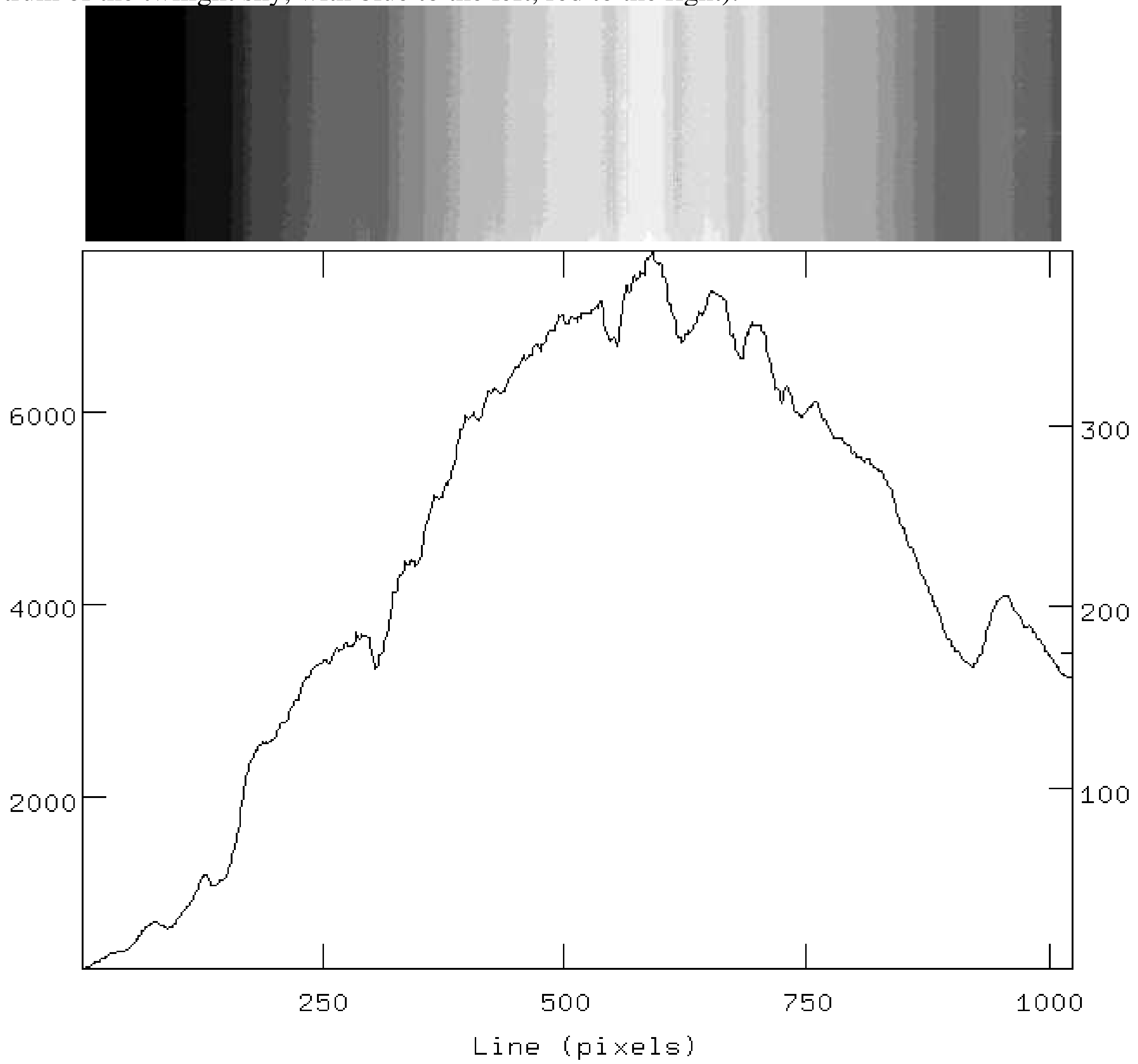
Astro 201: Introduction to Spectroscopy

First, a "photographic" style versus "line plot" style for illustrating spectra are equivalent to each other. Examine the two panels below. They represent the *same* spectrum (this happens to be an optical spectrum of the twilight sky, with blue to the left, red to the right).



Can you see that the bright parts of the "photographic style" spectrum correspond one-to-one with the high-value parts of the line plot? **ACTION 1:** Draw 4 or 5 vertical lines connecting prominent spectral features in the two panels.

In the photographic style the intensity of the spectrum is given by the "lightness" of the ink. In the line plot style the intensity of the spectrum is given by the height along the y-axis. In both styles, the x-direction corresponds to wavelength.

When displaying spectra, we will use both of these styles interchangeably.

Calibrating the spectrograph

There are two key elements in your spectrograph. The **diffraction grating** is where you put your eye at the narrow end, and the **entrance slit** is indicated by the pointy parts at the right side of the wide end. The rest of the wide end is occupied by a semi-transparent wavelength (and energy) scale. Light enters the slit and travels to the diffraction grating, where it is bent according to its wavelength so that individual lines will appear against the wavelength scale. *You must point the right-hand side of the spectrograph toward the light source, even though you must be looking "straight" to see the spectral lines.*

ACTION 2: point the spectrograph at any convenient bright light source and look into it. If necessary, rotate the diffraction grating **slightly** until the rainbow falls horizontally all the way across the wavelength scale.

Now, we need to check the wavelength scale itself using a lamp with lines of known wavelength. We use the Hydrogen lamp for this purpose, specifically the brilliant red H-alpha line (level 3 to level 2 transition in the Hydrogen atom). Its wavelength is 656.3 nm. **ACTION 3:** Observe H-alpha through the spectroscope. Estimate to the nearest nanometer the wavelength that it appears to land on. Record this in your report. **ACTION 4:** Compute the (you minus laboratory) difference in wavelength and record this in your report. This additive shift can be used to convert your measured wavelengths onto a more accurate scale by algebraically subtracting it from any wavelength you measure. There may indeed be additional warps or stretches in the spectrograph wavelength scale, but we will not correct for these.

Some Preparations

Below you will find a table of wavelengths of commonly seen lines for different elements. Below that you will find "photographic style" templates, with the one for Neon already sketched in as an example. **ACTION 5:** Using the listed wavelengths, sketch in all of the templates. If a table entry is marked with an "s" it indicates a bright line, but not all bright lines are marked.

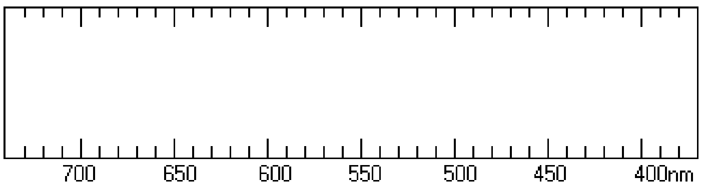
Notice that the template spectrum boxes are labeled with wavelength increasing to the left (and photon energy increasing to the right). **This is not standard!** But we plot this way because this is the way our spectrograph's wavelength scale is arranged..

Table 1: Optical wavelengths in nanometers.

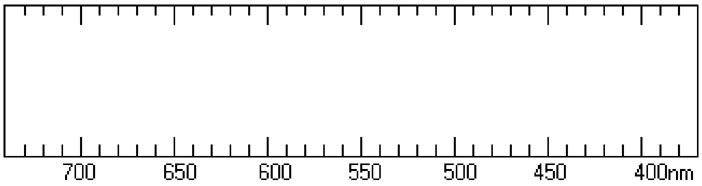
Hydrogen	571.9	667.8	487.6	Krypton
410.2	574.8	671.7	488.8	427.4
434.0	576.4	692.9	515.1	428.3
486.1	580.4	703.2	516.2	431.9
656.3	582.0	705.9	518.7	432.0
	585.2	717.3	522.1	435.5
Helium	588.2	724.5	542.1	436.3
402.6	590.2	743.9	545.2	437.6
412.1	594.5		549.6	440.0
414.4	597.6	Argon	550.6	445.4
438.8	602.9	394.9	555.9	446.4
447.1s	607.4	404.4	560.6	450.2
471.3	609.6	415.9	565.1	480.7
492.1	612.8	420.1	574.0	556.2s
501.5s	614.3	425.9	583.4	557.0s
587.5s	616.3	427.2	591.2	587.1s
667.8	621.7	430.0	592.8	645.6s
706.5	626.6	433.4	603.2s	758.7
	630.4	434.5	604.3	760.1
Neon	633.4	451.1	605.2	
511.6	638.3	442.4	605.9	Mercury
533.0	640.2	459.6	610.5	404.6
534.1	650.7	470.2	617.0	435.8
540.0	653.2	475.3	641.6	546.0
569.0	659.9	476.9		577.0
				579.0

TEMPLATE SPECTRA:

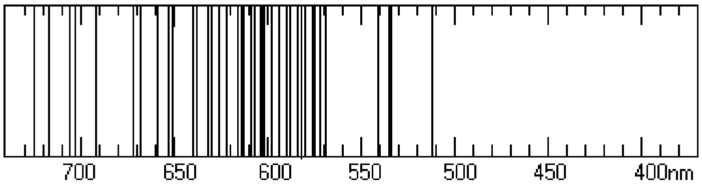
Hydrogen (H):



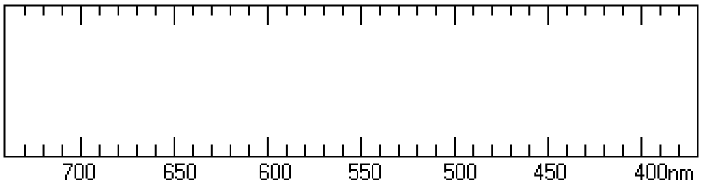
Helium (He):



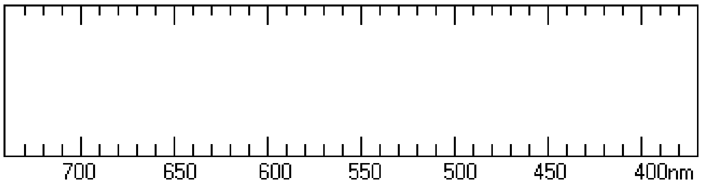
Neon (Ne):



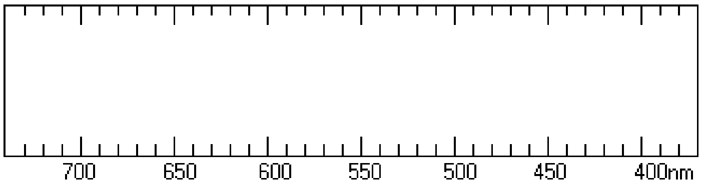
Argon (Ar):



Krypton (Kr):



Mercury (Hg):



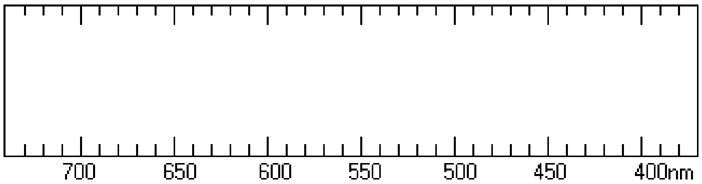
Charting more spectra

ACTION 6: For each of the following create (1) a description of the spectrum (continuous, absorption, or emission), (2) a table of observed wavelengths, *corrected via Action 4* above, (3) plot a "photographic style" spectrum in the boxes provided below, and (4) provide an identification of the elements involved. (If some of these cannot be done, provide an explanation.)

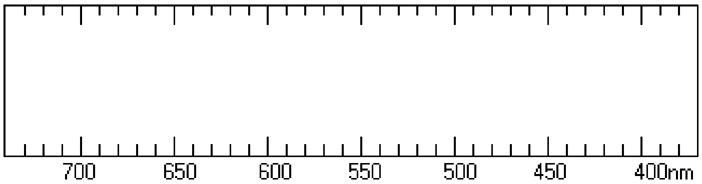
1. Laser. A unique identification may not be possible, but at least some elements can be ruled out.
2. Tungsten light bulb.
3. Fluorescent light bulb. You can identify one element for sure, but that may not be the only element present. Explain.
4. The Sun (sidewalk, clouds) if available, otherwise use the solar spectrum chart. Even a careful student may not be able to identify many elements in the solar spectrum using the fairly limited number of lines that are visible.
5. Each of 4 unknown gas tube spectra. Groups may internally share data tables to save time.

Write the wavelength data and comments on separate sheets.

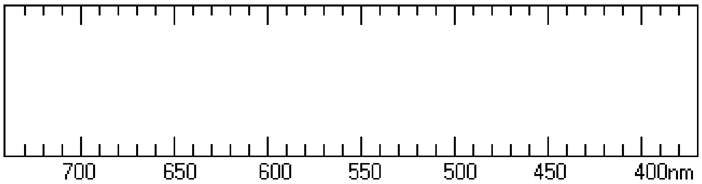
Laser:



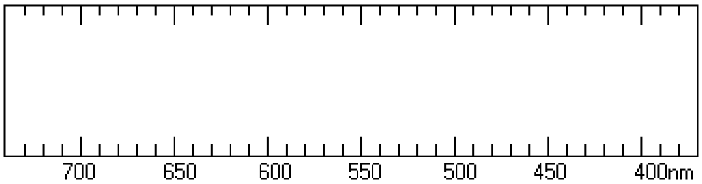
Tungsten bulb:



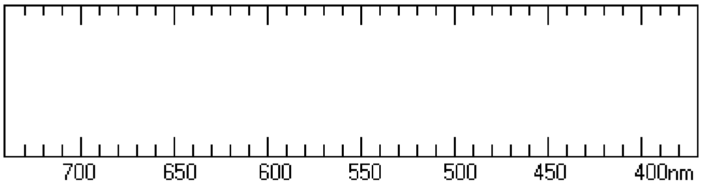
Fluorescent bulb:



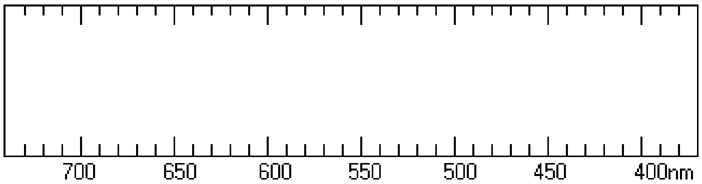
Sun:



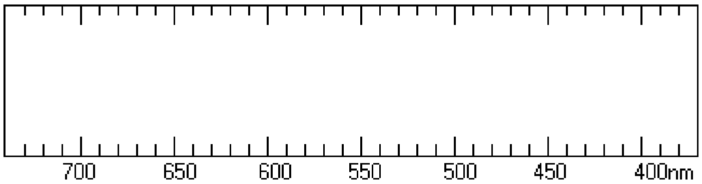
Gas tube 1:



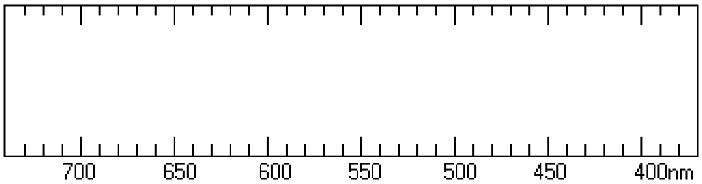
Gas tube 2:



Gas tube 3:



Gas tube 4:



ACTION 7: Answer the following wrap-up questions.

1. Give any comments you have about the spectra you have just observed.
2. Suppose you took a spectrum of a previously unseen astronomical object. How would you go about figuring out what elements or compounds the object was composed of?
3. Compute the wavelengths for H-beta (n=4) and H-gamma (n=5) using Balmer's formula (page 120). Compare them to the table 1 values.

Hopefully this exercise has given a glimpse into the mind-bogglingly useful nature of spectroscopy. Obviously there is a lot about spectra that we cannot cover during our short meeting time, but perhaps at least we have learned that there is a quite a lot going on in the world that is not immediately apparent to the human eye.

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