NAME: ______________________________ DATE: _______________ PERIOD: _____

FLAME TESTS

ATOMIC EMISSION AND ELECTRON ENERGY LEVELS

20 POINT LAB

BACKGROUND

Just as a fingerprint is unique to each person, the color of light emitted by an element heated in a flame is also unique to each element. In this experiment, the characteristic color of light emitted by calcium, copper, lithium, potassium, sodium, and strontium ions will be observed.

When a substance is heated in a flame, the atoms absorb energy from the flame. This absorbed energy allows the electrons to be promoted to excited energy levels. From these excited energy levels, there is a natural tendency for the electrons to make a transition or drop back down to the ground state. When an electron makes a transition from a higher energy level to a lower energy level, a particle of light called a photon is emitted (see figure 1). Both the absorption and emission of energy are quantized – only certain energy levels are allowed.

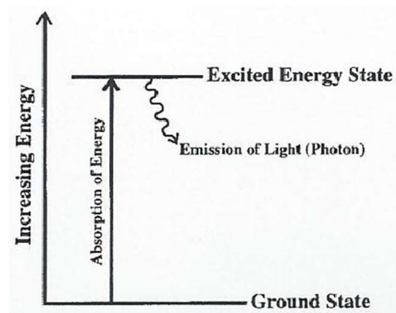

Figure 1. Absorption and emission of energy.

An electron may drop all the way back down to the ground state in a single step, emitting a photon in the process. Alternatively, an electron may drop back down to the ground state in series of smaller steps, emitting a photon with each step. In either case, the energy of each emitted photon is equal to the difference in energy between the excited state and the state to which the electron relaxes. The energy of the emitted photon determines the color of light observed in the flame. The flame color may be described in terms of its wavelength, and equation for photon energy maybe be used to calculate the energy of the emitted photon.

Equation 1. Photon Energy

$$\Delta E = \frac{hc}{\lambda}$$

ΔE is the difference in energy between the two energy levels in joules (J),

h is Planck's constant ($h=6.626 \times 10^{-34}$ J·sec),

c is the speed of light ($c = 2.998 \times 10^{8}$ m/sec), and

λ (lambda) is the wavelength of light in meters. The wavelengths of visible light are given in units of nanometers ($1 \text{ m} = 1 \times 10^{9}$ nm). See Table 1 on the following page.

The color of light observed when a substance is heated in a flame varies from one substance to another. Each element has a different spacing of electron energy levels, therefore the possible electron transitions for a given substance is unique. This means that the corresponding wavelength and color are unique to each substance. As a result, the colors observed when a substance is heated in a flame may be used as a means of identification.

The Visible Portion of the Electromagnetic Spectrum

Visible light is a form of electromagnetic radiation. Other familiar forms of electromagnetic radiation include X-rays, ultraviolet (UV) radiation, infrared (IR) radiation, microwave radiation, and radio waves. Together, all forms of electromagnetic radiation make up the electromagnetic spectrum. The visible portion of the electromagnetic spectrum is the only portion that can be detected by the human eye—all other forms of electromagnetic radiation are invisible.

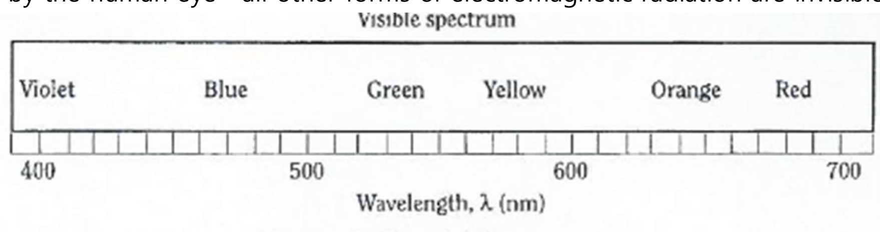

Figure 2. The visible spectrum.

The visible spectrum spans the wavelength region from about 300 to 700 nm (Figure 2). Light of 400 nm is seen as violet and light of 700 nm is seen as red. According to Equation 1, wavelength is inversely proportional to energy. Therefore, violet light is higher energy light than red light. As the color of light changes, so does the amount of energy it possesses.

Table 1 lists the wavelengths associated with each of the colors in the visible spectrum. The representative wavelengths may be used as a benchmark for each color. For example, instead of referring to green as light in the wavelength range 500-600 nm, we may approximate the wavelength of a green light as 520 nm. An infinite number of shades of each color maybe observed.

Table 1.

Representative Wavelength, nm	Wavelength Region, nm	Color
410	400-425	Violet
470	425-480	Blue
490	480-500	Blue-green
520	500-560	Green
565	560-580	Yellow-green
580	580-585	Yellow
600	585-650	Orange
650	650-700	Red

Refer to your textbook or an online image for an expanded figure of the energy and wavelength of electromagnetic radiation. It is important to note that the visible spectrum is only a very small region of the electromagnetic radiation spectrum.

SAFETY PRECAUTIONS

Copper (II) chloride is highly toxic by ingestion; avoid contact with eyes, skin and mucous membranes. Lithium chloride is moderately toxic by ingestion and is a body tissue irritant. Fully extinguish the wooden splints by immersing them in a beaker of water before discarding them in the trash to avoid trash can fires. Wear chemical splash goggles. You may wear a chemical-resistant apron to help protect your clothes. Wash hands thoroughly with soap and water before leaving and laboratory.

PRE-LAB QUESTIONS

Answers to the following before you start your laboratory:

1. *(Fill in the blanks)* When an atom absorbs energy, the electrons move from their _______________ state to a(n) __________________ state. When an atom emits energy, the electrons move from a(n) ____________________state to their ________________ state and give off ____________________. *(1 pt)*
2. Is a flame test a qualitative test or quantitative test for the identity of an unknown? Explain. *(1 pt)*
3. Explain the hazards and procedures associated with the following, answer in full coherent sentences: *(2 pts)*
   a. Copper (II) chloride:
   b. Lithium chloride:
   c. Burning wood splint:
   d. Mandatory and optional safety equipment:
4. Have your teacher initial before you start the laboratory: __________ *(1 pt)*

Materials

- Calcium chloride, $CaCl_2{\cdot}2H_2O$, 0.5 g
- Copper (II) chloride, $CuCl_2{\cdot}2H_2O$, 0.5 g
- Lithium chloride, LiCl, 0.5 g
- Potassium chloride, KCl, 0.5 g
- Sodium chloride, NaCl, 0.5 g
- Strontium chloride, $SrCl_2$, 0.5 g
- Barium chloride, $BaCl_2$, 05 g
- Unknown metal chloride, 0.5 g
- Dried fruit (banana, apricot, ect.)
- Tongs
- 8 Beakers, 250-mL
- Laboratory burner
- Scoop or spatula
- 8 wooden splints
- Water, distilled or deionized

Procedure

Preparing the solutions:

1. Label eight 250-mL beakers Ca, Cu, Li, Na, K, Sr, Ba and unknown.
2. Scoop ~0.5 grams of solid metal chlorides to each corresponding beaker.
3. Add distilled or deionized water to the beakers until they are about half-full
4. Place a wooden splint in each beaker.

Testing:

5. Light the laboratory burner.
6. Take one of the wooden splints in one of the metal chlorides, then place it in the flame. Try not to burn the splint but let the fire run over any salt crystals that might be built up on the splint. If necessary, repeat the test with the same splint and additional salt.
7. Record your observations for the flame color produced by the metal chloride in a data table.
8. Repeat and record the flame test for all of the known metals.
9. Perform a flame test on an unknown metal chloride and record its characteristic color(s) in the data table.
10. Perform a flame test on the dried fruit(s) by holding the fruit with a pair of metal tongs and record its characteristic color(s) in the data table.

Mr. Rast Note: To avoid having the metal salts fall into the burner and contaminate the fame colors, clamp the barrel of the laboratory burner to a ring stand at a 45˚ angle. The flame colors for many of these metal ions are very stable. Copper is an exception—the color of the copper flame changes quickly as copper compound begins to burn.

Name: ______________________________ Date: _______________ Period: _____

Data

(2 pts)

Sample	Color of Flame

CALCULATIONS

RESULTS TABLE

Sample	Metal/Flame Color	λ (nm)	λ (m) (scientific notation)	ΔE (J)

1. Use Table 1 in the *Background* section to record the approximate wavelength of light emitted for each known metal ion in the Results Table. *(1 pt)*
2. Convert each wavelength in the Results Table from nanometers to meters. Remember that 1 *nm* = 10^{-9} *m.* Show one sample calculation and record all values in the Results Table. *(2 pts)*

3. Use Equation 1 from the *Background* section to calculate the average energy (ΔE) corresponding to the observed flame color for each sample. Show one sample calculation and then record all values in joules in the Results Table. *(2 pts)*

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Analysis

Write the questions and answers to the following OR answer in complete sentences that reiterate the original question:

1. What evidence is there from your results that the characteristic color observed for each compound is due to the metal ion in each case? Describe and additional test that could be done to confirm that the color is due to the metal ion and not the chloride ion. *(2 pts)*

2. A glass rod was heated in a burner flame and gave off a bright yellow flame. What metal ion predominates in the glass rod? *(2 pts)*

3. The alkali metals cesium (Cs) and rubidium (Rb) were discovered based on their characteristic flame colors. Cesium is named after the sky and rubidium after the gem color. What colors of light do you think these metals give off when heated in a flame? *(2 pts)*

4. Based on your experimentation, what would be the primary element in the: *(2 pts)*
    a. unknown solution?

    b. Dried fruits? List all that were used.