Physics 223
Experiment 9: Measurement of Atomic Spectra

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Quantum physics has shown that the energy levels in an atom are discrete. The atom of each element has its own unique energy levels or "fingerprint". When an element in an excited energy state falls back to its ground state, it usually emits light with a set of characteristic frequencies which allows us to identify the element. By simply observing the light coming from distant celestial bodies, astronomers can identify the elements present in them. When the excited gas in a higher energy level makes a transition to a lower energy level, electromagnetic radiation is emitted. For hydrogen, the wavelength λ of the emitted radiation is described by the equation

$$\frac{1}{\lambda} = R\left(\frac{1}{l^2} - \frac{1}{u^2}\right)$$

where l and u are the principal quantum numbers of the lower and upper energy states respectively, and R=0.01097 nm^{-1} is the Rydberg constant. The principal quantum numbers l and u are integers and represent the numeric value that you are familiar with when you speak about the $1s$, $2s$, $2p$, $3s$, $3p$, $3d$, etc. The visible part of the spectrum that is the result of the excited hydrogen gas is known as the Balmer series. This is any transition from higher energy levels to the l=2 level.

You will be provided with a spectroscope (see Figure 1 for schematic diagram), a diffraction grating, and at least four gas discharge tubes. The gases are excited by a high voltage source, and light of various wavelengths is emitted when the atom deexcites. Unlike the laser source, the light from these sources will consist of more than one wavelength. However, because of the existence of quantized energy levels in these atoms, only light of certain discrete wavelengths are observed. Therefore, the interference pattern belonging to the first order of your grating, for example, will contain a set of lines corresponding to the various wavelengths present.

One of your light sources will be hydrogen gas, a second will be mercury. The others will be of unknown (to you!) gases. Use the spectrometer to study the interference pattern and obtain the wavelength of the visible spectrum of hydrogen and identify the wavelengths you measure according to the upper and lower quantum numbers. Next, take measurements on the unknown gases and, using tabulated values for atomic spectra, identify the unknown gas.

You will have to take special care to align the spectrometer carefully and there will be tradeoffs between slit aperture and visibility of the diffracted light.

CAUTION : Although it may seem convenient to use the spectrometer to measure the wavelength of the lasers. Permanent eye damage can result from looking at laser light through the telescope.
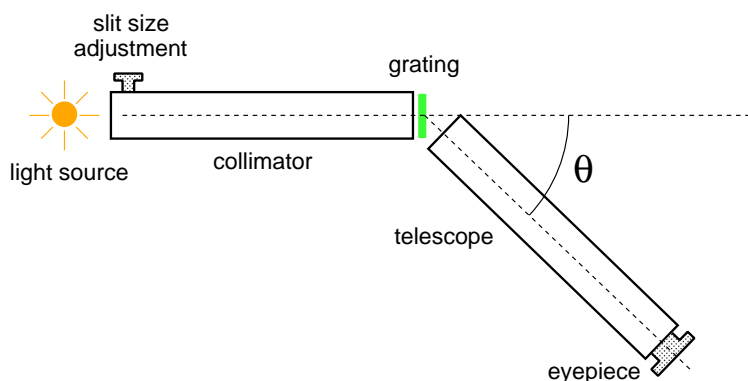

Figure 1: Schematic of a grating spectroscope.