Activity 1

Building a Spectroscope

Reading

Chapter 3, sections 1 and 2 and Chapter 4, section 1

Purpose

To build and use a spectroscope as an instrument to study the chemical properties of reflected or emitted light.

Materials

Simple Spectroscope:

old shoe box, 6 cm square of aluminum foil
tape
2 cm square of diffraction grating (holographic grating is the best)
scissors or a razor knife

Option: Quantitative Spectroscope

all of the above
a piece of graph paper about 3 cm x 10 cm with a small grid (1 mm square)

Option: Semi-Permanent Quantitative Spectroscope

all the supplies from Quantitative Spectroscope

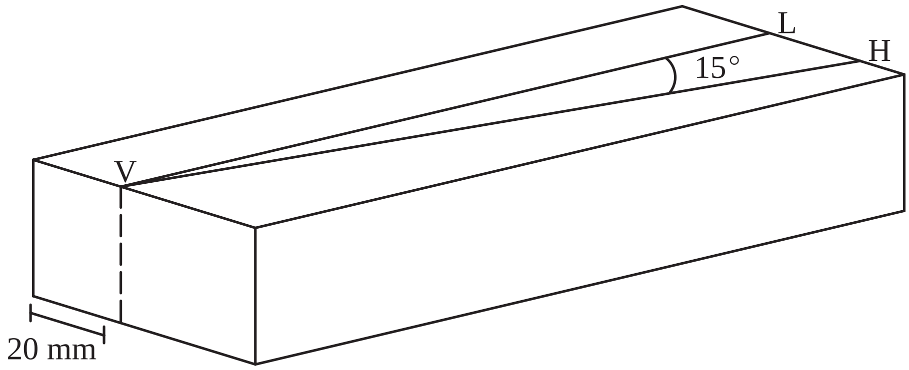
substitute a more substantial box for the shoe box. This could be made from 1/8" masonite, heavy cardboard, plastic, plywood, or even sheet metal, depending on the skills and equipment of the builder.

substitute 2 razor blades for the foil or use two sheets of aluminum cut from a soda can such that each is about razor blade sized with 1 straight edge.

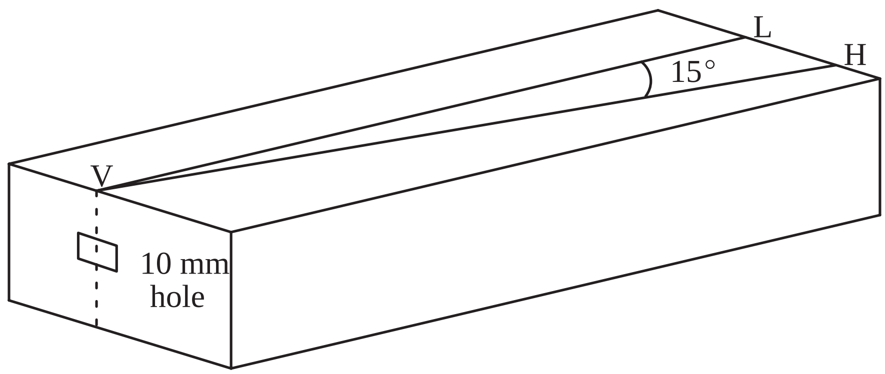
Option: Spectroscope kits can be purchased and assembled quickly.

Procedure

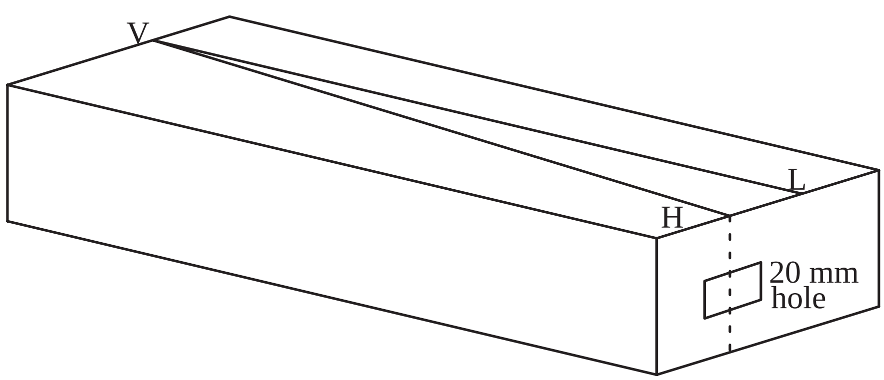
1. On the bottom of the shoe box lay out a 15° angle with the vertex about 20 mm in from one side as shown:



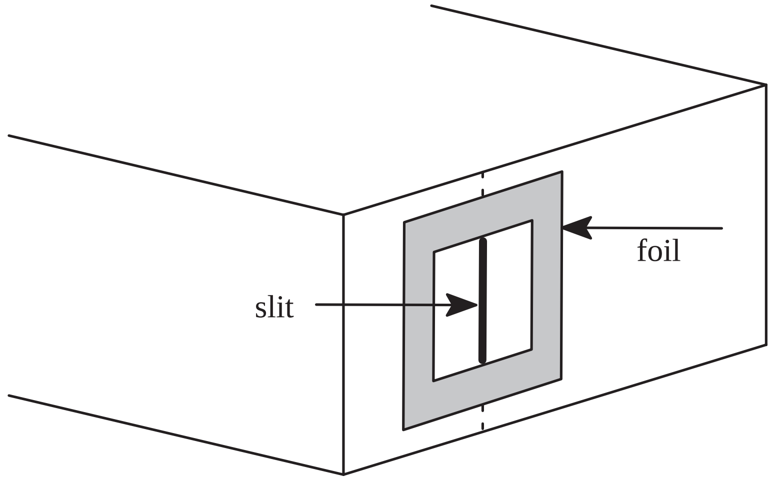
2. On the vertex end of the box cut a 10 mm square hole through the box, centered above the vertex (V) you drew and center in the end as shown:



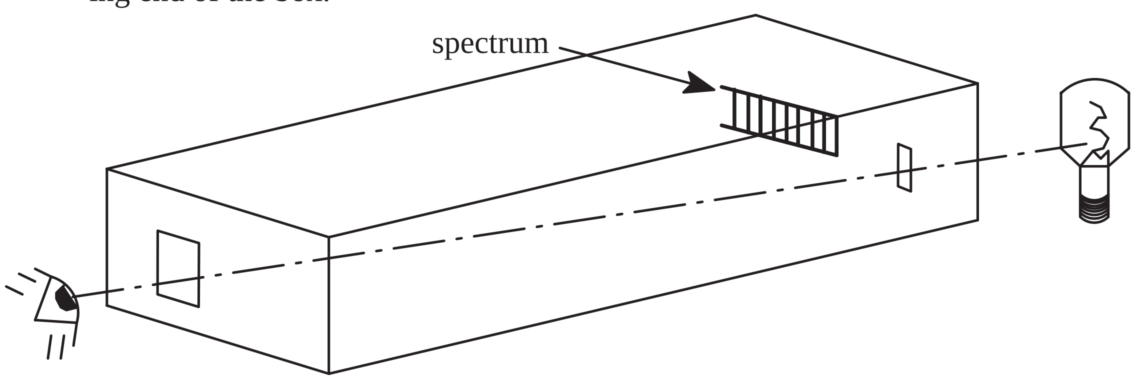
3. At the other end of the box cut a 20 mm square hole centered above the hypotenuse line (H) you drew on the box.



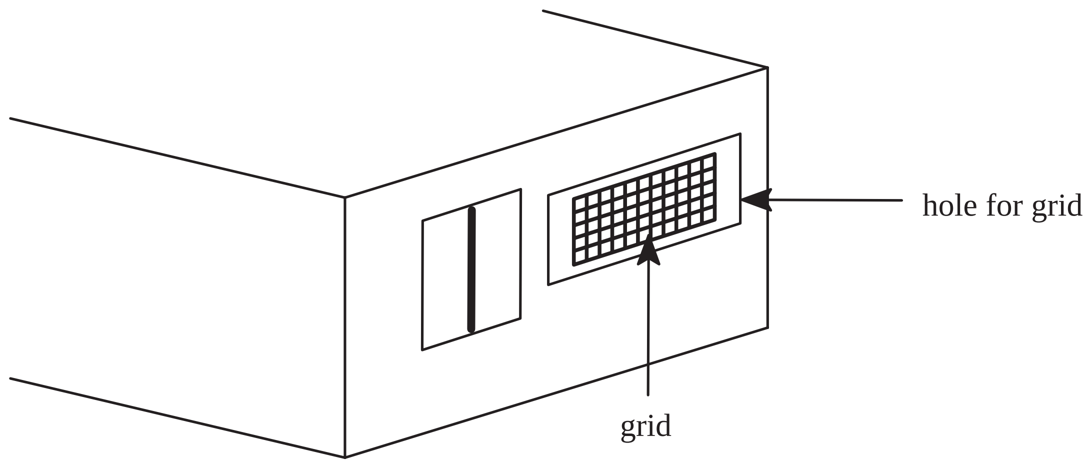
4. Center the foil over the 20 mm hole and tape it into place. Cut a vertical slit in the center of the foil, just filling the hole. Try to keep the slit very narrow—0.5 mm or less.



5. Put a small piece of tape on one edge of the grating—be careful not to get your fingers on the grating, handle it by the edges only.
6. Temporarily tape the grating over the vertex hole on the inside of the box. Set the square of the grating square with the hole.
7. Put the lid on the box, line up the slit with a light source as you look through the grating end of the box.



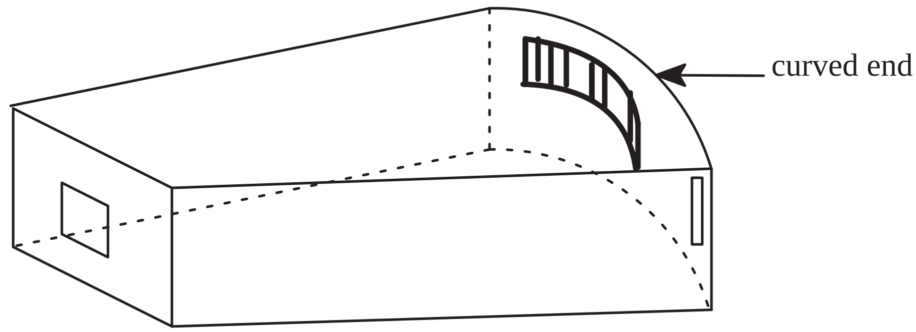
8. A spectrum of colors should appear on the inside of the box to the side of the slit.
9. If the spectrum doesn't appear, rotate the grating 90° and try again. When the grating is finally oriented so that the spectrum is parallel to the slit, tape the other 3 corners of the grating in place.
10. To make this a quantitative device, *ie.* to be able to make measurements on the spectra, a grid needs to be added to the system and then calibrated.
    With the box in use, note the position of the spectrum inside the box. If possible, put a pencil mark around the region occupied by the spectrum.
11. Cut out the region that you marked and center the piece of graph paper over the opening, taping it in place on the outside of the box.



12. Using a florescent light, carefully mark the position of the prominent green and purple lines (others can be used but you'll need to look up their wavelengths). The green line has a wavelength of 546 nm and the purple line a wavelength of 436 nm.
13. Count the grid lines between the marks and scale the grid accordingly. Put convenient numbers on the grid so that values can be read from the grid directly as the spectroscope is used.
14. After building the shoe box type of spectroscope, modify it to: have an adjustable slit, a more accurate grid, a more rugged box.
15. A better slit can be obtained by using 2 double-edged razor blades, or by using 2 pieces of aluminum cut from an aluminum beverage can (both the razor blades and the aluminum pieces are very sharp!). Use a note card, another razor blade, or another aluminum strip as a spacer for the slit.
16. A much better box than a shoe box could be made to house your spectroscope. Cigar boxes are OK but may be too small, and they're certainly hard to cut.
    If you plan to use masonite, plywood, etc. make sure that you lay out the box around the best geometry of the shoe box design. If 15° is not the best angle, change it. Remember the box design is best determined by the slit-grating-grid configuration and not by the size of the box.
17. The actual math relationship of spectral lines and box geometry is not linear, and therefore it loses accuracy the farther away from the calibration lines you make readings. If possible, use a larger number of known lines from Geissler tubes, or other gas discharge tubes and derive the scale formula required. Another method is to change the geometry of the box (a better method is to curve the grid-slit arrangement as shown below.

Using the spectroscope:

1. Make observations of a number of different light sources and use colored pencils to draw what you see as accurately as possible (a florescent light, a "black" light, the sun (be careful here), "grow lights," clouds, neon signs, etc.). You should note that



some light sources don't show a full spectrum but may show only a collection of colored lines or bands. The spectrum of the sun should show a number of black lines on the full rainbow of colors. Do not point your spectroscope directly at the sun. Record what you see and account for the differences.

2. If your spectroscope is a quantitative kind, determine the numerical position of the specific lines and bands. Try to correlate the numerical values with known values for given elements. Some of these are listed in the table that follows. With the black lines in the solar spectrum, try to identify the specific Fraunhofer lines that you can see, and then correlate them to values given for elements in the sun. Why are these lines black?

3. If a set of Geissler tubes or gas discharge tubes is available (neon signs and florescent tubes are gas discharge tubes), make a reference set of line values for specific elements. Try to carefully measure the lines from hydrogen, mercury, helium, and water vapor if these tubes can be obtained.

4. Try placing colored filters between the light source and the slit. Expensive glass filters used for photography, or gels used in theater lights are excellent, but again, costly. Simple colored cellophane from art supply stores or even packages can be used. Or try food coloring in a glass between the light and the slit to make your own colored filter. Explain how these filters can help or hinder your analysis (see Activity 5).

5. Light from burning sources can be analyzed also but can be hard if it's difficult to keep the material burning or if the burning by-products are dangerous. Try burning salt, sugar, salt substitutes, Rolaids®, etc. by using a Bunsen burner or a propane torch. Hold small amounts of material on a small wire loop held in the flame. Do any of these lines match any lines in the solar spectrum?

6. Set up a camera at the grating end of your spectroscope and try to photograph some of the spectra you produce. This is a good exercise in optics. Is it possible to photograph your spectrum of the sun and capture the black Fraunhofer lines?

Table of Solar Absorption Lines

(from the CRC handbook)

Line Name	Due To	Wavelength (nm)
M	Fe	372.8
L	Fe	382.0
K	Ca	393.4
H	Ca	396.8
h	H	410.2
g	Ca	422.7
G	Fe Ca	430.8 430.8
G'	H	434.0
F	H	486.1
b_4	Fe Mg	516.8 516.7
b_2	Mg	517.3
b_1	Mg	518.4
E_2	Fe	527.0
D_2	Na	589.0
D_1	Na	590.0
C	H	656.3
B	O O	759.4 762.1