I'm so Excited!!!

Lessons on Electrons

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Spectroscopy in the High School Classroom

Lesson Description:
Lesson Title: Atomic Fingerprints:
Topic/Unit: Energy of Electrons
Grade Level: 11th Grade Chemistry
Estimated Time Frame: 3 periods (170 minutes)
Nature of the Lesson: Inquiry Lab on spectroscopy

Rationale/Place in the Curriculum: This lesson is part of the unit on electron configuration, energy of electrons and atomic structure

Essential Prior Concepts: Mastery of the following concepts should be attained before teaching this lesson

1. Models of the atom
2. Electron Configuration with working knowledge of orbital's and valence electron location
3. Working knowledge of quantum theory
    a. $E=h\nu$
    b. $C=\lambda\nu$
    c. $\Delta E= E_2-E_1=h\nu$

Background Information for Teachers:

This lesson attempts to bridge the gap between the concrete and abstract. An electron is very abstract to the students. Since they cannot see it, it is very hard for them to understand how it occupies orbitals and spins. However when shown what happens as a direct result of moving these electrons real learning takes place because they can see it.

Light passing through an incandescent bulb separates into a continuous spectrum or rainbow of colors. Visible light is only a small portion electromagnetic radiation, which includes gamma rays, ultraviolet light, infrared radiation, microwaves, and x-rays. These light waves all travel through space and the speed of light (c) 3.00×10^{8}m/s. All of these waves can be characterized by their wavelength (λ)– distance between equivalent points of two waves, and their frequency (ν) – the number of peaks that pass a particular point in 1 second.

When light from a flame in which are being heated, one observes a line spectrum – characteristic wavelengths and frequencies emitted by each element. A line spectrum can be used to identify an element using a spectroscope. Another way of looking at elements characteristic wavelengths is through flame test. Each element when placed in the flame gives off a characteristic color. Max Planck proposed and explanation for the frequencies of light emitted by very hot solids and called it the quantum theory. According to his theory light is emitted in a discontinuous pattern in discrete packets called photons or quanta rather than a continuous wave, which was previously accepted. He found that the frequency of light increases proportionally with an increase in energy where Planck's constant is 6.63×10^{-34}Js. ($E=h\nu$).

Electrons which fall toward the nucleus from the excited state – after absorption of a photon an electron is elevated to a higher energy level- back to the ground state – electrons in their lowest energy levels - release potential energy which corresponds to a frequency of light, which in turn can be seen as a specific color. This principle is relied upon in the world daily. For example in the engineering of firework displays; different colors are made from the addition of different elements. The bright colors of neon signs in advertising are a direct result of excited electrons returning to the ground state.

Pennsylvania Standards:

3.4.12. A. Apply concepts about the structure and properties of matter

1. Apply rules of systematic nomenclature and formula writing to chemical substances.
2. Explain how radioactive isotopes that are subject to decay can be used to estimate the age of materials.
3. Apply the conservation of energy concept to fields as diverse as mechanics, nuclear particles and studies of the origin of the universe.
4. Quantify the properties of matter (e.g., density, solubility coefficients) by applying mathematical formulas

3.4.12.B. Apply and analyze energy sources and conversions and their relationship to heat and temperature.

1. Determine the heat involved in illustrative chemical reactions.
2. Evaluate mathematical formulas that calculate the efficiency of specific chemical and mechanical systems.
3. Apply appropriate thermodynamic concepts (e.g., conservation, entropy) to solve problems relating to energy and heat.

3.4.12.C. Apply the principles of motion and force.

1. Evaluate wave properties of frequency, wavelength and speed as applied to sound and light through different media.

Objectives:

Students will be able to:

1. Demonstrate understanding of the relationship between atomic structure and emission spectroscopy
2. Correctly use the instrumentation necessary (spectroscope) to view samples of continuous and bright line spectra.
3. Observe characteristic emission lines associated with electrical and thermal excitation.
4. Use knowledge gained to Determine the velocity, frequency or wavelength of any wave, given two of the three variables
5. Identify the components of unknown salt solutions by flame test emission
6. Determine that visible light is composed of waves of various frequencies
7. Calculate the energy of photon, given its frequency. Compare the wavelength, frequency or energy of different types of electromagnetic radiation.
8. Explain the meaning of the lines in a bright line spectrum of hydrogen, according to Niels Bohr
9. Define and compare ground state to excited state for an electron.
10. Draw and write correct electron configurations of neutral atoms in the ground and excited states.
11. Identify the neutral atom an electron configuration represents. as well as drawing this atom with an excited electron configuration.

Materials and Equipment:

1. Spectroscope
2. Meter Sticks
3. Diffraction Grating
4. Colored Pencils
5. Ring Stand with Clamp
6. Low Wattage Incandescent light source
7. Fluorescent Light Source
8. Bunsen Burner
9. Goggles
10. High Voltage Power Supply (Teacher use only!)
11. Elemental Gas Tubes (hydrogen, helium, neon, mercury, argon, etc)
12. Wood Splints
13. Solutions
    a. Barium chloride
    b. Calcium chloride
    c. Lithium chloride
    d. Sodium chloride
    e. Strontium chloride
    f. Mixture of unknown salts
    g. Beakers of water

Safety Precautions:

1. Goggles should be worn at all times!
2. All Wood splints should be placed in water before discarding.

Lesson Time Frame:

Period1: Visible Region of Spectrum – Sketch line spectra for different elements
Period 2: Line spectra and calculations for hydrogen
Period 3 Flame Test

Introduction and Motivation:

1. Bring in a prism to the classroom and hold it up to the window (hopefully it is sunny). Allow the prism to cast the continuous spectrum in sight of all students. Ask them what happened? This should spark a discussion on light and how white light is composed of all the colors and how only a very tiny bit of light is visible to the naked eye.
2. For the flame test portion of the lab, show a portion of a video with fireworks exploding. Ask the students how they know what fireworks will be what colors? This should spark discussion about different metals being used creating different colors based on the energy released when excited electrons come back to the ground state.

Lesson Body:

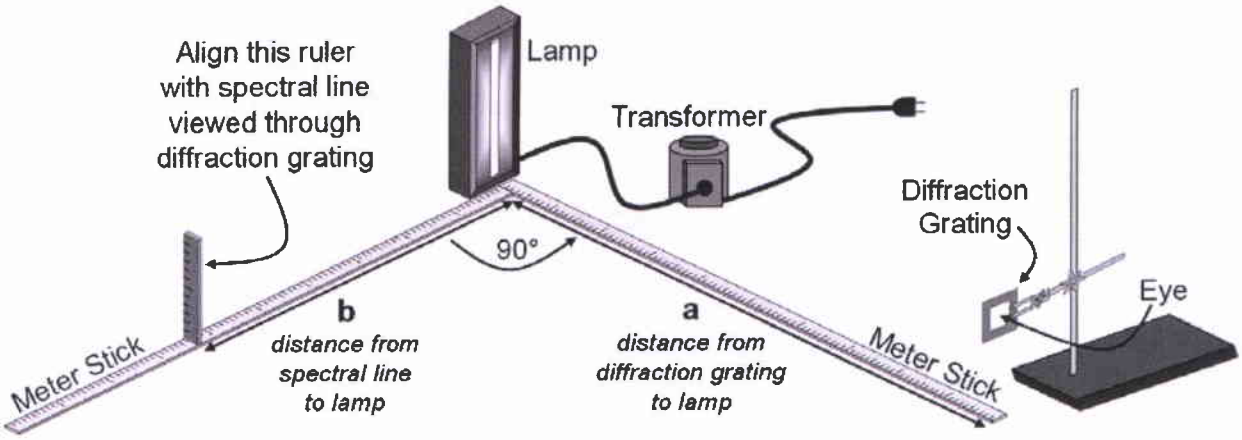
Period 1

1. Have students recall the models of the atom and emphasize Bohr.
2. Ask students to draw a rainbow. Note what color most students pick up first, second, third, etc. (Most students will have Red as the first color and violet as the last).
3. Show them this relates to the visible spectrum of light they just saw and have they draw it on their papers.
4. Explain that the wavelength, frequency and energy. From the drawings of the rainbow the students should be able to see that the color red has the longest wavelength so will have the longest frequency. Conversely, violet has the shortest wavelength and highest frequency. After checking for mastery of this concept and defining both wavelength and frequency, discuss infrared light (IR) as well as ultraviolet light (UV).
5. Students should be able to relate UV light with sunburn and IR light with remote controls or night vision. From this have them deduce that UV light is higher in energy than IR. Then dissect the words ultraviolet and infrared to determine where they may lie on the electromagnetic spectrum. (UV shorter wavelength, higher frequency, higher energy- IR longer wavelength, lower frequency, lower energy)
6. From this exercise students should be able to conclude that energy and frequency are directly proportional, energy and wavelength are inversely proportional, and wavelength and frequency are inversely proportional.
7. Go back to the spectrum on the wall and explain how it is a continuous spectrum and how different elements have what are called line spectra characteristic to them. White light contains all wavelength and frequencies, which is why you see a continuous spectrum. Elements are not like that and you will only see certain lines.
8. Show the high voltage source with the different element bulbs in place and explain that they will be drawing the line spectra for each element as accurately as possible.
9. http://phys.educ.ksu.edu/vqm/html/emission.html Excellent for a virtual simulation to show the students as well as use for reference for each element. Also good for students who are absent to use this as a makeup lab.

Assessment: Have student complete data table 1 and lab questions for period 1

Period 2: http://phys.educ.ksu.edu/vqm/free/h2spec.html Excellent for seeing the hydrogen line spectra and how it corresponds to the energy.

1. Set up apparatus as follows as seen below:



The figure above shows the apparatus for measuring the wavelength of light given off by hydrogen. The only measurements needed to calculate λ are the distance (a) from the grating to the light source, and the distance (b) between the light source and the appearance of the spectral line. λ can then be calculated using the Bragg equation: **$\lambda = d \sin \theta$** where *d* is the distance between the lines in the diffraction grating.

The gratings contain 1.50×10^4 lines per inch. You will need to convert this to lines/cm. (1 inch = 2.54cm) θ is the angle between looking straight at the light source and the peripheral image of the spectral line. Sin θ can be calculated in 3 steps:

1. $b/a = \tan \theta$
2. $\tan^{-1} (b/a) = \theta$
3. compute sin θ using the sine trigonometric function on your calculator

Student Procedure:

1. Using the apparatus described above set the diffraction grating 1meter from the light source. This will be distance a.
2. Tape the meter sticks at right angles of one another and darken the room.
3. Students should work in pairs. Student 1 looks through the diffraction grating and directs student 2 along the horizontal meter stick with a vertical ruler telling them to stop when they are directly in line with a spectral line. This is distance (b)
4. Fill in data table for period two showing work for 1 calculation.

Assessment: Have student complete data table, calculations, and questions for period 2.

Period 3 http://www.trschools.com/staff/g/cgirtain/Weblabs/spectrolab.htm - virtual lab for teacher and student referral for demo and confirmation of unknowns

Student Procedure:

1. Soak a wood splint in each of the salt solutions available as well as an unknown
2. Light Bunsen burner and adjust flame until it is almost invisible
3. Using spectroscope on right stand eye level with the faintest part of the flame, place a soaked wood splint into the flame and have partner who was looking through spectroscope record the results.
4. Place splint into beaker of water after color has been recorded
5. Repeat for all salts.
6. Use data from the known salts to identify the components of the unknown salt.

Assessment: Have student complete data table for period 3

Clean Up and Disposal: After rinsing wood splints, place in trash. Return solutions to back table for later use. Wash down table and wash hands before leaving the lab