PRE-TILT

Preparation for Group Activity
Bohr Theory and the Line Spectrum of the Hydrogen Atom

Introduction:

Spectroscopy is the use of light (electromagnetic radiation) to study matter. The emission and absorption of light by matter provides most of the information we have about the electronic structure of atoms and molecules. Comparing spectra predicted by theory to actual spectra provides the most important check of the "correctness" of our theories concerning the structure of the atom. Furthermore, spectroscopy is the most important tool in chemistry for following the course of chemical reactions and identifying compounds. It is used routinely in medical labs, research labs, quality control labs and forensic (crime) labs. Learning about spectroscopy of one type or another is a part of every course in the chemistry curriculum. In this activity we will explore the relationship between the allowed energy levels in the hydrogen atom and its atomic line spectrum.

Figure 2.7 in Zumdahl & Zumdahl shows the hydrogen atom spectrum that is in the visible portion of the electromagnetic spectrum and a diagram showing how the spectrum is obtained. In 1913, Niels Bohr, a Danish physicist proposed a model of the hydrogen atom that explained the appearance of the hydrogen atom spectra.

<u>Bohr's Model of the Hydrogen Atom</u>

1. The hydrogen atom consists of a heavy, positively charged nucleus, around which a single electron circulates.
2. The electron exists only in those paths for which its angular momentum ($m\nu r$) is an integral multiple of $\frac{h}{2\pi}$ .That is $m\nu r = n\left(\frac{h}{2\pi}\right)$ where m = mass of electron, h = Planck's constant, and *n* = integer 1, 2, 3, etc.
3. As long as the electron remains in such a path it neither gains nor loses energy.
4. Energy is absorbed or emitted from the atom only when an electron undergoes a transition from one allowed path to another. This transition is accompanied by the absorption or emission of a single photon, whose energy is

$$E_{photon} = h\nu_{photon} = |\ E_{final\ path} - E_{initial\ path}\ |$$

Learning Objectives:

After completing this activity you should be able to:

1. Explain the relationship of the Bohr Model to the line spectrum of hydrogen.
2. Use the energy level diagram of hydrogen as predicted by Bohr's Theory to calculate the wavelengths of the lines of the hydrogen atom spectrum.
3. Depict the transitions corresponding to absorption or emission of radiation on an energy level diagram.

Resources:

- Read sections 2.3 and 2.4 in Zumdahl & Zumdahl; inspect the line spectra in Figure 2.7b and study Bohr's postulates (given above) for his model for the hydrogen atom.
- Be able to define the following terms as used in this chapter: *Wavelength, frequency, electromagnetic spectrum, Planck's constant, continuous spectrum, line spectrum, energy levels, absorption,* and *emission*.

Name:

Pre-activity assignment (complete in advance and turn in on activity day):

1. Record the wavelengths of each of the lines in the spectrum for hydrogen from Figure 2.7b in Zumdahl and also ***calculate the frequency*** of each line.

2. State in words the **precise** meaning of the following equations: (Be specific. Don't just say "energy" - say the energy of what.)

   A) $v = \frac{c}{\lambda}$

   B) $E_{photon} = hv$

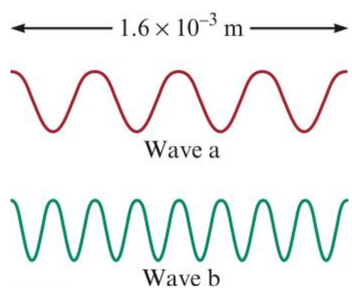
   C) $E_n = -2.18 \times 10^{-18}\,\text{J}\left(\frac{Z^2}{n^2}\right)$

   D) $\Delta E = E_{final} - E_{initial} = E_{photon} = hv$

3. Work the following problems (**2.42**, **2.45**, and **2.46** from Zumdahl)

2.42 A photon of ultraviolet (UV) light possesses enough energy to mutate a strand of human DNA. What is the energy of a single UV photon having a wavelength of 25 nm?

2.45 Consider waves ***a*** and ***b***, representing electromagnetic radiation:



i. Calculate the wavelength of both waves.

ii. Which wave has the longer wavelength? Which wave has the higher frequency and larger photon energy? Calculate these values.

iii. Which wave has the greater velocity?

iv. What type of electromagnetic radiation does each wave represent?

2.46 One type of electromagnetic radiation has a frequency of 107.1 MHz, another type has a wavelength of 2.12×10^{-10} m, and another type of electromagnetic radiation has photons with energy equal to 3.97×10^{-19} J/photon. Identify each type of electromagnetic radiation and place them in order of increasing photon energy and increasing frequency.