Workshop Tutorials for Introductory Physics
QI3: **Spectra**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
discrete, impurity, electromagnetic, excited, spectroscope, ground, photon, Earth, lower, spectrum, emitted, wavelengths, absorption, Spectroscopy, gravitational, spectrum

Spectra

A _____ is a device which uses a prism or a grating to separate light into its component wavelengths and is a valuable tool in discovering what things are made of.

Light emitted by low pressure gases contains only a _____ set of wavelengths, and is called a line spectrum. When atoms are excited, for example by passing a current through them in a discharge tube, their electrons will not all be in the _____ state. Many electrons will be in _____ states. When these electrons move from one energy state to a lower energy state they emit a _____.

In fact it is not really the electron which changes energy, but the whole atom, including the electron. In the same way we talk about the _____ potential energy of a person increasing when they climb up stairs, but in fact it is the system, the person and the earth, which gains potential energy. Without the _____ there, it wouldn't mean much to talk about the person's gravitational potential energy, and without the rest of the atom there, it doesn't make sense to talk about electron energy levels either.

The _____ of an element can tell us about the energy levels of that element. This _____ is unique to an element, and is called an emission spectrum, because the light is _____ by the sample. This is used for identifying contaminants in materials such as silicon which need to be of extremely high purity to make semiconductors. A small sample of the silicon is heated until it starts emitting light, and the spectrum of this light is compared to that of pure silicon. Any extra lines indicate an _____.

Another sort of spectroscopy uses the absorption of light by electrons as they move from _____ to higher energy levels. These spectra look like a rainbow with black lines in them, and are called _____ spectra. Absorption spectra are used to tell what stars are made from. The hot core of a star emits a continuous spectrum of radiation. Atoms in the outer cooler region then absorb some _____, leaving dark lines in the spectrum. This spectrum can be compared to absorption spectra for elements to find out what's in the star.

_____ is used for a vast number of applications, from monitoring blood oxygen levels to identifying contaminants. There are many other sorts of spectroscopy, which use parts of the _____ spectrum other than the visible, and excitations of molecules as well as atoms.

B. Activity Questions:

1. Emission spectra

Use the hand held spectroscopes to "look" at light from different sources, such as sunlight (out the window) and light from fluorescent tubes.
What are the differences in the spectra from the various sources?
Why are the spectra different?

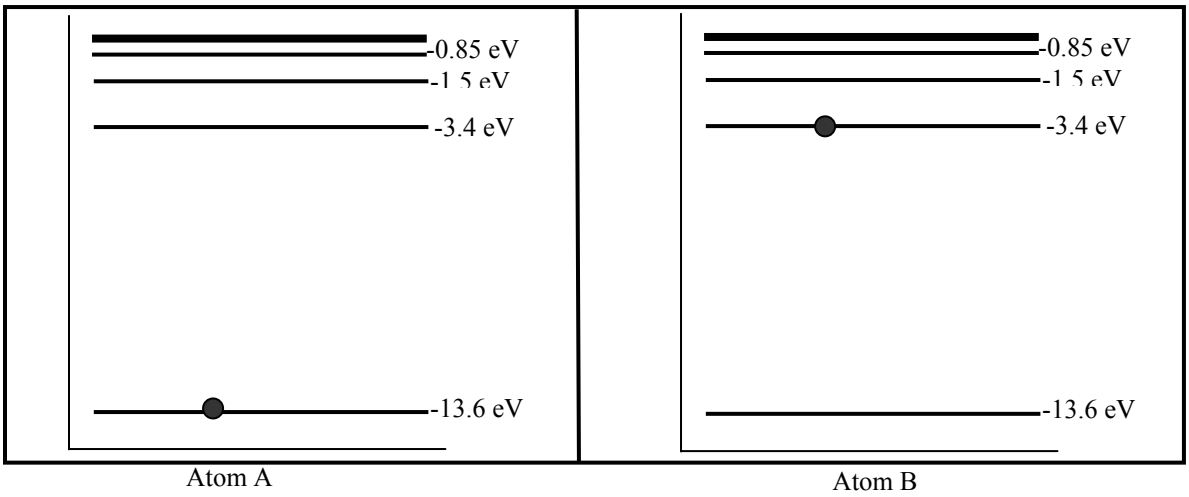
2. Identify the element

Use the spectroscope and the diagrams of various spectra to identify the type of atoms in the lamp.
What would a spectrum from a sample with several elements look like?

C. Qualitative Questions:

1. Some lines in the hydrogen spectrum are brighter than others. Why?

2. The diagram below shows the energy levels of a hydrogen atom. A black blob drawn on an energy level indicates that an electron occupies that energy level.



a. What, if anything, can happen to atom A if a photon of energy 10.2 eV approaches it? What can happen to the photon? If nothing can happen explain why not.
b. What, if anything, can happen to atom B if a photon of energy 10.2 eV approaches it? What can happen to the photon? If nothing can happen explain why not.
c. What, if anything, can happen to atom A if a photon of energy 2 eV approaches it? What can happen to the photon? If nothing can happen explain why not.
d. What, if anything, can happen to atom B if a photon of energy 2 eV approaches it? What can happen to the photon? If nothing can happen explain why not.

D. Quantitative Question:

Consider a hydrogen atom, ${}_1^1H$, which has one electron. In Bohr's model the electron can be in any one of many discrete energy levels. An electron in the ground state (n=1) energy level of hydrogen has an energy of -13.6eV, and in general $E_n = -13.6\text{eV}/n^2$.
a. Draw an energy level diagram for hydrogen.
Hydrogen has a red, a blue and several violet lines in its spectrum.
b. Which of these lines has photons of the highest energy and which has the lowest?
These lines are part of the Balmer series, which are transitions from n>2 to n=2.
c. Find the energy of the red photons. What wavelength does this correspond to? Mark this transition on your diagram.
d. Given that the visible range is from around 400 nm to 700 nm, to what part of the spectrum do photons from transitions from n>1 to n=1 belong?
e. What is the highest energy photon that an electron binding to a hydrogen nucleus can produce? What wavelength does this correspond to? Show this transition on your diagram.