LIGHT ANALYSIS WITH THE WIRELESS SPECTROMETER

Scientists use models to make predictions, solve problems, and test claims. As technology improves, new evidence either confirms or contradicts previous models. Today's atomic model is a product of centuries of refinement. In the early 1900s, Niels Bohr proposed an atomic model based on the work of many scientists including Ernest Rutherford and Max Planck. Bohr was familiar with hydrogen's line emission spectrum. He realized the energy of emitted light must be related to an atomic structure that included energy levels. Bohr hypothesized that emitted light was the result of an electron jumping from one energy level to another. He proposed the energy of an emitted photon is equal to the energy difference between the ground state and excited state. The distinct pattern of spectral lines unique to each atom could be related to energy levels.

Bohr's model was critical in the development of modern atomic theory because it provided the idea that electrons are organized according to energy levels outside of an atom's nucleus. Unfortunately the model failed to explain the emission spectra of elements beyond hydrogen. The value in studying Bohr's model lies in conveying a complex idea in a simple representation.

A spectrometer is a tool that allows the observer to study the line emission spectrum of atoms with energized electrons. Spectrometers allow scientists to identify elements present billions of light years away from Earth and also provide evidence for the quantum model of the atom.

Driving Question

How can emitted light identify an element and provide evidence for atomic energy levels?

Materials and Equipment

- PASCO Wireless Spectrometer
- Fiber optic cable
- Ring stand
- Multi clamp
- Gas spectrum tube
- Spectrum tube power supply

Safety

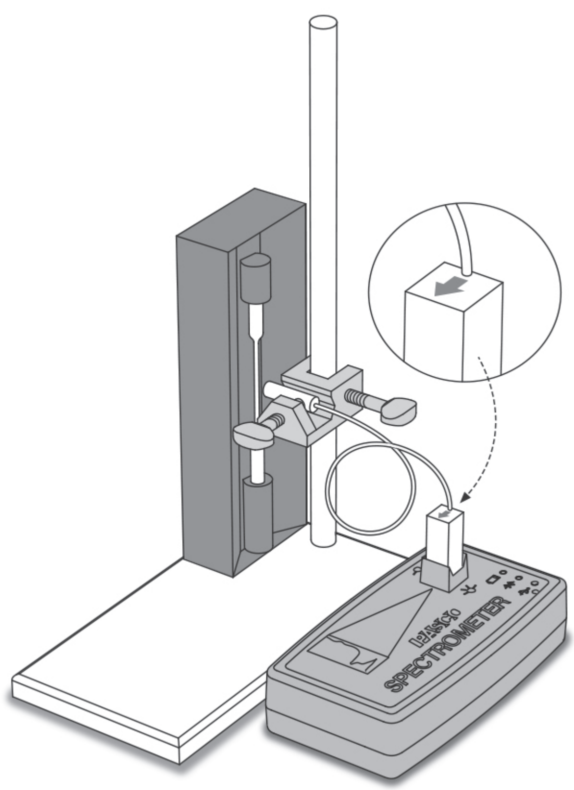
Follow these important safety precautions in addition to your regular classroom procedures:

- Wear gloves when handling the spectrum tube.
- Don't touch the high-voltage spectrum tube or power supply.
- Use caution around the high-voltage spectrum tube power supply.

Investigate

Complete the following lab procedure and analysis. Record observations, data, and explanations in your lab notebook.

1. Turn on the spectrometer and connect it to your computing device.
2. Place the rectangular end of the fiber optic cable in the cuvette opening of the spectrometer. Align the arrows on top of the housing as shown.
3. Use a multi clamp to secure the probe or rounded end of the fiber optic cable on a ring stand as shown.
4. Place the end of the probe a distance of 2 cm or less from the gas tube. Adjust the probe to point towards the tube. Do not allow the probe to directly touch the tube.
5. Open the Spectrometry app. Make sure ANALYZE LIGHT is selected in the menu at the top.
6. Ask your teacher to turn on the power supply.
7. Start recording data. SCALE TO FIT if necessary.
8. Adjust the probe angle and distance from the gas spectrum tube if the wavelength reading is either too intense or too weak. You can also use the sliders to adjust the integration time, number of scans to average, or smoothing on the left of the screen.
9. Stop collecting data when you have a stable reading. Ask your teacher to turn off the power supply.



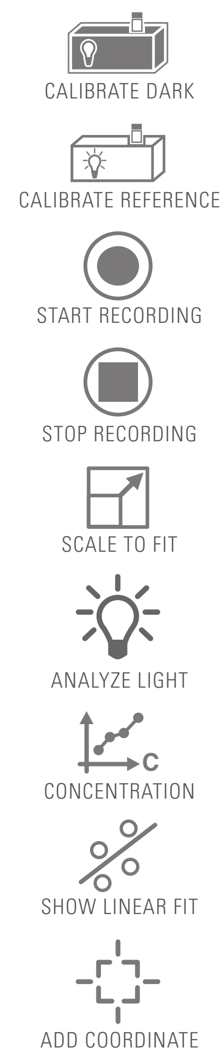


Table of Photon Energies for: ______________________________

Color of Photon	Wavelength (nm)	Energy (J)

Analyze Data

10. Scale the graph if necessary. Use the ADD COORDINATE tool to find the wavelengths in nm of each distinct peak. Check with your instructor to make sure you have identified all significant peaks.
11. Use the arrows at the bottom-right of the screen to view each reference spectrum.
12. Which element is contained in the gas tube? How can you tell?
13. Astronomers use high-powered spectrometers to analyze light throughout space. Explain how it is possible for an element to have the same line emission pattern every time it is energized, whether the element is in outer space or in a gas spectrum tube in a classroom.
14. Use the wavelength of the identified peaks to solve for the energy of emitted photons. Show your work and refer to the equations below.

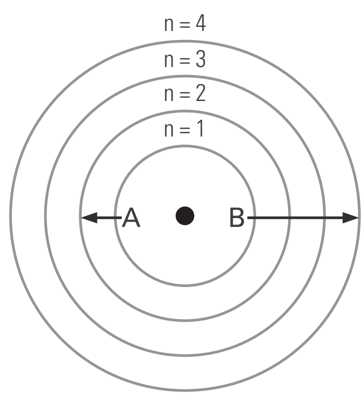
    If $E = h\nu$ and $c = \lambda\nu$, then $E = \frac{hc}{\lambda}$

    $1\text{nm} = 1 \times 10^{-9}\text{ m}$

    Planck's constant $h = 6.63 \times 10^{-34}\ J \cdot s$

    Speed of light $c = 3.00 \times 10^{8}\ m/s$

15. Enter the element you identified on the blank line in the table title above. Summarize the wavelength and energy of each peak representing photons emitted from the atoms in your spectrum tube in the table. List the colors in order from lowest energy to highest. Some elements may have multiple wavelengths for the same color, some may have fewer than five colors, or some may have more than five colors in the visible spectrum. Record no more than five colors in the table.
16. Which color has higher energy: red or blue? Use data to support your answer.
17. Is wavelength directly or indirectly related to energy? Use data to support your answer.
18. Is frequency directly or indirectly related to energy? Use data to support your answer.
19. Niels Bohr used mathematical relationships to predict the structure of the atom. He assumed lower energy electrons were closest to the nucleus and higher energy electrons were farther from the nucleus.



    a. Suppose an electron in its ground state (n = 1) were to absorb energy and transition to an excited state (n > 1), return to ground, and release a photon as it returns to n = 1. Which path will require less energy to complete, A or B? Explain your answer.

    b. Which light color is more likely to result from the path you identified as less energy: red or blue?

Extension

Which element(s) cause(s) a pickle to glow when electricity is passed through it? How much energy do the emitted photons contain?

CALIBRATE DARK
CALIBRATE REFERENCE
START RECORDING
STOP RECORDING
SCALE TO FIT
ANALYZE LIGHT
ANALYZE SOLUTION
CONCENTRATION
SHOW LINEAR FIT
ADD COORDINATE