ACTIVITY 2

Observing Light Patterns

Goal

In this activity, we will continue to investigate the properties of luminescent materials and devices by observing and exploring their light patterns as well as the light patterns from a gas lamp.

In Activity 1 we observed that luminescent devices and materials have different properties and utilize different methods of light emission. To explain the properties and operation of these devices and materials, we will construct a conceptual model of what is going on at the atomic level.

Luminescent materials, with the exception of the chemicals utilized in light sticks, are made up of solids which consist of a large number of atoms that are closely packed together and interact with one another in a complex manner. To begin to understand solids at the atomic level we will start with gases where the atoms are far apart and seldom interact. Once we build an atomic model that can explain the emission of light for gases we will return to luminescent materials and devices. Our model will not only explain the physical properties of the luminescent materials that we investigated in the first two activities but will also explain the spectral properties of these materials as well as light sources made up of gases - called gas lamps or gas discharge tubes. Thus, in order to be able to understand fully the properties of luminescent materials, we need to study the light emitted by both gas lamps and these materials more carefully.

We will use spectroscopes to look at the colors produced by each light emitting device. The spectroscope is a tool that breaks down light into its individual colors. These colors are displayed on a numerical scale.

In our investigations, we will be particularly interested in the energy of the light. Studies of light have revealed that two properties – brightness and color – are related to the energy of the light.

Light is emitted in small packets of energy. Each packet, called a photon, contains an amount of energy that is related to its color. One photon of red light has less energy than one photon of violet light. Other colors are between these extremes.

Our eyes interpret several different energies of photons as one color. For example, we see different shades of red. The spectroscope will help sort out all of the energies related to colors , even shades of the same color.

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Brightness is also a factor in the energy emitted by a light source. Clearly, the sun emits more energy than a candle, a flashlight, or an LED. Brightness is a measure of the number of packets (photons) of light energy. A bright light emits more photons than a dim light of the same color.

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. These very small numbers are inconvenient, so we will use a different unit of energy – 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.

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

First, you will use the spectroscope to observe light patterns emitted by hydrogen and mercury gas lamps. Gas lamps can be found everywhere from display signs (for example, neon gas) to streetlights (that is, mercury or sodium gas). In the laboratory, a gas lamp consists of a glass tube filled with a gas (called a gas discharge tube) and a high voltage power supply. When the gas tube is connected to the power supply and the lamp is turned "on", the gas tube emits light. The voltage applied across the gas tube is typically about 4000 volts.

Caution:
1) 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 with a spectroscope

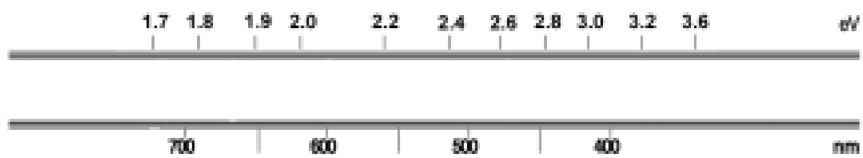
On the following scales, draw the pattern of emitted light observed with the spectro scope for the gas lamps.[Hint] Use colored pencils or markers to indicate the position of color(s). If necessary, add written descriptions of your observations. Answer the following questions when observing the light patterns of the various gas lamps with the spectroscope:

? How many different colors of light are emitted?
? What color(s) of light appear to be the brightest or most intense?

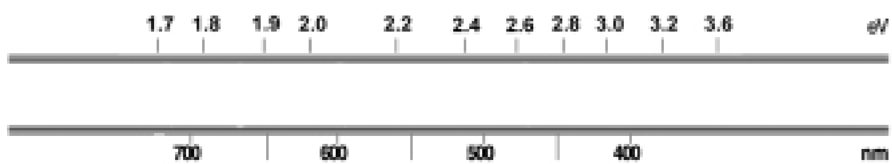
[Hint] To ensure that the light patterns are clearly visible, position the vertical slit of the spectroscope (found on the end with a screen) so that it is directly facing the light source and, if possible, hold the spectroscope less than a foot away from the light source. Dim the lights of the room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

Light Patterns Emitted by Gas Lamps

Hydrogen or _________________:



Mercury or ________________:



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

Gas Lamp	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 that result in the greatest number of photons emitted by each gas.

Gas Lamp	Greatest Number of Photons

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

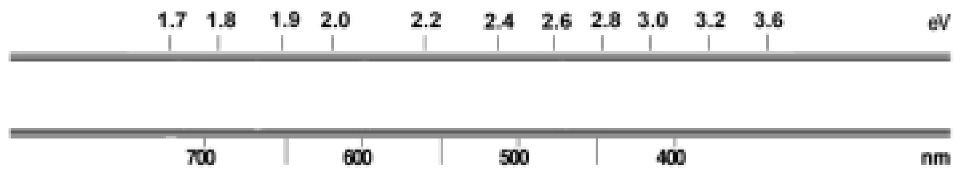
? What are the differences?

We will now use the spectroscope to observe the light pattern emitted by the fluorescent lamp. Recall that phosphorescent materials require visible light from a typical fluorescent lamp to emit light. The typical fluorescent lamp is one of the most efficient and economical sources of industrial and commercial lighting. Fluorescent lamps generally have a higher efficiency and longer life than incandescent light sources.

On the following scale, draw the pattern of emitted light observed with the spectroscope for the fluorescent lamp. Use colored pencils or markers to indicate the position of observed colors. If necessary, use written descriptions of your observations. Answer the same questions as before when observing the light patterns of the gas lamps:

- ? How many different colors of light are emitted?
- ? What color (energy) of light appears to be the brightest or most intense?
- ? What energy values (in eV) are observed for the color(s) of light emitted?

Light Pattern(s) Emitted by the Fluorescent Lamp



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

? How are they different?

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 continuous pattern of light observed for the fluorescent lamp is called a *continuous spectrum* for its broad pattern of various colors with no dark regions. The fluorescent lamp emits complex spectra consisting of both a discrete spectrum and a continuous spectrum.

? Based on your prior observations of the spectra of gas lamps, what do you think is responsible for the discrete spectrum emitted by the fluorescent lamp? How do you know?

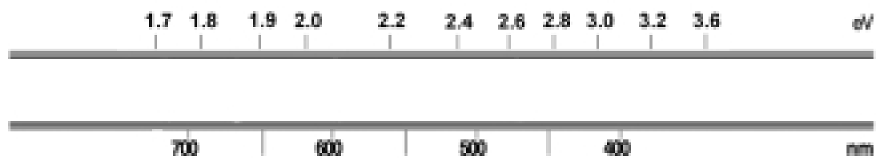
The descriptive name, "fluorescent lamp" provides a clue that the fluorescent lamp must somehow use fluorescence in its emission of light. The question of how fluorescence applies to the emission of light by the fluorescent lamp will be addressed in a later activity.

We will now observe the spectra emitted by other luminescent devices. Use the spectroscope to observe the spectrum of the object assigned by your instructor.

On the following scale, draw the light spectrum as observed with the spectroscope for the luminescent device assigned by the instructor. Use colored pencils or markers to indicate the position of the observed color(s). Answer the following questions when observing the spectrum for the light stick:

- ? How many different colors of light are emitted?
- ? What color (energy) of light appears to be the brightest or most intense?
- ? What energy values (in eV) are observed for the color(s) of light emitted?

Spectrum Emitted by _______________



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 with those of other students who looked at different luminescent devices. How are they similar?

? How are they different?

Summarize the results of all observations in the class and discussion by completing the following table.

Luminescent Device	Color(s) of Light Observed	Energy (in eV) of Brightest Light Observed
light sticks		
LED or Limelight		
phosphorescent object		
fluorescent object		

Summarize the results of your observations of the spectra of the gas lamps, fluorescent lamp, and the luminescent devices by completing the table below with the differences (placed above the gray boxes) and similarities (place below the shaded boxes) among the light sources.

Light Source	**Gas Lamps**	**Fluorescent Lamps**	**Incandescent Objects**
Gas Lamps		Similarities	
Fluorescent Lamps	Differences		
Incandescent Objects			

Your table should show some differences and similarities in the observed spectra emitted by gas lamps, fluorescent lamps, and the other luminescent devices. Spectra can be considered the fingerprints of matter. It allows us to identify not only the material found in artificial light sources (i.e. fluorescent lamps) but also natural ones like the sun and other stars.

The smaller number of colors and discrete nature of gas spectra hints that the emission of light by gases might be easier to understand than luminescent sources. We will now concentrate on gases in the next activity.