Atomic Spectra: Energy, Light, and the Electron

Introduction:

An atom consists of a nucleus, containing protons and neutrons, and tiny electrons, which move around the nucleus. Picture a beehive where the hive is the nucleus and the bees are the electrons! Atoms are most stable when the electrons are in the ground state close to the nucleus. When energy is applied to an atom, electrons will jump further from the nucleus into an excited state. This movement of electrons make the atom more unstable, so the electrons quickly relax back into the more stable ground state. As the electrons relax back to the ground state, energy is released as photons. Some of the photons released have wavelengths in the visible region of the electromagnetic spectrum. The various regions of the electromagnetic spectrum can be seen in Figure 1.

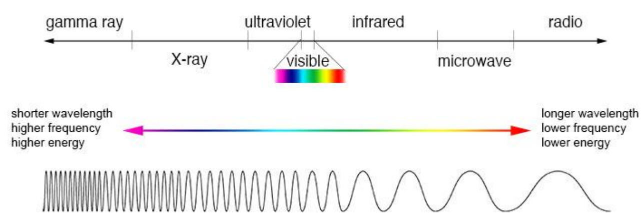

Figure 1. Regions of the electromagnetic spectrum.
https://imagine.gsfc.nasa.gov/Images/science/EM_spectrum_compare_level1_lg.jpgm

The photons released produce an emission spectrum. For example, Line A in the emission spectrum shown in Figure 2 represents when electrons relax from an excited state to the ground state. The electrons that release the most energy when they relax will produce photons that have the longest wavelength. So more energy is released for line A than for line B.

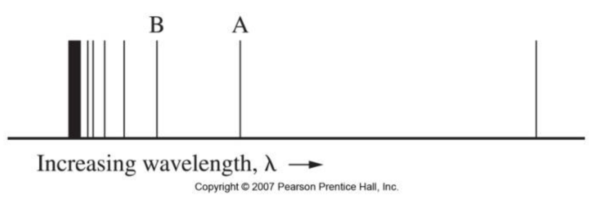

Figure 2. An examples of an emission spectrum

What's cool is, electrons in each atom behave differently, which means every atom will produce a different emission spectrum, much like a finger print. In this lab, you will see emission spectra using electric current in a plasma lamp. The lamp, which contains a thinly dispersed gaseous element, is used to excite the valence electrons of the gaseous element. When the electrons relax from the excited state, they will emit light in the visible region of the spectrum. We will be using spectroscopes to view the spectrum produced by these lamps. Figure 3 shows a diagram of the spectroscope works.

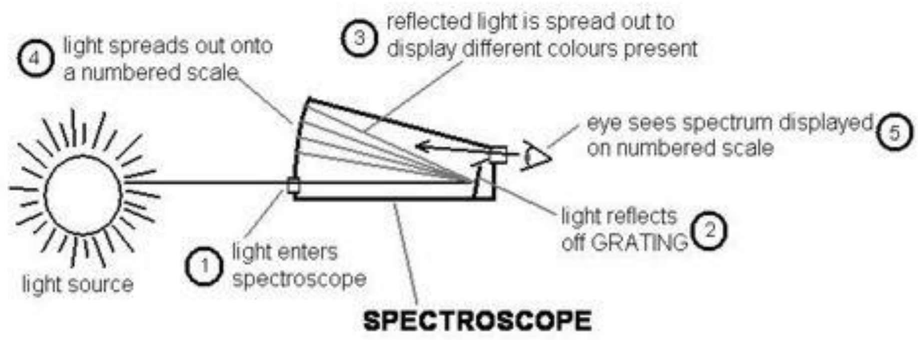

Figure 3. Diagram of a spectroscope, from: http://wikieducator.org/images/thumb/f/f4/Chemistry_-_Observing_Light_Spectrum_3.JPG/500px-Chemistry_-_Observing_Light_Spectrum_3.JPG

Since atoms behave differently when heated, the flame test can be used to determine the identity of ions or atoms in a solution. A flame test is performed by placing a compound containing a metal ion in a flame. For different atoms in the flame, energy transitions can occur from one atom to another, but the transitions will not be equal in magnitude. The unequal magnitudes of energy manifest themselves as different colors of light emitted by the free, gaseous atoms in the flame. This process accounts for the various colors emitted by fireworks, which contain a mixture of metal salts. The entire process is called flame emission and has the following significance: No two unlike elements can emit identical wavelengths (or colors) of light in a flame. For more information on flame colors see: http://www.compoundchem.com/2014/02/06/metal-ion-flame-test-colours-chart/

The unique colors of light emitted by metals can be effectively and easily used as an identifying test for the presence of the metal in a substance. With the proper equipment and conditions, the flame emission tests can also be used to quantitatively measure the amount of metal present in the substance.

In this lab, a salt, such as lithium chloride (LiCl) will be dissolved in water, the salt, in water, breaks into the cation, Li^+ and the anion Cl^-. Shown in equation 1.

$$LiCl\,(aq) \longrightarrow Li^+\,(aq) + Cl^-(aq) \qquad \text{Eqn 1.}$$

You will be preforming a flame test on several dissolved salts. The major difference between these salts is the cation, so the observations you have will be based solely on which cation is present. This is how fireworks work, the cation present in the mixture determines the color of the firework. For more information on firework colors and the environmental effect fireworks have, see http://www.compoundchem.com/2017/01/05/fireworks-environment/

In-Lab Experiment

Chemicals:
1 M Lithium Chloride ($LiCl$)
1 M Barium Chloride ($BaCl_2$)
1 M Calcium Chloride ($CaCl_2$)
1 M Strontium Chloride ($SrCl_2$)
1 M Copper Chloride ($CuCl_2$)
1 M Sodium Chloride ($NaCl$)
1 M Potassium Chloride (KCl)

Special Materials:
Q-tips
Cobalt glass
Lighting a Bunsen Burner Consult website for directions on proper handling:
http://chemlab.truman.edu/files/2015/07/Common-apparatus-and-procedures.pdf

Procedure:
You can start with step I or II first.
I. Flame Emission

Burners will be set up in the hoods. Use proper caution around flames (watch long hair, clothing, etc.). A q-tip will be in a test tube attached to each solution. Light the Bunsen burner. Find the q-tip next to the solution bottle. Dip the q-tip into the solution and put the q-tip in the flame. Observe the color of the flame and record your observations. For potassium, view the emission and then view it again through a piece of cobalt glass. See any difference? Return the q-tip to the test tube on the side of the solution container provided.

There are six unknowns. Perform a flame emission test on all six of the unknowns. Determine the identity of two unknowns, be sure to record the number of your chosen unknowns.

II. Plasma Emission

Obtain a spectroscope from your professor. To practice using the spectroscope, go in the hall and look at one of the lightbulbs on the wall. Hold the spectroscope horizontal with the narrow end towards you and the opposite side of the spectroscope. See Figure 3 for a diagram of how the spectroscope works. Place your eye near the small square on the narrow end of the spectroscope. Point the other end of the scope centering the small slit on the light bulb you wish to analyze. You should be able to see bands of colors with numbers increasing from left to right. If you don't switch spectroscopes with your lab partner and see if the view is different. Once you are successful in the hallway, go back to the lab.

There is an on/off switch on the side of each lamp. Turn off the lamp when you aren't using it. Walk around the lab and observe and record the colors of the gases in the arc lamps. These gases include helium (He), Hydrogen (H), Mercury (Hg), and Neon (Ne). IMPORTANT! The lamps should only be handled by the instructor or TA ONLY

Record what colors you see and in what order the colors appear. Describe the differences between any two of the lamps 1. Without the spectroscope 2. With the spectroscope.

Name ______________________________ Chem 100 Data Sheet

I. Flame emission

Observations of known metal ions:

Li^+ ____________________________

Ba^{2+}____________________________

Ca^{2+}____________________________

Sr^{2+}____________________________

Cu^+____________________________

Na^+____________________________

K^+ ____________________________

Describe the theoretical electronic process you are seeing when you look at the metal ions in the flame:

Why should you not use the same q-tip to test two different chemicals?

Determine the identity of the metal ion in two of the unknown compounds:

1. Observations of unknown #_____:

Identity of cation:____________

2. Observations of unknown #_____:

Identity of cation: ____________

II. Plasma emission

a. Unaided visual observation (without spectroscope)

Helium____

Hydrogen____

Mercury____

Neon____

Argon____

b. Aided visual observation (with spectroscope). Fill in units on the axis. Line intensity is important!

Helium

Hydrogen

Mercury

Neon

Argon

On the scale below, roughly draw the emission spectrum of a hypothetical element. This element only emits three wavelengths of light, but its net emissions appear white to the human eye. How can this occur? Indicate your reasoning.