

Fundamentals of Astronomical Imaging

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Lab 4: Spectroscopic Imaging of Gases

Materials:

- gas discharge tubes
- hand-held spectroscopes (provided in lab)
- 2 pages of “blank spectra” charts
- access to the website <http://jersey.uoregon.edu/vlab/elements/Elements.html>, where you can click on the elements in the periodic table to see absorption spectra of each element.

Background

In this lab you will observe, record, and identify *emission spectra* of a series of *gas discharge tubes*, with the goal of establishing the fact that the atomic spectra are “unique” and “identifiable.” Each discharge tube is filled with a specific atomic element (or molecule) in gaseous form. The gas is “excited” by electric current passing through the tube, meaning that the electrons bound to atoms in the gas absorb energy by jumping to higher orbitals. When the electrons are “de-excited” (don’t blame me, I did NOT make up the word), the electrons “fall back down” to lower orbitals and emit light with the corresponding wavelength via $E = h\nu = \frac{hc}{\lambda}$. If the energy is expressed in Joules,

Planck’s constant $h = 6.626 \times 10^{-34}$ Joule-second; if E is measured in electron-volts (eV), then $h = 4.136 \times 10^{-15}$ eV-second. Of course you already know that the velocity of light in vacuum is $c = 3 \times 10^8$ meters per second. If the wavelength is measured in nanometers (e.g., $\lambda = 600$ nm), then the corresponding energy in eV can be found via:

$$E = \frac{hc}{\lambda} = \frac{4.136 \times 10^{-15} \text{ eV} \cdot \text{s} \cdot 3 \times 10^8 \frac{\text{m}}{\text{s}}}{600 \times 10^{-9} \text{ m}} = 2.07 \text{ eV}$$

The gases in these tubes are often present in *gaseous nebulae*, such as our old friend M42 (the Great Nebula in Orion). The glowing gases in nebulae are energized not by an electric current, but rather by intense ultraviolet light from nearby hot (and often young) stars.

Your mission is to (1) build up a small library of (four to five) reference spectra of known elements; (2) verify that these reference spectra indeed match those of theoretical spectra for these same elements; (3) try to identify the “mystery elements” present in 3 discharge tubes, including the overhead fluorescent lights. This is precisely the same technique used by astrophysicists to determine the atomic (elemental) composition of gaseous nebulae like the Orion Nebula. Good luck...!

Procedure

Steps 1 and 3 below will be conducted during lab time; step 2 can be performed later.

1. **Record (by eye & hand) the spectra of a set of 4-5 discharge tubes with “known” elements.** Note the color of the glowing gas in the tube, as seen *without* the hand-held spectroscope. Then use the spectroscope to view a spectrum of the glowing gas in the tube. Do this by lining up the spectroscope slit with the tube and then looking to the right, where there is a reference wavelength scale. Note and record the positions *and colors* of the brightest emission lines visible in the spectrum, using the “blank spectra” chart. *Be sure to place each bright line you see at its approximate wavelength in the chart, as estimated from the wavelength scale under the spectrum when viewed through the spectroscope.*
2. **Verify that the spectra match those of reference spectra for the same elements** (available at the web site listed above). The precise method you use for this “verification” step is up to you, with the sole requirement being that you must present it in a clear & convincing manner in your lab report.
3. **Identify each element in a set of “mystery gases.”** After you view and record the spectra of “reference” elements, your instructor will show you a series of 2-3 “mystery” gases (gas discharge tubes with “unknown” elemental compositions), including the overhead fluorescent lights. Use the very same procedure described in Step 1 to record their appearances and spectra. The spectra should be recorded in sufficient detail so as to be able to compare them with your reference “library.”

Lab Report

1. Objective
2. Observations
 - notations of appearance and spectrum for each “reference” discharge tube (i.e., annotated chart of spectra)
 - notations of appearance and spectrum for each “mystery gas” discharge tube (including fluorescent lights)
3. Analysis and Results
 - Describe the process by which you compared the spectrum of each reference element (discharge tube) to its theoretical spectrum, to verify the identity of the element that was present in the tube. Be sure to summarize the potential pitfalls/uncertainties in your verification method (in particular, how “perfect” was the match?).
 - Describe the process by which you compared the spectrum of each “mystery” gas (discharge tube) to a reference spectrum, to verify the identity of the element(s) present in the “mystery” gas. Be sure to summarize the potential pitfalls/uncertainties in your verification method (in particular, how “perfect” was the match?).
4. Conclusions
 - What element, would you conclude, was in each “mystery” discharge tube?
 - How certain are you of your results, and what is the origin of your uncertainties (if any)? Can you suggest straightforward ways in which you would improve the experimental procedure so as to improve the quality/reliability of the results?