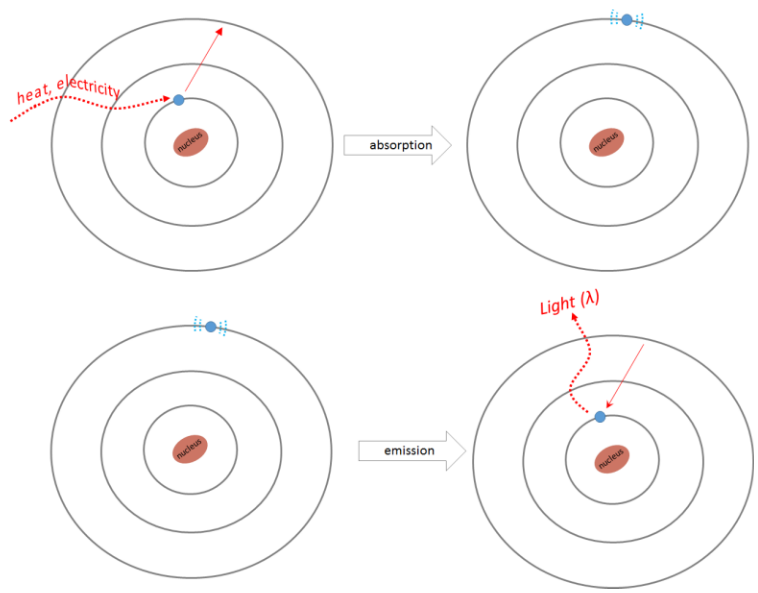
Flame Tests

But these three men, Sidrach, Misach, and Abdenago, fell down bound in the midst of the burning fire. And they walked in the midst of the flame*, praising God and blessing the Lord.* **Daniel 3:23**

Introduction



Atoms consist of a nucleus with electrons moving around it at different energy levels. In general, the farther away from the nucleus electrons are, the more energy they possess. Electrons may absorb energy, whether that energy comes from heat or electricity or light, by interacting with the substance of which they are part. When electrons in an atom absorb *enough* energy, they will jump from the current energy level to a higher energy level, away from the nucleus. This is an unstable state. At some point, the electrons will fall from the excited energy level to the original energy level while releasing the same amount of energy that had been absorbed. Some of the energy released is often in the form of light energy corresponding to a specific wavelength (or frequency). The greater the distance between the excited energy level and the original energy level, the greater the energy (or frequency) that is emitted.

The different colors of visible light vary in the energy they contain. The colors of the rainbow (Red, Orange, Yellow, Green, Blue, Indigo, Violet) are on an energy spectrum where red light has the lowest energy and violet has the highest. When an atom emits red light (after being exposed to heat) it indicates that an electron has fallen a relatively short distance from its excited energy level to its original energy level. The emission of yellow light would indicate that a greater distance had been covered, and violet would correspond to an even greater distance.

Metal atoms may emit several colors and the blend acts like a fingerprint. Different metal atoms produce different colored light patterns when exposed to a flame. If we observe the color of light made when a solution of metal is heated in a flame, we can tell which metal is present. You will obtain your metal solutions in the form of different salts that will be made into aqueous solutions. Recall that a salt is an ionic compound between a metal and a non-metal (or polyatomic ion). When in solution, the metal cation is disassociated from the non-metal ion. This makes it easier to observe the colored flames in some instances

Learning Objectives:

- Observe the energy emitted from different energy levels when salt compounds are ignited

Safety ⚠

- Both lighter and flames can cause burns to skin and clothing – wear protective clothing.
- Perform in open area and have a water source available to extinguish flames.
- Do not let flame near surrounding flammable materials

Materials Required:

From Chemistry Kit	Student Supplied
Safety Glasses and gloves	Distilled water
Copper(II) sulfate	Metal tweezers
Calcium chloride	Sticks [toothpicks; cheap, wooden chop sticks; slim craft sticks; or cotton swabs]
Sodium carbonate	Flame [cigarette lighter; grill lighter; matches; or candle]
Potassium bitartrate	Marker
Strontium chloride	Clean paper towels and water supply
Test tubes and holder	
Pipette	

Experiment

You will test the 5 metals both dry and wet. Some of the metals are easier to visualize in one way over the other. The 5 metals you are testing are: copper, calcium, sodium, potassium, and strontium.

Placing a small amount of dry compound on the end of a craft stick and applying a flame will be sufficient to view the colors of some metals. The burning colors of other metals are best viewed by soaking craft sticks or cotton swabs in an aqueous solution of the compound prior to subjecting to the flame. **Better results are obtained if the sticks are allowed to soak 24 hours or more.**

You may wish to have a lab partner take pictures of the colors produced by the flames so that you can compare them later.

Perform this experiment in a well-ventilated area. Ask for assistance with this experiment. Have plenty of water to douse the flames when finished.

1. Prepare Solutions: For best results – prepare 24 hours ahead of time:
    - Label 5 test tubes with the names of the 5 metals to be tested
    - Place 2 mL of distilled water in each test tube
    - Add approximately 1 gram of the solid salt to the appropriately-labeled tube
        - You do not need to weigh, simply add what will fit at the end of a knife
        - You may need to crush the Copper(II) sulfate before adding to water
        - Stir each test tube well using separate, clean craft sticks
        - Do not mix the solutions!
        - If all the solid goes into solution, add a little more until the solution is just undersaturated and you see a few granules at the bottom
        - If there is a great deal of powder left after stirring, add a little more water with a pipette
    - Place several craft sticks in each test tube solution
        - You may use a variety of items - slim craft sticks or cheap chop sticks work well
        - Allow the material to soak; keep the sticks submerged
            - ✓ Best results obtained by soaking sticks 24 hours – allowing the water to evaporate and the stick to absorb the metal enhances color results
            - ✓ However, if using cotton swabs, you will want to wrap with extra cotton and proceed to testing immediately

2. Prepare solids:
   - Label 5 plates with the names of the 5 metals you will test
   - Place a small amount of each solid on the appropriately-labeled plates
   - Assemble the remaining materials from the Materials List

3. Prepare the flame:
   - Test the butane cigarette lighter or grill/kitchen lighter
   - If you are using matches or a candle prepare these
   - The hotter the flame, the better
   - You will want to place the test material into the blue portion of the flame

4. Test Copper(II) sulfate :
   - Dry solid test
     - Scoop up some of the solid onto a clean, dry stick (or cotton swab)
     - Place the end of the cotton ball in the blue portion of the flame
     - Observe any color changes – See below for expected color changes
     - You may need to try a few times to catch the color change
     - **Look especially at the edges of the flame** – moving the stick into, and out of, the flame
     - Record your observations in Table 1
     - If you have an assistant, you may wish to take a picture so that you can compare colors
   - Moist stick test
     - Use the tweezers to remove a pick up a stick
     - As you did above, place the stick into the flame, observing color changes
     - You may even wish to remoisten the end of the stick, and pick up additional solid from the plate (make sure you read the correct labels and do not cross-contaminate)
     - Record your observations in Table 1
     - Have an assistant take a picture if you wish cotton the solid onto a clean, dry stick (or cotton swab)
   - Clean the tweezers if necessary and obtain clean water if it has been contaminated
   - When finished, dispose unused materials into the trash

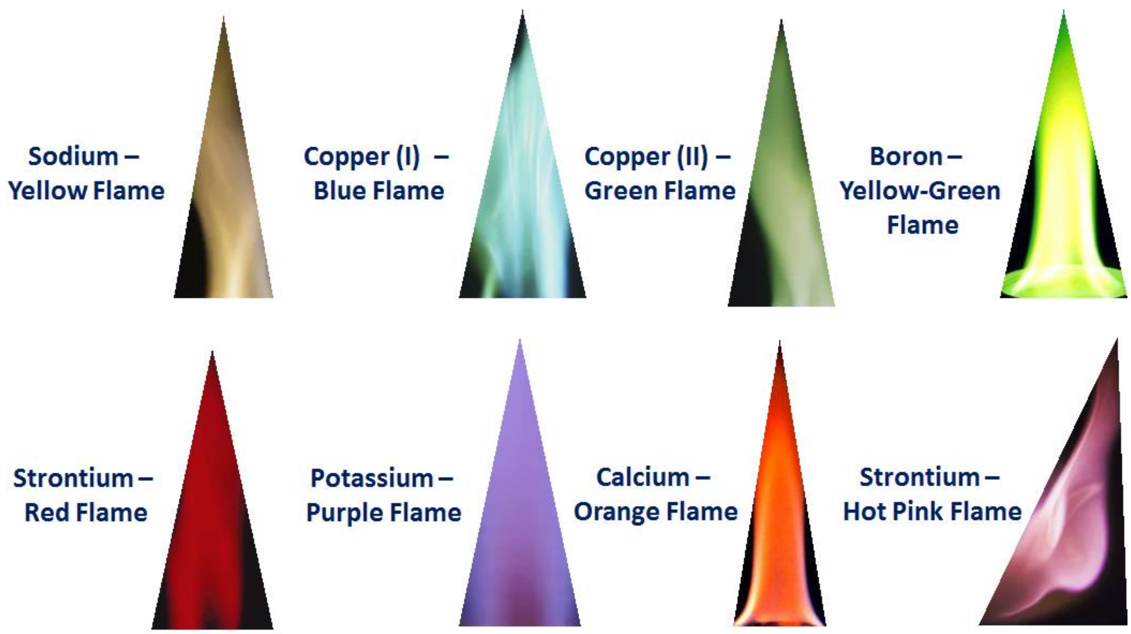
5. Test Calcium chloride, Sodium carbonate, Potassium bitartrate and Strontium chloride
   - Repeat Step 4 for each of the other chemicals
   - Be sure not to cross-contaminate
   - Record all observations in Table 1
   - Have an assistant take pictures of the colors if you wish

6. OPTIONAL – FOR FUN! Try your own tests!
   - Other cations will emit interesting colors
   - Here are some common household salts that you can test
     - Boric Acid (or borax, H_3BO_3) –
       - ✓ often used as antiseptic, pesticide or for laundry detergent
       - ✓ boron gives green flame
     - Water Softener Salt, Lite Salt or salt substitutes, De-icing agents (KCl) –

- ✓ potassium gives a purple or violet flame
- Epsom Salt ($MgSO_4$) –
  - ✓ used in foot-baths or as an anti-inflammation remedy
  - ✓ magnesium gives a white flame
- Some elements produce a blue flame (no apparent change in color)
  - ✓ Zinc
  - ✓ Selenium
  - ✓ Antimony
  - ✓ Arsenic
  - ✓ Lead
  - ✓ Indium

7. Complete Table 3:
   - Table 2 shows an approximation of wavelength, frequency and energy of colors
   - Using this information, rank the 5 chemicals from the chemistry kit from <u>lowest energy</u> to <u>highest energy</u>
   - Fill out the approximate wavelength and energy of the colors observed

8. Analyses and Conclusions
   - After completing the experiment, Table 1 and Table 3, answer the questions following



Flame Tests of Different Metal Salts

Lab Report for: ______________________________

Table 1 – Flame Tests

Substance	Observations with Dry Solid	Observations-Moist Stick
Copper (II) sulfate		
Calcium Chloride		
Sodium Carbonate		
Potassium Bitartrate		
Strontium Chloride		

Table 2

Visible Light
Approximate Wavelength, Frequency, and Energy

COLOR	WAVELENGTH (nm)	FREQUENCY (THz)	ENERGY (kJ/mol)
Red	700	428	171
Orange	620	484	193
Yellow	580	517	206
Green	530	566	226
Blue	470	638	254
Violet	420	714	400

Table 3 – Rank from Lowest to Highest Energy

Substance Tested	Color Observed	Approximate Wavelength	Approximate Energy

Data Analysis and Conclusions

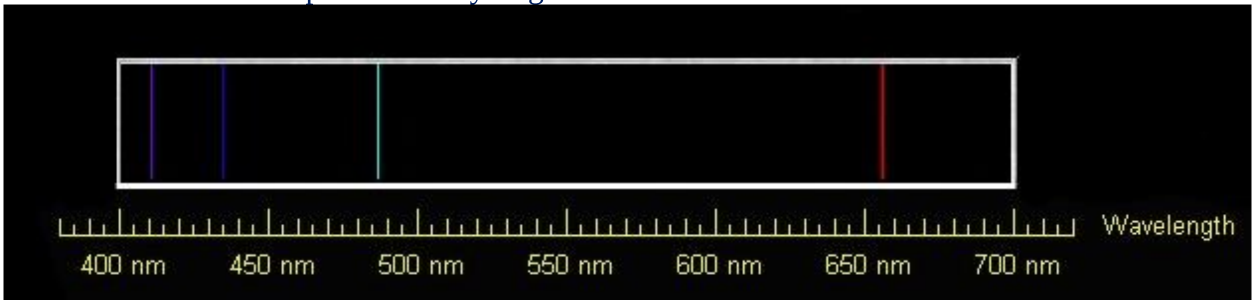
1. Write the electron configuration of each of the metals of the salt compounds that were used in the experiment. Hint: The periodic table is very useful and may be used as a guide.

ELEMENT	ELECTRON CONFIGURATION
Cu	
Ca	
Na	
K	
Sr	

2. How is the color of the flame produced when burning a salt compound related to the electron configuration of the metallic element in the compound?

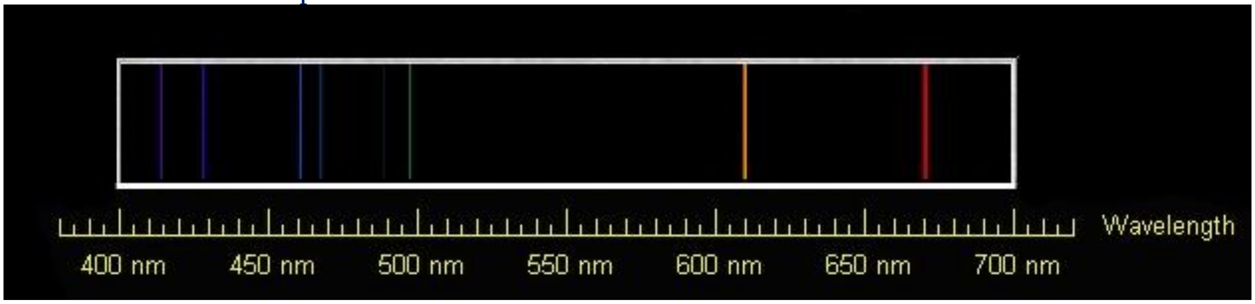
3. Based on the information given in the lab and the information in Table 2
    - Which of the flames to the right would correspond to the burning of Borax (boric acid)?
    - What is the approximate wavelength, frequency and energy of this color?

4. Below is the emission spectrum of hydrogen.

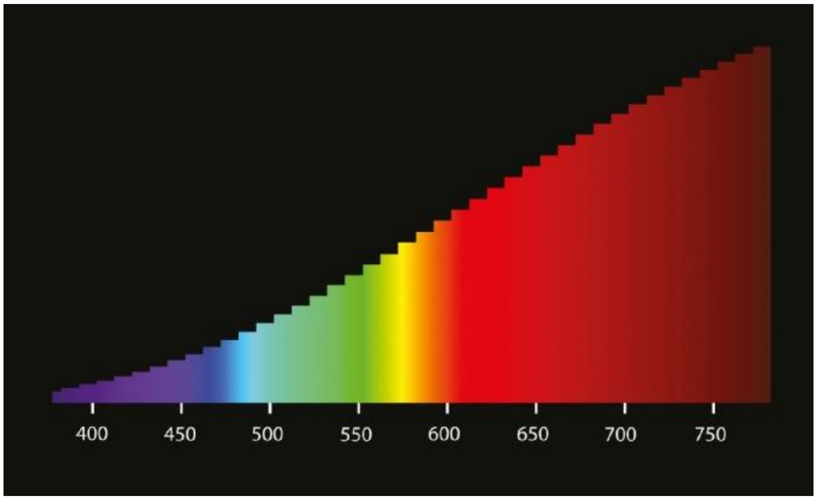


This is what you would see if you observed a light-emitting sample of hydrogen with diffraction grating. **Describe below what you see in the picture.**

5. Observe the emission spectrum of lithium below.



- How does lithium's spectrum differ from hydrogen's spectrum?
- Why does the spectrum for lithium look different from the spectrum for hydrogen?



Note: To the right is a picture of the emission spectrum of an incandescent light bulb. The incandescent light bulb spectrum shows a continuous display of all the colors of visible light. The spectra from hydrogen and lithium (above) show discrete bands of only certain wavelengths of light. This is because incandescent lights emit light at all wavelengths, producing a full "rainbow". On the other hand, the elements only produce light with the wavelengths given off by their electrons as they change energy levels. Therefore, elements do not have a complete spectrum.

6. What color line corresponds to the lowest energy? The highest energy?

7. Explain how what you learned from this lab and/or your textbook could be used by scientists to determine what elements compose the sun and other stars.