Name: Class:

SOLIDS & LIGHT

Visual Quantum Mechanics

ACTIVITY 8

Applying Energy Bands to Incandescent Lamps

Goal

We will apply what we have learned about energy bands and gaps to explain the physical properties of the incandescent lamp which we observed earlier.

In the previous activity, we developed the energy diagram representation of a solid (like the one inside an LED) starting from our observation of the LED spectrum and the energy level diagrams of gases. We concluded that energy bands must be present to obtain the characteristic broad spectra emitted by LEDs. We also found that the size of energy gap and the energy range of the two bands determine the color of light emitted by the LED.

The energy level model has successfully described the spectra emitted by gas lamps and LEDs. So, we will apply our model to explain the light emitted by incandescent lamps.

Open the *LED Spectroscopy* computer program and place any one of the LEDs in the socket.

Do not try to match the LED spectrum. Instead, use the program to construct an energy band diagram that would produce the spectrum emitted by an incandescent lamp when it is at maximum brightness.

? What is the range of energies (and colors) for the spectrum emitted by the incandescent lamp?

? How does the spectrum emitted by the incandescent lamp compare with the spectrum emitted by an LED?

In the space below sketch the resulting energy band diagram for your incandescent lamp.

? How does energy band diagram for the light emitted by the incandescent lamp compare with the energy band diagram for an LED?

The energy band diagram that we just constructed represents the diagram for a “white” (mixture of all colors) light LED. Although incandescent lamps emit “white” light, typical LEDs only emit light of a single color. Incandescent lamps are also different from LEDs in that when the electrical energy supplied to the lamp is increased, the color (and energies) of light emitted by the tungsten filament (a solid) changes from the red region of the spectrum to “white” light as the filament heats up.

The energy diagram in Figure 8-1 represents the bands and gaps for tungsten, the material in the filament of most incandescent lamps.

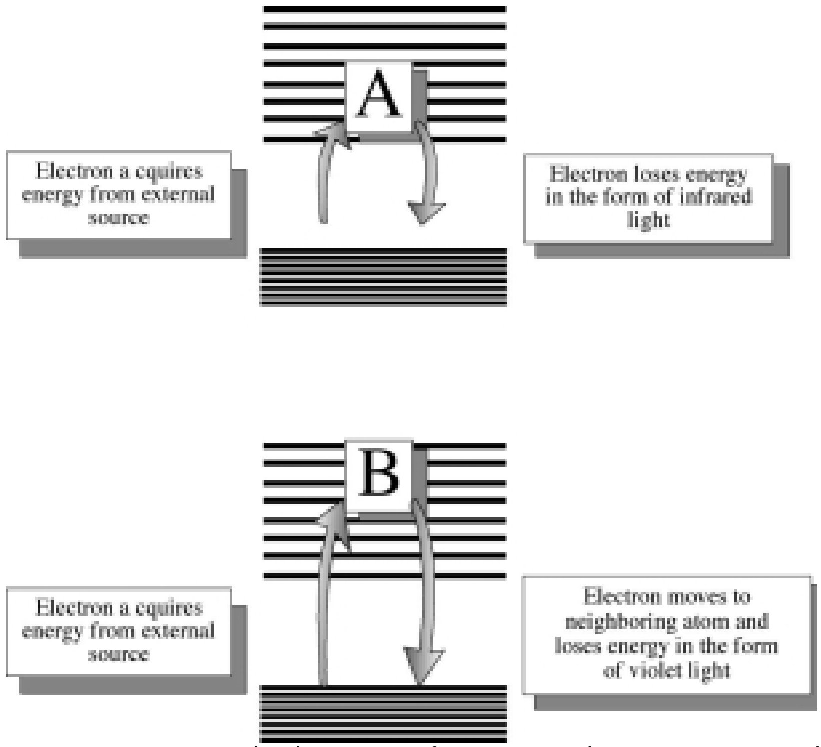

Figure 8-1: Energy Band Diagram of an Incandescent Lamp Filament

Since electrons seek lower energy levels, the electrons of the tungsten filament have energies associated with the valence energy band. When the battery provides sufficient electrical energy, electrons in the valence band make the transition to an energy level of the conduction band. (See Figure 8-1.) These electrons will then lose the energy they recently acquired when photons of light are emitted. As a result, the electrons make a transition back to the valence band of the filament. The light energy emitted can range from infrared to ultraviolet.

If the supplied energy is great enough, electrons from the valence band can make a transition to the highest energy level of the conduction band.These electrons make the transition back to the valence band by losing energy as photons of violet light (3.1 eV). Since enough electrical energy is being supplied to move electrons from the valence band to the highest energy level of the conduction band, the energy is more than sufficient for electrons to make a transition from the valence band to any energy level found between the lowest and highest energy levels of the conduction band. As a result, photons of light ranging from red (1.6 eV) to violet (3.1 eV) are also emitted.

When the energy supplied to the incandescent lamp is low, the color of the light has a large red component. At low voltages many of the electrons will receive just enough energy to reach lower energies in the conduction band. So, they can only emit light in the low energy end of the spectrum. Infrared light, which has a lower energy than visible light, is also emitted. This energy causes the lamp to be hot.

As the energy increases, the color of the light becomes “white.” The number of transitions that result in the release of photons in the middle or high energy end of the visible spectrum increases. Thus, the color of the light shifts from reddish to white.

Use this discussion to draw energy level diagrams that explain the color shift in an incandescent lamp. Draw one diagram for low voltages and another for higher voltages. Then describe the differences.

Unlike the incandescent lamp, the colors (and energies) of light emitted by the LED do not change with voltage. This difference is a reflection of the range of energies available in the conduction band of the materials that compose the devices. Incandescent lamps are made of electrical conductors that have a wide range of energies available in the conduction band. Semiconductors, which make up LEDs, have only a narrow range of energies in this band. This difference is displayed in the behaviors as the voltage (input energy) is changed.

An additional difference is the method by which the light-emitting electrons gain energy. In an LED electrical interactions directly transfer energy to these electrons. The incandescent process works differently. The energy to electrons comes from heating the material. In the incandescent lamp electricity causes the wire to become hot. The thermal energy is transferred to the electrons, and then they emit energy in the form of light. Incandescence is the process by which thermal energy is converted to light.

Homework

1. Electric cooking stoves emit heat and light from their burners. The heat that we feel is infrared radiation. The light that we see is always in the red end of the spectrum. With this information create an approximate energy level diagram for the material in the burners of an electric stove. Explain how you reached your answer.

2. Another example of incandescence is a glowing piece of metal in a fire. Use energy diagrams to explain why very hot metal emits light.