Flame Tests of Metal Cations

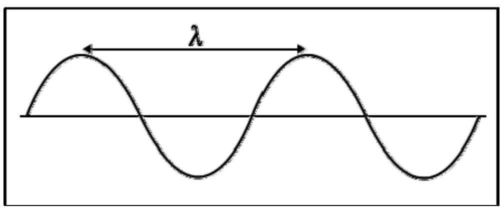
Objectives

The objectives of this lab are to:

a) Perform flame tests of metal cations in order to observe their characteristic colors,
b) Match the flame colors observed to an appropriate wavelength of visible light, and then perform calculations to determine the frequency and energy of the emitted photons,
c) Relate these results to the types of electronic transitions occurring in these elements,
d) Practice writing electron configurations for these (and other) elements.

Background

Electromagnetic radiation is composed of perpendicular waves oscillating in the electric and magnetic fields (through space or matter). These waves are characterized by their wavelength (λ) and frequency (υ). Wavelength is defined as the distance between successive crests (or troughs) on a wave, and is measured in meters. Frequency is defined as the number of waves that pass a given point every second, and is measured in 1/seconds, or Hertz (Hz).



All electromagnetic waves travel at the speed of light (c), or 2.998 x 10^8 m/s. The relationship between the wavelength, frequency and speed of an electromagnetic wave is given by the equation:

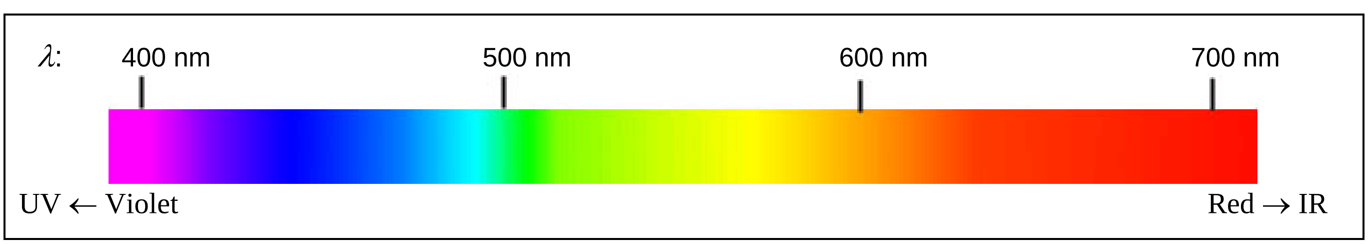
$$c = \lambda \times \upsilon$$

Electromagnetic radiation also occurs as discreet packets of energy (or quanta) called photons. The energy per photon (in Joules) is given by the equation:

$$E_{photon} = h \times \upsilon$$

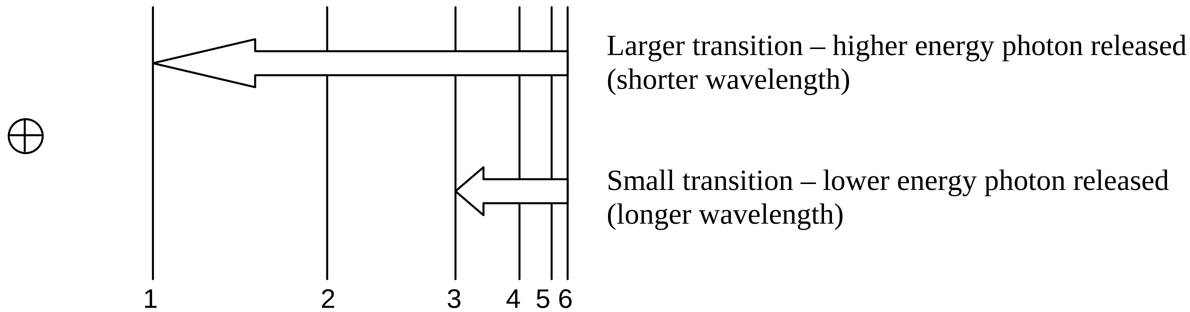
Here, h is Planck's constant, which has a value of 6.626 x 10^{-34} J•s.

Visible light is the most familiar example of electromagnetic radiation. Differences in the wavelengths of visible light are manifested as different colors, shown in the Color Spectrum below (colors can be seen in the PDF document on-line). Other examples of electromagnetic radiation include X-rays, ultraviolet light, infrared light, microwaves and radio waves.

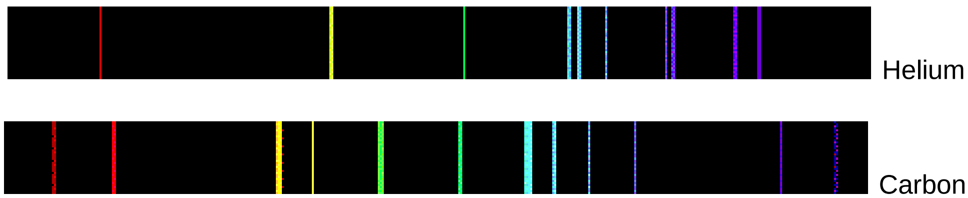


So, how does electromagnetic radiation relate to flame tests? Well, when an atom (or ion) absorbs energy, its electrons can make transitions from lower energy levels to higher energy levels. The energy absorbed could be in the form of heat (as in flame tests), or electrical energy, or electromagnetic radiation. However, when electrons subsequently return from higher energy levels to lower energy levels, energy is released predominantly in the form of *electromagnetic radiation*.

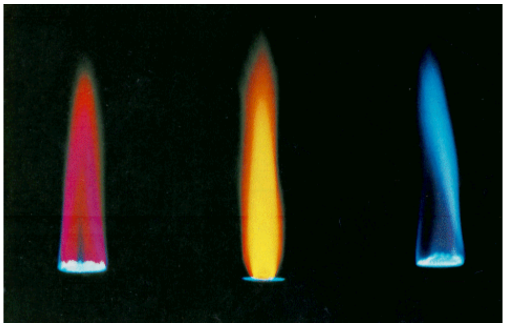
The spacing between energy levels in an atom determines the sizes of the transitions that occur, and thus the energy and wavelengths of the collection of photons emitted:



If emitted photons are in the visible region of the spectrum, they may be perceived as lines of different colors (note that photons outside the visible spectrum may also be emitted, but cannot be seen by eye). The result is called a *line emission spectrum*, and can serve as a 'fingerprint' of the element to which the atoms belong. For example, the line spectra shown below for the elements helium and carbon are clearly quite different.



Unfortunately, techniques more sophisticated than those used in this lab are required to obtain such line spectra. To the naked eye, when an element is vaporized in a flame (or an electrical discharge) the emission spectrum will appear to be just *one color*. For example, helium gas when excited by an electrical discharge emits light that appears an orange-peach color. This one color results from a *combination of all lines* of the emission spectrum, in proportion to their intensities. As many elements will still produce distinctive colors under such conditions, simple flame tests can be used to identify these elements. In fact, flame tests were used to identify elements long before the invention of modern techniques, such as emission spectroscopy.



Procedure

Safety

Exercise appropriate caution when using the Bunsen burner.

Materials and Equipment

Looped platinum or nichrome wires, wash bottle with distilled water, Bunsen burner, and the following solutions: LiCl (*aq*), NaCl (*aq*), KCl (*aq*), $CuCl_2$ (*aq*), $BaCl_2$ (*aq*), $CaCl_2$ (*aq*).

Experimental Procedure

This experiment will be performed as an instructor demonstration only.

Your instructor will dip a looped wire into one of the solutions supplied, and then hold it in the Bunsen burner flame. Students will record the dominant flame color observed. The table below contains a list of appropriate colors to choose from. Your instructor will then repeat this for the remaining five solutions, using a fresh looped wire each time.

Analysis: For each metal cation tested, obtain the wavelength of light corresponding to the observed flame color from the table below. Note that the wavelengths supplied here are in nanometers. Using these wavelengths, calculate the frequency and energy of the photons emitted during the flame tests. Finally, answer the questions and perform the exercises as indicated on your Report form.

Dominant Color	Approximate Wavelength (in nm)*
Red	701
Red-Orange	622
Orange	609
Orange-Yellow	597
Yellow	587
Yellow-Green	577
Green	535
Green-Blue	492
Blue	474
Blue-Violet	455
Violet	423

*****Wavelength values here are given for the mid-range of the color indicated.