

## **Niels Bohr**

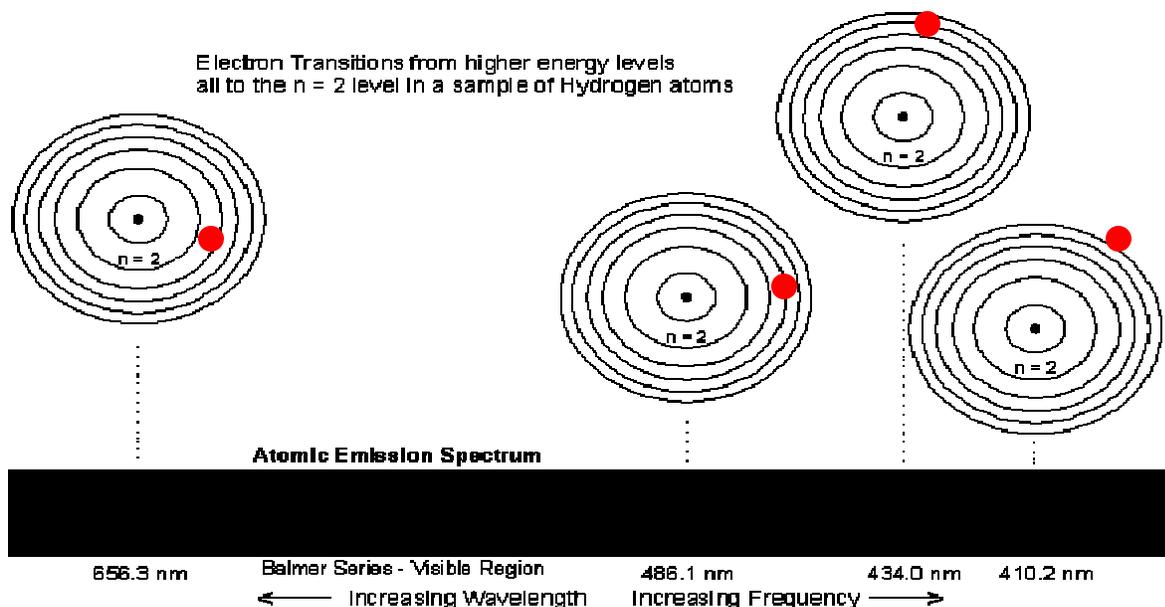
*“And anyone who thinks they can talk about quantum theory without feeling dizzy hasn't yet understood the first word about it.” Niels Bohr*

Bohr was one of the great chemistry revolutionaries of the twentieth century. He introduced two innovative ideas that changed forever the way chemists thought about atomic structure. The first concept was the idea that the electron orbited around the nucleus, much the way that a planet orbits around the sun. This came to be known as the planetary model. The other ground-breaking theory stated that an electron could drop from a higher-energy orbit to a lower one, emitting a photon (light quantum) of discrete energy (Wikipedia, 2006). This became a basis for quantum theory.

The basis of Bohr's theory was rooted in Max Planck's theory of light. Planck theorized that light is packaged in individual bundles that may not be broken down, nor made bigger or smaller. He called each bundle of light energy a quantum, or a photon. Planck also suggested that the color of light is directly related to the energy of the quantum. The energy of the quantum is directly proportional to the frequency of the radiation, meaning that color red has less energy than the color violet (Quagliano, 1975).

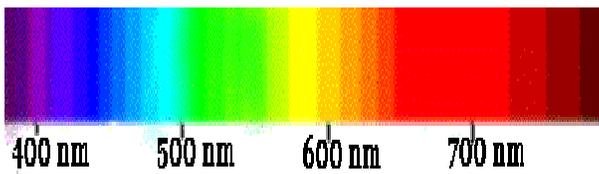
From Planck's theory, Bohr attempted to explain the structure and properties of the chemical elements, in particular, the complex patterns observed in the spectra emitted by each element. Scientists already knew that hot gaseous atoms emitted light in certain color patterns. Bohr hypothesized why scientists saw particular colors when viewing the emission spectra of various gaseous atoms. He focused first on hydrogen, the simplest of the atoms. Hydrogen emitted only red, green, blue and violet light. Because hydrogen did not have a neutron, by the process of elimination he theorized that the light emitted must be related to the attraction between the electron and the proton.

Bohr theorized that the electrons must orbit the nucleus in allowed energy levels of the atom. To understand an allowed energy level, many sources have compared them to a step ladder. It is impossible to be in-between the rungs on a ladder and therefore your foot must rest on one of the rungs. As you move higher up the ladder and away from the ground, the potential energy increases. This is similar to Bohr's theory in two ways. Bohr stated that electrons must exist in an energy level and may not be in-between, hence, "n" must always be a whole number. In addition, Bohr's diagram is like a ladder in the sense that energy must be spent to move to a different energy level. Typically, electrons prefer to be in their ground state, meaning they prefer to be in an energy level closest to the nucleus. When electrons are not in their ground state, they are considered to be in an excited state. Electrons may jump to a higher energy level if they are heated or charged with electricity. If an electron jumps to a higher energy level, it must take up the exact quantum necessary for that particular jump and a photon will be given off if the electron jumps from a higher energy level to a lower energy level (Quagliano, 1975).



*Hydrogen electrons in their excited state jump back to  $n=2$  to produce spectral lines. The above diagram was adapted from <http://www.avogadro.co.uk/light/bohr/spectra.htm>*

The reason various colors are seen on the hydrogen emission spectrum is related to what energy level the electron is jumping from and which energy level it ends up. In the case of hydrogen, the electrons prefer to be in the first energy level. The wavelength, and therefore color observed, depends upon where the excited electrons are jumping from. Red (656nm) is observed if the electron jumps from the third energy level (n=3) to the second (n=2). Violet (410 nm) is observed if the electron jumps from the sixth energy (n=6) to the second (n=2) level.



*Continuous Spectrum of Visible Light*



*Emission Spectra of Hydrogen*

For each line observed, the electrons must jump from their excited state to the second energy level which is called the Balmer Series. J.J. Balmer discovered that the series of lines in the visible region could be calculated using the formula  $\nu = (1/4 - 1/n^2) \times (3.29 \times 10^{15} \text{ s}^{-1})$ , where n = a whole number such as 3, 4, 5, etc. (Oxtoby, 1998).

Although Bohr's theory did explain the lines in the hydrogen spectrum, it could not explain the spectra line of larger atoms with its single quantum number (Tillery, 2004). Scientists such as Louis de Broglie, Heisenberg, and Schrodinger later discovered that different elements emit different emission spectra when they are excited because each type of element has a unique energy shell or energy level system and each element has a different set of emission colors because they have different energy level spacings (<http://www.800mainstreet.com/spect/emission-flame-exp.html>).

This particular theory had several impacts on humans. Because each emission spectrum is unique to each element, astronomers were now able to use spectroscopy to identify the chemical compositions of different celestial objects without actually traveling there. Pyrotechnics, which is a huge business ranging from rock concerts to fourth of July firework displays, is another

area where knowledge of emission spectra of different elements is needed. All of the beautiful colors seen are a direct result of the heating of various elements to excite the electrons to move to higher energy states. Scientists are also conducting research at The National Synchrotron Light Source, a research facility where scientists may use a synchrotron machine to collect data in the field of materials science, specifically, antidepressants, joint diseases, HIV, transistors, chip technology for computers and (Tillery, 2004). A synchrotron machine is a machine that uses powerful magnets to guide electrons shot through an electron gun through a vacuum and as they round each bend in the ring, they give off energy in the form of light (Tillery, 2004).

# Flame Test Lesson Plan

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## **1. GUIDING INFORMATION:**

### **a. Student and Classroom Characteristics (integrated from MISEP Education Course)**

There are approximately 24 eighth grade students in each of my five eighth grade physical science classes. The classes meet for 45 minutes daily. Students are not tracked by academic ability, but instead grouped heterogeneously. One of the five classes is an inclusion class in which there are special education students mainstreamed with regular education students. The special education students range from auditory impaired to attention deficit disorder. There is a support teacher in that class who modifies tests and provides the students who have IEPs specifically for science with additional support. There is also an interpreter who signs for four auditory impaired students.

The environment of each of the classes is one of excitement, energy and positive attitudes. Each of the five classes learns the same subject matter. The students are on task and focused for the majority of the class period. They enjoy coming to science class and are most eager to learn when a hands-on activity is taking place. Students are often required to relate their findings to the real world, and specifically their lives. They are enthusiastic about discussing topics that they can connect with.

Group work is an essential part of each class. Students typically work in groups of two, three or four to conduct investigations and activities. The tables in the class, each which seat three students, are moved regularly to suit the activity being taught that particular day. This may include rows, two tables pushed together to form bigger tables, or a horseshoe shape. Students may find themselves at any given table on any given day depending on the activity and group work. Additionally, groups may work at the lab stations located on the sides of the classroom. There are sinks and gas jets at each of the five stations.

Students are often asked to think critically and apply higher order thinking skills. It is frequently required that students explain *why* scientific phenomena occur. Seldom are students asked to memorize facts but instead they must apply scientific concepts to prove mastery of content. Student expectations range from designing and implementing their own experiments using the scientific method to conducting teacher designed guided activities to participating in a classroom discussion. A driving, or essential, question is presented to the students at the beginning of the investigation and the teacher refers back to that question throughout the related activities. An evaluation may simply be to answer, in detail, the driving question at the end of the lesson.

### **b. Prior Knowledge**

Students have background knowledge of how to draw a Bohr diagram to represent an atom. They have an understanding of the relationship between valence electrons and the periodic table of elements. Students have also learned about quantum number ( $s, p, d, f$ ) and electrons in their lowest (ground state), but have not yet been introduced to electrons in the excited state. Students have recently studied light and the electromagnetic spectrum and are familiar with terms such as wavelength in relation to color.

## 2. PURPOSES:

### Objectives

- Students will be able to explain why elements emit unique emission spectra.
- Students will be able to predict the color of flames of given materials.
- Students will be able to evaluate flames through a diffraction grating and identify the element based on its emission spectra.
- Students will be able to explain how the light energy an atom emits is related to its inner structure.

### d. State Standards

**5.3C-1** Express physical relationships in terms of mathematical equations derived from collected data.

**5.6A-8** Know that different levels of energy of an atom are associated with different configurations of its electrons.

**5.7B-4** Explain the nature of electromagnetic radiation and compare the components of the electromagnetic spectrum from radio waves to gamma rays.

## 3. RATIONALE:

This lesson is designed to integrate the concepts of light, color and quantum theory. Students at this level have not explored chemistry in any depth and this is their first exposure to quantum theory. It will serve as background knowledge when they take chemistry at the high school. The idea of teaching quantum theory arose through articulation between the high school chemistry teachers and the middle school teachers.

In middle school, it is important to stress the idea of the connection between math and science. As a result, this lesson will serve as an interdisciplinary lesson which will incorporate math in the form of dimensional analysis and solving mathematical equations for wavelength and change in energy. The concept of constants will also be discussed.

## 4. CLASSROOM PREPARATION:

### a. Instructional Materials

#### Chemicals:

Calcium chloride

Cupric chloride

Lithium chloride

Potassium chloride

Sodium Chloride

Strontium Chloride

Water (distilled)

#### Equipment:

Beakers, 250 mL (2)

Bunsen Burner

Watch glasses (6)

Wooden splints, soaked in water (6)

### b. Management and grouping patterns

This lesson will be a hands-on, inquiry based investigation. Students will work in groups of two to three students.

### c. Safety

“Cupric 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 into the trash to avoid trashcan fires. Wear chemical splash goggles, chemical resistant gloves and a chemical-resistant apron.” (Flinn Scientific)

## 5. TEACHER NOTES

Metals emit light in patterns which are unique to each metal. By heating metals, electrons are forced into their excited state. Because electrons naturally want to be in their ground state, they will eventually transition back to the lowest available energy level. When this occurs, a photon of light is emitted. This photon determines the color of light, as may be calculated using the equation  $\Delta E = hc/\lambda$ .

Math Facts:

- $\Delta E$  represents the difference in energy between energy levels in joules.
- $h$  = Planck's constant ( $6.626 \times 10^{-34} \text{ J} \cdot \text{sec}$ )
- $c$  = speed of light ( $2.998 \times 10^8 \text{ m/s}$ )
- $\lambda$  = wavelength in nm

### Sample Data Table:

<u>Metal</u>	<u>Color of Flame</u>
Calcium	Orange
Copper	Green
Lithium	Red
Potassium	Violet
Sodium	Yellow
Strontium	Red

### Data Analysis Table:

<u>Metal</u>	<u>Color of Flame</u>	$\lambda$ (nm)	$\lambda$ (m)	$\Delta E$ (J)
Calcium	Orange	600	$6.0 \times 10^{-7}$	$3.3 \times 10^{-19}$
Copper	Green	520	$5.2 \times 10^{-7}$	$3.8 \times 10^{-19}$
Lithium	Red	650	$6.5 \times 10^{-7}$	$3.1 \times 10^{-19}$
Potassium	Violet	410	$4.1 \times 10^{-7}$	$4.8 \times 10^{-19}$
Sodium	Yellow	580	$5.8 \times 10^{-7}$	$3.4 \times 10^{-19}$
Strontium	Red	650	$6.5 \times 10^{-7}$	$3.1 \times 10^{-19}$



Name: \_\_\_\_\_ Date: \_\_\_\_\_ Period: \_\_\_\_\_

## The Flame Test Student Worksheet

### Part I

#### Procedure

1. Put on safety goggles.
2. Your *SPECT-acular* science teacher will light your Bunsen burner.
3. There will be six splints soaking in water.
4. Record the sample letter on your data table.
5. Your teacher will bring around the chemicals to place on your splints.
6. Record observations of the chemical prior to burning.
7. Carefully place the first substance sample into the flame.
8. Observe the color of the flame and record on the data table.
9. Place the splint into the waste beaker... not the trashcan!
10. Burn the remaining samples one at a time.
11. After you have burned all six samples and extinguished them in the waste beaker of water, you may throw away the used splints in the trashcan.

**Homework:** *RESEARCH*...Based on what you know about atomic structure, EMS, and quantum theory explain why you observed different colors for different samples. Identify what metals you think you may have tested at your station. Explain below.

Name: \_\_\_\_\_ Date: \_\_\_\_\_ Period: \_\_\_\_\_

# Data Table: FLAME TEST

Sample Letter	Observation of Metal	Color of Flame	Metal Identification

## Data Analysis and Questions:

Metal/ Color of Flame	$\lambda$ (nm)	$\lambda$ (m)	$\Delta E$ (J)

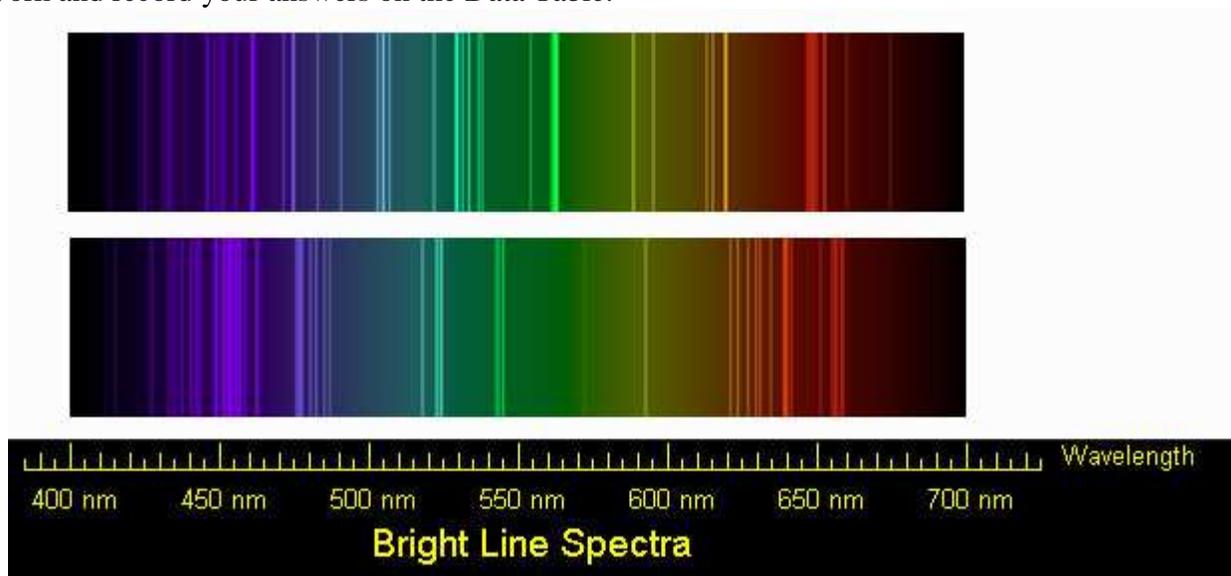
## Analysis:

1. Use the table provided by your **SUPER** science teacher to record the approximate wavelength of light emitted for each metal in the Data Analysis Table.
2. Convert each of the wavelengths in the Data Table from nanometers to meters. Record the wavelengths in meters in the Data Analysis Table. Show at least one sample calculation in the space below.
3. Your **MERRY** math teacher will provide you with the equation to calculate the change in energy ( $\Delta E$ ) for each metal. Show each “set up” on a separate sheet of paper. Record the values in Joules in the Data Analysis Table.
4. Predict the color of the flame if the following materials were heated in the flame. Explain your predictions.
  - a. Cupric nitrate
  - b. Sodium sulfate
  - c. Potassium nitrate
5. Explain in your own words why we see particular colors when certain metals are heated. You should include a diagram to support your ideas.

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## Part II (Extra Credit)

Use the image below to view the spectra of calcium (top) and sodium (bottom). Solve for frequency and energy of the two brightest emission lines for each element. Use the brightest lines. Show your work and record your answers on the Data Table.



*Image adapted from:*

[http://imagine.gsfc.nasa.gov/docs/teachers/lessons/xray\\_spectra/student-worksheet-flame.html](http://imagine.gsfc.nasa.gov/docs/teachers/lessons/xray_spectra/student-worksheet-flame.html)

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