ATOMIC RAINBOW

LEARNING OBJECTIVES:
Students will be able to:
• Observe light patterns emitted by various light sources.
• Use spectral patterns to determine discrete energy levels within an atom.

NGSS CONNECTIONS
PS4.B Electromagnetic Radiation: An object can be seen when light reflected from its surface enters the eyes (4-PS4-2)
LS1.D Information Processing: Different sense receptors are specialized for particular kinds of information, which may be then processed by the brain. (4-LS1-2) Animals receive different types of information through their senses, process the information in their brain, and then respond to the information.
4-PS3-2 Energy can be transferred from place to place by light and electric currents.

QIS KEY CONCEPTS
Chemistry 2.3 Students will be able to describe the experimental evidence for quantization
Physics 2.2 Students will describe that many properties of quantum systems are quantized, meaning that they are restricted to discrete values, and explain experimental evidence for quantization.

MATERIALS:
Diffraction grating/glasses
Colored pencils or markers
Various light emitting devices such LEDs with battery source, glow sticks, Christmas tree lights, etc.

ENGAGE or PHENOMENON
Look at the ceiling lights with the diffraction glasses. Identify the colors you see.

EXPLORE
Explore different types of light sources (incandescent, fluorescent, Christmas tree lights, LED, glow sticks, etc.).
1) Use the diffraction glasses to observe light emitted by a glow stick. Compare the colors of different glow sticks if possible.
2) Use the diffraction glasses to observe different colors of Christmas tree lights as well as clear lights, incandescent lights, and fluorescent lights.
3) Use the diffraction glasses to observe the color emitted by a LED. (Note: use a coin battery, not a 9V battery, and light the LED by placing the longer “leg” of the LED on the positive side of the battery and the “short” leg of the LED on the negative side. This will allow you to easily hold the LED between your thumb and forefinger). Compare different colors of LEDs if possible.
4) Observe and record the colors seen using the diagrams below. Use markers or colored pencils to mark where the colors would be located on the energy scale by using the “Range of Energies” Chart. Repeat using different light sources.
5) Rank the observed light sources based on the energy emitted, assuming red light has less energy than blue light.

6) Assume an electron volt (eV) has $1.6 \times 10^{-19}$ J of energy. What is the relationship between the color of light and the related energy?

**EXPLAIN**

Have students share their results from the Explore. There may be several groups that tested the same light sources, how do their results compare?

Ans: Should be similar with slight changes depending on intensity, different viewers, etc.

If red has less energy than blue, rank the light sources based on the energy emitted?

Ans: See Energy Chart
Compare the different light sources and the observed light patterns.

Ans: Some light sources, such as the glow sticks, have several light patterns. Others, such as LEDs, have one main color. Incandescent and fluorescent lights will have multiple colors, but may have one that is predominant.

An electron volt (eV) is $1.6 \times 10^{-19}$ J of energy. Based on data collected, what is the relationship between the color of light and the related energy?

Ans: red has less energy, $1.6-2eV$, than blue or violet, $2.8-3.1eV$)

EXTEND

Have students research colors animals can see or detect. A good resource is
https://askabiologist.asu.edu/colors-animals-see

Have students research the uses of light and develop a list of ideas for future use.

BACKGROUND

Human eyes are amazing! Our eyes allow us to see 2-3 miles in the distance as well as galaxies that are light years away. We do not all see exactly the same colors, but we typically break the colors down to the colors seen in the rainbow (red, orange, yellow, green, blue, violet) or ROYGBV. The rods and cones in our eyes allow us to see around a million different colors. The 3 main cones are red, green, and blue and each cone responds to a different wavelength of light. The colors seen by humans are referred to as visible light and they are a very small part (0.00035%) of the electromagnetic spectrum which also includes radio waves, microwaves, infrared, ultraviolet, and gamma rays as shown in the diagram (credit NASA
https://science.nasa.gov/ems/01_intro)
The electromagnetic field (EM) is composed of photons (light). Photons have no charge, no rest mass, and travel at the speed of light. They are the quantum form for all EM radiation including light, radio waves, microwaves, X-rays, gamma rays, and visible light. Visible light (for humans) can be broken down into the colors we see in a rainbow, ROYGBIV, which are the same colors you see when you look through the diffraction glasses. Humans see colors that are different from other animals such as bees. Bees have a broader range of color than humans and they can see UV. This is an advantage to them because they can see patterns on flowers that attract them (patterns we can’t see). Dogs only see 2 colors while birds see more colors than humans.

Diffraction glasses bend the light (i.e. refract) and the result is a spectrum of colors (visible light). The commercial glasses have thousands of tiny slits very close together. When light hits the slits, it bends and breaks into component colors giving the rainbow spectrum (ROYGBIV). When viewing different types of light sources, the light bends differently and you will see different colors or if it is a specific LED you may only see one color. Different lighting sources may give different spectrums.

Astronomers use several properties of light, including wavelength, to learn about objects in the universe. However, properties of light are also used in countless ways including the medical profession for diagnosis and treatment of diseases, in geology to determine composition of minerals, and in chemistry to make semiconductors for phones and computers. Understanding properties of light is critical for current technology, which relies on light for circuits, sensors, and communication. These are based on the quantum properties of light. Researchers are developing quantum sensors to be used in quantum computers, develop personal medicine, detect when volcanoes will erupt, numerous military applications, and even detecting unseen objects in the ground. Applications are endless, but are important.


Electromagnetic Radiation (EM) is relevant in many areas of our everyday lives such as heating food in microwave ovens, guidance systems in airplanes, cell phones, WiFi, medical imaging, night vision cameras, treatment of cancer and other diseases. EM radiation, such as infrared radiation, can be interpreted as “heat” by humans. Some animals, such as snakes, can “see” infrared radiation in a way humans can’t so that means they can “see” us even if we think we are hiding. Other creatures such as vampire bats, mosquitoes, some snakes and beetles utilize this portion of the spectrum for vision or to detect movement or heat from bodies for food.

A very important source of infrared radiation is the sun and plants utilize this energy to make usable sugars during the process of photosynthesis, a process that is critical to the food chain process. Chlorophyll absorbs energy from light, which is then used to convert carbon dioxide to carbohydrates. There are several types of chlorophyll produced during the photosynthesis process and these are generally referred to as chlorophylls a (found in higher plants and algae), b (found in higher plants and green algae), c (found in diatoms, dinoflagellates, and brown algae), and d (found only in red algae). All of them reflect green light, but their structural differences result in the appearance of different shades of green. Students often think that plants are green because they absorb green light, but they actually reflect green and absorb the other colors.