Part 1: Background Information and Context

Activity
Colored Flames
This activity explores the emission of various colors of light by igniting metal salts. The flame used is a source of energy which will cause the electrons in a metal ion to jump up to an excited state. When the electrons come back down from their excited state, they give off light. This process of electrons changing state from "relaxed" to "excited" is known as quantum mechanics. Depending on the element in the salt used, observers will see different colors of light emitted as the salt is combusted. From this activity, observers will learn that thermal energy raises electrons in metal atoms to a higher energy state. And that when the electrons come back down from this higher energy state, they will emit energy in the form of light to return to the more stable ground state.

Suggested NGSS Dimensions to Address (click on the titles to learn more from the K-12 Framework)

Science and Engineering Practices

- Asking Questions
  - Students can observe the flame tests or conduct them in pairs, make observations, and ask questions.
- Modeling
  - Students could model what they think may happen if an atom is exposed to a high amount of energy. A lesson sequence on general atomic structure would need to precede this lesson sequence to make this possible. The students should have more experiences to strengthen their model and revise over time.
- Carrying Out Investigations
  - Students could conduct the experiment to make individual observations and collect data.
- Constructing Explanations
  - After students have seen the flame tests and have participated in other experiences (consider Colorful Gases), they could explain how the flame test experiment works using their revised models.

Disciplinary Core Ideas

- PS1.A Structure of matter
  - 9-12: The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter, including chemical reactions and nuclear processes. Repeating patterns of the periodic table reflect patterns of outer electrons. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy to take the molecule apart. (HS-PS1-1)
- PS4.A Wave Properties
  - 9-12: The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the medium through which it is passing. Waves can be used to transmit information and energy. (HS-PS4-3)
- PS4.B Electromagnetic Radiation
  - 9-12: Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation. (HS-PS4-3)

Crosscutting Concepts

- **Cause and Effect**
  - Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
- **Systems and System Models**
  - Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering
- **Energy and matter: Flows, cycles, and conservation**
  - Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

Part 2: Lesson Facilitation for Phenomenon

Teacher Background

All atoms have electrons traveling around their nucleus in what is called orbitals. These orbitals are areas around an atom in which the electrons have the highest probability of being found. There are many different orbitals found within an atom and each orbital has its own specific energy level associated with it. Provided enough energy, electrons can go up in energy levels. However, electrons prefer to be in lower energy levels and as a result, they fall back down to their lower energy levels. When this process happens, electrons emit electromagnetic radiation (light) with energy that is proportional to the difference in energy levels that the electron has traveled. Furthermore, each element has its own unique ground state energy level which means that every element emits its own unique spectra of light when its electrons undergo a transition in energy levels.

Materials

1. 5 liters Methanol
2. 5 spray bottles (1/2 liter each)
3. Bunsen burner or propane torch
4. 50 g lithium chloride
5. 50 g copper sulfate
6. 50 g sodium chloride
7. 50 g potassium chloride
8. 50 g magnesium sulfate
9. 50 g Borax
10. Protective gloves
11. 5 Safety goggles
12. Blast shield to protect the audience

Procedures

The below write-up is best designed for a high school-level chemistry class, not for elementary or middle school students, and it should be conducted by an experienced chemistry teacher. An alternative approach to this activity that can be conducted at the middle school level is to take a piece of nichrome wire and embed it in a wooden dowel. Prepare the same solutions as below except omit the methanol. Take the wire loop and heat it in a propane flame. Dip the wire loop in one of the metal salt solutions and then place the wet loop in the propane flame. The flame will take on a color characteristic of the element.

1. Use nitrile gloves and wear goggles when preparing the salt solutions!
2. Take 25 g of lithium chloride salt, add it to a ½ L spray bottle and add 200 mL of water. Shake well to dissolve the salt.
3. Then, fill the spray bottle with methanol, put the spray lid on the bottle and shake to mix the lithium chloride salt solution.
4. Repeat step 2 for all five salts. For the copper sulfate solution, add 25 g of Borax for green color.
5. Before you conduct the activity, make sure the audience is 5-10 feet away.
6. Behind a blast shield and wearing a flame-proof lab coat, nitrile gloves, goggles, and a face protector, ignite the Bunsen burner or propane torch and carefully spray each respective salt into the flames to demonstrate the colors given off by the metal ions.

Reference Material

http://www.instructables.com/id/How-to-make-colored-flames/

Safety Concerns
Avoid ingestion and skin contact of methanol and salt solutions. If ingested, seek medical help immediately. If skin contact occurs, wash contaminated area with water for at least 15 minutes. Keep away from the flame of the Bunsen burner. Methanol is extremely flammable and burns with nearly colorless flame that is difficult to see. The presenter should make sure that the students are a safe distance from the Bunsen burner and that the students only spray the flame with the salt solutions. Make sure students are wearing eye protection. Have students wash their hands after the activity. This activity should only be conducted with a teacher/ supervisor who has a background in science.

Reference Material
http://www.sciencelab.com/msds.php?msdsId=9927227

3-Dimensional Questions

1. What do you notice about the flames?
2. What do you wonder about the flames?
3. What does this activity remind you of?
4. Based on your observations, what do you think is causing the appearance of the flames to change?
5. What does the heat provide to the reactants in the reaction?

5E Model Alignment/Suggestions

Phenomenon: Fireworks as a phenomenon would work well here.
Engage:
Consider using this activity as a demonstration and having students **ask questions** about what they see through a prompt such as "Make 5 observations and 3 questions about the following demonstration". Consider having the students make a general **cause and effect** statement that unites all of the flame tests i.e. "Heating different metal salts causes the flames to turn different colors."
Explore:
1. Students could **conduct** this experiment on their own and collect data to analyze for cause and effect relationships.
2. After conducting an investigation, students could **model** what they think is happening to the atom when energy is added. In order for this to be a reasonable task, students should have prior experiences modeling the general structure of atoms.

Explain:
After further explorations in this area (consider Colorful Gases) and teacher instruction, the students can **construct an explanation** of how the different metal salts produce different colored flames when exposed to a large amount of energy.