1.3B: Monochromators

The two most common ways of achieving monochromatic radiation from a continuous radiation source are to use either a prism or a grating.

Explain in general terms the mechanism in a prism and grating that leads to the attainment of monochromatic radiation. Compare the advantages and disadvantages of each type of device. What is meant by second order radiation in a grating? Describe the difference between a grating that would be useful for the infrared region of the spectrum and one that would be useful for the ultraviolet region of the spectrum.

A prism disperses radiation because different wavelengths of radiation have different refractive indices in the material that makes up the prism. That causes different angles of refraction that disperse the radiation as it moves through the prism (Figure $1.3B.12$).

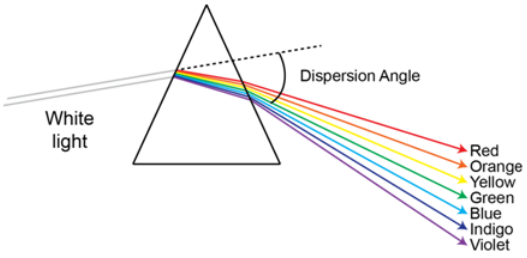

Figure $1.3B.12$. Dispersion of radiation by a prism.

A grating is a device that consists of a series of identically shaped, angled grooves as shown in Figure $1.3B.13$.

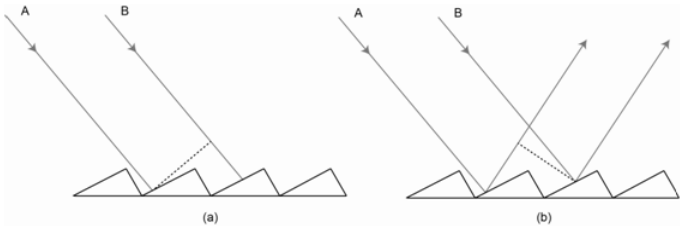

Figure $1.3B.13$. Representation of a reflection grading. A and B represent beams of radiation.

The grating illustrated in Figure $1.3B.13$ is a reflection grating. Incoming light represented as A and B is collimated and appears as a plane wave. Therefore, as seen in Figure $1.3B.13$a, the crest of the wave for A strikes a face of the grating before the crest of the wave for B strikes the adjoining face. Light that strikes the surface of the grating is scattered in all directions, one direction of which is shown in Figure $1.3B.13$b for A and B. An examination of the paths for A and B in Figure $1.3B.13$ shows that B travels a further distance than A. For monochromatic radiation, if B travels an integer increment of the wavelength further than A, the two constructively interfere. If not, destructive interference results. Diffraction of polychromatic radiation off the grating leads to an interference pattern in which different wavelengths of radiation constructively and destructively interfere at different points in space.

The advantage of a grating over a prism is that the dispersion is linear (Figure $1.3B.14$). This means that a particular slit width allows an identical packet of wavelengths of radiation through to the sample. The dispersion of radiation with a prism is non-linear and, for visible radiation, there is less dispersion of the radiation toward the red end of the spectrum. See Figure $1.3B.14$ for a comparison of a glass and quartz prism. Note, the glass prism absorbs ultraviolet radiation in the range of 200-350 nm. The non-linear dispersion of a prism means that the resolution (ability to distinguish two nearby peaks) in a spectrum will diminish toward the red end of the spectrum. Linear dispersion is preferable. The other disadvantage of a prism is that it must transmit the radiation, whereas gratings usually rely on a reflection process.

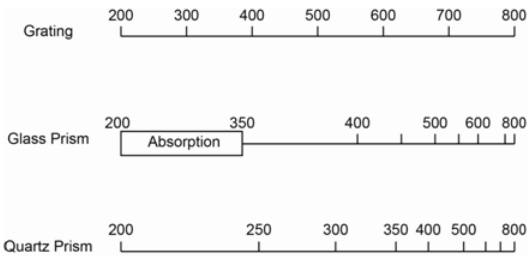

Figure 1.3B.14. Comparison of the dispersion of a grating, glass prism and quartz prism from 200-800 nm.

An important aspect of a grating is that more than one wavelength of radiation will exhibit constructive interference at a given position. Without incorporating other specific design features into the monochromator, all wavelengths that constructively interfere will be incident on the sample. For example, radiation with a wavelength of 300 nm will constructively interfere at the same position as radiation with a wavelength of 600 nm. This is referred to as order overlap. There are a variety of procedures that can be used to eliminate order overlap, details of which can be found at the following: Diffraction Gratings.

The difference between gratings that are useful for the ultraviolet and visible region as compared to those that are useful for the infrared region involves the distance between the grooves. Gratings for the infrared region have a much wider spacing between the grooves.

Explain the significance of the slit width of a monochromator. What is the advantage(s) of making the slit width smaller? What is the disadvantage(s) of making the slit width smaller?

As discussed earlier, the advantage of making the slit width smaller is that it lets a smaller packet of wavelengths through to the sample. This improves the resolution in the spectrum, which means that it is easier to identify and distinguish nearby peaks. The disadvantage of making the slit width smaller is that it allows fewer photons (less power) through to the sample. This decreases the signal-to-noise ratio and raises the detection limit for the species being analyzed.
