

# Analysis of Spectral Lines

## **Why?**

Many devices give off visible light when heated or when an electric current is passed through them. Everyday examples include light bulbs, stove and toaster oven elements, and neon signs. Visible light may be separated into individual colors of light by passing the light through a prism or a diffraction grating (which may be found in a spectroscope). White light and sunlight consists of all the colors of the rainbow, but the light given off by an excited element consists of light of specific colors. A display of the different colors is called an emission spectrum of the element. Just like fingerprints can be used to identify an individual, an emission spectrum can be used to identify the presence of an element.

## **Success Criteria**

- Describe how a bright line spectrum is produced in terms of energy transitions of the electrons in an atom as they move from one energy level to another.
- Qualitatively relate the energy of electronic transitions to the specific colors of light observed.
- Accurately identify the presence of an element in an unknown mixture by comparing the emission spectrum of a mixture with the emission spectrum of specific elements.

## **Resources**

- Demonstration of light emitted by various spectral tubes that is observed through a diffraction grating or spectrophotometer (spectroscope?).
- <http://people.westminstercollege.edu/faculty/ccline/elements/elements1.html>
- <http://jersey.uoregon.edu/vlab/elements/Elements.html>

## **Prerequisites**

- Bohr Model of the atom, visible light spectrum colors /energy relationships

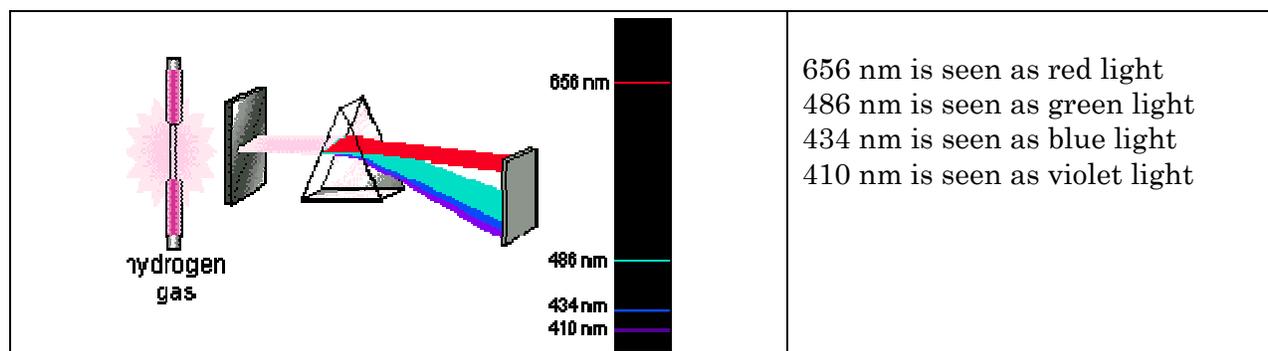
## **Vocabulary**

- Ground state, excited state, spectral lines, emission spectrum, electronic transitions

## Model 1: Production of an Emission Spectrum

In Bohr's atomic model an atom's electrons are assigned to specific energy levels. The atom is in its **ground state** when the electrons occupy the lowest possible energy levels. When an electron absorbs sufficient energy it moves to a higher energy level to produce an **excited state**. When the electron releases the energy, it drops back to a lower energy level. The energy is released in the form of light. The wavelength of the emitted light indicates the difference in the energy of these two levels. Each wavelength of light corresponds to a specific color of light (which may or may not be visible). Consequently, atoms emit a characteristic set of discrete wavelengths - not a continuous spectrum.

Since each element has its own unique electron arrangement, the light that is emitted by the atoms produces an emission spectrum that can be used to identify the element. In other words, an atomic spectrum can be used as a "fingerprint" for an element because it is unique for each element and reflects the energy levels occupied by the electrons in an atom of the element.



### Task

Use the **Resources** to explore the spectra produced by various elements.

Observe the spectra emitted by different gases in spectrum tubes as they are shown by your teacher or presented on the web site.

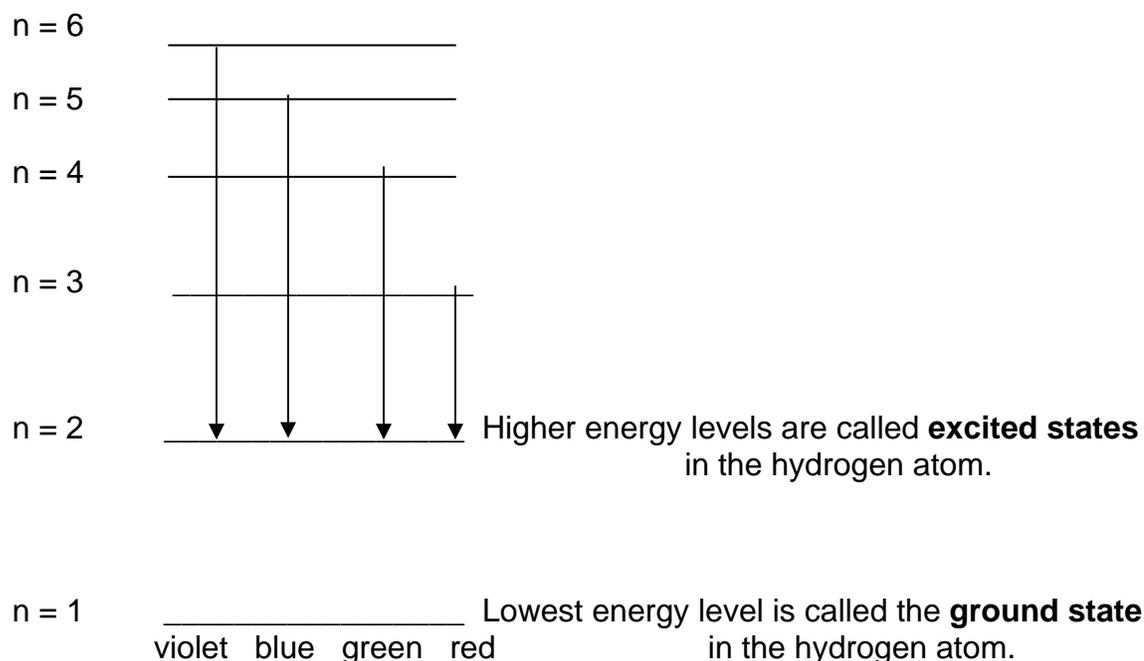
Record the colors that are observed for each of the gas samples below. If a mixture of gases produces a spectrum, try to identify the lines that are formed by each of the gases in the mixture.

## Key Questions

1. What is the difference between an excited and ground state of an atom?
2. What happens when electrons move from the excited state to the ground state?
3. What colors of visible light are found in the emission spectrum of hydrogen?

## Model 2: Energy Level Diagram for the Hydrogen Atom

If atoms only emit discrete wavelengths of light, then an atom's energy levels can only have discrete energies. The energy level diagram below illustrates some of the energy levels found in a hydrogen atom, with arrows showing the corresponding electron transitions that produce its visible emission spectrum. The transitions shown are from excited states to the second energy level. Transitions to the first energy level (the ground state for the hydrogen atom) do not fall in the visible range (but in VU & IR range).

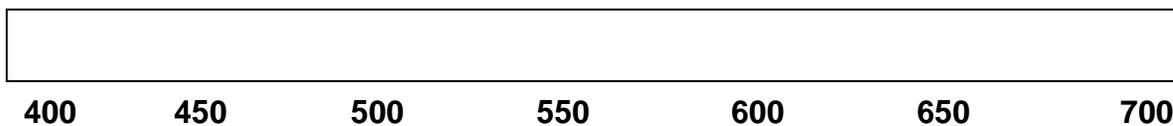


## Key Questions

4. What happens to the energy of the electrons to produce the observed spectral lines?
5. For the element hydrogen, which color (wavelength) of light is produced by the largest energy drop of an electron? Explain your answer.
6. Which color of light does the smallest energy drop of an electron produce? Explain your answer.
7. Why do different elements emit different colors of light?

## Exercises:

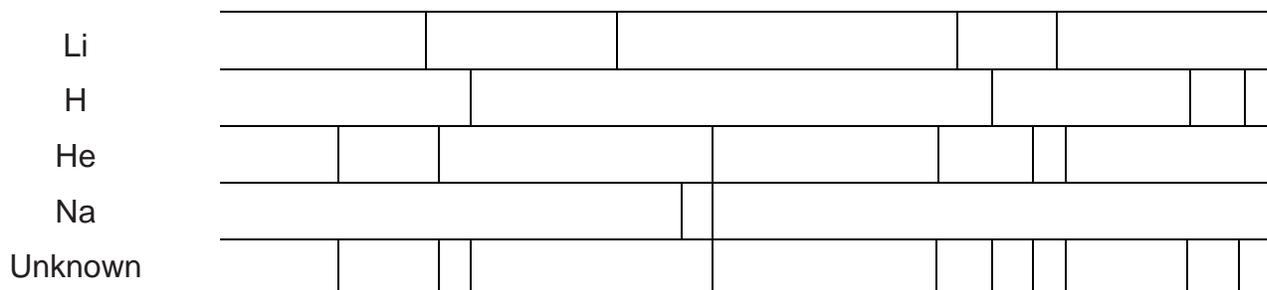
1. Using the web-link cited in the **Resources**, draw the emission spectrum for the element lithium in the box below.



2. In Model 2 all of the transitions stop at  $n=2$ . If transitions to  $n=1$  were to be shown in the diagram (draw an arrow from  $n = 6$  to  $n = 1$  on the diagram of model 2);
  - a. Would you expect the energy from  $n=6$  to  $n=1$  transition to be greater than or less than from  $n=6$  to  $n= 2$  transition?
  - b. Would you expect the spectral line to be in the infrared (IR), or ultraviolet (UV) region of the spectrum? Explain your answer.

**Problems:**

1. Below are the bright line spectra of four elements and the spectrum of an unknown gas.



<http://www.nysedregents.org/testing/scire/sciarch/pschemtestau03.pdf>

- a) Which elements are in the unknown?
- b) Why are you able to exclude the presence of the other elements?
- c) Young stars are mostly hydrogen with a small abundance of helium and other elements. Is the unknown a likely spectrum for a young star? Explain your answer.
2. In a forensic investigation, it was suspected that a toxic chemical, which contains the element copper and accumulates in large amounts in hair as well as other tissues, poisoned the victim. Using your knowledge of emission spectra, design a method by which you can confirm the presence of this toxin in the victim. Include the resources and equipment would you need to make a definitive determination.