Electromagnetic Spectrum and Stars

Section	Points
Concepts/Objective 5	
Variables/Hypothesis 5	
Observations/Data 5	
Procedure 5	
Questions/Conclusion 10	
Total	
Regents Minutes	

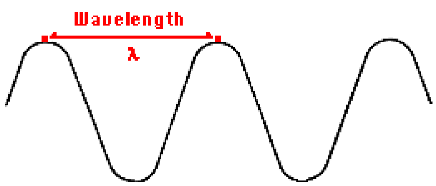
Project Director	
Safety Director	
Materials Manager	
Technical Manager	
LabQuest #	
Laptop #	

Introduction/Pre-Lab

The light that we see with our eyes – visible light – represents only a small portion of the electromagnetic spectrum. Developing the technology to detect and use other portions of the electromagnetic spectrum – the "invisible" light that our eyes cannot see – has had a tremendous impact on our daily lives. When you listen to a radio, heat your food in a microwave oven, use a remote control, or have an X-ray taken, you are using "invisible" light.

In astronomy, scientists use the properties of light to learn about celestial objects that are too far away to visit. Each portion of the electromagnetic spectrum provides unique clues about the nature of our universe. The missions and research programs in NASA's Astronomical Search for Origins program use innovative technologies to observe the universe at a variety of wavelengths (ultraviolet, visible, and infrared) in search of the answers to two enduring human questions: Where did we come from? Are we alone?

Visible light is part of the electromagnetic spectrum that we receive from the sun and is made up of the colors red, orange, yellow, green, blue, indigo, and violet (**ROY G BIV**). When sunlight passes through a prism, the light is bent and the colors within that light can be seen. All light travels in waves. Each type of light has its own specific wavelength and frequency. Wavelength is the distance between identical locations on waves that are next to each other (figure 1).



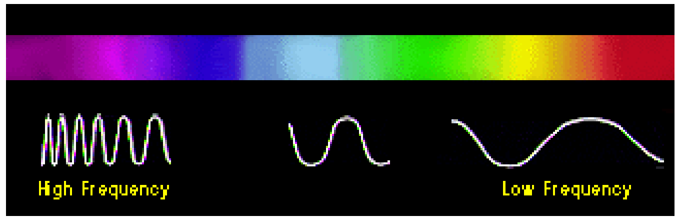


Figure 1: Example of measuring wavelength.

Figure 2: Frequencies of the visible spectrum

Frequency is the number of wavelengths that pass a given point each second. Each color of light has a different wavelength. As shown in figure 2, red has the longest wavelength and violet has the shortest wavelength. (Frequency = # of waves ÷ time)

Different celestial objects produce different types of spectra. The spectrum of an object is one means of identifying what type of object it is. How different spectra arise is shown in the schematic diagram below.

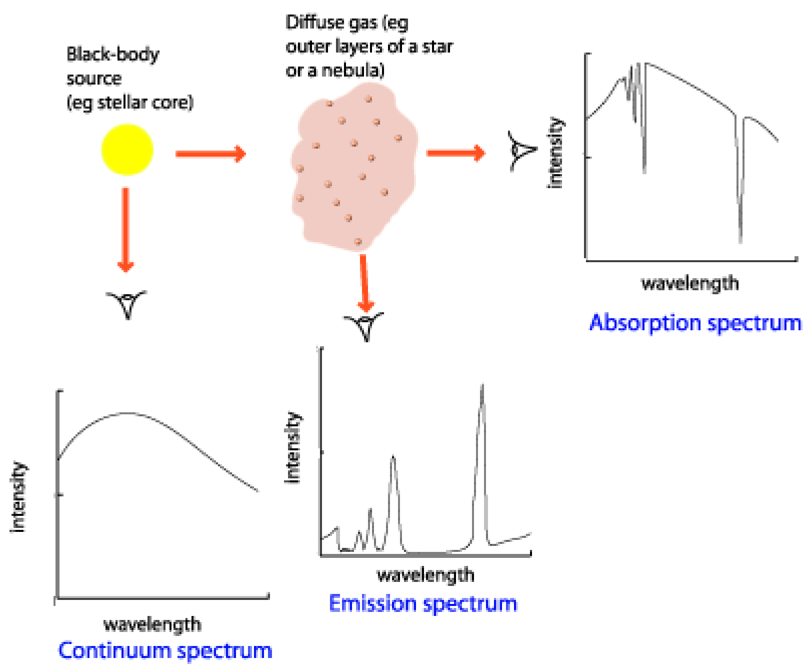


Figure 3: How continuous, emission and absorption spectra can be produced from same source.

Continuum spectrum: In this diagram, a dense hot object such as the core of a star acts like a black body radiator. If we were able to view the light from this source directly without any intervening matter then the resultant spectrum would appear to be a continuum as shown in Figures 3 and 4.

Absorption spectrum: Most stars are surrounded by outer layers of gas that are less dense than the core. The photons emitted from the core cover all frequencies (and energies). Photons of specific frequency can be absorbed by electrons in the diffuse outer layer of gas, causing the electron to change energy levels. Eventually the electron will de-excite and jump down to a lower energy level, emitting a new photon of specific frequency. The direction of this re-emission however is random so the chances of it travelling in the same path as the original incident photon is very small. The net effect of this is that the intensity of light at the wavelength of that photon will be less in the direction of an observer. This means that the resultant spectrum will show dark absorption lines or a decrease in intensity as shown in the dips in the absorption spectrum top right in the diagram above. Stellar spectra typically look like this.

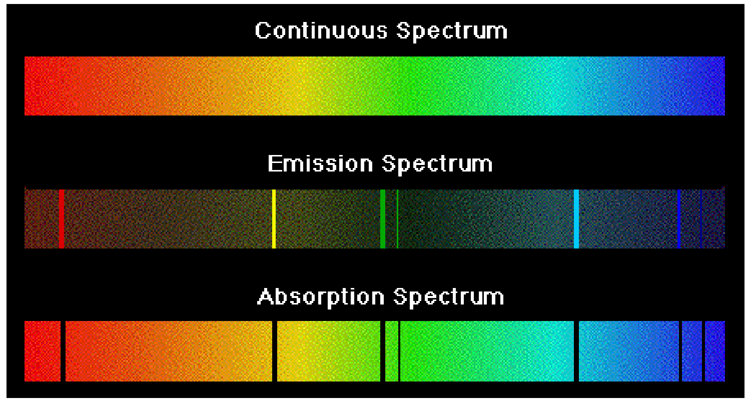


Figure 4: Appearance of spectra through a spectroscope.

Emission spectrum: A third possibility occurs if an observer is not looking directly at a hot black body source but instead at a diffuse cloud of gas that is not a black body. If this cloud can be excited by a nearby source of energy such as hot, young stars or an active galactic nucleus then the electrons in atoms of the gas cloud can get excited. When they de-excite they emit photons of specific frequency and wavelength. As these photons can re emitted in any direction an external observer will detect light at these wavelengths. The spectrum formed is an emission or bright line spectrum, as shown by the middle spectrum in Figure 1

Spectroscopes can be used to determine the unique electronic spectrum for each element, a result of the individual and discrete arrangement of electrons around each atom. When atoms absorb energy, electrons move into higher energy levels. These electrons then lose energy by emitting light when they return to lower levels. Each discrete line in an emission spectrum corresponds to one exact frequency of light emitted by the atom. Much knowledge about the composition of the universe comes from studying the atomic spectra of stars, which are hot glowing bodies of gases. No two elements have the same emission spectrum. In this lab we will be looking at the emission spectrum of various gas discharge tubes using the spectroscopes. These different gas discharge tubes will give off different colors depending on the element in each tube.

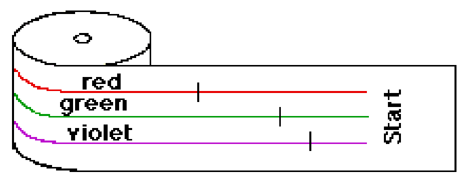
Materials

Materials:

- Red, Green and Violet colored pencils
- Meter stick
- Manila folder
- Scissors
- Masking tape
- 140cm adding machine tape
- Spectroscope
- Gas tubes
- Incandescent light
- Fluorescent lamp
- Halogen lamp

Procedure Part I:

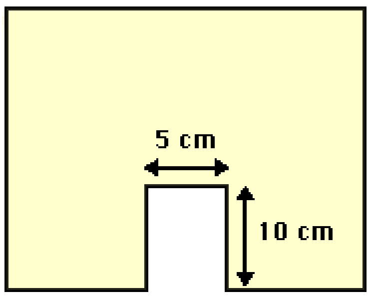
1. Draw a vertical line 20cm from the beginning of the adding machine tape and label it "**Start**".
2. Draw a vertical line 100cm away from the start line and label it "**End**". There should still be 20 cm left over.
3. Draw three evenly spaced lines along the tape from "**Start**" to "**End**". The top line should be red and should be drawn 1cm down from the top. The middle line should be green and should be drawn 3cm down from the top. The bottom line should be violet and should be drawn 5 cm down from the top.

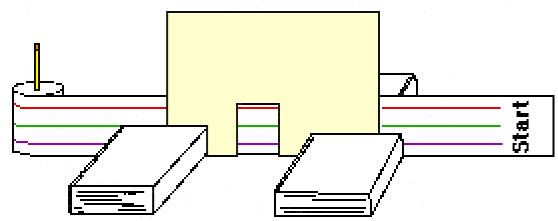


Note: This is how to get started, keep labeling the colors until you reach 100 cm.

4. Divide the red line every 14cm and mark darkly with the red colored pencil every 14cm.
5. Divide the green line every 10cm and mark darkly with the green colored pencil every 10cm.
6. Divide the violet line every 8cm and mark darkly with the violet colored pencil every 8cm.
7. Use masking tape to fasten the "**End**" side of the adding machine tape to a pencil or pen and roll the adding machine tape up partway.
8. Cut a manila folder along its crease. Then cut a rectangle out of the center of one of the long sides. This rectangle should be about 10 cm high and 5 cm wide.

9. Set the manila folder cut out on the table supporting it with the four books. Feed the end of the adding machine tape through the narrow space between the manila folder and the two back books until "Start" appears in the middle of the opening in the manila folder.





10. **Trial Run (Use the Red Colored Line):**
    - One person will keep track of time. They will begin timing as they slowly pull the tape through the folder at a consistent speed. Make sure to note down the time when you are done.
    - One person will hold the pencil steady during the run.
    - One person will be a recorder and keep a tally of the wavelength marks as they become apparent.
11. **Trial 1 (Red Line):**
    - Use the same setup as above.
    - Be sure to pull the tape at a slow consistent speed.
    - Make sure to record the time and to tally the number of wavelength lines seen.
12. **Trial 2 (Green Line):**
    - Use the same setup as in the Trial Run.
    - Be sure to pull the tape at a slow consistent speed.
    - Make sure to record the time and to tally the number of wavelength lines seen.
13. **Trial 3 (Violet Line):**
    - Use the same setup as in the Trial Run.
    - Be sure to pull the tape at a slow consistent speed.
    - Make sure to record the time and to tally the number of wavelength lines seen.
14. Make sure everyone in the group has filled in the data on their own data sheets.

15. Determine the average number of wavelengths seen for each of the colors. Do not use the Trial Run data. To find the average, add the three totals and divide by three.
16. Determine the frequency for each of the colors. Do not use the Trial Run data. To find the frequency, divide the average for each color by the time.

OBSERVATIONS/DATA

TABLE__:____

	Trial Run		**Trial 1**		**Trial 2**		**Trial 3**		**Average**	**Frequency**
	Tally	**Total**	**Tally**	**Total**	**Tally**	**Total**	**Tally**	**Total**		
Red										
Green										
Violet										
Time										

1. Look at the wavelengths and frequencies of the three waves. What patterns do you notice about the relationships between the three colors?

2. Which color had the shortest wavelength?

3. Which color had the longest wavelength?

4. Which color had the highest frequency?

5. Which color had the lowest frequency?

6. What is the relationship of the red ***wavelength*** to the green ***wavelength***?

7. What is the relationship of the red ***wavelength*** to the violet ***wavelength***?

8. What is the relationship of the red ***frequency*** to the green ***frequency***?

9. What is the relationship of the red ***frequency*** to the violet ***frequency***?

10. If waves are moving at the same speed, what is the relationship between ***wavelength*** and ***frequency***?

11. Based on the above relationship, if you were to look at a blue wave, would it have a higher or lower ***frequency*** than the green wave?

12. Based on the above relationship, if you were to look at an orange wave, would it have a longer or shorter ***wavelength*** than the green wave?

SCIENCE CONCEPTS ***(5 points)***

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Investigative question

How can light and the electromagnetic spectrum be used to study the temperature and composition of distant celestial objects?

OBJECTIVE

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VARIABLES ***(5 points)***

Manipulated Variable (Independent):____

Responding (Dependent):____

HYPOTHESIS (If…then…because)

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Lab 2

1. Examine the light sources listed on your data table. They will not necessarily be shown in order.
    a) Write down what type of spectrum you see (continuous, emission, absorption).
    b) Draw a rough copy of the spectrum you see onto your data table. Show sharp and fuzzy lines, bright and faint lines.
    c) Color in the spectrum in the appropriate places.

2. Use the table of known spectra to identify the gas in each light source

3. Observe the overhead lights. Overhead lights are gas lamps with a white fluorescent coating placed on the tube. This coating distorts the spectrum and converts some blue light to redder colored light. Draw the spectrum you see onto your data table. Use the spectroscope to identify one of the gases found in the overhead lights.

4. Observe an incandescent lamp. Draw the spectrum you see onto your data table. While observing an incandescent lamp, separately take each of the colored filters and move them in front of the spectroscope. Describe what you see for each of the filters. What happened to the spectra?

5. Neon lights are made of colored tubing. Neon gas by itself emits a distinct spectrum and appears orange to the eye. How would you make a neon sign with blue and white lettering?

6. Observe light from the sun and draw the solar spectrum on your data table. ***NEVER LOOK DIRECTLY AT THE SUN!!!*** The Sun displays an absorption line spectrum. Examine the solar spectrum and locate the dark absorption lines. At what wavelengths do the dark absorption lines appear?

7. Observe a halogen lamp. Draw the spectrum you see onto your data table. Of the examples we've looked at today, what spectrum does halogen most closely resemble?

DIAGRAM OF THE EXPERIMENT (based on the procedure) ***(5 points)***

OBSERVATIONS/DATA *(5 points)*

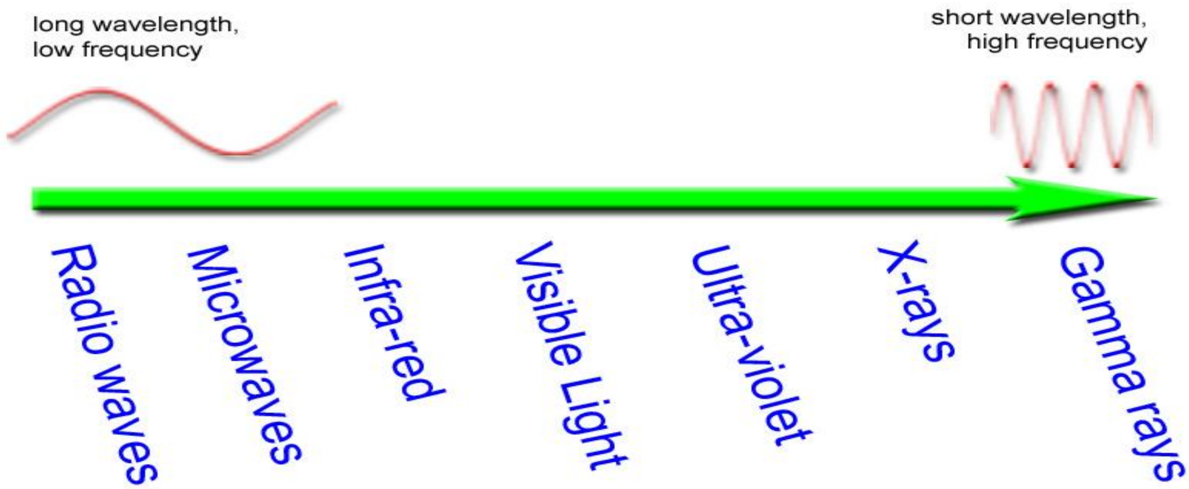
TABLE__:____

Light Source	Spectrum Type	Colors Observed **(Wavelength in thousands of Angstroms)**	Identified Gas
Tube #1		700 nm 600 nm 500 nm 400 nm	
Tube #2		700 nm 600 nm 500 nm 400 nm	
Tube #3		700 nm 600 nm 500 nm 400 nm	
Tube #4		700 nm 600 nm 500 nm 400 nm	
Tube #5		700 nm 600 nm 500 nm 400 nm	
Tube #6		700 nm 600 nm 500 nm 400 nm	
Fluorescent **(Overhead Lights)**		700 nm 600 nm 500 nm 400 nm	
Incandescent		700 nm 600 nm 500 nm 400 nm	
Halogen		700 nm 600 nm 500 nm 400 nm	

DATA ANALYSIS

Use the data below to label the Frequency ranges on the electromagnetic spectrum.

EMR Bands	Frequency Range (hertz)
Radio and Microwave	Near 0 to 3.0×10^{12}
Infrared	3.0×10^{12} to 4.6×10^{14}
Visible	4.6×10^{14} to 7.5×10^{14}
Red	4.6×10^{14} to 5.1×10^{14}
Orange	5.1×10^{14} to 5.6×10^{14}
Yellow	5.6×10^{14} to 6.1×10^{14}
Green	6.1×10^{14} to 6.5×10^{14}
Blue	6.5×10^{14} to 7.0×10^{14}
Violet	7.0×10^{14} to 7.5×10^{14}
Ultraviolet	7.5×10^{14} to 6.0×10^{16}
X-Ray	6.0×10^{16} to 1.0×10^{20}
Gamma Ray	1.0×10^{20} to ...



In what region of the spectrum do the identified wavelengths from this lab fall?

Why do you think it is limited to such a small region?

QUESTIONS *(10 points)*

1. What gases can be observed in the fluorescent light?

2. How would you make a neon sign with blue and white lettering?

3. At what wavelengths do the dark absorption lines appear in the solar spectrum?

4. What has a spectrum most similar to the spectrum of a halogen lamp?

What relationships did you observe between the variables?

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What predictions can you make based on your observations?

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CONCLUSION

I accept or reject my hypothesis (circle one)

What evidence did you use to accept or reject your hypothesis?

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How can you use this knowledge?

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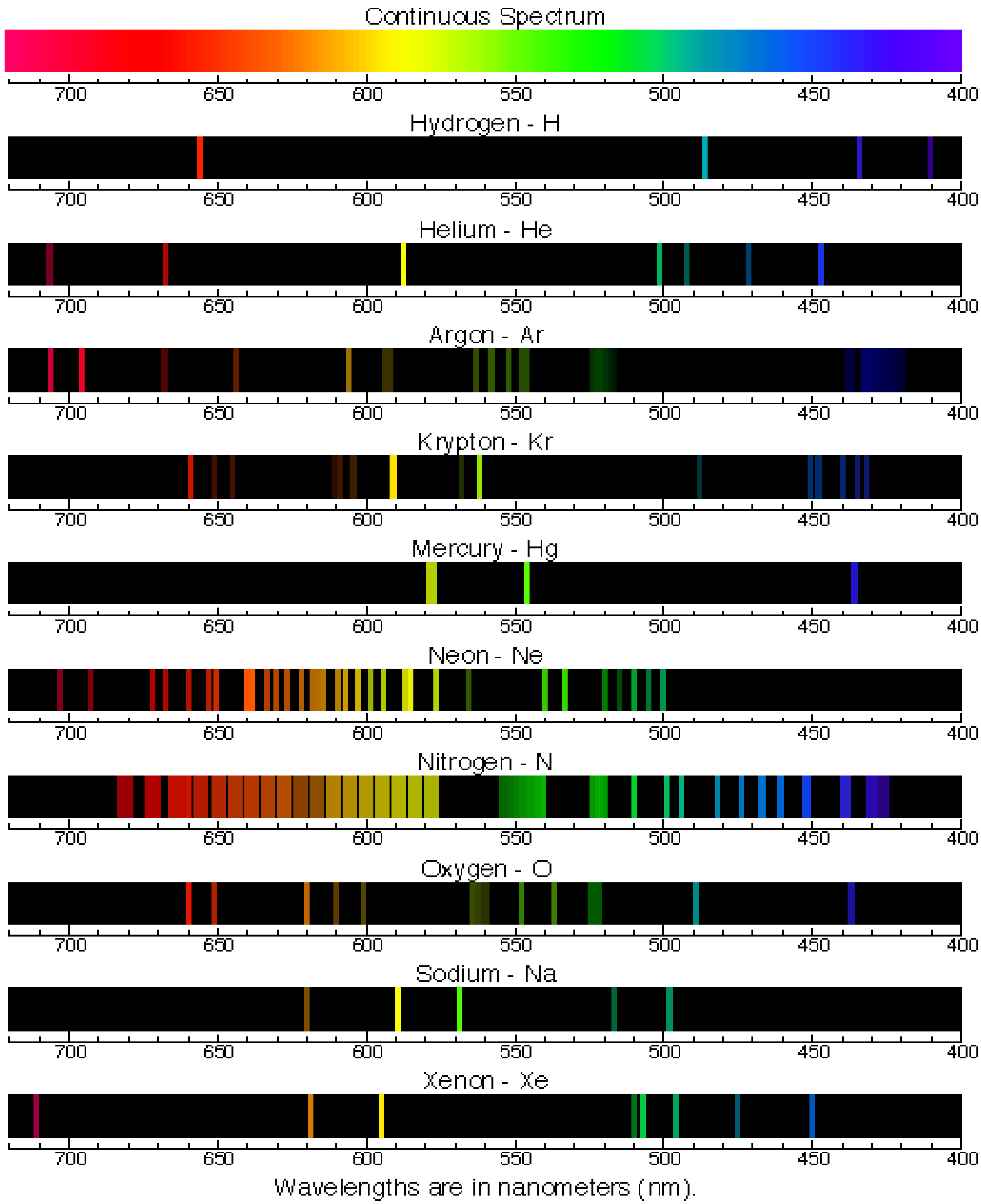
Turn in your data table, graph, and answers to the questions above along with your lab report.


Continuous Spectrum
700 650 600 550 500 450 400
Hydrogen - H
Helium - He
Argon - Ar
Krypton - Kr
Mercury - Hg
Neon - Ne
Nitrogen - N
Oxygen - O
Sodium - Na
Xenon - Xe
Wavelengths are in nanometers (nm).