Name: ________________________

Astronomy 101 Lab: Spectra

<u>You will access your textbook in this lab.</u>

Pre-Lab Assignment: In class, we've talked about different kinds of spectra and what kind of object produces each kind of spectrum. You will be looking at these different kinds of spectra in the lab. Answer the following questions before coming to lab.

A) What kind of spectrum is produced by a hot solid or a hot, dense gas?

B) What kind of spectrum is produced by a hot, low-density gas?

C) If you pass a continuous spectrum through a cool, low-density gas, what kind of spectrum will result?

D) What happens to the peak wavelength of a blackbody spectrum as the blackbody gets hotter?

Objective: The purpose of this lab is to observe and analyze the various types of spectra.

Procedure: You will be working in three stations to complete this lab.

Continuous spectrum: The light bulb you will use in this part is connected to a small transformer that will allow you to vary the electrical current through the bulb. If the setting on the transformer is low, the temperature of the filament in the bulb is low and the filament is dim. If the setting is high, the temperature and brightness of the bulb will be high.

Turn the transformer setting to about 40 and look at the bulb with a diffraction grating (one of the small rectangular slides). This is a film etched with many microscopic lines that breaks up the light into its component colors, or wavelengths. Look directly through the slide at the bulb and then move your eye to the side and you'll see the object's spectrum. This is a continuous spectrum. Only observe the spectrum that appears nearest to the lamp (it will repeat itself several times as you look farther from the lamp).

1. Without looking through the grating, what color is the filament?

2. You should see a continuous spectrum using the diffraction grating. Describe the spectrum, including the colors you can see.

The room should be as dark as possible for the next step. While looking through the grating, turn the transformer setting down until at least one of the colors of the spectrum is no longer visible.

3. Which color disappeared from this spectrum first? Which color would you expect to disappear second?

4. Without looking through the grating, what color is the filament?

A sheet on the table shows two graphs of continuous spectra, plotting the intensity of the radiation at each wavelength, *but the values for intensity have been removed*. The two curves have been labeled by a letter.

5A. If these two curves were produced by the filament in the lightbulb, which of the two curves represents the spectrum you saw when the bulb was hotter? Explain your answer.

5B. If these two curves were produced by the filament in the lightbulb, which of the two curves represents the spectrum you saw when the bulb was brighter? Explain your answer.

Emission spectrum: Two sets of four spectrum tube power supplies are located in the classroom. The spectrum tubes are mounted vertically in the power supplies and are labeled by a letter. You will observe the spectra from the four tubes and match each element with one of the patterns on the sheet of unknown spectra. Before you proceed, read these safety guidelines carefully:

- Turn off the power supply after thirty seconds of use, then wait thirty seconds before turning it on again. This prevents the tubes from getting too hot over time.
- If you think that there is a problem with a particular tube, check with the lab monitor. DO NOT adjust the tube yourself.

There should also be spectroscopes on the table in front of each tube. Light from the tube enters a narrow slit and passes through a diffraction grating to yield a spectrum. This spectrum should appear to the right of the slit against a wavelength scale. The scale is illuminated by the ambient light in the room. **If you don't see a spectrum with the wavelength scale, move the spectroscope until the slit on the left gets as bright as possible.**

Look at each tube with the spectroscopes and observe each spectrum. You should see a series of bright, colored lines superimposed over a wavelength scale. This is an emission spectrum. Each color has a specific wavelength associated with it, which can be determined by looking at the scale. The numbers are either in Ångstroms, running from 4000Å to 7000Å ($1Å = 1\times10^{-10}$ meters), or in nanometers (nm), running from 400 nm to 700 nm ($1 \text{ nm} = 1\times10^{-9}$ meters). In some of the tubes, you may notice that superimposed on the bright lines is a fainter continuous spectrum like that seen in part A. This faint rainbow comes from molecules and we will ignore this.

You've been provided a sheet of known spectra. Match each spectrum you've observed with one of the known spectra and record your answer.

Identify the gas in each tube by listing the element next to each letter.

6A. ***6B.*** ***6C.*** ***6D.***

7. Explain in a few sentences how you determine which gas was contained in each tube.

8. What similarities do you notice between each spectrum? What differences do you notice?

Absorption spectrum: The spectroscopes by the window will show you the spectrum of the sky. Do not point it at the Sun! If you use the largest spectroscopes, you will see some lines in the continuous spectrum where the brightness is slightly fainter. They aren't completely dark, but you should notice the brightness isn't continuous.

The third type of spectrum is the absorption line spectrum. This spectrum is produced when a continuous spectrum is passed through a cool, low density gas. The gas absorbs exactly the same colors when it is cool as it emits when it is hot. Rather than seeing bright lines superimposed on a dark background, as we see in an emission spectrum, you would see dark (absorption) lines superimposed on a bright background (the continuous spectrum).

9. Write down the wavelengths <u>(include units</u>) and colors of three of the absorption lines.

Nonvisible spectrum: The classroom has two handheld infrared cameras.

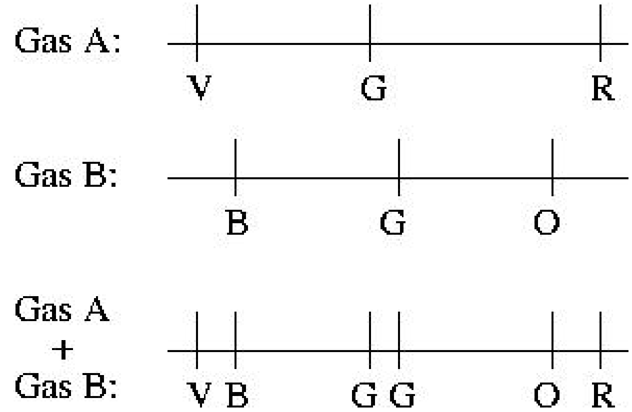
10. What part of the classroom gives off the most infrared light? What region of the classroom gives off the least infrared light?

11. Compare how visible light passes through glass versus infrared light.

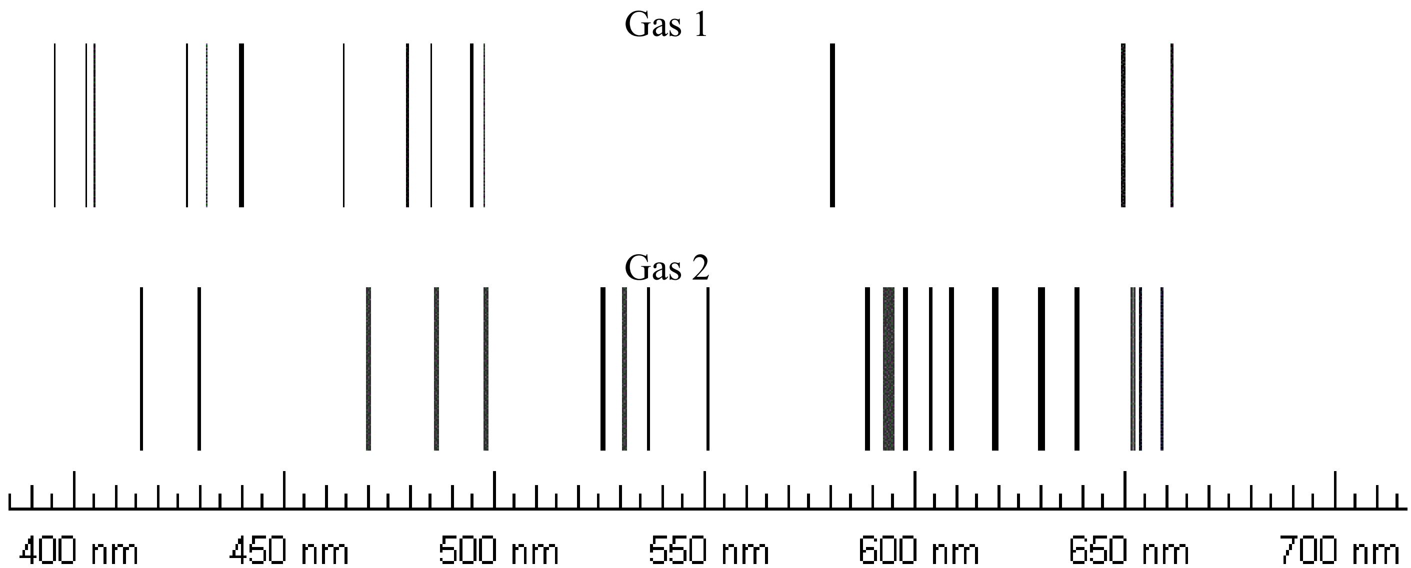
12. Why do most objects you see emit infrared light but not visible light? (Recall that emitted light is not the same as reflected light.)

The remaining sections of the lab do not have any stations with them. If you've completed the work with the equipment or are waiting to use some equipment, you may complete the following questions with your partner.

Spectrum with multiple elements: If two or more gases were mixed together, the emission line spectrum of the mixture would contain the lines of each gas. The identities of the individual gases can be ascertained by determining what gases would produce the individual lines in the spectrum of the gas mixture. See the example to the right, where "V," "G," "O," and "R" stand for the colors of the rainbow.



The spectra shown below each contain two elements. Use the unknown spectra you've identified to identify the elements within each spectrum.

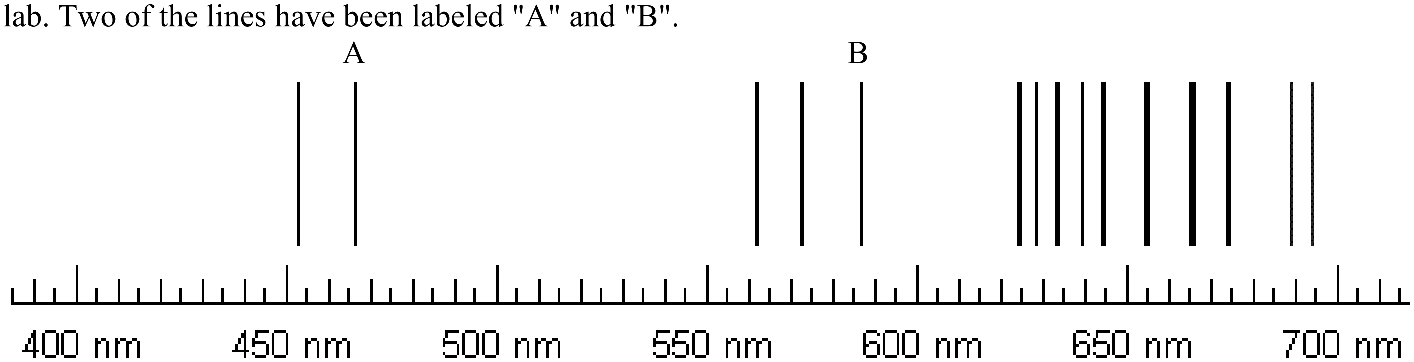


13A. Elements in Gas 1:

13B. Elements in Gas 2:

14. Explain your answer to the previous question in a couple sentences below.

Doppler effect: This effect applies to all waves and can be caused by the motion of either the source or the observer. The spectrum shown below is oxygen, but it has been Doppler-shifted from what you've seen earlier in lab. Two of the lines have been labeled "A" and "B".



15. Has the spectrum been redshifted or blueshifted? Is the gas moving toward the observer or away from the observer?

16. Measure the wavelength of line A on the stationary spectrum provided in the classroom.

17. Calculate the change in wavelength for line A between the Doppler-shifted spectrum above and the stationary spectrum. Include units.

18. Use the formula below to calculate the relative velocity of the gas based on the change of wavelength, the original wavelength, and the speed of light. Include units.

$$\text{velocity} = \frac{(\text{change in wavelength}) \times (300{,}000{,}000 \text{ m/s})}{\text{stationary wavelength}}$$

Kirchhoff's laws: Kirchhoff's laws tell us what sort of spectra we would expect from a particular source. Given what you've done in this lab, fill in the table below.

19.

Conditions of matter	***Type of spectrum we observe***
hot solid	
hot, dense gas	
hot tenuous (low density) gas	
cool, tenuous gas (with light shining on it)	

When we point a special spectrometer at the Sun (don't really do this!) we see a continuous spectrum with dark absorption lines.

20A. Based on Kirchhoff's laws, what are the conditions of the layer of the Sun that is producing the continuous spectrum?

20B. What is the composition of the layer of the Sun producing the absorption lines? Express your answer relative to the layer in part A, and consider both temperature (hotter / cooler) and density (more dense / less dense).

Analyzing the Solar System: The gases chosen for the lab are some of those found in the atmospheres of the planets in the Solar System. See Section 10.3 and Section 11.3 of your textbook.

For each of the following gases, list all the planets that have significant (≥1%) amounts of the gas in their atmospheres. Remember that the planets with a permanent atmosphere are Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. *(Mercury's atmosphere isn't permanent.)*

21.

Gas	***Planet(s) that have significant amounts of this gas in their atmosphere(s)***
Carbon Dioxide	
Helium	
Hydrogen	
Methane (CH_4)	
Nitrogen	
Oxygen	

From Earth, we can receive light from many objects in the Solar System. Use Kirchhoff's laws to answer the following questions.

22A. You've seen in the question above that we can analyze planetary atmospheres by spectroscopy. Can we use spectroscopy to determine the elemental composition of a solid planet or moon, like Mars? What kind of spectrum would you see? Explain your answer.

22B. Can we use spectroscopy to determine the elemental composition of an asteroid, a rocky object? What kind of spectrum would you see? Explain your answer.

22C. Can we use spectroscopy to determine the elemental composition of a comet, an icy object with a thin gaseous halo and a long, tenuous tail? What kind of spectrum would you see? Explain your answer.