

# **Ozobot Bit Classroom Application: Illustration of the Emission Lines of the Balmer Series**

## **Created by**

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## **Topics**

Physics

Chemistry

Spectrum

Emission Lines

Balmer Series

Bohr Atom

Energy States

## **Ages**

Grades 9-12

## **Duration**

10-15 minutes

# Ozobot Bit Classroom Application: Illustration of the Emission Lines of the Balmer Series

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Students always seem to enjoy viewing emission spectra of gases such as hydrogen, helium, and neon, to mention just a few. The simplest way to view these spectra qualitatively is to view them through a diffraction grating mounted to a piece of cardboard. This technique allows the student to identify different gases by their unique spectra. If the class wants to do a quantitative experiment, then it is common to use an emissions spectrometer such as those available through Vernier Software and Technology. The most frequently studied gas quantitatively is hydrogen (H), as it is the simplest of all of the elements, having one proton and one electron.

Johann Balmer came up with an empirical relationship between the visible spectral lines of Hydrogen. A few years later, Johannes Rydberg did some adjustment of Balmer's equation making it more general. His equation eventually led to the discovery of additional spectral series in the early 20<sup>th</sup> Century—the ultraviolet Lyman series and the infrared Paschen series.

It wasn't until 1911 that a causal explanation for the spectral lines of hydrogen emerged when Niels Bohr proposed a model of the hydrogen atom that would eventually be referred to as the Bohr Model of the atom. His model assumed that the electron orbited in one of many discrete energy states, with the lowest energy state when the electron is nearest the central proton, the so-called ground state. If the hydrogen atom received some additional energy, by either photon absorption or an inelastic collision, the electron jumps up to a higher energy "excited" state at a greater radius orbit. It is not until the electron transitions back down to a lower energy state that it emits a photon. The visible Balmer series represents electron transitions from excited states in which  $n > 2$  back down to the  $n = 2$  state. Figure 1 shows the Bohr representation of these transitions. The transitions are well-known as H- $\alpha$ , H- $\beta$ , H- $\gamma$ , and H- $\delta$ .

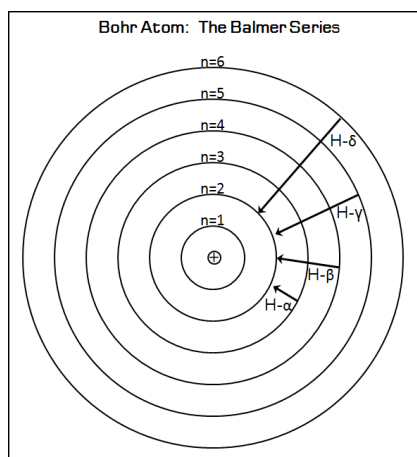


Figure 1

Energy level diagrams are commonly used to show the transitions from the higher energy to the lower energy states. This is where Ozobot Bit makes his appearance as an excited electron making transitions from the higher energy states ( $n=6$ ,  $n=5$ ,  $n=4$ ,  $n=3$ ) down to the  $n=2$  state, which characterizes the Balmer series of hydrogen. For reference while studying this classroom application, Figure 2 shows a small version of the Ozobot Bit map that students will be using. A full page version that can be printed for actual use with Ozobot Bit appears on the last page of this document.

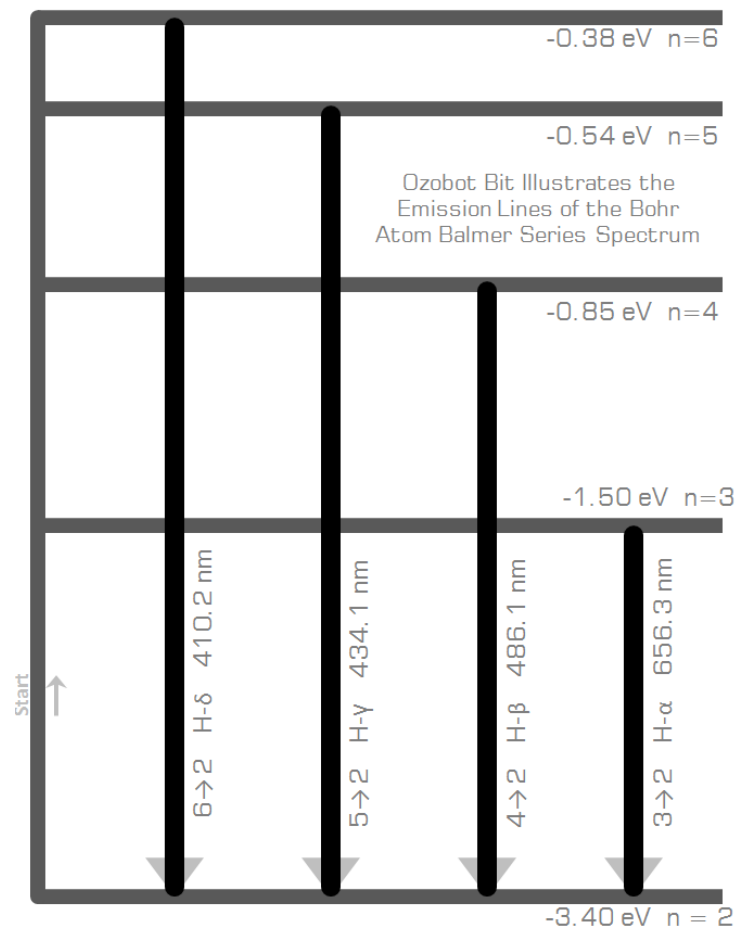


Figure 2

The energy levels for  $n=6$  to  $n=2$  are shown as horizontal lines and are labeled with the energy in units of eV (electron Volts). The ground state  $n=1$  is not shown as its energy is  $-24.58$  eV. If it had been shown, the higher energy level states would have been crowded together near the top of the figure. Note that the energy levels shown by the horizontal lines are not to exact scale, but do show that they get closer and closer together as  $n$  increases.

The vertical lines with gray arrow heads at the bottom represent the four visible transitions  $6 \rightarrow 2$ ,  $5 \rightarrow 2$ ,  $4 \rightarrow 2$ , and  $3 \rightarrow 2$ . Each of the transitional lines also shows the common name for the line H- $\alpha$ , H- $\beta$ , H- $\gamma$ , and H- $\delta$ , as well as the wavelength of the photon given off during the transition. The wavelength is expressed in nm (nanometers), *i.e.*, billionths of a meter. H- $\alpha$  is a **red** spectral line, H- $\beta$  is an **aqua** colored spectral line, H- $\gamma$  is a **violet** spectral line, and H- $\delta$  is a **near-ultraviolet** spectral line.

## **Running the Ozobot Bit Program**

1. Load the program *BohrAtomBalmerSeries.ozobot* into Ozobot Bit
2. Make sure that Ozobot Bit is calibrated on paper before running the program.
3. Make sure that Ozobot Bit has clean wheels and plenty of battery charge.
4. Place Ozobot Bit at the location labeled “Start” and facing the direction shown by the gray arrow.
5. Start Ozobot by double-pressing the start button.
6. Ozobot will show a white LED for about two seconds. Then the LED will turn off and Ozobot Bit will start moving.
7. He will first illustrate the  $3 \rightarrow 2$  transition for the H- $\alpha$  spectral line, and will show a **red** LED while transitioning, in accordance with the actual color of the photon emitted during the transition.
8. Next, he will illustrate the  $4 \rightarrow 2$  transition for the H- $\beta$  spectral line, and will show a **aqua** LED.
9. Next, he will show the  $5 \rightarrow 2$  transition for the H- $\gamma$  spectral line, and will show a **violet** LED.
10. Finally, he will show the  $6 \rightarrow 2$  transition for the H- $\delta$  spectral line, and will show a “near ultraviolet” LED.
11. Steps 7 through 10 will be repeated over and over until you turn Ozobot Bit off or he runs out of battery charge.

**Classroom Exercise #1:** Given the well-known equations  $E = hf$  and  $c = f\lambda$ , where  $E$  is the energy of a photon whose frequency is  $f$  and whose wavelength is  $\lambda$ ,  $h$  is Planck’s constant  $6.63 \times 10^{-34}$  joule-s. and  $c$  is the speed of light  $3 \times 10^8$  m/s, ask the students to do a tiny bit of algebra and show that  $\lambda = hc/E$ .

**Classroom Exercise #2:** Considering the differences in energy levels shown in the Ozobot map for this project and the equation from classroom exercise #1, calculate the wavelengths corresponding to the four Balmer series transitions. How well do they compare to the wavelengths shown on the transition lines on the Ozobot map?

