EXPERIMENT 6B

Spectroscopy

Continuous Spectrum:

In 1670, physicist Isaac Newton observed continuous rainbows of colors when shine sunlight passed through a prism. As years passed, other great scientists conclusively demonstrated that light must travel in waves. Lately, scientists discovered that light itself is a type of electromagnetic wave. The behavior of electromagnetic wave depends on its wavelength. With the discovery of gamma rays in 1900, all wavelength ranges have discovered so that electromagnetic spectrum was completed filled. Generally, they are classified by wavelength into radio wave, microwave, infrared, visible light, ultraviolet, X-rays and gamma rays. Areas of light that possess short wavelengths are located on the left of the spectrum. The colors displayed are within the visible spectrum (between 380 - 750 nm).

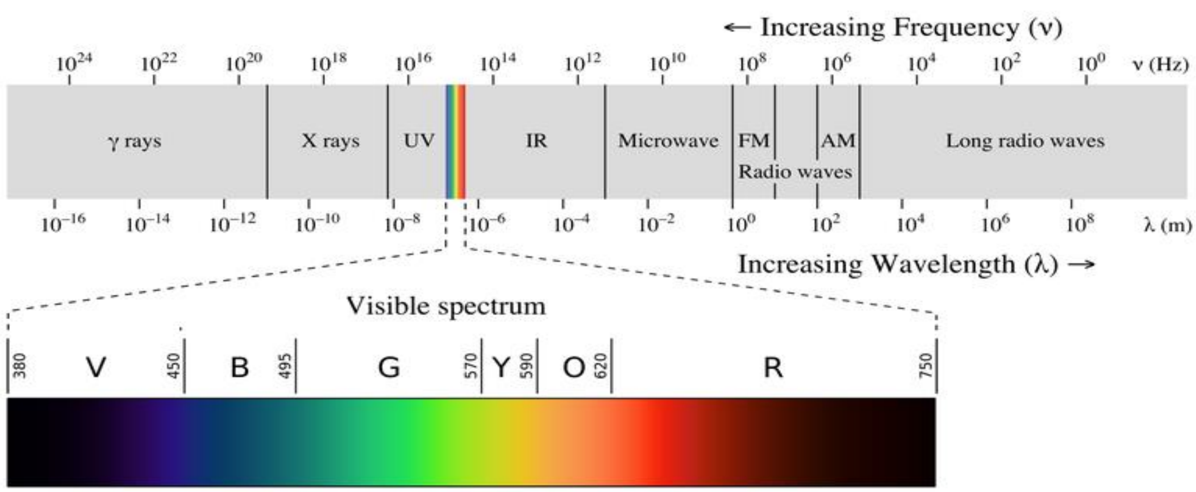


Figure 7.1: The distribution of electromagnetic waves with respect to frequency and wavelength, highlighting visible part of the electromagnetic spectrum. (Philip Ronan, Gringer)

Electromagnetic waves are typically described by the frequency and wavelength. Since an infinite range of wavelength of electromagnetic waves travels at the speed of light (c), the relation is illustrated by the following equation:

$$\lambda = \frac{c}{f}$$

where c = 3.0×10^8 m/s; λ is the wavelength; f is the frequency.

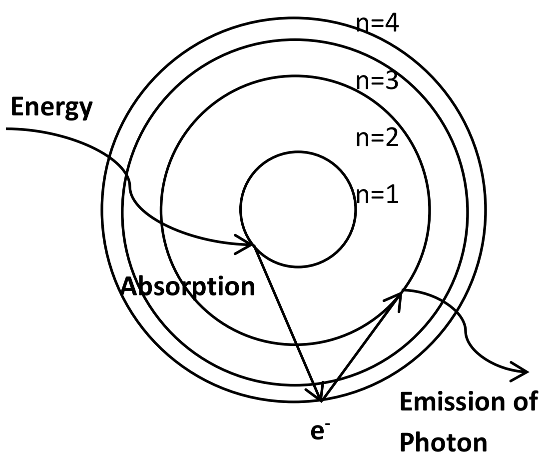
Note – frequency and wavelength are inversely proportional to each other.

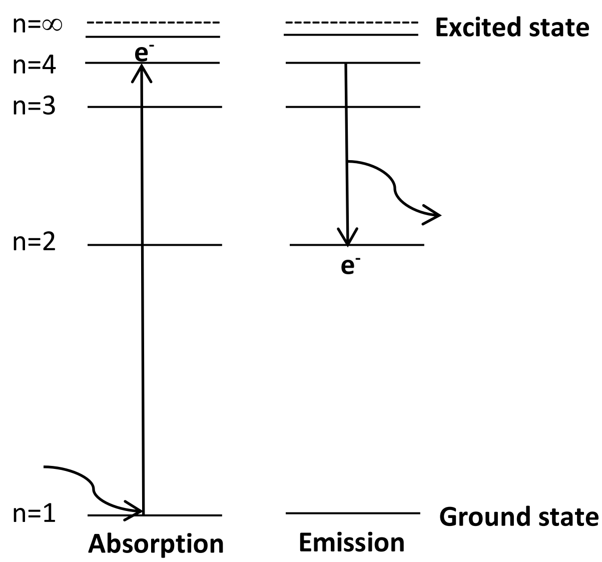
Atomic Emission Spectra:

In 1826, physicist John Herschel observed monochromatic lines of pure color on a dark background when the shine light from heated gas passed through a spectroscope. Herschel's discovery was studied extensively in the 1800's. It was realized that a heated gas emits a unique combination of colors, called emission spectrum, depending on its composition.

The nucleus of the atom contains protons and neutrons. Atoms also possess electrons, which are located outside the nucleus. In a neutral atom there is the same number of electrons as protons. For example, the silver atom has 47 protons and 47 electrons. An electron is a negatively charged particle with a mass that's about 1800 times smaller than that of the proton or the neutron. Protons are positively charged and neutrons are neutral.

The arrangement of the electrons in an atom is called its electronic structure. For simplicity, let's consider the simplest of the atoms, hydrogen. There is only one proton and one electron in a hydrogen atom. We can't see electrons in an atom so we have to study them indirectly. One piece of evidence about the arrangement of electrons is the electromagnetic spectrum. For example, the spectrum of hydrogen is an important piece of evidence that light interacts with matter through the absorption and emission of discrete packets of energy, called quanta. We now call these quanta "photons."





In the figures above both emission and absorption are shown. On the right side of the figure an electron moves from the n = 4 energy level to the n = 2 energy level. A photon is emitted from the atom with an energy equal to the difference between n = 4 and n = 2 energy levels. On the left side of the figure the absorption of a photon by an atom is represented. When energy is absorbed by the atom, the electron is promoted from the n = 1 energy level to the n = 4 energy level. For this to take place, the energy must match the energy difference between the n = 1 and n = 4 energy levels. The hydrogen atom is most stable when the electron is in the lowest energy level (n = 1). This level is often called the ground state. If a sample of hydrogen atoms is heated electrons can be promoted to higher energy levels (n = 2, 3, 4 ...). When the electrons move back to lower energy levels, photons will be emitted. Because only specific energy levels are possible, only specific wavelengths of light will be produced. The result is what's called an emission line spectrum or a bright line spectrum. Each line (wavelength or color) is associated with the transition of the electron from one energy level to another.

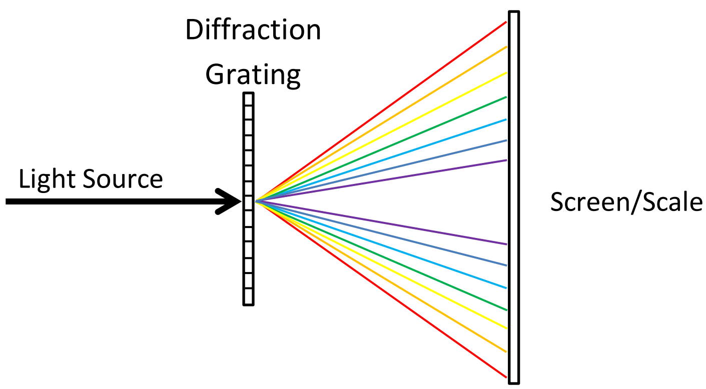
1. Flame Test

Atoms can gain energy from various sources. Frame is one of the most common sources to be used to excite metal atoms. Sodium, lithium, strontium, potassium and barium salts produce unique colors if vaporized in a Bunsen burner flame. In this lab, the instructor will demonstrate a flame test experiment. During a flame test experiment, 2% metal chlorides solutions are directly placed into a flame. Record your observation in the table below:

Metal ion	Color
Sodium	
Lithium	
Potassium	
Strontium	
Barium	

2. The Hydrogen Spectrum

The use of electrical current is a common way to excite gaseous atoms. In this lab, the instructor will use a diffraction grating to show the spectrum of hydrogen. Diffraction grating is a piece of clear plastic with thousands of very closely spaced lines etched on its space. Different light waves will interfere with each other as they travel across diffraction grating. What you end up with a separation of colors (wavelengths) of which the incoming light beam was composed.



1. A discharge tube filled with hydrogen gas is placed into the power supply which can apply high voltage.

2. Turn on the power supply. The hydrogen gas discharge tube produces a signature reddish cast color.

3. Place a diffraction grating (25,400 lines/inch) in front of the discharge tube; it will split the different wavelengths. Three most prominent color lines should be observed on the diffraction grating.

4. Write down your observation in the space below:

3. The Rydberg Equation

In 1885, Johann Balmer derived a mathematical formula to calculate the visible wavelengths of the hydrogen spectrum displayed. The visible spectrum of light from hydrogen displays four wavelengths, 410 nm, 434 nm, 486 nm, and 656 nm. In 1888, Johannes Rydberg generalized the Balmer's equation for all transitions of hydrogen:

$$\lambda = \frac{91.15\ nm}{\frac{1}{n_f^2} - \frac{1}{n_i^2}}$$

where λ is the wavelength; n is equal to the energy level (initial and final)

Use the Rydberg equation to calculate the wavelengths of emission photons in different electron transitions of hydrogen atoms and then identify the electromagnetic regions. Also, you should be able to convert wavelength to frequency.

Electron Transition	Wavelength (nm)	Frequency (Hz)	Electromagnetic region
n=5 to n=1	95	3.15×10^{15}	Ultraviolet
n=5 to n=3			
n=5 to n=2			
n=4 to n=2			
n=3 to n=2			
n=4 to n=1			

4. Determining Elements by Using the Quantitative Analysis Spectroscope

As we discuss before, spectra can be used as “fingerprinting” in the identification of substances, because each element produces its own characteristic lines in spectrum. The separation of light can be achieved by using a diffracting grating. Quantitative analysis spectroscope, a device uses diffracting grating with other components which can easily and quickly determine the emitted light of definite wavelengths of an element in its gaseous form.

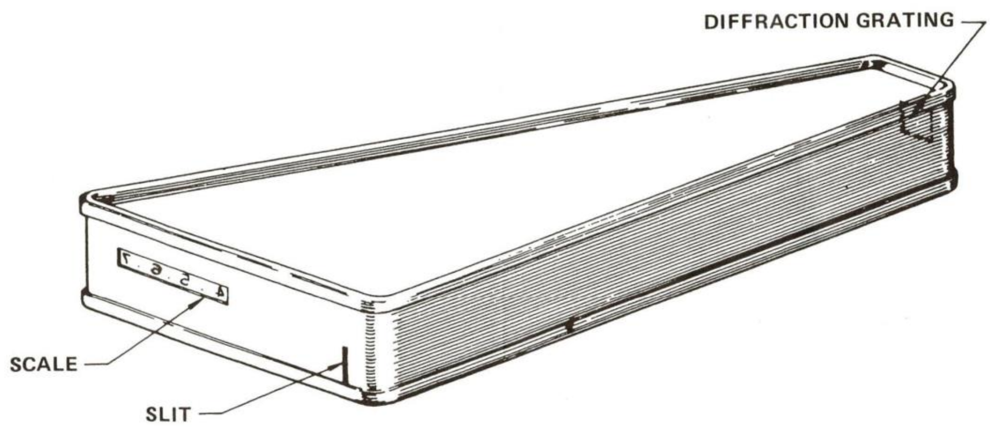


Figure 9.2: The quantitative analysis spectroscope (Werner Schulz)

<u>Procedure:</u>

1. You will break into groups by the instructor. About 4-5 students per group.

2. Turn on the light source. **Tubes should be powered for 30 seconds and not more than two minutes (to avoid burning of bulbs).**

3. Point the slit of the spectroscope directly at the discharge tube.

4. View the emission lines with the scale that appear on the right hand side, and record the color and wavelength for each line in the date table. The number on the scale represents 1000 Å or 100 nm unit.

*** The visibility of the spectrum can be improved by holding the hand round the narrow end of the spectroscope using the thumb and the index finger to keep stray light from around the eye.**

5. Identify the element in the discharge tube by comparing observed lines to the standard spectra.

6. Repeat for the reaming discharge tubes.

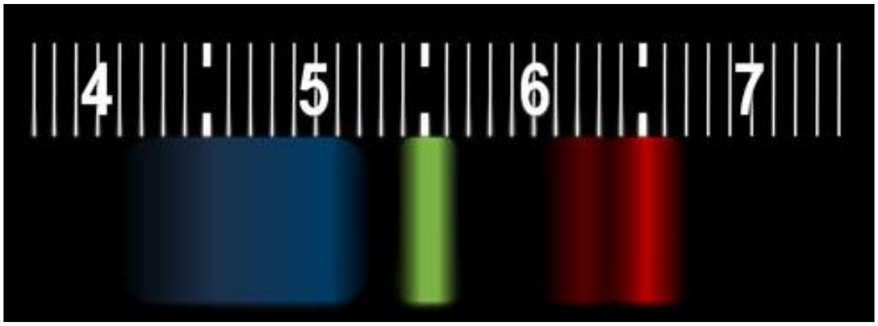


Figure 9.3: An example of the view of the scale. The bright red band has a wavelength of 650 nanometers. The green band is about 550 nanometers. The wide blue band ranges from 450 nanometers (nm) and 520 nm (Ken Costello).

<u>Date table:</u>

	Emission Line Wavelength in nm (top) and Color (bottom)								**Element**
Example	430	480	650						Hydrogen
	Violet	Green	Red						
1									
2									
3									
4									
5									