

Name:

Class:

LUMINESCENCE
It's Cool Light!

Visual Quantum Mechanics

ACTIVITY 3

Introducing Energy Levels in Atoms

Goal

In this activity, we will use the *Gas Lamp Spectroscopy* computer program to understand how the spectral properties of gas lamps leads to discrete energy level models of atoms.

In the previous activity, we found that gas lamps emit distinct colors and therefore energies of light. These energies are emitted by the atoms in the gas. Atoms are the smallest components of a substance that possess the same physical and chemical properties of the substance. Unfortunately, atoms are too small to see so we will use experimental observations in addition to computer simulations to build an atomic model of light emission.

Although the atom is very small, it has a definite structure. Each atom in a gas tube consists of a positively charged nucleus at the center and negatively charged electrons outside the nucleus. As a result of the opposite charges on the electrons and the nucleus they attract each other. This attraction causes the electron to change energy as it approaches the nucleus.

These energy changes must obey the conservation of energy law. When an electron's energy decreases, some other form of energy must appear. For an electron in an atom the energy appears as light. Thus, by looking at the light emitted by gas atoms we are seeing the result of energy changes in atoms.

We will now use *Spectroscopy Lab Suite* to determine what the distinct spectral lines emitted by gases can teach us about the energy change of atom-bound electrons.

In *Spectroscopy Lab Suite*, select *Emission* under *Gas Lamps*. In this program, we can

- Select a gas tube and drag it to the gas lamp socket. The spectra for that gas will appear at the top of the screen.
- Add energy levels for an electron by using the Add Energy Level button.
- Move the energy levels by grabbing them at the left of the energy scale and dragging them to the desired position.

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- Create changes (represented by vertical arrows) by selecting the electron's initial energy (it turns green) and dragging the arrow to the electron's final energy. A colored spectral line on the lower spectrum will indicate the light emitted by the energy change that you have created. If the light is not in the visible spectra, it will not appear on the screen
- To match the energy changes with the gas spectrum you may move the initial and final energies. After inserting the changes you will see the spectral line change in an appropriate fashion.

Drag the figure of the hydrogen gas tube to the gas lamp socket. Look at the top of the right screen to see the spectral lines for hydrogen.

Create a transition that will match a line in the lower spectrum with one of the computer-generated spectral lines of hydrogen.

- ? How many electron energy levels are needed to create one spectral line?
- ? What is the energy of the spectral line as indicated by the eV scale?
- ? What is the difference in energy between the electron's initial total energy and its final total energy?^{H int}

Move the initial energy to a different value.

- ? What happens to the spectral line?

Now, move the final energy until the spectral line returns to the correct position.

- ? What is the energy difference between the initial and final energies?

^{Hint} Use the energy scale found on the right of the potential energy diagram.

The emission of one photon occurs when an electron makes a transition from a higher allowed total energy to any lower allowed total energy. The energy of this photon is equal to the difference of the electron's final and initial allowed total energies. Many such transitions create each spectral line that we see. Thus, the energy of the spectral line will remain constant as long as the difference in the electron's final and initial energies is constant.

Now create and move other energy levels and transitions until the bottom spectrum matches the top spectrum.

Sketch the resulting energy level diagram for hydrogen in the space below.

? How many energy levels are needed to create these three spectral lines?

? How many electron transitions are needed to create these three spectral lines?

? What other, if any, possible electron transitions can take place with the allowed energy levels illustrated on the screen?

Compare your energy diagrams with those of other students.

Describe the similarities and differences.

Repeat the steps to determine the energy levels and transitions necessary to produce the spectral lines emitted by mercury.

Sketch the resulting energy level diagram for the mercury gas in the space below.

? How is the energy level diagram for the mercury gas similar to the diagram for hydrogen?

? How are they different?

An important conclusion from this analysis is that we can explain the spectrum of gas atoms with just a few energy levels and a few transitions. Atoms always emit photons with the same energies, and each type of atom always has the same spectrum. From our matching of the spectra we must conclude that an electron can have only a few of all possible energies in an atom. These energies are called allowed energies.

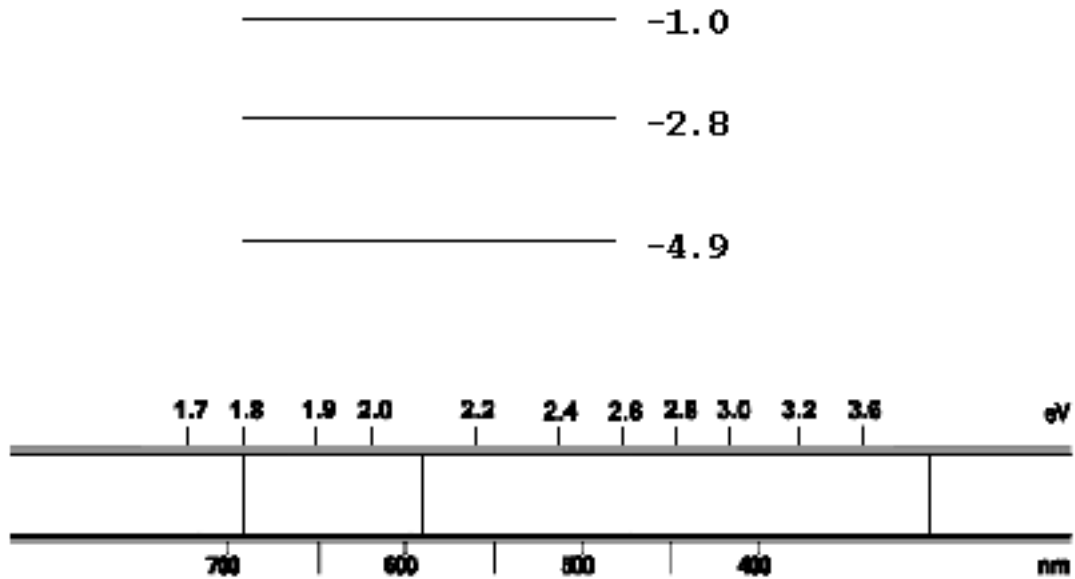
To emit a photon of light an electron moves from one allowed energy to another. The energy of the photon is equal to the difference between the electron's initial and final energy. Because we see photons of only a few energies, we conclude that only a few energy differences exist for each atom.

We also conclude that different types of atoms have different energy levels and transitions. The conclusion arises from the different spectra for each element.

Energy levels in atoms are sometimes described as "quantized", because of their relation to discrete, separated values. The electron transition is a change from one quantized energy to another. Thus, the general study of the behavior of electrons and other small objects is called quantum mechanics.

Homework

- 3-1) Construct the spectrum of light emitted by a gas represented by the following energy level diagram.



- 3-2) Visible light ranges in energy from 1.6 eV (red) to 3.1 eV (violet). How much of the resulting spectrum lies in the visible range?
- 3-3) Confirm your answers by using *Gas Lamp Spectroscopy*.