Name: Answer Key

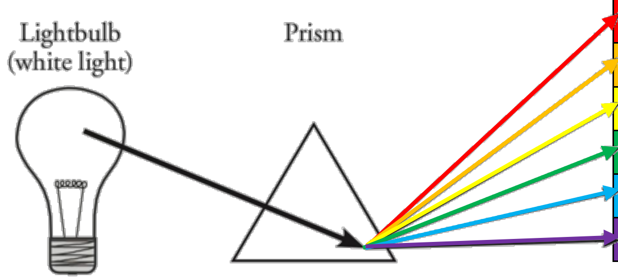
Electron Energy and Light

How does light reveal the behavior of electrons in an atom?

Why?

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.

Model 1 - White Light



Color	Photon Energy ($\times 10^{-19}$) (J)	Wavelength Range (nm)	Speed (m/s)
Reds	2.69-3.18	625-740	3.00×10^8
Oranges	3.18-3.37	590-625	3.00×10^8
Yellows	3.37-3.52	565-590	3.00×10^8
Greens	3.52-3.82	520-565	3.00×10^8
Blues	3.82-4.52	440-520	3.00×10^8
Violets	4.52-5.23	380-440	3.00×10^8

1. Trace the arrows in Model 1 and shade in the table with colored pencils where appropriate.
2. What happens to white light when it passes through a prism?

   It is refracted and spreads into a spectrum (rainbow).

3. Why are the color labels in the table in Model 1 plural (*i.e.,* "Reds" rather than "Red")?

   There are bands of colors rather than a single wavelength/color.

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

   Yes (in a vacuum).

5. Do all colors of light have the same energy? If no, which colors have the highest energy and the least energy, respectively?

   No: violet has the highest energy and red has the least energy.

6. Consider the light illustrated in Model 1.

   a. Which color corresponds to the longest wavelengths?

   Red has the longest wavelength.

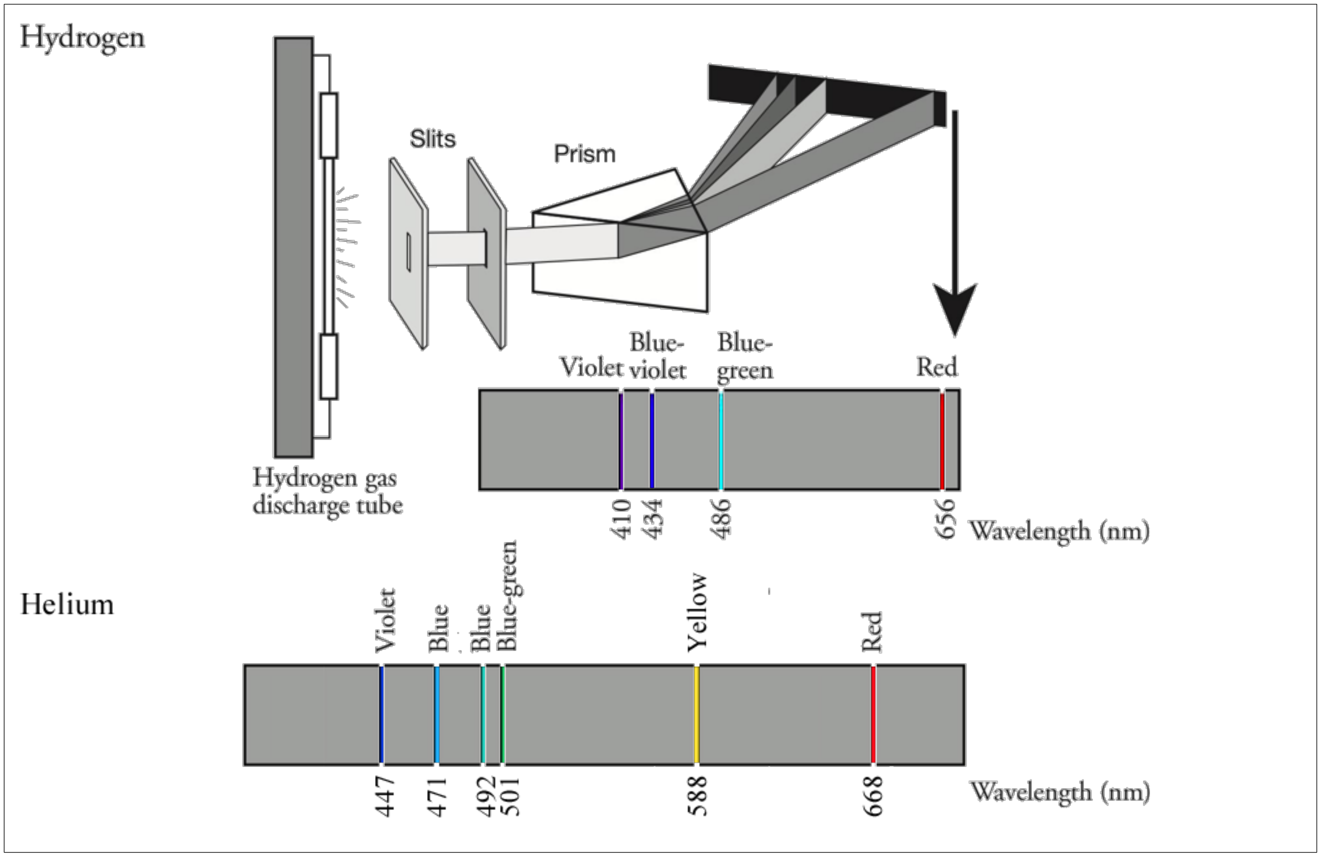
   b. Which color corresponds to the shortest wavelengths?

   Violet has the shortest wavelength.

   c. Is the relationship between wavelength and energy of light direct or inverse? Explain.

STOP

Model 2 - Emission Spectra for Hydrogen and Helium Atoms



Use the spectroscopes to observe the spectra of hydrogen and helium in the fume hoods then complete the following instructions. The spectra you observe will have their wavelengths reversed compared to Model 2.

7. Use colored pencils to color the hydrogen and helium spectral lines within their respective spectra in Model 2.

8. List the spectral lines for hydrogen gas by color and corresponding wavelength.

   410 nm: Violet; 434 nm: Blue-violet; 486 nm: Blue-green; 656 nm: Red

9. The spectral lines for helium were produced using the same method as hydrogen. List three of the colors and corresponding wavelengths for helium's spectral lines as its light passes through a prism.

   447 nm: Violet; 501 nm: Blue-green; 588 nm: Yellow

10. Consider the hydrogen spectrum in Model 2.

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

    Violet (410 nm) is the shortest wavelength.

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

    Red (656 nm) is the longest wavelength.

11. Consider the hydrogen spectrum in Model 2.

    a. Which color of light has the most energy?

    Violet (410 nm) has the most energy.

    b. Which color of light has the least energy?

    Red (656 nm) has the least energy.

12. Does a gas discharge tube filled with helium emit the same wavelengths of light as a tube filled with hydrogen? Use evidence from Model 2 to support your answer.

    No; although some colors are called the same, the exact wavelengths are different.

13. "The spectral lines for atoms are like fingerprints for humans." How do the spectral lines for hydrogen and helium support this statement?

    Just as each fingerprint is unique, each element has a unique spectrum.

Circle the appropriate word to complete each statement in Questions 14-17.

14. Electrons and protons (**attract**/repel) each other.
15. As an electron gets closer to the nucleus the (**attraction**/repulsion) to the nucleus gets (**stronger**/weaker).
16. 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) potential energy.
17. 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**) potential energy.

STOP

Read This!

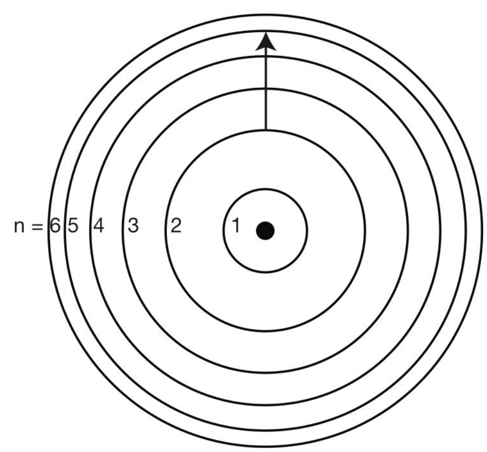
Niels Bohr modified Rutherford's Nuclear Atom model to explain how light interacted with the electrons in an atom to produce spectral lines. His model included electrons orbiting the nucleus at specific energy levels. Electrons absorb energy from various sources (electricity) when they move from lower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

18. What does the black dot in the center of the model represent?

    The black dot is the nucleus.

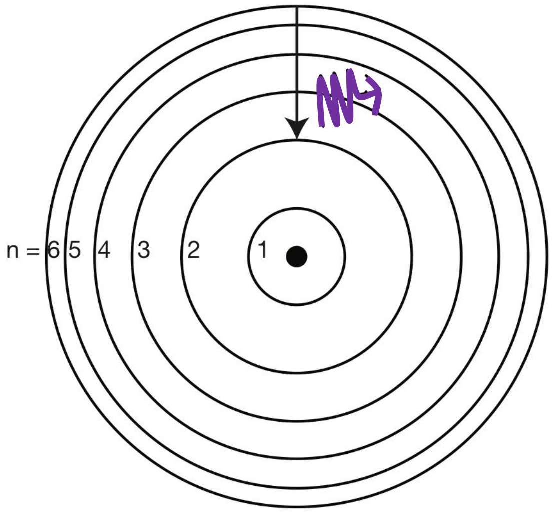
19. Is energy absorbed or released for the electron transition from n=2 to n=5, shown in the diagram to the right? Explain.

    Energy is absorbed by the electron moving from n=2 to n=5.

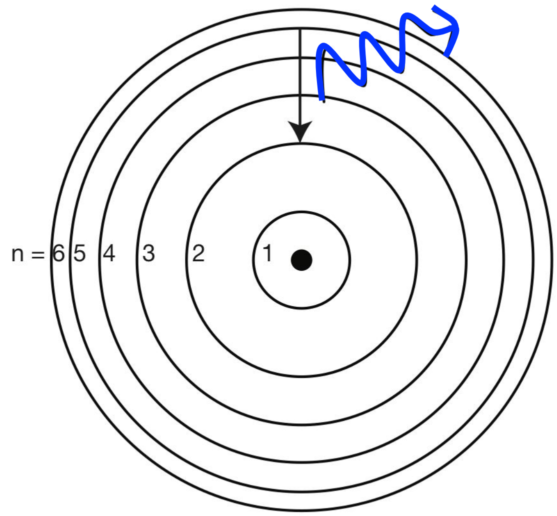


Model 3 - Bohr Model of a Hydrogen Atom

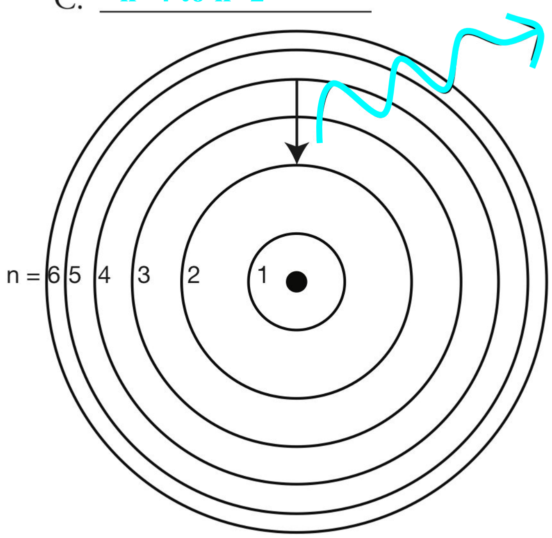
A. n=6 to n=2



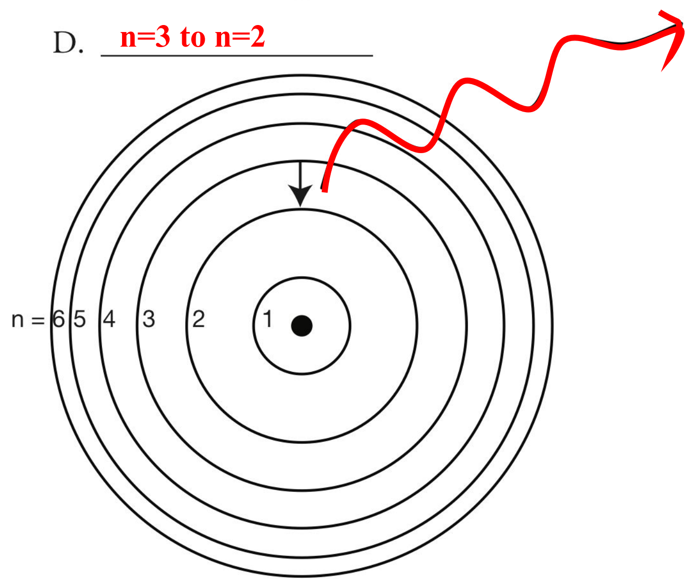
B. n=5 to n=2



C. n=4 to n=2



D. n=3 to n=2



20. 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 the corresponding wavelength and 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

21. Label the remaining drawings in Model 3 with the electron transitions that are occurring, the wavelengths and corresponding colors as given in example A in Model 3. See Model 2 in order to identify the color of spectral lines produced in each of the hydrogen atom electron transitions shown in Model 3. Use colored pencils to trace the light wave in each of the four pictures with the appropriate color.

22. Consider the electron transitions in Model 3.

   a. Which of the electron transitions involves the most energy?

   Transition A (n=6 to n=2) involves the most energy.

   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 *relaxes* through 4 energy levels, it experiences the greatest change in attractive force to the protons in the nucleus.

23. Explain why a single atom of hydrogen cannot produce all four hydrogen spectral lines simultaneously. *(Hint: how many electrons are in a hydrogen atom?)*

   Since each H atom has only one electron, that single electron cannot simultaneously produce all 4 of the visible lines (and multiple additional lines in spectral regions we cannot see).

24. If Question 23 is true, how can we see all four colors from a hydrogen gas discharge tube simultaneously? *(Hint: how many atoms of hydrogen are in the discharge tube?)*

   There are a large number of H atoms present (remember, even if we have a very small fraction of a mole, that still represents trillions or more atoms), each being excited and producing random spectral lines. Additionally, after relaxing, a H atom can be re-excited and produce additional spectral lines.

For additional information, see the **Neon Lights & Other Discharge Lamps** PhET at https://phet.colorado.edu/en/simulation/discharge-lamps and the online notes.