

EXERCISE C How many lines per cm are in a grating that produces the first-order maximum of 633-nm light at 18° ?

EXERCISE D You are shown the spectra produced by red light shining through two different gratings. The lines in spectrum A are farther apart than those in spectrum B. Which grating has more lines/cm?

* 24-7 The Spectrometer and Spectroscopy

A **spectrometer** or **spectroscope**, Fig. 24-27, is a device to measure wavelengths accurately using a diffraction grating (or a prism) to separate different wavelengths of light. Light from a source passes through a narrow slit S in the “collimator.” The slit is at the focal point of the lens L , so parallel light falls on the grating. The movable telescope can bring the rays to a focus.

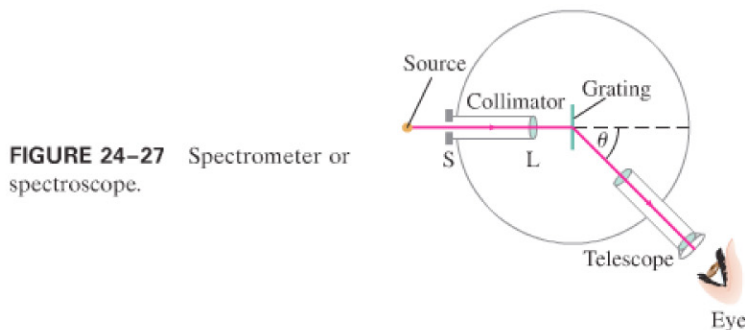


FIGURE 24-27 Spectrometer or spectroscopy.

Nothing will be seen in the viewing telescope unless it is positioned at an angle θ that corresponds to a diffraction peak (first order is usually used) of a wavelength emitted by the source. The angle θ can be measured to very high accuracy, so the wavelength of a line can be determined to high accuracy using Eq. 24-4:

$$\lambda = \frac{d}{m} \sin \theta,$$

where m is an integer representing the order, and d is the distance between grating lines. The line you see in a spectrometer corresponding to each wavelength is actually an image of the slit S . The narrower the slit, the narrower—but dimmer—the line is, and the more precisely we can measure its angular position. If the light contains a continuous range of wavelengths, then a continuous spectrum is seen in the spectroscopy.

In many spectrometers, a reflection grating is used, and sometimes a prism. A prism works because of dispersion (Section 24-4), bending light of different wavelengths into different angles. (A prism is not a linear device and must be calibrated.)

An important use of a spectrometer is for the identification of atoms or molecules. When a gas is heated or an electric current is passed through it, the gas emits a characteristic **line spectrum**. That is, only certain discrete wavelengths of light are emitted, and these are different for different elements and compounds.[†] Figure 24-28 shows the line spectra for a number of elements in the gas state. Line spectra occur only for gases at high temperatures and low pressure and density. The light from heated solids, such as a lightbulb filament, and even from a dense gaseous object such as the Sun, produces a **continuous spectrum** including a wide range of wavelengths.

Figure 24-28 also shows the Sun’s “continuous spectrum,” which contains a number of *dark* lines (only the most prominent are shown), called **absorption lines**. Atoms and molecules can absorb light at the same wavelengths at which they emit light. The Sun’s absorption lines are due to absorption by atoms and molecules in the cooler outer atmosphere of the Sun, as well as by atoms and molecules in the Earth’s atmosphere. A careful analysis of all these thousands of

[†]Why atoms and molecules emit line spectra was a great mystery for many years and played a central role in the development of modern quantum theory, as we shall see in Chapter 27.