Flame Test

**Objective**

In this lab students will learn about atomic energy levels, emission spectroscopy, and flame tests for element identification.

**Overview**

Students will use small samples of 6 chloride salts of different metals. These they will place into a flame in order to observe the colors produced. These colors come from the excitation of electrons which then resume their ground states by emitting light of very specific colors.

**Background**

The electrons in an atom occupy different energy levels, as you know. When all of the electrons are at the lowest possible energy level they are said to be in the **ground state**. Electrons do not always stay in the ground state. Sometimes they can be promoted to a higher-energy electron shell. This can happen in two ways. First, the electron can absorb a photon of just the right amount of energy to move it from one quantum shell to another. Second, when atoms are heated or energized with electricity their electrons can gain energy. This promotes them to the higher-energy shell. When an electron is in a higher-energy shell it is said to be in an **excited state**.

Electrons in excited states do not usually stay in them for very long. When electrons lose their energy they do so by emitting a photon of light. Photons are particles with energy but no mass. Their energy is directly proportional to the frequency of the light (remember: E = hf). The photons emitted precisely match the quantum energy difference between the excited state and the ground state.

The light produced by very hot atoms in the gaseous state is a unique spectrum for each element. To observe the spectrum requires the use of a prism, diffraction grating, or spectroscope. Before, complex instruments were invented to observe elemental spectra chemists sometimes identified metals in compounds by doing a flame test. Salts are a type of compound which include a metal and a non-metal. Sodium chloride (NaCl) is the most familiar example of a salt but others include calcium chloride(CaCl2) and copper(II) chloride (CuCl2). In flame tests salts that are dissolved in water are evaporated using a hot flame. In the flame the metal atoms become excited and produce their characteristic spectrum of light. However, since the observer does not use a spectroscope only one color is observed. It turns out that many metals produce a unique single color under these conditions. Some metals do produce very similar colors but a practiced eye can often distinguish them. It is a traditional art of the chemistry laboratory to use these colors to identify specimens of compounds that contain unknown metals.

This ability of metal atoms to produce these colors is put to use by practitioners of the art of fireworks manufacture. By including different metal salts, or mixtures of metal salts, in the exploding shell of a firework, these artists can produce beautiful displays in nearly all the colors of the rainbow.

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| --- | --- | --- | --- |
| Representative wavelength, nm | Wavelength Region, nm | Energy | Color |
| 410 | 400-425 | Highest | 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 | Lowest | Red |

**Materials**

* 7 small beakers
  + one for distilled water
  + 6 for the metal chlorides
* 1 inoculation loop
* 1 Bunsen burner
* sharpie for labeling
* matches
* distilled water
* a series of metal chlorides such as CaCl2, CuCl2, LiCl, KCl, NaCl, and SrCl2
* 2 unknown metal chlorides

**Safety**

* Wear goggles or risk sitting out the lab
* Treat all chemicals in this lab as toxic. Do not touch any of them with your bare hands.
* Wash well with water immediately if you touch chemicals accidentally
* Use caution with the burner
  + Do not leave burner unattended
  + Place burner near middle of lab bench
  + Tie back long hair
  + Do not wear baggy clothing in the lab
  + Hot objects look like cold objects: be cautious!
* CuCl2 (Copper(II) Chloride) is highly toxic by ingestion; avoid contact with eyes, skin and mucus membranes.
* LiCl (Lithium Chloride) is moderately toxic by ingestion; avoid contact with eyes, skin and mucus membranes.
* Wash your hands with soap and water after you complete the day’s lab work, even if you didn’t touch any chemicals directly.

**Procedure**

Remember to record your observations in your lab notebook before you leave class. When making observations, be sure to use all of your senses except taste. Never taste anything in the chemistry lab. Chances are good you will regret it if you do.

1. Label all nine of your beakers. Label six of them with the chemical formulas of the six salts to be used in the lab. Label one for the water rinse. Either 50-mL or 100-mL beakers will be fine.
2. Collect a small sample (less than 2 mL) of each of the known metal salt solutions which your teacher has provided and carry them all to your lab bench.
3. Obtain an inoculation loop for your group.
4. Obtain 10 - 20 mL of distilled water in your labeled beaker.
5. Each group member must record information in a neat table with the following columns. Make this table before you even turn on the gas.
   1. Name & Formula of Metal Chloride
   2. Metal Ion
   3. Color of Flame
   4. Approx. Wavelength (nm)
   5. Approx. Wavelength (m)
6. Clean the inoculation loop by swirling it gently in the distilled water. Then, once you light the burner, heat the loop until it glows red hot. This step removes any ions clinging to the loop from previous experiments.
7. Light and adjust your Bunsen burner. Be sure to clean your loop carefully. Do not leave the loop in the flame too long as it can cause the loop to degrade and break.
8. To do a flame test with each metal salt get a film of the solution of a salt inside the loop and bring it into the hottest part of the flame. If this produces poor color then try the edge of the burner flame. Repeat the dip into the salt solution as often as necessary to see the flame test color. Be sure not to over-heat the loop.
9. Carefully note the color of each metal salt when it is put in the flame. Use the chart on the previous page to estimate the approximate wavelength of the color you see. Use the Representative Wavelength values. Record all data in the table you made earlier.
10. Clean the inoculation loop using distilled water and heat each time you change from one metal salt to another. Failing to do so will result in mixed flame test colors. Again, do not over heat the loop.
11. Clean out the beaker using the method recommended by your instructor (hazardous wastes must be disposed of properly). Usually, all leftover solutions will be collected in designated waste containers for hazardous waste disposal.
12. Wash all equipment carefully and thoroughly using the tub of soapy water provided. By gently scrubbing the beakers with a brush and the soapy water you will be able to wash off the labels you put on them. Please do so!
13. Your teacher has prepared two solutions with two of the metal salts. They are labeled Unknown 1 and Unknown 2. Your teacher will demonstrate their flame test colors for the entire class.
14. As a class, discuss which element you think the unknowns represent and ask your teacher to demonstrate the flame test colors of the elements you think are the correct ones. Use a deductive process to narrow down the possibilities and be sure to do so based on comparison to known flame test colors.

**Questions**

1. Why do different metals have different characteristic flame test colors?
2. Most salts contain a metal and a non-metal. Look at the compounds we tested and determine whether it is the metal or the non-metal that is responsible for the color produced in the flame test for that salt. How can you be sure your answer is correct?
3. What colors did the unknowns produce in the flame? What are the unknowns?
4. Why do the chemicals have to be heated in the flame before the colored light is emitted?
5. Could flame tests be useful in determining identities of metals in a mixture of two or more salts? If so, what problems might arise? If not, why not? Explain your answer.
6. Which method is better for precisely identifying elements: examining the full spectrum using a spectroscope or using a flame test? Use your experience in the lab with both of these methods in answering this question. Justify your answer.