How Is That Color Produced from That Light Source?

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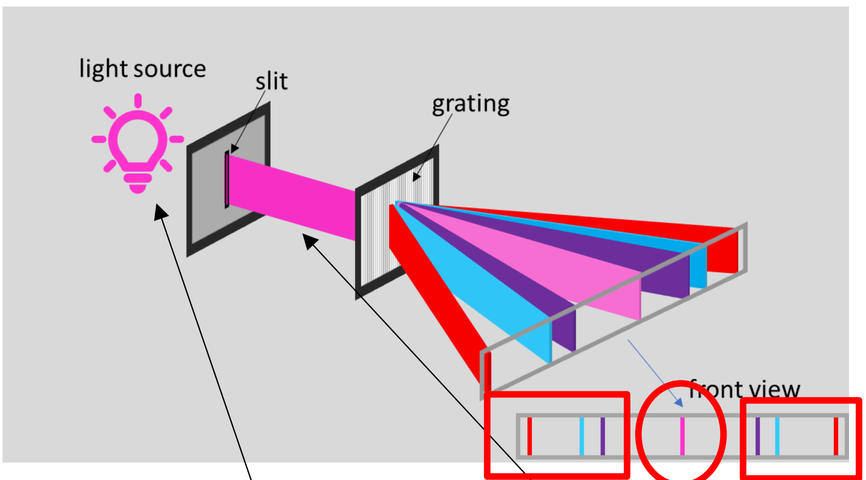
Group member: Kobe **Group member:** Chris

15 minutes for this section

Information: Luminescence is the emission of light by a substance that has *not* been heated. Most modern-day light results from luminescence, examples being light-emitting diodes light bulbs (LED light bulbs) and fluorescent lamps/bulbs.

A prism or diffraction grating separates emitted light according to its wavelength. The resulting pattern produced by a prism or diffracting grating is called a spectrum. The presence (or absence) of different components from the emitted light in the spectrum is characteristic of the substance producing it.

Model 1: The spectrum resulting from the emission of light by excited hydrogen atoms.



Key Questions:

1. The light source emits light from excited hydrogen atoms. What is the color of this emitted light? Pink
2. The emitted light passes through a slit, which produces a well-defined beam of light. Describe the beam produced after the light passes *through the slit*.

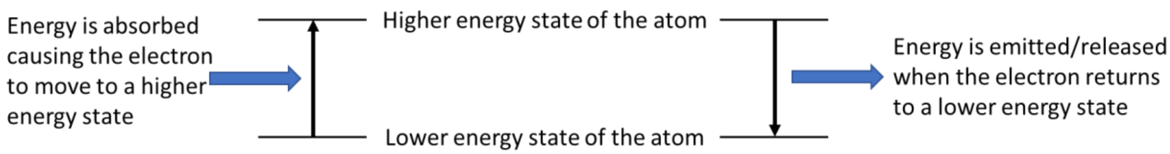
   There's no interference of waves going another direction from the source. Its a direct singular wave of light

3. The purpose of a grating is to separate the light according to wavelength. The resulting pattern from the emitted light after is passes through the grating is called a *spectrum*. Identical spectra are produced on both sides of the original light.
   a. Draw a circle around the original light in the middle of the front view representation.
   b. Draw a square around each spectrum produced by the original light (use the front view representation).

c. What are the three colors of light present in the original emitted light?

Red, cyan, purple

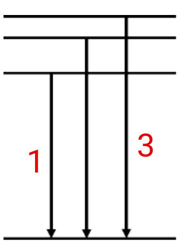
Emission of light can be understood by examining the diagram below.



- Energy is added to an atom or molecule (often from an electrical source).
- Energy is absorbed causing electrons to move away from the nucleus to a higher energy (or excited) state.
- Attraction to the nucleus causes electrons to return to the lower energy state.
- This "relaxation" emits (or releases) energy. *The energy released is equal to the difference between the two states.* The color, or wavelength, of the light corresponds to this difference.

The process described above would produce *one* line in an emission spectrum. Each line in a spectrum results from a unique transition between a higher and a lower energy state of the atom. Since the emission spectrum from excited hydrogen atoms contains three lines there must be three unique transitions.

4. A diagram representing the transitions for excited hydrogen atoms is shown. Notice that there are three.
    a. Put a "1" next to the arrow which represents the transition producing the red line in the emission spectrum. Why did you pick this one?



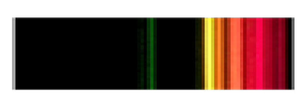
Red has the lowest energy, so to go from red to happy is the lowest one

    b. Put a "3" next to the arrow which represents the transition producing the purple line.

Each element (and each molecule) has a distinct emission spectrum that tells us about the allowed energy states and allowed transitions of electrons in these atoms. The identity of elements (and molecules) can often be determined based on their unique spectra.

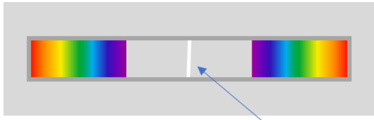
Exercises:

5. The emission spectrum of excited neon atoms is shown. Name at least one key difference between this spectrum and that of excited hydrogen atoms.



It's more blurred and not distinct lines

6. The emission spectrum resulting from the light outside is shown. How is this spectrum different from the one produced by emission from excited hydrogen atoms?



It shows every color of visible light instead of a couple

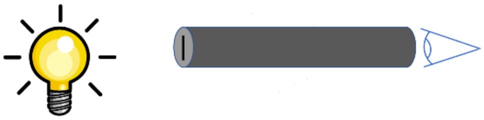
A <u>continuous spectrum</u> contains all the wavelengths with no breaks while a <u>line spectrum</u> contains only discrete wavelengths appearing as lines.

<u>Entire class discussion:</u>

<u>Method development</u>:

<u>Items needed for *each* member of the group:</u> Eisco spectroscope, double-sided foam tape pad with hole in center (on first bench), and sheet of white cardstock (one per group, on first bench).

7. Examine the Eisco spectroscope (black cylinder). One end of the spectroscope has a 1 cm diameter window, and the other end has a narrow slit. The spectroscope has a grating and will produce spectra like those observed in Model 1. A spectrum can be observed by pointing the end with a slit at a light source and looking through the end with the window.



   Point the spectroscope at a light source (the light in the room) making sure that the slit is vertical (up and down) as shown in the figure above. Look through the window of the spectroscope at the other end. The spectroscope needs to be close to your eye as shown in the figure. Each group member needs to do this with their spectroscope. As shown in Model 1, a spectrum of the light source is present on both sides of the slit. Write down (or draw) the colors you observe.

   red, orange, green, teal, purple

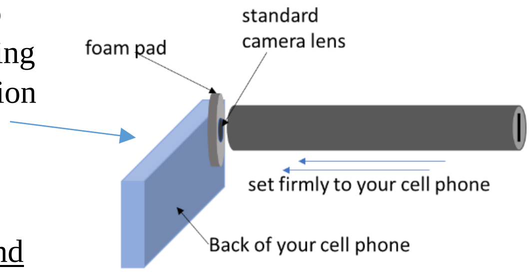
   Is this a line or continuous spectrum? line

8. You are going to take a picture of the spectrum produced by the spectroscope. Follow the below instructions to attach the spectroscope to the camera lens on your cell phone (each group member must do this).
   a. Examine the double-sided foam tape pad with a hole in the center. The hole has been cut out so that the camera lens can still be visible to take pictures.
   b. Before attaching the foam pad to your cell phone, you need to find out which lens is for the standard camera (most cell phones have multiple lenses). You can do this by selectively covering lenses. If the standard camera lens is covered, there

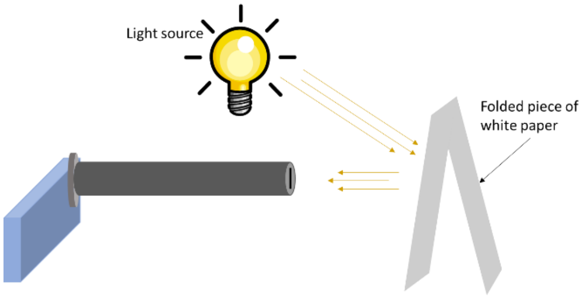
will be no image on the cell phone camera. If you are having problems identifying the standard camera lens, ask the teacher or lab assistant for help. For an iPhone 13/14 Pro, you will need to go to Settings>Camera. Scroll down and enable (turn on) Macro Control. Now, in the camera app turn off the automatic switching of lenses.

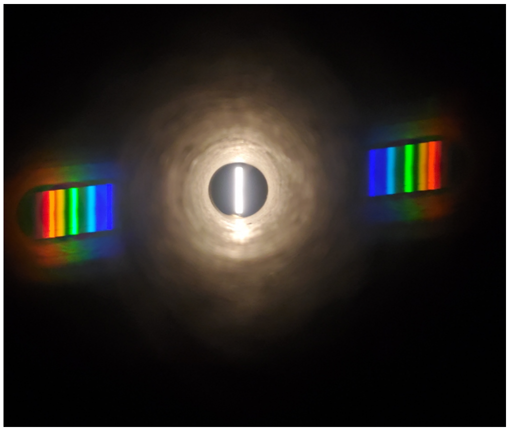
c. You will now attach the foam pad to your cell phone. For this step, you need to remove the cell phone case. Remove the protective paper on one side of the foam pad and attach it to your cell phone so that the standard camera lens is visible through the hole.

d. The spectroscope will now be attached to the camera lens on your cell phone by using the other side of the foam tape pad. Position your phone in *landscape orientation*, remove the other protective paper, and center the spectroscope over the standard camera. <u>Make sure the slit on the other end of the spectroscope is as close to *vertical* as possible (see picture).</u> Do not worry about residue from the foam tape pad, it can be removed with a little bit of careful washing.



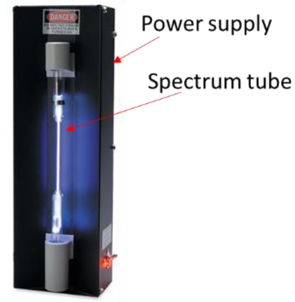
e. The cell phone camera often takes better pictures from light that is reflected off a white surface or piece of white paper. Fold the sheet of white cardstock in half and orient it so that the light source reflects off it towards your camera. With your cell phone camera, you should now see a nice spectrum from the light source. You will now use this technique (reflecting off white paper) to take a picture with your cell phone.





Information: As described above, a higher energy state (or excited state) of an atom or molecule is produced by absorption of energy. This energy for this excitation can be produced by various methods. One common method results from passing an electric current through the material. In this case, electrical energy is transferred to the atom or molecule. This will be illustrated below.

9. At several marked locations in the laboratory, there are power supplies which contain glass tubes of atoms of elements or molecules. The power supply provides electrical energy for excitation.
    a. Power supplies containing glass tubes of hydrogen, helium, carbon dioxide, mercury, and neon are set up in the laboratory. Identify their locations.
    b. Describe a method you can use to acquire the emission spectra from these atoms of elements or molecules.



Do the same thing we did for the light bulb in the previous step, put a white card behind the light and take a picture looking through the spectroscope at it

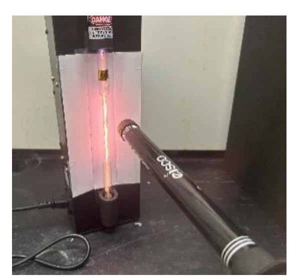
Turn off the lights in the room. The doors may need to be left open so that the students still have some visibility.

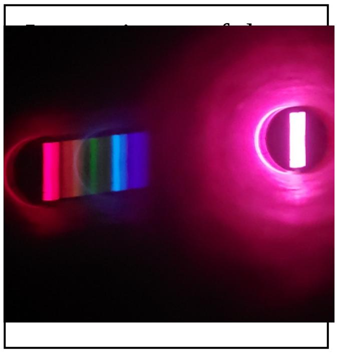
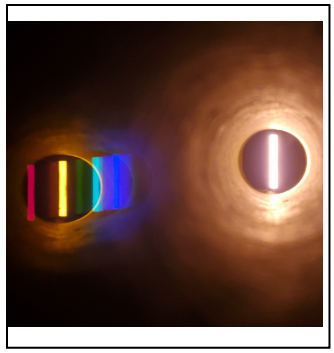
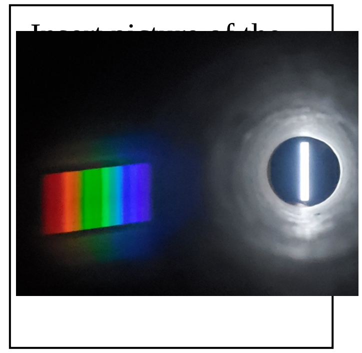
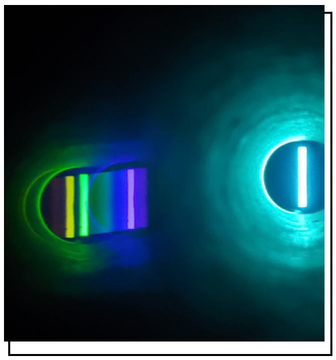
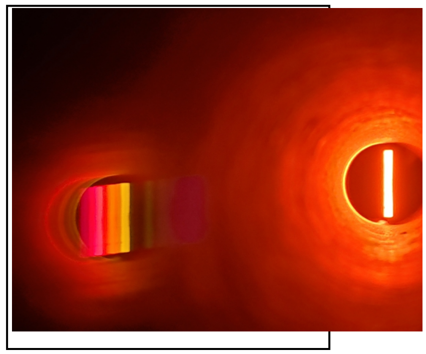
<u>Individual data collection (each person in the group will acquire their own data):</u>

10. You will need to visit the various locations with power supplies/gas tubes. Doesn't have to be in the order specified in the table.
    a. Turn on the power supply. Light should be emitted from the gas tube.
    b. Without the spectroscope (to the naked eye), write down the observed color produced by emission from the atoms of elements and molecules.

Element/molecule	**Observed Color**
Hydrogen	Pink
Helium	Yellow
Carbon dioxide	blueish white
Mercury	Cyan
Neon	Red

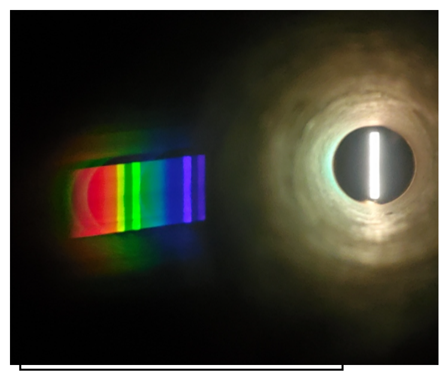
    c. Examine the emission spectra with your cell phone and attached spectroscope. Point the spectroscope at the light reflected off the white paper on the back of the power supply (don't point directly at the source). The end of your spectroscope should be close to the paper (2-3 inches). Take a clear picture of each element or molecule. Compare your spectra with your group members.
    d. Turn off the power supply.



11. In one location, a light source is set up which is used for providing light/heat to reptiles (called reptile light).
    a. The reptile lamp should be turned on. Don't turn it off when done.
    b. Describe the light pattern produced from this light source with your naked eye.

It looks a lot like normal light like we did in the first example but a little bluish



    c. Examine the emission spectrum with your cell phone and attached spectroscope. Point the spectroscope toward the center of the light (it will have a blue color) focused on the black paper. The end of your spectroscope should be about 6 inches away from the black paper.

<u>Compilation of group data and group analysis</u>:

12. As mentioned previously, the emission spectrum produced from each element/molecule is unique. Indicate at least one feature which makes each spectrum different from the others.
    a. Helium

    Helium has very distinct colors and space between its main color and the rest

    b. Carbon dioxide

    It's the most continuous of all the spectrums

c. Mercury

It has very distinct colors and has the most green

d. Neon

It only comes from half the spectrum, only in the range of red yellow and orange

13. Without the spectroscope (to the naked eye), the light produced from excited carbon dioxide molecules and the light produced from excited mercury atoms appear similar. The emission spectra, however, are different. How?

Mercury is closer to a line spectrum while CO2 is closer to continuous. The sum of all the colors appears similar while the amounts of specific colors may differ.

14. The *blue* light produced from the reptile light largely results from the excitation of atoms in one of the sources studied previously (helium, carbon dioxide, mercury, or neon). Compare this spectrum with those you took previously and identify the element in this light source. The red region in the spectrum from the reptile light does not come from the blue light source. You need to ignore the red region when identifying the element.

a. Element in light source Mercury

b. What are the key features in the blue light of the reptile lamp leading to this identification?

The purpleish part is stronger than the darker blue around it in both and ignoring the red part, they look very similar only that mercury is more distinct than continous

15. You should have observed three distinct lines in the emission spectrum of hydrogen.

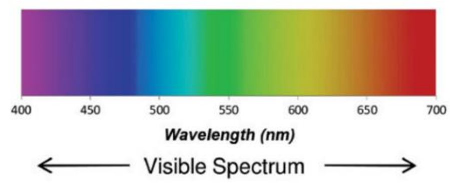
a. What are the colors of these lines?

Pink

Cyan

Purple

b. Using the provided visible spectrum, do your best to estimate the wavelength of each observed color. Write these down next to the indicated color above.

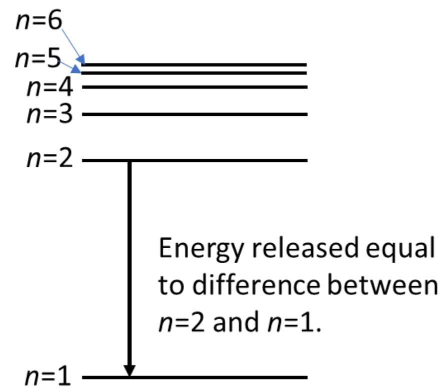


Pink: 700 nm

Cyan: 525 nm

Purple: 400 nm

16. As described above, each line can be attributed to a transition from a higher energy state to a lower energy state. The emitted energy would then be equal to the difference between the two energy states. For the hydrogen atom, the energy states are often described with integer values (see diagram). The lowest possible value of *n* is 1, which describes the lowest allowed energy state. A transition between the *n*=2 energy state and the *n*=1 energy state is depicted in the diagram. A transition can occur between any two *n* values.



   a. The spacing (or energy difference) between states is very important. Look at the spacing between *n*=1 and *n*=2. Now, look at the difference between *n*=3 and *n*=2. And so forth. What do you notice?

      The distance gets shorter

   b. Which is greater in energy, the transition between *n*=4 and *n*=2 or the transition between *n*=2 and *n*=1?

      between n=2 and n=1

17. For hydrogen atoms, the wavelength of the emitted energy for a transition can be calculated using the Rydberg formula given below. In this equation, n_f is the *n* value of the final state and n_i is the *n* value of the initial state. For example, the transition from *n*=2 to *n*=1, n_f would be 1 and n_i would be 2.

$$\frac{1}{\lambda} = 1.097 \times 10^7 m^{-1} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

   a. Calculate the wavelength in nanometers of the *n*=2 to *n*=1 transition. You should notice that this wavelength is well below the visible region and in the ultraviolet (between 100 and 400 nm).

      122 nm

   b. The transition producing the lines in your observed spectrum or hydrogen are indicated below. Using the Rydberg equation, calculate the wavelength of these transitions.

Transition	**Wavelength (nm)**
n=3 → *n*=2	656
n=4 → *n*=2	486
n=5 → *n*=2	434

   How well do these wavelengths agree with your estimates performed earlier?

They're kindof close, you can tell which wavelength is supposed to be with color at least but they're off

Ask the teacher or lab assistant to check your work above before proceeding.

Class data: In the class data sheet (link in Canvas), input the identification for the retile light.

Information: Direct heating is another method which can be utilized to produce a higher energy state (or excited state) of an atom or molecule by absorption of energy. This direct heating is often provided by a flame.

Method development:

Items needed for *each* member of the group: Eisco spectroscope (already attached to the cell phone).

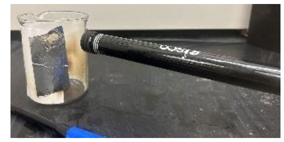
18. There are three different solutions in the hoods. Each solution contains one dissolved metal halide salt which will be identified by observing the emission spectrum after direct heating. Each member of the group will analyze all solutions. Your group will then identify the metal in each solution by coming to a consensus after examining each person's spectrum.
19. Describe a method you can use to acquire the emission spectra of the metal halide salts in solution.

Heat up the solution and take a picture of the spectrum when its heated

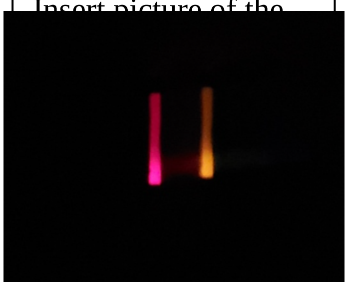
Individual data collection (each person in the group will acquire their own data):

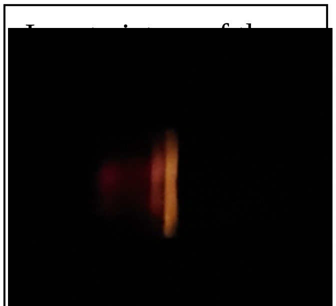
20. The below information will assist you in acquiring the emission spectra of the halide salts dissolved in solution.
    a. Dispense a few milliliters of the unknown solution into the 50 mL beaker.
    b. Secure a cotton ball with the provided tongs and *saturate it completely* with the solution in the beaker. If necessary, add more solution to the beaker.
    c. Place the saturated cotton ball in the large beaker which is mostly wrapped with white paper.
    d. Ignite the cotton ball with the lighter.

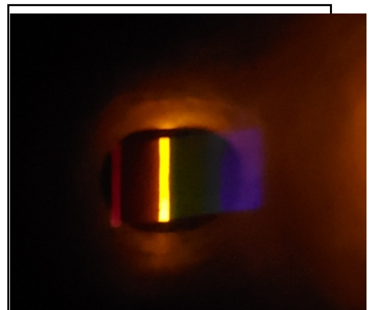
e. Wait a few seconds and acquire several pictures of the emission spectra with your cell phone and attached spectroscope. Point the spectroscope through the opening on the beaker toward the paper on the back side which is well illuminated by the flame. *Don't point the spectroscope at the base of the flame*. You should see one or multiple lines. Use the best picture for analysis. Remember, each group member needs to do this. Record the color of the flame to the naked eye.



Solution 01 Flame Color	Solution 02 Flame Color	Solution 03 Flame Color
Pink	Orange	Yellow







f. Extinguish the flame. Each group needs to prepare and burn their own cotton ball.

<u>Compilation of group data and group analysis</u>:

21. Using the provided reference emission spectra at the end of the activity, identify the metal in each solution. You also need to indicate the unique feature (or features) which led you to identify the selected element.

Solution	Element	Unique feature (or features)
Solution 01	Strontium	Has two lines, the rest only have one
Solution 02	Lithium	It's all orange ish red
Solution 03	Sodium	Its all clearly yellow

Class data: In the class data sheet (link in Canvas), input the identified metal in each solution.

Information: A light-emitting diode (LED) is a semiconductor device that emits light when current flows through it. The wavelength of the light emitted depends on the bandgap of the semiconductor material. By utilizing a different semiconductor material (or modifying it), the bandgap can be changed. This will result in a different observed color.

Method development:

Items needed for *each* member of the group: Eisco spectroscope (already attached to cell phone), LED bulb and controller (one for each group, on first bench), lamp base (one for each group), and sheet of white cardstock (one for each group, on first bench).

22. You have an LED bulb with a controller and a lamp base. Using the controller, the LED can produce different colors. Note: Always switch off the lamp base when removing or installing the bulb. Select a few options on the controller and observe the colors.
23. Describe a method you can use to acquire spectra from the LED bulb.

    Put a white card behind the buld and look through the spectroscope

Individual data collection (each person in the group will acquire their own data):

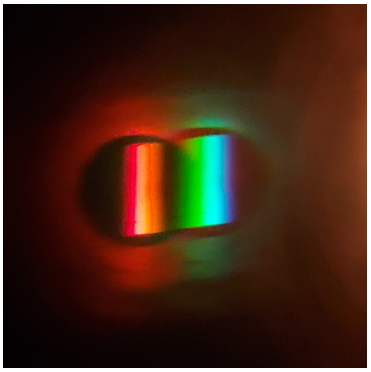
24. Examine the blue ("B"), the green ("G"), and the red ("R") options from the LED with the spectroscope attached to your cell phone. You may need to adjust the brightness of the bulb with the controller. Write down what you observe. Remember to observe the light reflected off the white sheet of cardstock.
    a. Blue Only blue lines
    b. Green

       Green lines with a very light blue line
    c. Red

       A single red line
25. You will now examine other colors produced by the LED bulb.
    a. Select the *yellow* option on your color.
        i. Examine with your naked eye. Which visible colors do you think make up the emitted yellow light?

           red yellow and orange

ii. Examine the emitted yellow light with the spectroscope. With your cell phone take a picture. Compare your spectrum to those acquired by your group. Note: You may need to adjust the brightness of the bulb to optimize photo quality.



iii. Is this a line or continuous spectrum? ___line___ Which colors produce yellow?

Red, orange, green, blue

b. Select the *purple* option on your controller.

i. Examine with your naked eye. Which visible colors do you think make up the light? Blue red purple

ii. Examine the emitted purple light with the spectroscope. With your cell phone take a picture. Compare your spectrum to those acquired by your group. Note: You may need to adjust the brightness of the bulb to optimize photo quality.

iii. Is this a line or continuous spectrum? ___line___ Which visible colors produce purple?

red, orange, blue, purple

Compilation of group data and group analysis:

26. For LED bulbs, how are the different colors, such as yellow and purple, produced?

By mixing the different energy levels of the primary colors red, green, and blue

Make sure all items are clean and return them to the drawer or bench. Finish cleaning any glassware used by rinsing with distilled water. Before you leave, ask the teacher or lab assistant to examine your data and laboratory space. Note: Your data must be entered into the spreadsheet before you leave.

Application of principles (to be completed individually):

27. Describe the difference between a line spectrum and a continuous spectrum.

A line spectrum has black spaces between colors and doesn't blend together as much
A continuous spectrum doesn't have black spaces and blends together gradually

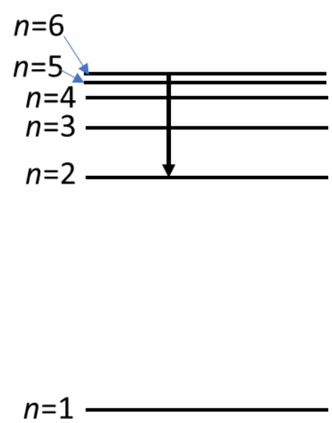
28. How are the individual lines produced in an emission spectrum from hydrogen atoms (see beginning part of laboratory activity)?

By separating the original light into the specific wavelengths of the colors that make it up

29. A transition for an excited hydrogen atom is indicated on the diagram.

a. Calculate the wavelength of this transition. Show your work.

$$\lambda = \frac{1}{(1.097 \cdot 10^7) \cdot \left(\frac{1}{2^2} - \frac{1}{6^2}\right)} = 410nm$$



b. Would this transition be visible to the naked eye? __Yes_____ Explain why or why not.

The visible light range is between 400 nm and 700 nm. 410 nm is within that range

30. The following emission spectrum was acquired for a material containing *two* unknown elements. Using the provided reference spectra, determine the identity of the two unknown elements.

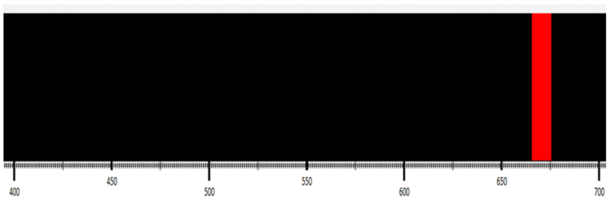
Lead and strontium

31. All colors from the LED bulb are produced from a combination of red, green, and blue (RGB). What RGB combination from the LED bulb could be used to produce orange?

Red and green

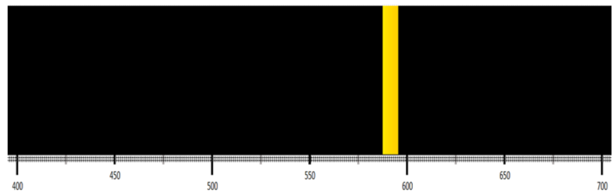
This lab activity must be submitted in Canvas by the due date.

Reference emission spectra:

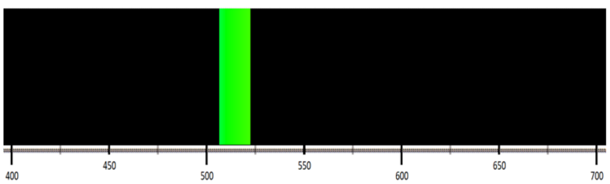


Lithium

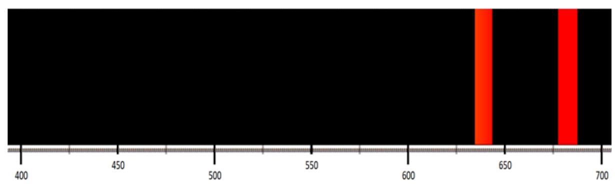
A faint orangish line may also be observed.



Sodium

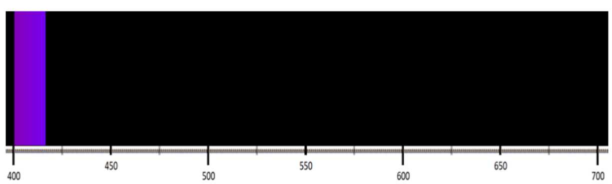


Copper



Strontium

A faint yellowish line may also be observed.



Lead