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.

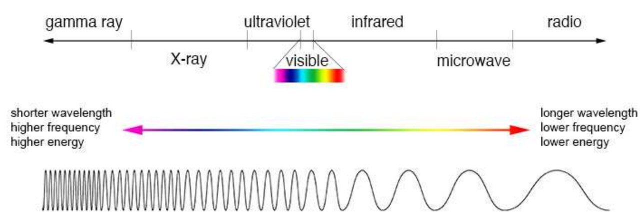


Figure 1. Regions of the electromagnetic spectrum[1]

The photons released produce an emission spectrum. Each vertical line in the emission spectrum shown in Figure 1 represents a photon emitted when an electron 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.

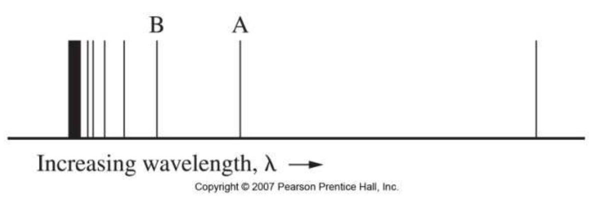


Figure 1. An examples of an emission spectrum

The observably cool thing is, electrons in each atom behave differently, which means every atom will produce a different emission spectrum, much like a fingerprint. In this lab, you will see emission spectra produced using electric current in a plasma lamp. The lamp bulb contains a thinly dispersed gaseous element, and high voltage is used to excite the valence electrons of the gaseous element. When the electrons relax from the excited state, they emit light in the visible region of the spectrum. We will be using spectroscopes to view the spectrum produced by these lamps.

Since electrons can also be excited by heat, a flame test can also be used to determine the identity of ions or atoms in a solution. A flame test is performed by placing a sample containing a metal ion into a flame. For an atom in the flame, energy transitions can occur from any one orbital to any another higher energy orbital, but the transitions will not be equal in magnitude. The unequal magnitudes of energy manifest themselves as different colors of light emitted by the 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 significance that no two unlike elements can emit identical wavelengths (or colors) of light when heated. For more information on flame colors see: http://www.compoundchem.com/2014/02/06/metal-ion-flame-test-colours-chart/

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

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

You will be performing flame tests on several dissolved salts. The difference between these salts is the cation (they all have chloride as the anion), so the observations you have will be based solely on which cation is present.

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:
Application swabs
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:
I. Flame Emission

Burners will be set up in the hoods. Use proper caution around flames (be aware of long hair and clothing near flames, etc.). Light the Bunsen burner. An application swap will be in a test tube attached to each solution. Dip the swab into the solution and hold the swab in the flame. Observe the color of the flame and record your observations. View the potassium chloride emission and then view the emission (flame) through a piece of cobalt glass. See any difference? Return the swab in the container provided. Do not put a hot swab in the trash can.

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 the unknowns you determined on your data sheet.

II. Plasma Emission

Obtain a spectroscope from your professor. Hold the spectroscope horizontal with the narrow end towards you and the opposite side of the spectroscope pointing to the right. Place your eye near the small square on the narrow end of the spectroscope. Point the other end of the scope in the direction of the light source 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.

Walk around and observe and record the colors of the gases in the arc lamps. These gases include argon (Ar) helium (He), hydrogen (H), mercury (Hg), and neon (Ne).

IMPORTANT! The lamps should ONLY be handled by the instructor or TA.

Record the colors you see and record in what order the colors appear. Describe the differences between any two of the lamps, first without the spectroscope, and second, 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 wire loop or q-tip to test two different chemicals?

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

1. Observations of unknown #_____:

Identity of cation:____________

2. Observations of unknown #_____:

Identity of cation: ____________

II. Plasma emission

a. Unaided visual observation color (without spectroscope)

Helium____

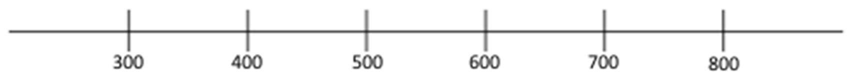
Hydrogen____

Mercury____

Neon____

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

Helium

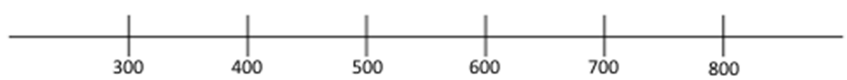


Hydrogen

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? Give your reasoning.