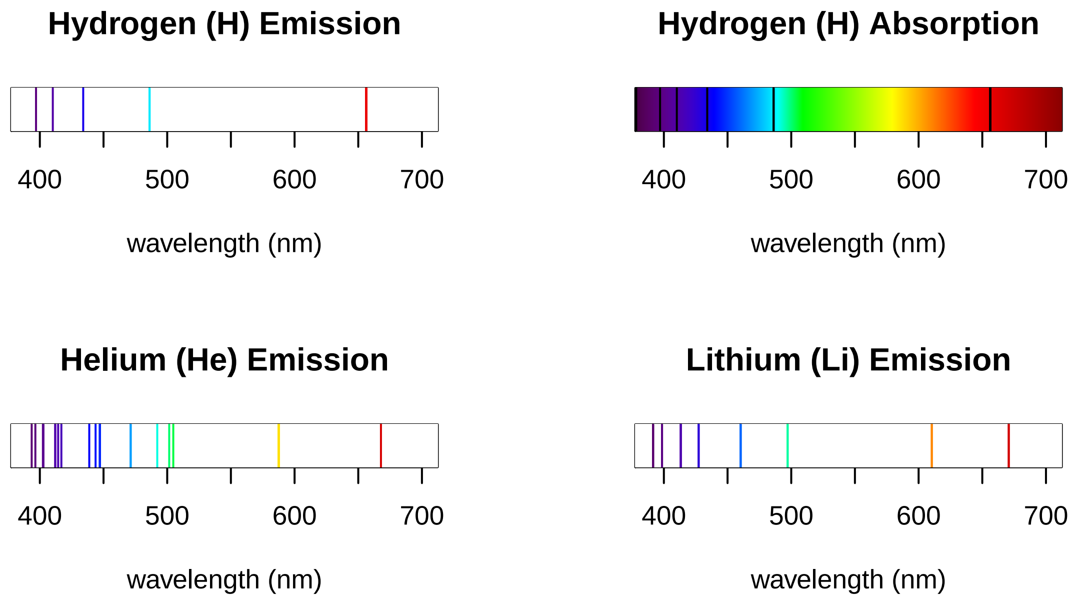
Key for Atomic Emission/Absorption Worksheet

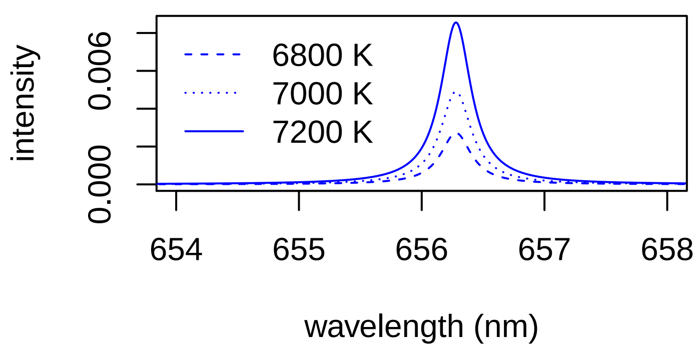
Shown below are the atomic emission and atomic absorption spectra for H in the top row, and the atomic emission spectra for He and for Li in the bottom row. The vertical lines give the wavelengths of light emitted or absorbed.



Examine this set of spectra. In what ways are they similar? In what ways are they different? Do you see any pattern(s) in the emission lines for the individual atoms?

- Similarities
  - the emission lines and the absorption lines for hydrogen are at the same wavelengths
  - all three elements have more lines at shorter wavelengths than at longer wavelengths
- Differences
  - helium and lithium have more emission lines than is the case for hydrogen
- Pattern(s)
  - the gap between successive emission lines becomes smaller at shorter wavelengths
  - this is true for H and mostly true for He and Li

Shown below is a portion of the atomic emission spectrum for hydrogen at several temperatures.



What conclusion(s) can you reach regarding how temperature affects atomic emission?

- increasing temperature results in the emission of a greater amount of light, but does not affect the wavelength of light emitted.

Suppose we define the distance from the whiteboard in our classroom to the opposite wall as a length of L. If I walk halfway from the whiteboard to the opposite wall, then I travel a distance equivalent to $1/2$ L and a cumulative distance of 0.5 L. Let's call this Event 1. If I now walk half of the remaining distance, then I travel a distance equivalent to an additional $1/4$ L and a cumulative distance of $0.5 + 0.25 = 0.75$ L. Let's call this Event 2. Continue this pattern for three additional cycles and complete the following table.

Event	Fraction of L Traveled	Cumulative Distance Traveled
1	$1/2$	0.500 L
2	$1/4$	0.750 L
3	$1/8$	0.875 L
4	$1/16$	0.9375 L
5	$1/32$	0.96875 L

What pattern(s) do you see in these values? How is this pattern similar to the emission spectrum for hydrogen?

- The denominator for the fraction of L traveled increases from 2 to 4 to 8 to 16 to 32, a pattern of $1/2^n$ where n is 1, 2, 3, 4, 5. As seen below, the cumulative distances (filled circles) are closer together as we move from right (cumulative distance = 0) to left (cumulative distance = 1 L); this is similar to what we see for hyrogen.

We can write the following equation to predict the cumulative distance traveled in units of L

$$\text{cumulative distance traveled} = 1\ L \times \left\{ \frac{1}{2^{n_1}} - \frac{1}{2^{n_2}} \right\}$$

which is a function of two variables, n_1 and n_2, with $n_2 > n_1$ and where their values are restricted to the integers $0, 1, 2, \ldots$ What values of n_1 and n_2 give the cumulative distance in the first row in our table? For the last row? Can you create a general rule for the values of n_1 and n_2 that explains the data in our table?

- For the first row, $n_1 = 0$, $n_2 = 1$ and cumulative distance is $1/2^0 - 1/2^1 = 1 - 0.5 = 0.5$ L.
- For the last row, $n_1 = 0$, $n_2 = 5$ and cumulative distance is $1/2^0 - 1/2^5 = 1 - 0.03125 = 0.96875$ L.
- General rule is $n_1 = 0$ and $n_1 =$ event number.

The wavelengths for hydrogen's emission lines follow a pattern that obeys the following equation

$$\frac{1}{\lambda} = (1.09737 \times 10^{-2}\ \text{nm}^{-1}) \times \left\{ \frac{1}{n_1^2} - \frac{1}{n_2^2} \right\}$$

where $n_2 > n_1$, and where $n_1 = 2$. The longest emission line in the spectrum for hydrogen is at 656 nm. Show that this wavelength is consistent with this equation.

- We expect the wavelength of 656 nm corresponds to $n_1 = 2$ and $n_2 = 3$. Substituting into our equation

  $$\frac{1}{\lambda} = (1.09737 \times 10^{-2}\ \text{nm}^{-1}) \times \left\{ \frac{1}{2^2} - \frac{1}{3^2} \right\} = 0.0015241\ \text{nm}^{-1}$$

  gives $\lambda = 656$ nm.

If n_1 is 3, what is the smallest value for n_2 and what is the corresponding wavelength for its emission line.

- If n_1 is 3, then the smallest value for n_2 is 4. The corresponding wavelength is

  $$\frac{1}{\lambda} = (1.09737 \times 10^{-2}\ \text{nm}^{-1}) \times \left\{ \frac{1}{3^2} - \frac{1}{4^2} \right\} = 5.3344 \times 10^{-4}\ \text{nm}^{-1}$$

  which gives $\lambda = 1875$ nm.