SPECTROSCOPY:
Quantitative Analysis with Light (#9.1)

John R. Amend, PhD, Montana State University
Dale A. Hammond, PhD, Brigham Young University-Hawaii

Learning Objectives :

The objectives of this experiment are to:

- Identify band and line spectra, and relate the physical state of a light-emitting substances to the type of spectrum observed.
- Determine the relationship between the colors of the visible spectrum and wavelength and frequency.
- Determine the relationship between the energy, frequency, and wavelength of light waves.
- Examine the fingerprint nature of spectra.
- Construct a spectrograph calibration chart and identify an unknown element by measurement of it's emission spectrum.
- Use Bohr's energy-state model to explain the atomic spectrum of hydrogen gas.

Introduction:

An introduction to atoms, ions, electrons and molecules, and the importance of electrons to understanding it all. This experiment is in a way an experience into a foreign language - the language of electrons. To understand this language, we first have to learn a little about its words, which are the colors of light. This we will do in the first part of the experiment. We will see how the colors or *spectra* of light produced by hot atoms uniquely identify them, and finally, we will look at some of the experimental evidence that caused Niels Bohr to propose that electrons run in planetary orbits around their nuclei.

Background: Light Is a Form of Wave Motion:

One of the more convincing bits of evidence supporting the wave model for light is the star pattern observed when a light is viewed through a close-mesh screen. Formation of an "interference pattern," and the spacing of the bands is related to the wavelength of the light. Wavelength is defined and assumes that light has some properties normally attributed to waves, be they water waves, sound waves, or just waves on a jump rope. Constructive and destructive "interference." is discussed.

Using the Spectroscope:

A spectroscope or 35 mm diffraction grating slide is used to examine the following types of spectra.

Problem I: Solid vs. Gaseous Spectra:

Te spectrum of an incandescent light bulb is compared to the spectrum of several discharge tubes, with that of a fluorescent lamp, and with a yellow flame to determine the difference in origin of line spectra and band spectra.

Problem II: Color and Wavelength:

A study of the arrangement of colors in the band spectrum of the incandescent light bulb with the wavelength to determine which colors have the longest wavelength and which the shortest wavelength?

Problem III: The Energy of Light:

The relationship between the energy of an electron transition and color is explored light-emitting-diodes (LEDs) on the ***MicroLAB*** **Energy of Light** board and **Energy of Light** program, determining the **Voltage versus Wavelength and Energy versus Frequency** relationship.

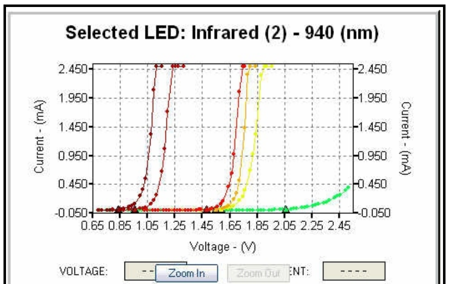

Figure 1. Graph showing the relationship between voltage and color of the LED.

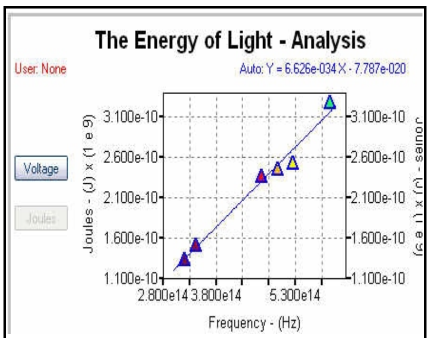

Figure 2. Graph of voltage converted to Joules and wavelength converted to frequency. Slope has units Js, which is Plank's constant

Problem IV: The Fingerprint Nature of Spectra:

A Bunsen or Tirrel burner is used to use the diffraction gratings to examine the flame spectrum of several metal salts to determine the origin of the flame color. You will also view the spectrum of several gas discharge tubes and record them in your notes.

Problem V: Identification of an unknown element from its discharge spectrum::

It is possible to identify elements and even mixtures of elements by observation of their spectra. In this part of this experiment students are asked to identify an unknowns using the program **Atomic Spectrum** using images containing a mercury spectrum and the unknown spectrum. Students will calibrate the computer screen using the mercury spectrum, use that calibration to determine the wavelengths of the unknown, then use a built in table of metallic spectral values to identify the unknown.

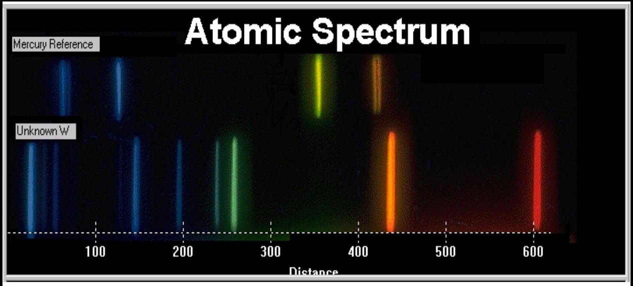

Figure 2. Format of the images with the mercury spectrum on top and the unknown spectrum on the bottom.

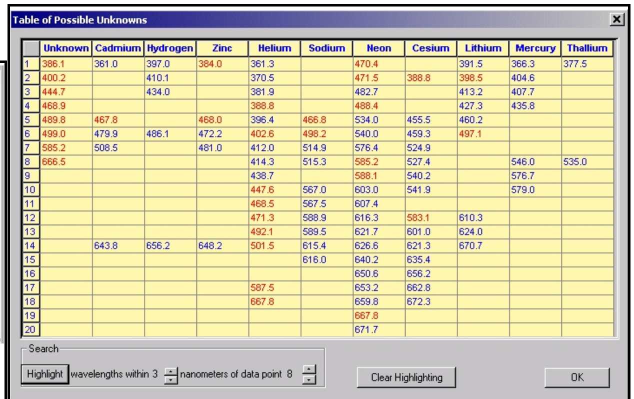
Table of Possible Unknowns

	Unknown	Cadmium	Hydrogen	Zinc	Helium	Sodium	Neon	Cesium	Lithium	Mercury	Thallium
1	386.1	361.0	397.0	384.0	361.3		470.4		391.5	366.3	377.5
2	400.2		410.1		370.5		471.5	388.8	398.5	404.6	
3	444.7		434.0		381.9		482.7		413.2	407.7	
4	468.9				388.8		488.4		427.3	435.8	
5	489.8	467.8		468.0	396.4	466.8	534.0	455.5	460.2		
6	499.0	479.9	486.1	472.2	402.6	498.2	540.0	459.3	497.1		
7	585.2	508.5		481.0	412.0	514.9	576.4	524.9			
8	666.5				414.3	515.3	585.2	527.4		546.0	535.0
9					438.7		588.1	540.2		576.7	
10					447.6	567.0	603.0	541.9		579.0	
11					468.5	567.5	607.4				
12					471.3	588.9	616.3	583.1	610.3		
13					492.1	589.5	621.7	601.0	624.0		
14		643.8	656.2	648.2	501.5	615.4	626.6	621.3	670.7		
15						616.0	640.2	635.4			
16							650.6	656.2			
17					587.5		653.2	662.8			
18					667.8		659.8	672.3			
19							667.8				
20							671.7				

Search
Highlight wavelengths within 3 nanometers of data point 8
Clear Highlighting
OK

Figure 3. Table showing the wavelengths of the unknown and 10 other elements for identifying the unknown.

VI: Some Support for Bohr's Planetary Electron Model:

Niels Bohr was a young Danish postdoctoral student working for Earnest Rutherford when Rutherford’s research group discovered the nucleus of the atom.Because only certain colors of light were emitted by hot atoms, Bohr proposed that electrons run in “planetary orbits” around atomic nuclei. Electrons can be pushed to outer orbits by heating the atom, and give off light when they fall back to inner orbits. Bohr used known laws of physics predict the wavelength of light produced as an electron falls from an outer, higher energy orbit to an inner, lower energy orbit for the element hydrogen, the simplest element in the periodic table. Students are give the observed wavelengths for jumps from levels 3 to 2 and 5 to 2, and are asked to calculate those levels for comparison, as well as levels 4 to 2 and 6 to 2.

Table 4 : Hydrogen Spectral lines

Jump	Observed	Calculated
3--2		656.5 nm
4--2		nm
5--2		434.2 nm
6--2		nm

Instructor Resources Provided

- Sample Report Sheets providing the format to organize the data collection with sample data.
- Questions to consider, answer and turn-in with suggested answers.
- Tips and Traps section to assist the instructor with potential problems and solutions.
- Sample ***MicroLAB*** screen shots and graphs.
- Laboratory preparation per student station.

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P.O. Box 7358	Bozeman, MT	59771-7358