Name:____

Chemistry 117 Laboratory
University of Massachusetts, Boston

SPECTRA

PRELAB ASSIGNMENT

In Part 3B, on page 6, you will find a table of spectral properties for several atomic transitions. On each line A, B and C of that table there is sufficient information given for you to figure out the blank properties. Fill out all twelve blanks before coming to lab and write your answers in the table. Line D will be filled out in the laboratory.

This experiment is in three parts that may be done in any order.
- In Part 1 we observe the colors that different metal ions emit when excited in a flame. These colors can be used as a method of detecting the presence of these metal ions in sample.
- In Part 2 we use a spectroscope to compare the spectra of light emitted by an incandescent bulb, a gas discharge tube and a fluorescent light.
- In Part 3 we again use spectroscope to study the relationship between light emitted by excited sodium atoms and the energy levels of those atoms.

IN THE LABORATORY

General Instructions for Using a Spectroscope

When you direct the spectroscope at a light source and look into the eyepiece, you will see the light sources through a vertical slit on the left and the spectrum of the light source projected onto a wavelength scale on the right.

Adjust the position of the spectroscope until the light source as seen through the slit is as bright as possible. Also, if the wavelength scale is too dim to read, move the white reflector to direct more outside room light onto the small window.

When the light source contains discrete spectral lines, one or more vertical colored lines will appear on the wavelength scale and you will be able to read each line's wavelength. The wavelength reading varies as you move your eye horizontally back and forth with respect to the

eyepiece. You should record the wavelength seen when your eye is centered in front of the eyepiece. Take the average of the highest and lowest wavelengths that you can see.
The numbers on the wavelength scale are in angstroms which are not SI units. However, in this experiment we will use only the preferred unit nanometers (nm). Therefore, be prepared to convert all angstrom readings to nanometers. Conversion factors are:

$$10^{10} \text{ angstroms/meter and } 10^{9} \text{ nm/m.}$$

Therefore, a wavelength of 5432 angstroms is __________ nm.

The uncertainty in the readings will be about 50 angstroms or 5 nm. Therefore, you must record each wavelength reading with three significant figures, which is appropriate to this uncertainty.

Part 1. Flame Emission Colors.

1. Rinse out a 50-mL beaker and fill it with about 30 mL of HCl 1M.

2. Obtain a test tube holder containing seven test tubes and a dip wire. Rinse these test tubes thoroughly with deionized water. Label the test tubes as follows:

   Ba^{2+} Ca^{2+} Cs^{+} Li^{+} K^{+} Na^{+} and X (unknown)

3. Pour an inch or so of solution in each test tube from the appropriate reagent bottles.

4. Light a Bunsen burner and adjust for a really hot flame. You have a hot flame when there is a distinct light-blue cone inside the larger pale-blue flame. The light-blue cone itself is unburned gas and is cold. The hot part of the flame is just <u>above</u> the light-blue cone.

CAUTION: THE DIP WIRE’S GLASS HANDLE IS EASILY MELTED.
HOLD ONLY THE TIP OF THE DIP WIRE IN THE FLAME.

For each of the seven solutions in the test tubes:

5. Clean off the dip wire by rinsing in the dilute HCl and holding the end of the wire in the flame. Impurities on the wire impart a color to the flame. When the impurities are vaporized off, the Bunsen flame will return to its original almost colorless pale blue. If impurities remain after the wire glows hot for 10 seconds, start again with another rinse.

6. Dip the wire into the sample solution and then into the flame and observe the color.

The solute and solvent vaporize. Some of the solute metal ions capture free electrons from the flame and become electrically neutral metal atoms in excited states. These excited metal atoms then emit their characteristic color. If you see a yellow flame and another color, the yellow is sodium impurity, the other color is the one you want.

7. Write down the characteristic colors on the data sheet.

8. Clean off the wire with repeated HCl rinses and flames before testing another sample.

9. The unknown solution (X) contains the same metal ions as one of the other six. By matching colors, decide the identity of the metal ions in the unknown.

Part 2. The Spectroscope.

Before doing this part read the "General Instructions for Using a Spectroscope" on page 1.

10. Use the spectroscope to observe the continuous spectrum of the incandescent bulb. The grating in the spectroscope disperses the light according to wavelength and projects it onto the scale. Each color covers a range of wavelengths.
    - Read the wavelength at the center of the reds, convert to nanometers and record on the data sheet.
    - Read the center of the greens and the center of the blues. Record these in nm on the data sheet.

11. Use the spectroscope to observe the line spectrum of the mercury vapor discharge tube. You should see three lines whose colors are orange, green and violet. Record the wavelengths of these lines in nanometers on the data sheet.

12. Use the spectroscope to observe the mixed continuous and line spectrum of the fluorescent light. The line spectrum is emitted by the vapor inside the tube and the continuous spectrum is emitted by the coating on the inside wall of the tube after being excited by ultraviolet light from the vapor. Record the wavelengths of as many discrete lines as you can distinguish.

What is the vapor inside the fluorescent tube?

Part 3. Sodium Vapor Energy Levels.

Part 3A. Calibration of the spectroscope using known He lines.

Before doing this part read the "General Instructions for Using a Spectroscope" on page 1.

13. Use a spectroscope to observe the line spectrum of a helium gas discharge tube. If you look carefully, you can see seven lines whose colors are listed in the first column in the table under Part 3A on the data sheet. **If you don't see seven lines, ask your instructor for help.** The known wavelengths$_{(l)}$ of these lines are given in the second column. Record your wavelength readings (r) of these lines in the third column.

14. Calculate the Spectroscope Error (ε) for each line. ε is (λ - r). Write these errors in the fourth column.

15. Plot Spectroscope Error (ε) vs the Wavelength reading (r) on the ruled coordinates on the top of page 6. This graph is a calibration curve for the spectroscope and is used to calculate the correct wavelength corresponding to each spectroscope reading.

Part 3B. Sodium line emission spectrum.

The next procedure cannot be done alone. One student must produce a flame spectrum in a Bunsen burner flame and another student must observe through a spectroscope.

16. Light a Bunsen burner flame and adjust for a hot flame. Set the spectroscope entrance slit about two inches from the flame and use the dip wire and the sodium salt solution to generate a sodium emission spectrum in the flame.

17. Read the wavelength of the intense yellow line in the spectroscope. Record this wavelength reading on the line marked Part 3B on the data sheet.

18. Use the calibration curve from Part 3A to correct for the spectroscope error as follows: Find the spectroscope error (ε) corresponding to your wavelength reading on your graph. Then calculate the corrected wavelength $\lambda = r + \varepsilon$ and write this in the table on the line marked "Transition D".

Fill in all the blank entries in the table in Part 3B. Lines A,B and C should already be completed as part of your prelab assignment. Fill in line D now.

Part 3C. The energy level diagram of sodium.

In Part 3B you have already calculated photon energies for the transitions A, B, C and D between several spectroscopic states of sodium. Use this information together with the transition diagram to calculate the four excited state energy levels relative to the ground state $[Na]_{3s}^{1}$. The energy units here are kilojoules per mole of photons. Write these four energy levels on the four blank lines.

Your report consists of pages 5 and 6.

Name ________________________________ Lab Section ____________________________

Partner(s) _____________________________

Spectra

Part 1. Flame Emission Colors.

Metal	Barium	Calcium	Cesium	Lithium	Potassium	Sodium
Color						

Unknown solution flame color		**Unknown metal**	

Part 2. The Spectroscope.

Observe the continuous spectrum of the incandescent light. What wavelength (in nm) is the center of:

red light	green light	blue light
nm		

Observe the line spectrum of the mercury vapor discharge tube. What is the wavelength of the:

orange light	green light	violet light

Observe the mixed spectrum of the fluorescent light. Read the wavelengths of as many lines as you can distinguish. You should see at least three.

What vapor is emitting the line spectrum?

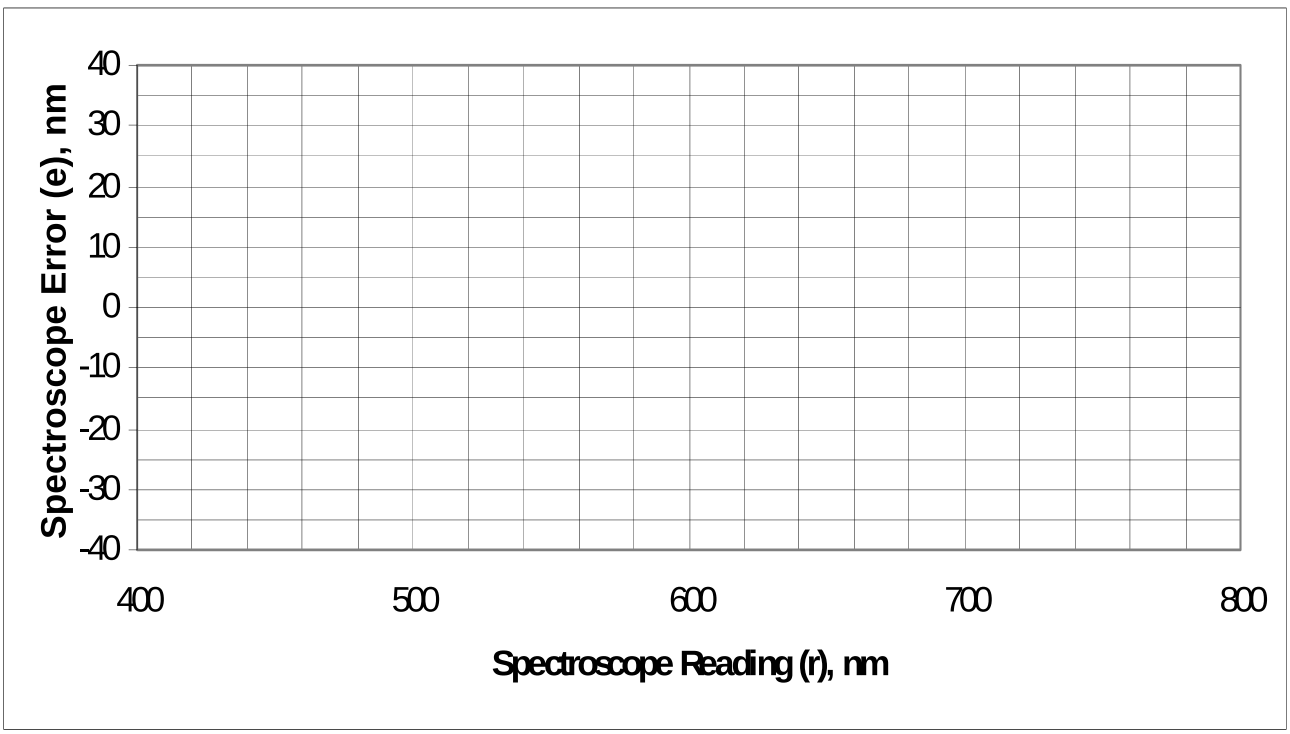
Name ________________________________ Lab Section ________________________________

Partner(s) ______________________________

Part 3. Sodium Vapor Energy Levels.

Part 3A. Calibrate the spectroscope using known He lines.

Color	**Known λ, nm**	**Reading r, nm**	**Spectroscope Error ε=(λ – r), nm**
Violet	447		
Blue	471		
Blue green	492		
Green	502		
Yellow orange	588		
Red	668		
red	706		



Name ________________________________ Lab Section ___________________________

Partner$_{(s)}$ _____________________________

Spectra

Part 3B.

Sodium emission line wavelength reading.	
Spectroscope error at this wavelength from the graph.	
Use your calibration curve to calculate the corrected wavelength.	

Copy this corrected wavelength as “Transition D” in the table below.

Transition	Wavelength	Spectral Region	Frequency s^{-1}	Photon Energy J/photon	Photon Energy kJ/mol
A. $[Na]4p^1$ ⬭ $[Na]3s^1$				$6.02x10^{-19}$	
B. $[Na]4s^1$ ⬭ $[Na]3p^1$			$2.63x10^{14}$		
C. $[Na]3d^1$ ⬭ $[Na]3p^1$	819				
D. $[Na]3p^1$ ⬭ $[Na]3s^1$		visible			

Part 3C. Sodium energy level diagram.

Energy above the ground state $[Na]3s^1$**:**

$[Na]4p^1$	kJ/mol
$[Na]3d^1$	
$[Na]4s^1$	
$[Na]3p^1$	
$[Na]3s^1$ (ground state)	zero