Observing Spectra in Your Environment

Materials : Diffraction grating, colored pencils or crayons, paper. You will get a piece of diffraction grating from the instructor at the first meeting. It looks like a small piece of transparent plastic. Hang on to it, and avoid getting fingerprints on it. Diffraction gratings are not sold in most stores. If you lose yours, ask the instructor or order from Edmund Scientific. You do not have to give the grating back.

Environment: In this lab, you will be observing different light sources and drawing their spectra. You will be observing continuous and emission spectra. Normal incandescent light bulbs and halogen light bulbs produce continuous spectra, Compact fluorescent and normal fluorescent light bulbs produce emission spectra.

Some of the most distinctive spectra come from "Neon" signs. These are the kind of lighted sign where the light comes from a fluorescent tube, as in the photo. Typical signs like this might say "BAR" where the letters are formed from the glass tubes. The decorative lights on the tower of the Century Theater in downtown Pleasant Hill are the right kind. Black Lights are fine. The photo has four different colors of lights, so you could use this for four different emission spectra.

You should not expect to complete this lab at home indoors. Most of the lights we use at home produce continuous spectra, so they will not do as different sources

(The kind of colored light where the color comes from a plastic or glass cover is NOT the right thing. The tail lights of your car, traffic lights, most MacDonald's signs are not the right thing). Benicia is a center for artists who make custom signs using gas discharge, so you might be able to find a studio with a large selection.

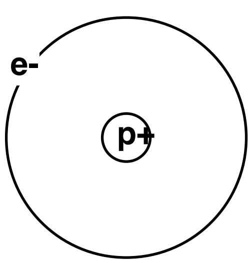
If you live in an area where there are no commercial establishments, or if you are color blind, discuss the situation with the instructor.

Activity: Observe and draw the spectra of at least 6 **different** sources. Include one continuous spectrum and 5 different emission spectra.

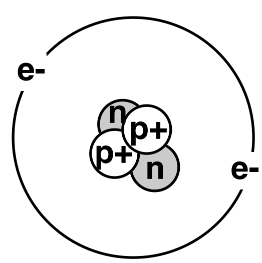
Background: In astronomy we usually receive only light from star, planets, and galaxies. Fortunately, this light tells us much more about the body than might be expected. The atoms, molecules, and ions in all materials reveal their identities by the light they absorb and emit. (Ions are atoms or molecules that have a different number of positive particles, protons, from the number of negatively charged particles, electrons).

A simple model of an atom consists of a nucleus with massive positive and neutral particles. The positive particles are named protons; the neutral particles are named neutrons. Electrons, which are negatively charged, orbit the nucleus as in the figure below. The attraction of unlike charged particles causes the electron to move in an orbit as close as possible to the nucleus.

Hydrogen Atom
1p, 1e



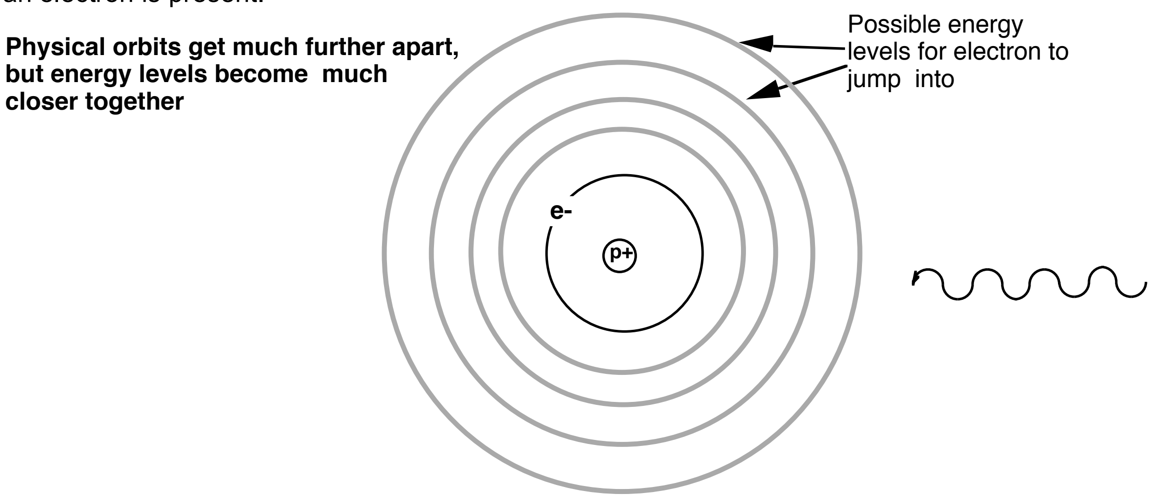
Helium Atom
2p, 2n, 2e



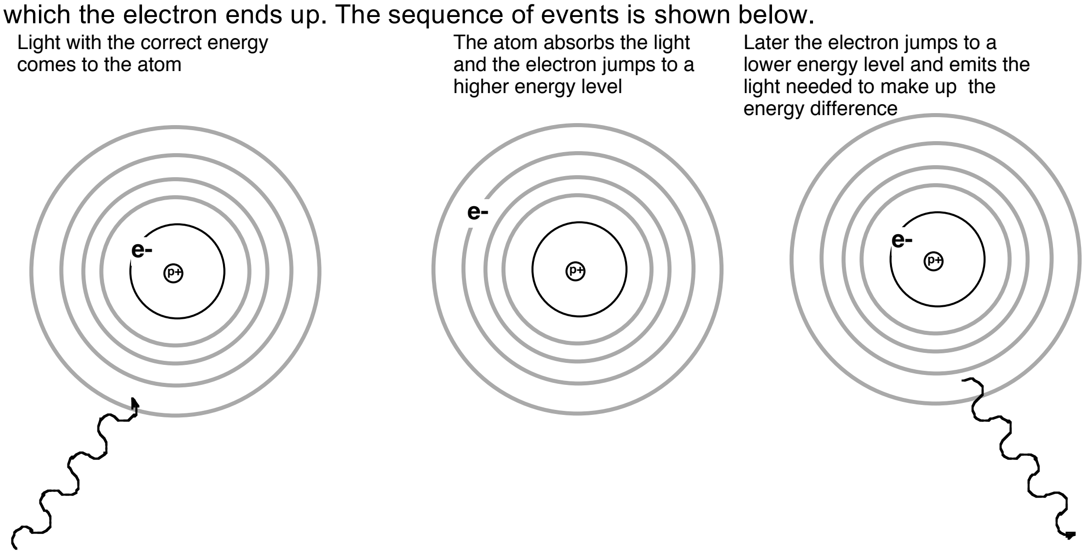
The electron orbits above are drawn as though they were circles. They actually extend in three dimensions. The regions where the electrons are found for hydrogen and for helium as shown above are roughly spherical shells with some thickness.

Other atoms are similar in layout to the hydrogen and helium atoms, but with larger numbers of protons and electrons. Not all electrons move in the same orbits. When there are more electrons they move in regions of differing shapes, and differing sizes. At most two electrons can move in an orbit of the same shape and size.

Electrons may not remain in the same orbit around the nucleus forever. When an atom encounters light, when it collides with another atom, or is affected by an electric field it can change its energy. A gain in energy usually moves an electron further away from the nucleus than it was previously. Only specific, distinct regions are available to the electron, each one corresponding to a fixed amount of energy (and fixed energy differences between the levels). Schematically, the hydrogen atom is depicted as having many possible energy levels, which the electron MIGHT go into. These are the only orbits that the electron can have. In the figure below, the possible energy levels are in lighter ink. There is nothing present at the higher levels unless an electron is present.

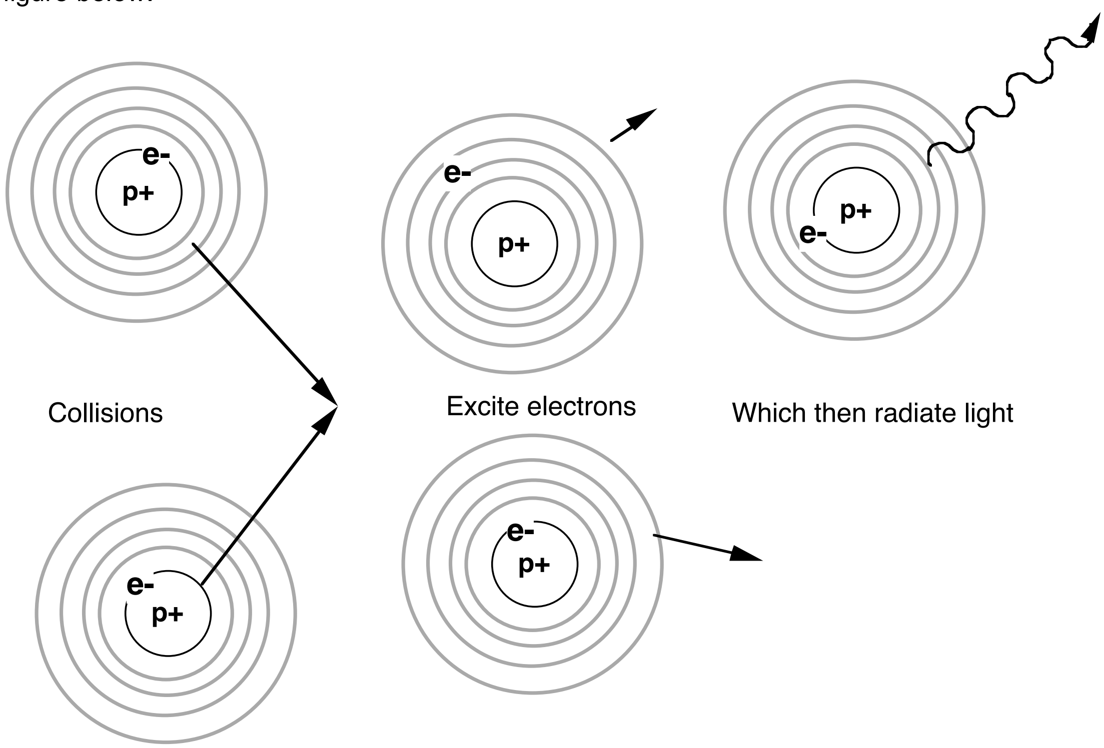


Each type of atom, molecule and ion has its own unique set of possible energy levels where the electrons can go. When an atom encounters light, it will absorb the light **only** if the light is at just the right energy to make up the difference between the level the electron starts at and the level at which the electron ends up. The sequence of events is shown below.



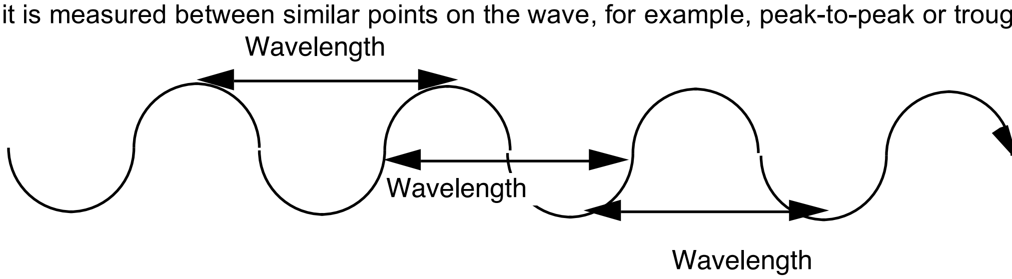
The direction of the outgoing light is usually independent of the direction of the incoming light. Notice that the electron in the figure above has jumped up TWO levels, rather than one. This is perfectly all right, if the light has enough energy (and some other relationships between the levels are met). The electron need not come down to the original lowest level all at once. It could come down one level, emit a photon, and then come down to the lowest level, emitting another photon.

Electrons can be made to jump to higher energy levels as a result of a collision of the electron's atom with another atom. Collisions like this occur due to the fact that any TEMPERATURE other than absolute zero (Kelvin) indicates the speed of the atoms. The atoms don't really go anywhere, they just jitter around, hitting one another. When a collision causes an electron to jump to a higher level, the speeds of the colliding atoms are reduced. Later the electron jumps down to a lower level, and gives off a photon, which carries the difference in energy, as shown in the figure below.



The way that we observe the energy in a photon is usually as its COLOR**.**

Color corresponds to the amount of energy, that the light carries (equivalently the wavelength and frequency of the light). The wavelength of the light is the distance between like parts of the wave. There is no special place on the wave from which the wavelength is measured, so long as it is measured between similar points on the wave, for example, peak-to-peak or trough-to-trough.



We do not sense all wavelengths with our eyes, but of the wavelengths we do see, red is the longest wavelength, about 7000Å, while blue is at about 4000Å. The symbol, Å, indicates the Ångstrom unit, 10^{-10} meters.

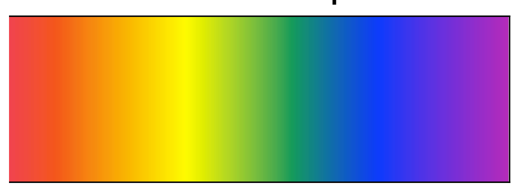
In this exercise you will examine the spectrum of colors given by a variety of materials. I

The gases, which we will look at, have their electrons disturbed by an electric field (yet another way to cause the electrons to jump). The light emitted by the gas has the specific energy, which the electron gives up as it returns to a lower level. When we look at things with our eyes, we see all the colors all at once and it is difficult to know exactly what types of light are being given off. To make it more apparent, we will split up the light using a diffraction grating. This separates the light so that EVERY DIFFERENT LOCATION CORRESPONDS TO A DIFFERENT WAVELENGTH. Even when the difference in color is imperceptible, the difference in position will that the wavelengths are different. When astronomers use diffraction gratings to separate the colors of light from a celestial body, they measure the exact position of the light, rather than the perceived color, to determine the wavelength. The pattern of wavelengths at which light is absorbed or emitted identifies:

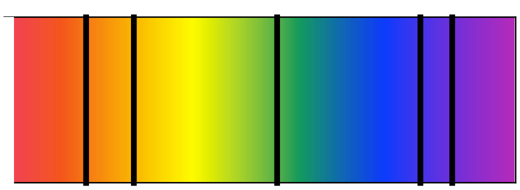
Composition
Temperature
Speed of approach or recession
Pressure
Magnetic field

The simplest type of spectrum to understand is called an **emission spectrum**. In this case, we see light with the specific energies, which are being emitting. The spectrum looks like bright lines, with a dark background. This occurs when there is a gas giving off the lines, it is not very dense, and there is nothing bright behind it.

When material is dense, as in a solid or liquid, the atoms or molecules all try to give up the correct, distinct amounts of energy called for by their energy levels. They are, however, altered by collisions with other atoms or molecules. These collisions occur so frequently that the energy levels are spread out. The atoms emit energy, but the lines are all smeared together and all that can be seen is a continuum of colors, like a rainbow. This is called a **continuous spectrum**. In a continuous spectrum the properties of the individual atoms and molecules are obscured and the only thing, which can be determined, is the temperature of the material (and that it is so dense that things are smeared together).



If a sample of diffuse material is illuminated by a bright continuous spectrum, some of the light of the continuous spectrum will be just the right energy to raise electrons from one level to a higher one. This light can be absorbed by the material in the front. When it is reemitted, the light need not go in its original direction. If we observe the light after it has gone through the diffuse material, we will see that there is LESS light in the wavelengths, which have been absorbed and reemitted by the diffuse, material than there is in other wavelengths. This looks like dark lines on top of a rainbow of colors. The dark lines are at the same wavelengths, which the material emits. It is called an **absorption spectrum**. The atmosphere of a star or planet will usually give an absorption spectrum. All the things in the list above can be determined about the material, which is absorbing the light (and the fact that there is a diffuse gas in front of a bright source).



Stars and planets normally give absorption spectra, and you will get to analyze. The lines are thin and will not be visible with your diffraction grating. Astronomers let the light of a star come through a narrow slit (like the thin tube of the neon lights, but thinner). The various colored images of the slit allow the dark lines to be seen.

Record your observed spectra below. Use colors. Try to keep red on the same side for all your drawings. Remember to include the continuous spectrum from a regular light bulb, the continuous spectrum and 5 different emission spectra. The spectrum you drew at your instructor meeting can be stapled to the back and CAN count as some of your spectra. When it says location, tell what building and location of the building if you are looking at a sign. Description is like sign, light bulb etc. If you find a light with a variety of colors, like the one at the start of the lab, you can use each color as a separate sample.

Turn in
Objective
Conclusion
Drawings and documentation of spectra

1 Location, description of source________________________________

Type of Spectrum (absorption, emission, or continuous)________________

2 Location, description of source________________________________

Type of Spectrum (absorption, emission, or continuous)________________

3 Location, description of source________________________________

Type of Spectrum (absorption, emission, or continuous)________________

4 Location, description of source______________________________

Type of Spectrum (absorption, emission, or continuous)_______________

5 Location, description of source______________________________

Type of Spectrum (absorption, emission, or continuous)_______________

6 Location, description of source______________________________

Type of Spectrum (absorption, emission, or continuous)_______________

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