Name: Class:

ACTIVITY 2

Exploring Light Patterns

Goal

We will continue to investigate the properties of LEDs and the incandescent lamp by observing and exploring the light patterns emitted by some devices.

In the previous exploration we saw that incandescent lamps and LEDs have quite different properties when the energy supplied to them is varied. Further, LEDs that look alike on the outside can emit different colors of light, even though they are not painted any color. Thus, the LED, a rather recent invention, acts quite differently from ordinary lamps. Our goal for this series of activities is to understand how these devices work. To accomplish this understanding we need to learn about the emission of light by atoms. Because we cannot see atoms as they emit light, we will need to build a conceptual model of what is happening at the atomic level and use this model to understand LEDs.

The LED is made up of a very small solid consisting of a large number of atoms which are closely packed together and interact with one another in a complex manner. When energy is supplied to the LED, these complex interactions result in the light emitting properties that you have seen. In these solids each atom is very close to its neighbors. Just as with closely spaced people the nature of the interactions can be difficult to understand at first. Thus, we will begin with atoms that are far away from each other; study how they emit light and then work back to a situation where atoms are close together.

Atoms are relatively far apart in a gas. In fact, one of the defining properties of a gas is that the atoms or molecules have only a few interactions with each other. So, we will supply electrical energy to gases confined in a tube. These gas lamps, which are somewhat similar to fluorescent tubes, will emit light. By investigating this light we will be able to build a conceptual model of how gas atoms emit light. We will then extend this model to the closely spaced atoms in a solid and, thus, to LEDs.

 Visual Quantum Mechanics is supported by the National Science Foundation under grants ESI 945782 and DUE 965288. Opinions expressed are those of the authors and not necessarily of the Foundation.

In our investigations we will be particularly interested in the energy of the light emitted by the gas. Two factors — brightness and color — contribute in very different ways to the energy of a light. When we think about the definition of energy, the brightness makes sense. A bright light has more energy in it than a dim light. This conclusion matches the observation from the first activity — as we increased the electrical energy supplied to the lamps, they became brighter.

The color connection is not quite so obvious. Atoms emit light in small packets of energy . These packets are called photons. Each individual photon contains an amount of energy that is related to its color. So, if we wish to discuss the energy of one of these photons, we need to know its color.

For light that we can see the energy ranges from red at the low energy to violet at the high-energy end. Not visible but still a form of light are infrared photons with an energy lower than red and ultraviolet photons which have energies higher than violet. The order of energies for the various colors of photons is shown below.

Low energy photons:	Infrared
	Red
	Orange
	Yellow
	Green
	Blue
	Violet
Higher energy photons:	Ultraviolet

Each time an atom produces light, it emits one photon. Thus, in our investigations we will be primarily interested in the energy of individual photons. As we will see, this energy will tell us something about the atoms of a material. Thus, the color of a light will be an important variable. Each photon of visible light carries a very small amount of energy. This energy ranges from about 2.56×10^{-19} Joules for red light to 4.97×10^{-19} Joules for violet. Using these very small numbers is inconvenient, so we will use different units – the electron volt (eV). In these units, visible light energies range from about 1.6 eV (red) to 3.1 eV (violet) – much easier numbers to deal with.

The brightness of the light is related to the number of photons emitted. A dim light will emit fewer photons than a bright light. Thus, we have two measures of energy — brightness and color. Because color is related to the light from each individual atom, we will concentrate on it.

Most light is composed of several different colors. To separate the colors we use a spectroscope. Inside the spectroscope you will see each of the colors which are present in the light. If you look at white light through a spectroscope, you will see all of the colors of the rainbow. Other light will have fewer colors. This display of color is called a spectrum.

Some spectroscopes provide scales directly in eV. Others show measurements in nanometers (nm) or Ångstroms (Å). If yours uses one of these units, recording your observations on the scales provided on the following pages will enable you to determine the energy value in eV directly.

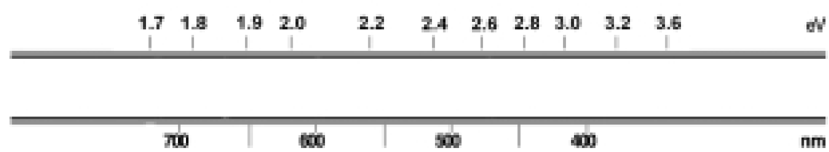
> Caution: (1) Some power supplies for gas tubes have exposed metal contacts. Because the gas lamp is a high voltage light source, do not touch the metal contacts that connect the gas tube to the power supply.
> (2) Never look at the sun or a tanning lamp with a spectroscope. Eye damage may occur from brightness and from high energy ultraviolet photons.

On the following scales, draw the pattern of emitted light observed with the spectroscope for three gas lamps.[Hint] Use colored pencils or markers to indicate the position of color(s). Add a written description to record which colors seem bright

Light Patterns Emitted by Gas Lamps

Hydrogen or ________________:

Color of the light without spectroscope__________



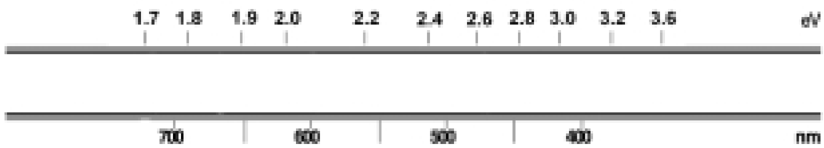
Helium or __________________:

Color of the light without spectroscope__________

[Hint] To ensure that the light patterns are clearly visible, position the vertical slit of the spectrometer (found on the end with a screen) so that it is directly facing the light source and, if possible, hold the spectrometer less than a foot away from the light source. Dim the lights of the room so that the light patterns may be seen. The room, however, should be lighted enough for the energy scale to be seen.

Mercury or _________________:

Color of the light without spectroscope__________



In the table below record the color of light emitted by each gas lamp that is related to the greatest and least energy per photon.

Gas	Greatest Energy	Least Energy

? How can you tell which particular color of light emitted by each gas lamp results in the greatest number of photons emitted?

In the table below record the color(s) of light for which the greatest numbers of photons are emitted by each gas lamp.

Gas	Greatest Number of Photons

? What are the similarities among the light patterns observed for the various gases?

? What are the differences?

Now use the spectroscope to observe the light pattern emitted by the clear incandescent lamp. Connect the incandescent lamp to the circuit that you used in Activity 1 (See Figure 1-2) but without the use of the voltmeter. We will observe the light emitted by the incandescent lamp with the spectroscope when it is at maximum brightness.

? On the following scale, draw the pattern of emitted light observed with the spectroscope for the incandescent lamp. Use colored pencils or markers to indicate the position of observed colors. Add a written description to indicate any colors that are brighter or dimmer than others do.

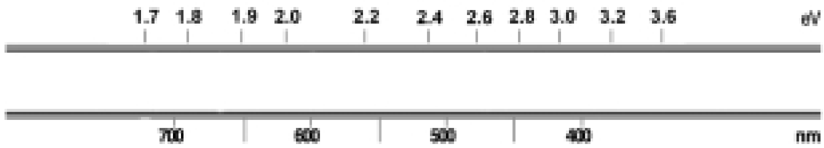
Light Emitted by the Clear Incandescent Lamp

? In terms of the color, intensity, and patterns of light emitted, how is the incandescent lamp similar to the gas lamps?

? How are they different?

Now look at the spectra of one colored incandescent lamp as assigned by your teacher. Record the spectrum below and indicate the portion of the spectrum with the brightest light.

Color of light ______________.



The pattern of light emitted by gas lamps is called a *discrete spectrum*. These light patterns appear as a limited number of bright lines of certain colors. The pattern of light observed for the incandescent lamp is called a *continuous spectrum* for its broad pattern of various colors with no dark regions.

Reduce the brightness of the incandescent lamp by using the potentiometer and the trimmer tool.

? What do you notice about the color of light that is emitted as you reduce the brightness to the point where light is barely visible?

Use the spectroscope to observe the light emitted by the lamp when the brightness is reduced.

? How is the resulting spectrum similar to what you observed before?

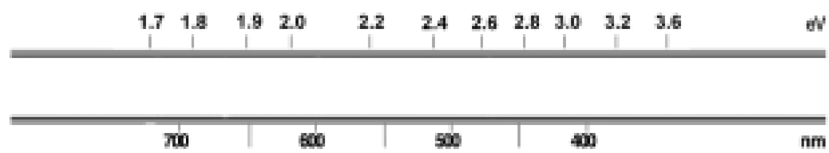
? How is the resulting spectrum different from what you observed before?

? Which situation - when the incandescent lamp is bright or dim - results in the greatest number of photons emitted?

? Which situation results in the emission of a larger number of high-energy photons? Explain how you reached your answer.

We will now compare the spectrum emitted by the LED to those emitted by the gas lamps and the incandescent lamp. Carefully remove the incandescent lamp from the circuit and insert the LED that is assigned to you by your instructor. Recall the appropriate manner in which to connect the LED to the circuit so that it will emit light. The best way to observe the light spectrum emitted by the LED is to look at the top of the LED down from above. Recall that the LED focuses light through the top.

Spectrum emitted by a _____________ LED.



After everyone has completed the investigation, each group should share its results with the entire class. The resulting discussion should focus on the following questions.

Compare your observations for LEDs and incandescent lamp with other students who looked at different colors of light sources.

? How are they similar?

? How are they different?

Summarize the results of the class's observations of the LEDs by completing the table below.

LED	**Color(s) of Light Observed**	**Energy (in eV) of Brightest Light Observed**

Summarize the results of the class's observations of the incandescent lamp.

Summarize the results of your observations of the light emitted by each source, their spectra and their physical characteristics by completing the table below with the differences and similarities among the three light sources.

Light Source	**Gas Lamps**	**Incandescent Lamps**	**LEDs**
Gas Lamps			
Incandescent Lamps			
LEDs			

Similarities

Differences

As we stated above, gas atoms have fewer interactions than atoms in solids. The spectra for gases show only a few energies while the spectra of solids contain a large number of energies. This observation is a hint that light emission from gases might be less complex than emission from solids. So, we will concentrate on gases in the next activity.

Homework Questions:

Use the spectroscope to observe the light emitted by the fluorescent lights. Notice that the fluorescent lights emit complex spectra that consist of bright lines of several energies and a continuous spectrum. The continuous spectrum is a result of high-energy light interacting with the coating found inside the lights. Based on what you have observed in this activity, what do you think is responsible for the discrete spectrum?

Identify the gas that creates this spectrum.

How do you know?

Spectra can be considered the fingerprints of matter. It allows us to identify not only the material found in artificial light sources but also natural ones like the sun and other stars. We will focus on this procedure in a later activity.