have observed the diffraction of water waves as the waves passed the metal barrier. The diffraction of light provides strong evidence for the wave nature of light.)

The amount of deflection that takes place depends on the distance between the grooves on the diffraction grating and the wavelength of the light striking the grating. When a mixture of light is shined onto the diffraction grating, the wavelengths in the mixture will be deflected to different degrees. The regular spacing of the many grooves on the grating causes light of a particular wavelength to build up along a particular direction (or directions). The diffraction grating therefore separates a beam of mixed light (for example, white light) according to its wavelength—and, therefore, according to its color.

When using their spectroscopes, students observe light through a narrow slit in the foil of the spectroscope. As this narrow beam of light strikes the diffraction grating, wide-angle beams of light are scattered from each groove. These beams are synchronized—the waves within them are in step with each other—along a specific direction or directions. The waves are said to be coherent. (See the diagrammatic representation of coherent and incoherent waves in the sidebar "Light in Step—A Laser Component" in Lesson 21 in the Student Guide.) Each groove individually scatters light over a wide range of directions; however, because these beams are in sync they interfere with each other. The result is that, in any given direction, only a particular wavelength will be reinforced; the rest cancel each other out. Students will observe a more clearly defined spectrum for white light using their spectroscopes than the one they observed using a prism in Lesson 8.

The diffraction grating can be a much more effective and versatile tool for separating a beam of light of mixed wavelengths into its component wavelengths (or colors) than a prism. This is because a diffraction grating can be made with any desired groove spacing and thus any desired separating power. The separating power, also called spectral resolution, is therefore more easily altered with a diffraction grating than with a prism. The resolution provided by a prism is determined by its composition—something that is not so easily changed. Different spectral resolutions can be observed for the spectrum of sunlight in photos in the reader "The Science of Spectroscopy."

READING SELECTIONS

The reader "The Science of Spectroscopy" explores how spectroscopy is used to analyze substances found both on Earth and in the universe.

STUDENT MISCONCEPTIONS

Students may think that light from any source can be split into the same component spectrum as that of sunlight. (In fact, different light sources produce different spectra in which some colors and wavelengths found in sunlight may be absent.)

MATERIALS FOR LESSON 10

For the teacher

1 razor blade*
1 sheet of diffraction grating
1 spectrum tube power supply
1 neon spectrum tube
1 helium spectrum tube
1 hydrogen spectrum tube

For each student

1 copy of Student Sheet 10.1: Using a Simple Spectroscope
1 narrow cardboard tube, 3.8 cm in diameter; 22.7 cm in length
1 square of aluminum foil, 12 cm × 12 cm
1 square of black paper, 15 cm × 15 cm with a 1.5-cm × 1.5-cm hole

For each pair of students

1 pair of scissors*
1 metric ruler, 30 cm (12″)
1 box of colored pencils
Masking tape*

For the class

2 sets of light stand apparatus with 60-W white tungsten lightbulbs:
- light stand
- bulb holder
- extension cord

2 sets of light stand apparatus with compact fluorescent lightbulbs:
- light stand
- bulb holder
- extension cord

Access to 4 electrical outlets, 110 V–120 V
Access to a source of daylight

*Needed, but not supplied

PREPARATION

1. Place the assembled light stands around the room.
2. Make sure the room can be darkened easily.
3. Cut out 32 2-cm × 2-cm pieces of diffraction grating from the sheet of diffraction grating provided.

Getting Started

1. Distribute the squares of diffraction grating. Tell students to examine them carefully, taking care to hold them by the edge to avoid getting fingerprints on the grating. After a few minutes, ask the following questions:

What do you observe?

Where have you observed this before?

What does this piece of plastic do to white light?

2. Define the piece of plastic as a diffraction grating. Discuss "How the Piece of Plastic Separates Light." Explain that students will use the grating in constructing the spectroscope, which they will use to examine the spectra from various light sources.

Inquiry 10.1 Using a Simple Spectroscope

PROCEDURE

1. Have students construct their spectroscopes by following the instructions outlined in Step 2 in the Student Guide. You may wish to outline or demonstrate the construction process before students start making their spectroscopes.

2. Use the razor blade to make the single slit you cut in the foil at the end of each spectroscope as narrow as possible.

SAFETY TIP

Do not allow students to handle the razor blade. Cut the slits for them.

3. Students should follow Steps 4–6 to observe the spectra of daylight, tungsten (incandescent) lightbulbs, and compact fluorescent lightbulbs, recording their observations on Table 1 in Student Sheet 10.1: Using a Simple Spectroscope.

NOTE Make sure the room is dark enough to allow students to observe spectra. You might also consider having students observe the room lighting. If these are fluorescent tubes, you may obtain slightly different results from those obtained using the compact fluorescent lightbulbs supplied with the kit.

4. Facilitate a class discussion in which students compare their observations for each of the three spectra. Invite students to comment on the three spectra. They may discuss them in terms of the presence or absence of color, the difference in the brightness of the colors that make up the spectra, or the brightness of the spectra as a whole. Students usually observe that daylight has a continuous spectrum with all the "colors of the rainbow." (The tungsten—incandescent—lightbulb has a continuous spectrum, but is brighter in the lines for red and orange. The compact fluorescent lightbulbs have a discontinuous, mainly red-orange-green-blue spectrum. Students may observe this spectrum, but may not notice the black lines in it.) If students do not notice the black lines, draw their attention to them and ask, What is missing?

5. Encourage students to speculate as to why the spectra differ. Their answers may include the use of different glowing materials, different methods of producing light (filament lightbulbs, as compared with fluorescent tubes, or the nuclear fusion of the Sun), the temperature of the light source, and the amount of energy emitted.

6. Have students gather around the spectrum tube power supply with their spectroscopes, student sheets, and colored pencils. Make sure that all students have a clear view of the supply, so that they can observe and record the spectra of the different tubes.

> **SAFETY TIP**
>
> The spectrum tubes get very hot. Do not touch these tubes when viewing the spectrum. Warn students not to touch the spectrum tubes, as they may cause a painful burn.

7. Insert the neon spectrum tube into the spectrum tube power supply. Explain to students that the spectrum tube power supply passes electrical energy into the neon spectrum tube and makes the gas inside it glow. Switch on the power supply. Students should look at the neon tube through their spectroscopes. Ask some students to describe what they see. Have students complete the appropriate row in Table 1 on the student sheet.

> **SAFETY TIP**
>
> Be sure to switch off the power supply to the spectrum tube before changing tubes. The high-voltage power supply causes the tubes to heat up quickly. Use a cloth when removing them from the power supply.

8. Repeat the procedure with the helium and hydrogen spectrum tubes.

9. Challenge students to suggest what conclusions they can reach from their observations. Focus on ideas that relate specific spectra to specific gases. (Each gas has its own spectrum—a "fingerprint" for that particular element.) Ask students how this observation could have any practical use. Focus on ideas that involve using the spectroscope to determine the composition of different substances.

10. Have students write their names on their spectroscopes before you collect them for redistribution in the next lesson.

REFLECTIONS

1. Have students discuss A–C in the Student Guide with their groups. After a short discussion, they should record their answers on the student sheet. Circulate around the room and use this as an opportunity to assess each student's grasp of the major concepts of spectroscopy.

2. If there is enough time, have students read "The Science of Spectroscopy" and provide brief oral summaries of its key content.

3. Consider having students review the question bank cards generated in Lesson 1. Reclassify the ones students can now answer.

HOMEWORK

Have students research the use of spectroscopy in astronomy.

EXTENSIONS

■ **Science**

1. Have students use their spectroscopes to observe spectra of several compounds. The following compounds are readily available and will produce interesting results: copper sulfate, sodium chloride, potassium chloride, and barium sulfate. Place a small nichrome wire loop into dilute hydrochloric acid and then into the compound so that some of the compound adheres to the loop. Heat the compound over a medium burner flame. When the compounds are heated, colored flames characteristic of the metal in each compound can be observed.

SAFETY TIP

Be sure students wear lab aprons and splash-proof safety goggles when working with the loops, acid, compounds, and the flame.

■ **Science**

2. Have students use library resources or the Internet to investigate and write a paragraph about the discovery of the element helium.

■ **Science** ■ **Technology**

3. Have students use their spectroscopes to examine other light sources, including LEDs, mercury vapor street lamps, and yellow sodium street lamps. They might also view an incandescent lightbulb attached to a dimmer switch at different brightnesses.

ASSESSMENT

- Use students' illustrations and descriptions of spectra from Table 1 on the student sheet to determine whether they have constructed their spectroscope properly and correctly observed and recorded the appearance of spectra from different light sources.
- Use students' answers to A under "Reflecting on What You've Done" on the student sheet to determine whether they recognize what happens to light when it passes through a spectroscope.
- Use students' answers to B and C under "Reflecting on What You've Done" to assess whether they recognize the following points:
  - Different light sources produce different spectra.
  - The colors in a spectrum are related to the wavelengths produced by the light source.
  - Spectra can be used to identify substances.

Name: ____________________

Class: Date:

Student Sheet 10.1
Using a Simple Spectroscope

A. Use colored pencils to record in the second column of Table 1 exactly what you observe through your spectroscope. Write any observations or comments in the third column of the table.

Table 1 Spectra From Various Light Sources

Light Source	Spectrum (Drawing)	Observations/Comments
Daylight		
Incandescent lightbulb		
Compact fluorescent lightbulb		
Neon spectrum tube		
Helium spectrum tube		
Hydrogen spectrum tube		

(continued)

Student Sheet 10.1 (continued)

B. Write a short paragraph describing the spectra from these three light sources—daylight, incandescent lightbulb, and compact fluorescent lightbulb.

REFLECTING ON WHAT YOU'VE DONE

A. What happens to light when it passes through your spectroscope?

B. What can you now say about the spectra from various light sources?

C. How could this information be useful?