Chemistry Honors Name _________________ Date ________ Period ______
Partner Lab Atomic Emission Spectra

What is light?

Sounds like a simple question, right? Believe it or not, we don't really know. You have probably heard two different ways of talking about light. There is the "particle" theory, in which particles of light are called **photons**. There is also the "wave" theory, where waves of light are called **light waves**. In 1924, Albert Einstein stated that "there are therefore now two theories of light, both indispensable, and as one must admit today in spite of twenty years of tremendous effort on the part of theoretical physicists, without any logical connections." Modern physicists believe that light can behave as both a particle and a wave, but they also recognize that either view is a simple explanation for something more complex.

Light waves come in many sizes. The size of a wave is measured as its wavelength (λ), which is the distance between any two corresponding points on successive waves, usually crest to crest or trough-to-trough. The energy of a light wave can be determined once you know its frequency. The mathematical expression is:

$$\mathbf{E = \frac{c \cdot h}{\lambda}}$$

E= energy
c = speed of light (3.0×10^8 m/s)
h= Planck's constant, 6.626×10^{-34} J·s
λ= greek symbol, lamda, wavelength

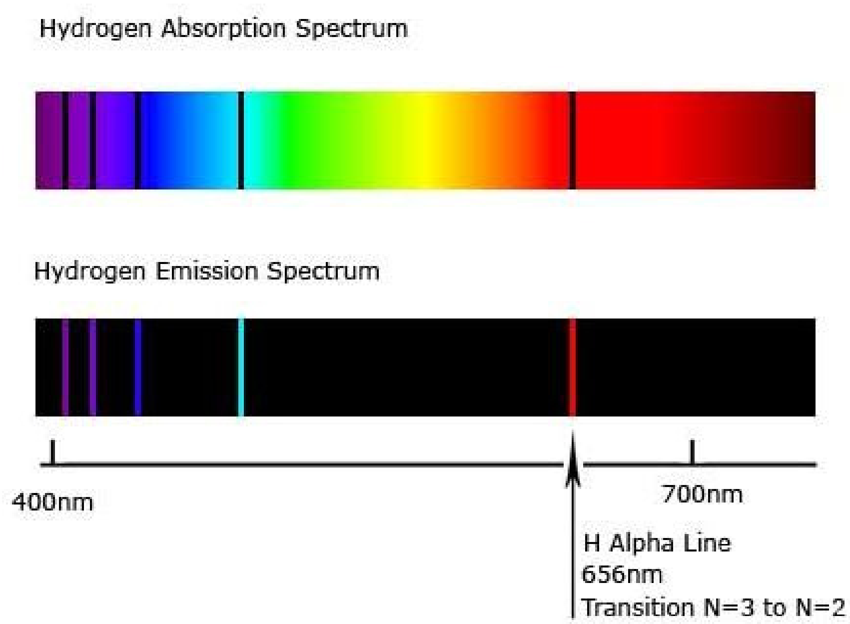
Wavelength is solved by knowing the frequency of the wave, *v*.

$\lambda = c/v$ <u>or</u> $c = \lambda \cdot v$

The relationship that these two formulas demonstrate is that the greater the frequency the smaller the wavelength and the smaller the wavelength the greater the energy. Wavelength and frequency have an inverse relationship and energy and wavelength have an inverse relationship. You do not have to know how to solve for these formulas, but you must understand the relationship that is represented by them.

What is a spectrum?

Anything that has a temperature emits light. We call this light *thermal radiation* or *blackbody radiation* in physics. A spectrum is a graph of the intensity (basically the number of photons) vs. wavelength (equivalent to the energy of the photons). The higher the temperature of the object, the more energetic the light that can be produced. Since a longer wavelength means less energy, the photons of the highest energy are to the left.
There are two forms of spectrum for an element, absorption and emission.



What does an absorption spectrum look like?

The image above is a hydrogen absorption spectrum. It looks like a continuous spectrum with a few specific colors missing, and that's exactly what it is. Those missing colors are light with a specific wavelength that has been ***absorbed*** by a hydrogen atom.

What causes absorption lines?

- The electrons in atoms have very specific energies at different levels. To jump from a lower to higher energy level, they must be given energy exactly equal to the energy difference between the two levels.
- If a photon comes along with exactly that energy, it will give all its energy to the electron, which will jump to a higher level. This is absorption.
- If we are looking at a source of a continuous spectrum, and a cloud of hydrogen gas is in front of that source, the cloud will absorb specific energies of photons (specific to hydrogen energy levels) from the continuous light coming from that source, and we'll see dark lines in the spectrum where light was removed.

What does emission spectrum look like?

Looking at the two images above, the emission spectrum of hydrogen corresponds with the missing lines from the hydrogen absorption spectrum. This means the energy, frequency and wavelength for the missing lines on the absorption spectrum are the same in the emission spectrum.

What causes emission lines?

- The atoms in the electron cloud absorb photons, allowing the electrons to shift into higher energy levels.
- The electrons “fall” back down into their original energy state, emitting a photon in a random direction in the process.
- Some of these photons will travel in the direction of the initial photon; others will not.
- If you look at the energy source, you will see a continuous spectrum minus all the photons that are not traveling in the initial direction. This is an absorption spectrum.
- If you don’t look at the energy source, you will only see the photons that are being emitted. This is the emission spectrum.

Why are the wavelengths missing from absorption spectra the only wavelengths where light is present in emission spectra?

- Electrons in a given atom have specific energy levels
- The electrons can only jump from one energy level to the next; cannot “stop” in between energy levels
- In order to change energy levels, the electron must either absorb or emit a photon of the appropriate energy
- The energy of a photon corresponds to its wavelength
- The electrons in the thin cloud of gas end up absorbing (and emitting) photons of the same wavelength over and over again

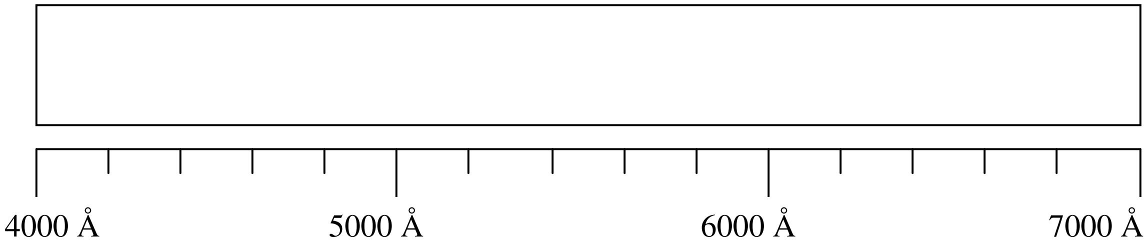
Procedure

a. Draw the spectrum.
   i. If possible, draw each emission line in its correct location. (If you have too much trouble looking at the scale through the diffraction grating scope, draw the lines at the correct relative distances from one another.)
   ii. Bands will be brighter at one end than the other. Draw the line at the bright end and use shading to indicate the width.
b. Label each line as bright, moderate, or faint using the letters b, m, and f.
c. Mark the colors (red, orange, yellow, green, blue, violet) over each line or group of lines.

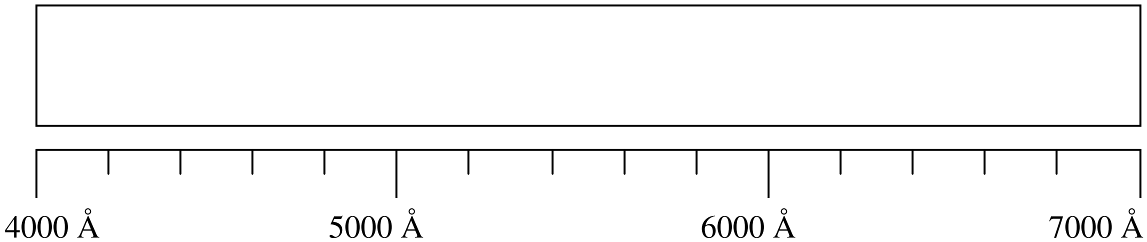
Questions you should be able to answer:

1. Hydrogen is the simplest atom, having only one proton and one electron. How does its spectrum compare with the spectra of other substances?
2. Since wavelength is uniquely related to color, why is it generally important to record wavelengths, which must be measured on a scale, rather than colors, which can be readily seen?
3. Compare the emission spectra of each of the elements. Are they each the same? If not, can we hypothesize that each element must have a unique spectrum signature, like a fingerprint?
4. Stars have absorption spectra. This means that a star composed of hydrogen would have a spectrum showing every color except for a few dark absorption lines where those specific wavelengths of light were absorbed. Those lines would correspond to the few colored lines which you saw in your hydrogen emission spectrum. Now, in reality, stars are composed of many different elements, and even molecules. Thinking about the activity you just did, how do you think astronomers are able to figure out all the different substances that are present in stars?

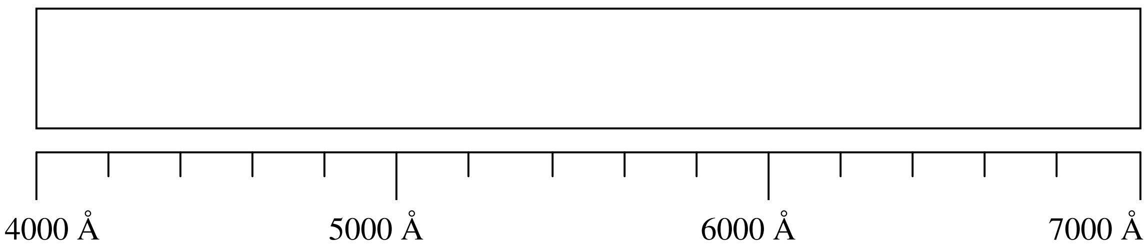
Hydrogen



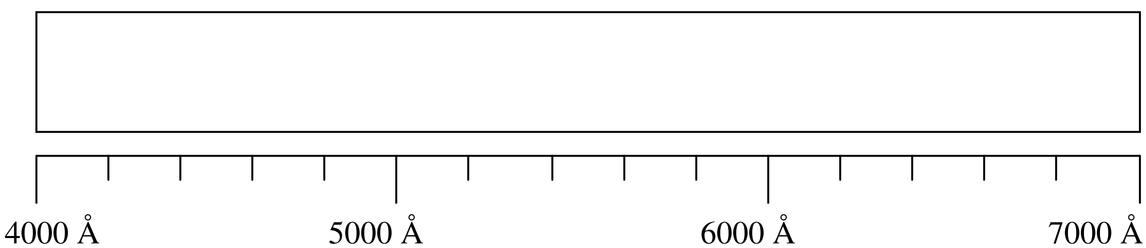
Helium



Nitrogen



Oxygen



Argon