Smartphone Spectroscopy

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? Turn your smartphone camera into a spectroscope to find out!

Concepts

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

Materials

Flinn C-Spectra® (holographic diffraction grating), 1-cm square

Ruler, cm

Smartphone camera

Tape

Safety Precautions

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

Procedure

1. Using tape, secure a 1-cm square piece of diffraction grating over the camera lens on the smartphone device. Ensure that the whole camera lens is completely covered.
2. Open the camera application and aim at a light source. You may need to rotate the smartphone until a clear spectrum of the light is visible and the spectrum is as wide as possible.
3. View various light sources and note any differences in bands of colors, the width and intensity of the bands, and any dark lines in between. *Note:* Be sure to turn the flash off if taking photos of the spectra.

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 only 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 spectrum tubes, black lights or ultraviolet lights (students should wear goggles and not look directly at 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 stu-dents to record the type and color of each light source viewed with the unaided eye, take a photo and 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.

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- Visit the following website at http://chemistry.bd.psu.edu/jircitano/periodic4.html to view emission and absorption spectra of the elements (accessed September 2016).
- To further explore absorption and emission spectra this spectroscope could be used with the following Flinn Scientific Student Laboratory Kits: *Absorption Spectroscopy Kit* (Catalog No. AP8823), *Flame Test Kit* (Catalog No. AP5607), and *Flame Test/Emission Spectroscopy Kit* (advanced level, Catalog No. AP1716).

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 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

In 1814, Joseph von Fraunhofer, a German optician, noticed that when sunlight 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 1). 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!

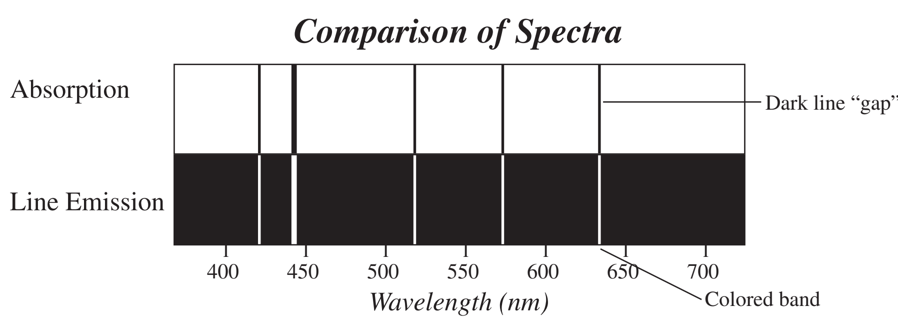

Figure 1. Comparison of Spectra

Acknowledgment

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References

Schwabacher, Alan. "What does the Spectroscope do?" http://uwm.edu/~awschwab/specweb.htm#diffract (accessed September, 2016).

Materials for *Smartphone Spectroscopy* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP1714	Flinn C-Spectra®, 8″ × 10″ Sheet

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