How Does Light Help Us Understand the Behavior of Electrons in Atoms?

Why are we doing this?

From fireworks to stars, the color of light is useful in finding out what's in matter. The emission of light by hydrogen and other atoms has played a key role in understanding the electronic structure of atoms. Trace materials, such as evidence from a crime scene, lead in paint or mercury in drinking water, can be identified by heating or burning the materials and examining the color(s) of light given off in the form of bright-line spectra.

Your Learning Outcomes

You will be able to:

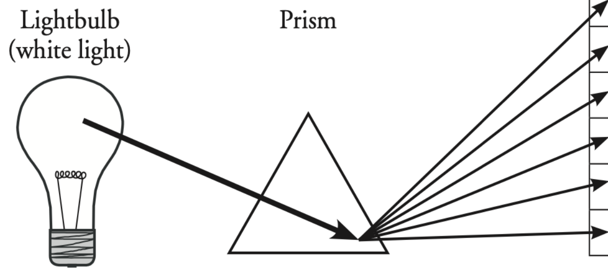
1. Describe the relationship between the color of visible light and its wavelength.
2. Describe the relationship between a spectral emission line and an electron transition.
3. Use the Bohr model of an atom to model electron transitions between energy levels.

The Plan

1. Assign roles*.
    a. ***Manager*** – This person will keep the team on task and provide direction to the group. This person is responsible for uploading the group's work to Gradescope. Make sure you make a note of everyone in the group. You must add everyone's name when submitting your answers to Gradescope.
    b. ***Spokesperson*** – This person will represent the group be responsible for speaking for the group to the rest of the class.
    c. ***Recorder*** – This person will be responsible for recording the team's answers to the Critical Thinking Questions in an organized and coherent manner.
    d. ***Analyst*** – This person will be responsible for critical analysis of the team's work (i.e., the Devil's Advocate). This person should make sure everyone understands what is happening before the group moves forward.
2. Complete the Critical Thinking Questions as a group.
3. Submit your team's work via Gradescope. Groups may choose to work in a Word document or write out their answers on a separate sheet of paper. All work must be upload to Gradescope as a PDF file.

**Students may choose to complete this activity independently if they are unable to attend discussion due to illness or injury; in which case, the student must perform all roles and complete all aspect of the activity. To receive full credit, documentation as to the need for the absence from discussion must be included with the submission and your TA must be notified of the absence.*

Model 1: White Light



Color	Photon Energy ($\times 10^{-21}$) (J)	Wavelength Range (nm)	Speed (m/s)
Reds	269–318	625–740	3.00×10^8
Oranges	318–337	590–625	3.00×10^8
Yellows	337–352	565–590	3.00×10^8
Greens	352–382	520–565	3.00×10^8
Blues	382–452	440–520	3.00×10^8
Violets	452–523	380–440	3.00×10^8

1. What happens to white light when it passes through a prism?
   It is broken into all of the colors of the visible light spectrum.

2. Do all colors of light travel at the same speed?
   Yes

3. Do all colors of light have the same energy? If no, which colors have the highest energy and the least energy, respectively?
   No. The blues and violets have the most energy. The reds and oranges have the least energy.

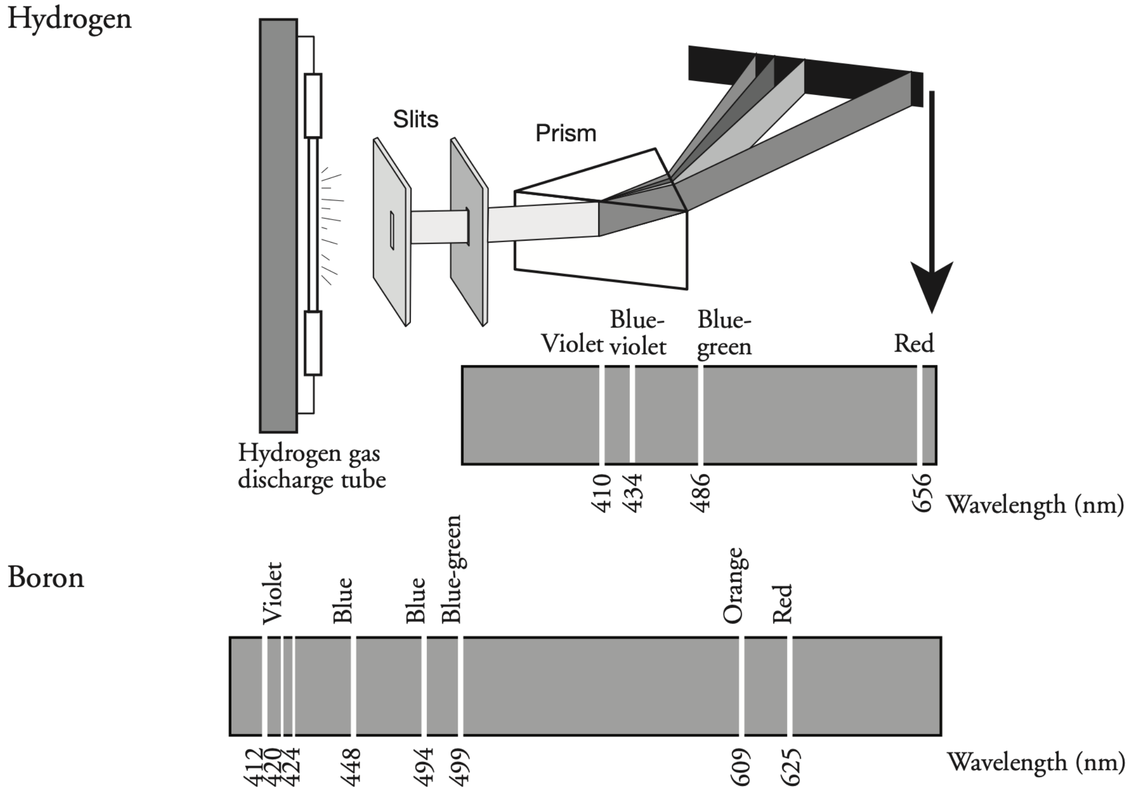
4. Using Model 1:

   a. Which color corresponds to the longest wavelengths?
      Reds

   b. Which color corresponds to the shortest wavelengths?
      Violets

   c. Write a sentence that describes the relationship between wavelength and energy of light.
      As the wavelength gets shorter, the energy of light increases (inversely proportional).

Model 2: Emission Spectra for Hydrogen and Boron Atoms



5. Consider the hydrogen spectrum in Model 2.

   a. Which color of light corresponds to the shortest wavelength?
   Violet

   b. Which color of light corresponds to the longest wavelength?
   Red

   c. Which color of light has the most energy?
   Violet

   d. Which color of light has the least energy?
   Red

6. Does a gas discharge tube filled with boron emit the same wavelengths of light as a tube filled with hydrogen? Use evidence from Model 2 to support your answer.
Hydrogen produces four different wavelengths (colors) of light, while boron produces eight. Even though some of the wavelengths are similar (they both contain a red and blue-green line), they are not the same; therefore, the colors of the spectral lines are slightly different.

Information

Watch this short YouTube video demonstration of a continuous and discrete spectra using a diffracting grating (similar to a prism).

https://www.youtube.com/watch?v=m69GjvN3n0M

7. "The spectral lines for atoms are like fingerprints for humans." How do the spectral lines for hydrogen and boron support this statement? Using evidence from Model 2 and the video to support your claim.
   As shown in Model 2 and the video demonstration, each element has a its own unique set of spectral lines. Therefore, the emission spectra for each element is different (like a fingerprint).

Circle the appropriate word to complete each statement in Questions 8–11.

8. Electrons and protons (attract/repel) each other.

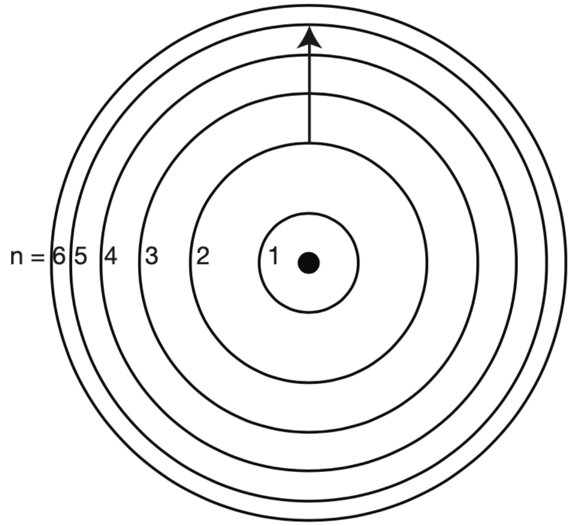
9. As an electron gets closer to the nucleus the (attraction/repulsion) to the nucleus gets (stronger/ weaker).

10. For an electron to move from an energy level close to the nucleus to an energy level far from the nucleus it would need to (gain/lose) energy.

11. For an electron to move from an energy level far from the nucleus to an energy level close to the nucleus it would need to (gain/lose) energy.

Information

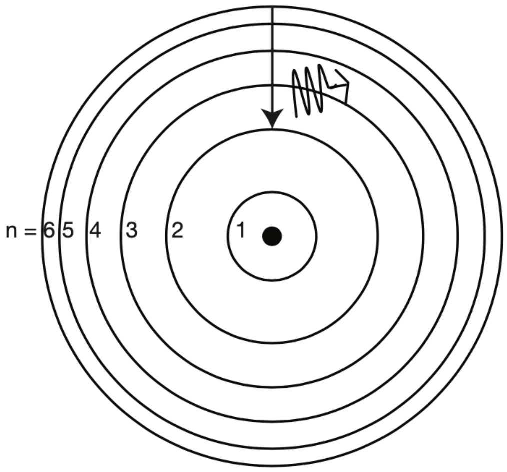
Niels Bohr modified Rutherford's Nuclear Atom model to explain how light interacted with the electrons in an atom to produce spectral lines. His model included electrons orbiting the nucleus at specific energy levels. Electrons absorb energy from various sources when they move from lower energy levels (ground state) to higher energy levels (excited states). Energy is released as electrons return to their lower energy levels.



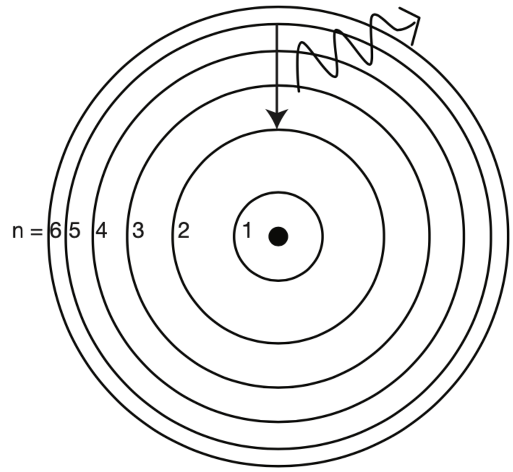
12. Is energy absorbed or released for the electron transition shown in the diagram to the right? Explain your reasoning.
    Energy must be absorbed in order for the electron to jump from energy level 2 to energy level 5. This energy is needed to pull the electron away from the protons in the nucleus.

Model 3 – Bohr Model of a Hydrogen Atom

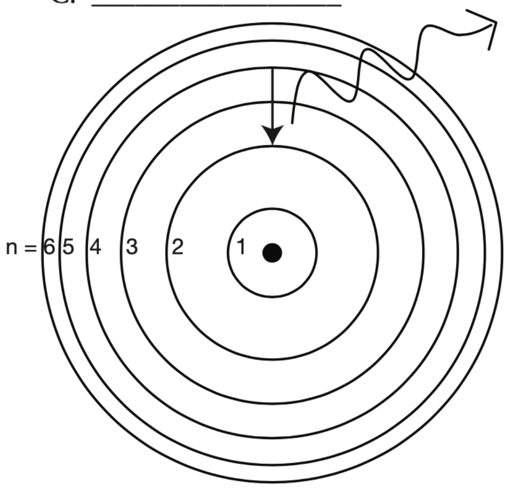
A. n=6 to n=2, violet, 410 nm



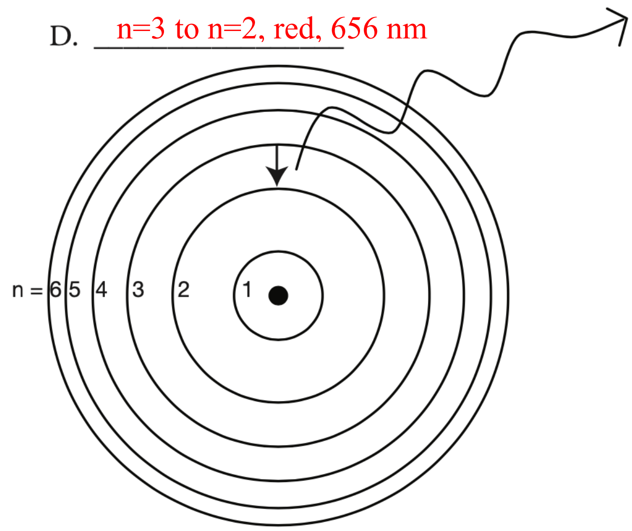
B. n=5 to n=2, blue-violet, 434



C. n=4 to n=2, blue-green, 486



D. n=3 to n=2, red, 656 nm



13. Identify the drawing in Model 3 that depicts a hydrogen atom with an electron moving from energy level 5 to energy level 2. Refer to Models 1 and 2 for the following questions.
    a. Label the picture with "n=5 to n=2" and list the corresponding color of light emitted.

    b. This electron transition (absorbs/releases) energy.

    c. This electron moves from a (lower/higher) energy state to a (lower/higher) energy state.

    d. Is light absorbed or released in the electron transition?
    Released

14. Label the remaining drawings in Model 3 with the electron transitions that are occurring (n=? to n=?), the wavelengths and corresponding colors of the light emitted. See Model 2 to identify the color of spectral lines produced in each of the hydrogen atom electron transitions shown in Model 3.
    Labeled above in Model 3.

15. Consider the electron transitions in Model 3.
    a. Which of the electron transitions involves the most energy?
       n=6 to n=2, violet, 410 nm.
    b. Explain why this transition involves the most energy based on your understanding of the attractive forces between the electrons and protons in the atom.
       As the electron moves towards the nucleus of the atom, there is a stronger attractive force. This releases energy because the electron moves to a lower potential energy. The larger the transition, the more energy is released.

16. Explain why a single atom of hydrogen cannot produce all four hydrogen spectral lines simultaneously.
    A single atom of hydrogen only has one electron, so it can only produce one spectral line per electron transition.

17. If Question 16 is true, how can we see all four colors from a hydrogen gas discharge tube simultaneously?
    There are millions of hydrogen atoms in the discharge tube. Each one can have a different transition occurring. Therefore, some fraction of the atoms will produce each of the various spectral lines to create the complete atomic emission spectrum for hydrogen.