Build a Spectroscope

Introduction

A spectroscope is a device for forming and observing the color spectrum of visible light. A spectrum is produced when light from any source is bent or dispersed. Does every type of light show the same spectrum? Find out by using common household materials and a holographic diffraction grating to build a simple, working spectroscope.

Concepts

- Diffraction of light
- Absorption spectra
- Continuous spectra
- Emission spectra

Materials

Flinn C-Spectra® (holographic diffraction grating),1.5-cm square
Cardboard tube (paper towel size)
Cellophane tape
Construction paper, black
Electrical tape, black
Hole punch
Pencil
Ruler, cm
Scissors

Safety Precautions

The materials used in this activity are considered safe. Do not look directly at the Sun, even through the spectroscope. Please follow all classroom safety guidelines.

Procedure

1. Using the end of the cardboard tube as a guide, trace two circles having the same diameter as the tube onto black construction paper.
2. Carefully cut out each circle, making sure the diameter is no smaller than the tube. Each circle must completely cover the open end of the tube.
3. Using the hole punch, make a hole in the center of one of the circles.
4. Cut a 1.5-cm square piece from the sheet of C-Spectra. *Caution:* Wear gloves or hold the grating by the edges. Fingerprints and scratches will reduce the effectiveness of the grating.
5. Take the circle with the punched round hole and, holding the square of C-Spectra by the edges, cover the hole with the C-Spectra. Secure with small pieces of cellophane tape. *Do not place any tape over the part of the C-Spectra that will be visible through the hole* (see Figure 1).

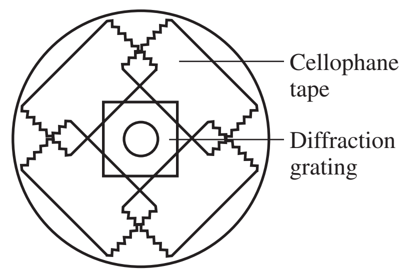

Figure 1.

6. Use the electrical tape to secure the circle with the C-Spectra facing inward to one end of the cardboard tube. Use enough tape so that light enters the tube only through the hole, not around the edges.

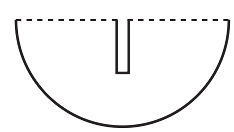

Figure 2.

7. Fold the other black circle in half and cut a 1-cm slit in the middle of the half-circle, starting at the fold.
8. Make an identical slit 1 mm from the first one, then cut the resulting small strip from the circle (see Figure 2).
9. Unfold the circle. There should be a slit approximately 2 cm × 1 mm in the middle of the circle. The edges should be clean, not frayed.
10. Press pieces of electrical tape firmly around the edges of the circle with the slit, *but do not fasten to the tube yet*. Use enough tape to completely cover the edge of the circle (see Figure 3).

11. Hold the circle with the slit over the open end of the tube and look at any light source through the hole in the other end containing the C-Spectra. Rotate just the tube until a clear spectrum of the light is visible on both sides of the slit and the spectrum is as wide as possible. Tape the circle with the slit to the end of the tube in this position (see Figure 4).
12. View various light sources by looking through the end of the tube containing the C-Spectra and aiming the slit at the light. Note differences in bands of colors, the width and intensity of the bands, and any dark lines in between.

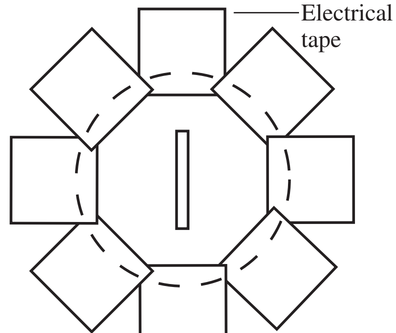

Figure 3.

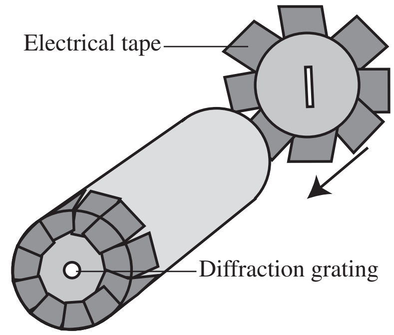

Figure 4.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-PS1 Matter and Its Interactions
PS1.A: Structure and Properties of Matter
MS-PS2 Motion and Stability: Forces and Interactions
PS2.A: Forces and Motion
PS2.B: Types of Interactions

Disciplinary Core Ideas: High School
HS-PS1 Matter and Its Interactions
PS1.A: Structure and Properties of Matter

Science and Engineering Practices
Developing and using models
Constructing explanations and designings olutions

Crosscutting Concepts
Cause and effect
Energy and matter
Structure and function

Tips

- The C-Spectra diffraction gratings are washable and can be cleaned with a soft cloth and mild detergent. Fingerprints and scratches will reduce the effectiveness of the grating.
- The transparency of the C-Spectra makes it difficult to locate when placed on a flat surface. To reduce the number of "lost" squares, keep the C-Spectra pieces in one location and ask students to obtain the grating when ready to tape it in place. This will also help minimize the amount of handling of the C-Spectra.
- Students can look at various light sources around the school—fluorescent, incandescent, or other sources that might be in the lab, such as black lights or ultraviolet lights (students should wear goggles and not look directly at the ultraviolet light).
- Have students use the spectroscope to look at different light sources in their homes and neighborhoods. (Evening works best.) Suggested light sources include fluorescent and incandescent lights, street lights, and "neon-type" signs. Ask students to record the type and color of each light source viewed with the unaided eye, then draw and label each spectrum they see using colored pencils or crayons. Discuss the "homework" spectra in class the next day.
- Students can also look at various solid-colored objects to see which colors are absorbed by the object and which are reflected. Looking at light that has passed through different colored filters is another option.
- Visit the following Web site at http://jersey.uoregon.edu/vlab/elements/Elements.html to view emission and absorption spectra of the elements (accessed March, 2013).
- *Build a Spectroscope* is available as a student laboratory kit, Flinn Catalog No. AP7161. See a free video at flinnsci.com, keyword AP7161vid.
- To further explore absorption and emission spectra this spectroscope could be used with the following Flinn Scientific Student Laboratory Kits: AP8823—Absorption Spectroscopy Kit, AP5607—Flame Test Kit, and AP1716—Flame Test/Emission Spectroscopy Kit (advanced level).

Discussion

Spectroscope

The spectroscope uses a *diffraction grating* to separate light into its component colors. When light strikes the grooves on the diffraction grating film, it is separated, or diffracted, into its component wavelengths. Longer wavelengths (red) will diffract, or bend, more than shorter wavelengths (blue/violet). C-Spectra is a holographically produced diffraction grating. Holographic gratings are an ideal choice for spectroscopy experiments because they produce less stray light than ruled gratings. In fact, they can reduce stray light by a factor of 10–100 compared to ruled gratings.

Emission Spectra

When light given off by a hot gas is diffracted, the light is found to be made up of sharp, brightly-colored lines at specific wavelengths—the result is called a *line emission spectrum*. In the late 1850s, two scientists, Gustav Kirchhoff and Robert Bunsen, placed various substances in a flame, allowed the light from the flame to pass through a prism, and viewed the resulting spectra. They found that each element produced a unique spectrum that was different than any other element. It is now known that when an atom absorbs energy, the atom's electrons will "jump" to a higher energy level. This process is sometimes called "exciting" the electrons. As the excited electrons release the extra energy and return to their normal or "ground" state, electromagnetic radiation is emitted at specific wavelengths. Simply stated—when an element absorbs energy from heat, light, or other sources, electrons in the substance become excited and then emit the "extra" energy in the form of light upon returning to the ground (non-excited) state.

Just as a fingerprint is unique to each person, the color of light emitted after excitation of an element is unique to that element. The emission spectrum produced from exciting an element contains only specific wavelengths of light. The brightly-colored lines viewed in a spectroscope are due to the electrons in various excited states returning to their lower energy ground states. These emission lines can be observed using spectrum tubes containing specific gases such as mercury, hydrogen, or helium. Using the spectroscope to observe flame tests of metal ions reveals only diffracted, diffuse colors, not discrete lines.

Absorption Spectra

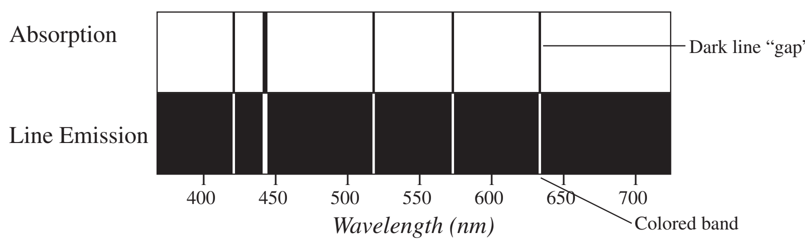

Figure 5.

In 1814, Joseph von Fraunhofer, a German optician, noticed that when sunlight was passed through a prism, the rainbow-colored spectrum contained a series of dark lines. These lines are now called *Fraunhofer lines*. *Absorption spectra* result when a source of white light travels through a relatively cooler gas. As photons from the light source travel through the gas, some of them interact with the atoms and excite electrons. Photons at that particular wavelength are absorbed by the gas, thus resulting in "gaps" or dark lines in the continuous spectrum. The dark lines in an absorption spectrum match the same wavelength as the brightly-colored lines in the emission spectrum of the same element (see Figure 5). Sunlight appears to be a continuous spectrum, containing all colors; however, it is actually an absorption spectrum, with dark lines caused by gases in the Sun's atmosphere absorbing certain wavelengths. By analyzing the pattern or dark lines in the Sun's absorption spectrum and comparing the pattern to absorption spectra of other elements, astronomers have detected over 60 different elements in the Sun's atmosphere!

Acknowledgment

Special thanks to David A. Katz, Tucson, AZ for providing the idea for this activity to Flinn Scientific.

Materials for *Build a Spectroscope* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP1714	Flinn C-Spectra®, 80 × 100 Sheet
AP6011	Tape, Electrical, Black, 60-ft
AP1814	Paper, Construction, 90 × 120, Black
AP7161	Build a Spectroscope—Student Laboratory Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

