Experiment #3
Light and Energy

Introduction

The **electromagnetic (EM) spectrum** is described in your text as the entire range of radiant energy including gamma rays, X-rays, ultraviolet, visible, infrared, microwave, and radio radiation.

In this experiment we will gain an understanding of the visible portion of the EM spectrum and, by analogy, an understanding of other parts of the EM spectrum. We will:
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- Use mathematics to describe the relationship between the wavelength, frequency, and energy of light
- Separate white light into its colored components
- See how white light interacts with colored solutions
- Examine the transmission and absorption of light by a colored solution
- Examine the visible **spectra** from several sources of light
- Study the quantum mechanically determined flame emission spectra of several elements.

Background:

During this laboratory, we will use a **visible spectrophotometer**. A spectrophotometer is an instrument that is used to separate light into its different colors, and measure it. Single colors, described by their characteristic wavelengths (or frequencies and energies), interact with the sample. A photodetector determines the amount of light that is absorbed by the sample.

A spectrophotometer consists of a light source, a wavelength selector (a grating or prism), a sample, a detector, and a read-out device. Figure 1 illustrates this:

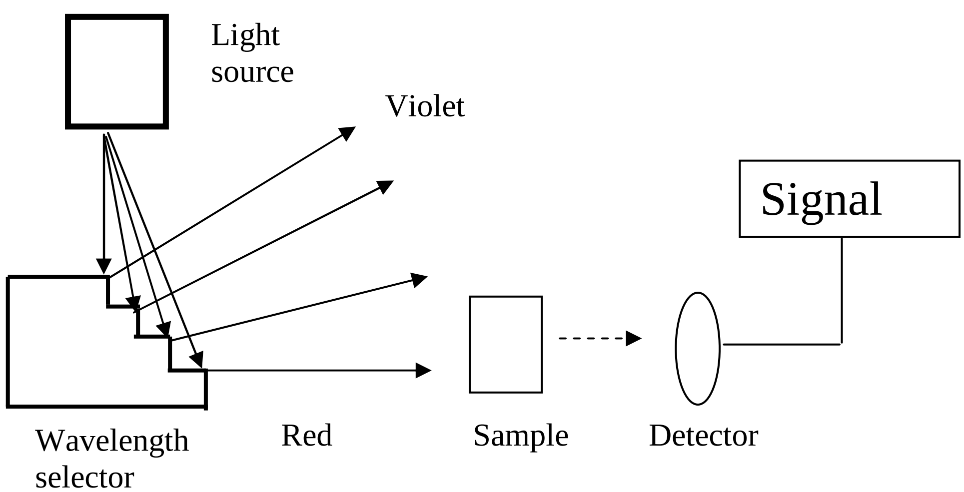

Figure 1. Spectrophotometer.
By rotating, a wavelength selector can send light of different colors toward the sample and detector.

Experiment I : Emission Spectra

1. **DEMONSTRATION IN THE LECTURE ROOM!**

The first part of this experiment will take place in the lecture room at the start of the lab period. At the front of the room are four light sources:

a. tungsten bulb
b. mercury source
c. sodium source
d. fluorescent lamp

You will be given a small piece of **"diffraction grating".** Your instructor will show you how to look through this so as to see a spectrum from each of these sources. It will take a bit of practice, but you should be able to describe the spectra (rainbow colors) which you see.

Briefly describe what you see for each of these sources in Table I.

Table I :

Light Source	Colors Observed
tungsten bulb	
mercury source	
sodium source	
fluorescent lamp	

2. EXPERIMENT IN THE LAB!

1. Set up (and possibly adjust) a **Bunsen burner**.

2. You will need a piece of **nichrome (or platinum) wire** inserted into a **glass rod** and a **small test tube** partly filled with **dilute hydrochloric acid (HCl).** This is used to clean the wire.

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BE VERY CAREFUL with this acid as it is dangerous!!!!!

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3. First heat the free **tip** of the wire in the burner flame till it glows red and plunge the hot wire into the hydrochloric acid.

4. Then **heat the wire again**.

5**. Repeat this cycle of heating and quenching** in acid till the flame is not discolored when the wire is introduced into it.

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Your wire should be cleaned this way between each of the suggested solutions for best results.

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PLEASE NOTE: The chemical solutions you will need may be labeled by the full name or maybe just by the chemical symbol. In this experiment you are only concerned with the metallic part of the name (the cation) and thus you don't care whether the solution is sodium nitrate, sodium chloride, or sodium sulfate, just that it has SODIUM in it, etc. If you have any questions, please ask!

6. Place **a small drop of the solutions** (in turn) directly on the **loop at the end of the wire** and **heat them in the flame.**

7. **In Table II**, write down your **observations concerning the colors of the flame** resulting from each of the metal ions. You may well wish to repeat some of the metals more than once.

8. Identify not only the colors of the flame but tell **how long the color persists or its brightness**.

Table II :

Known Metal Atoms	Color(s) Observed	Relative Brightness
barium (Ba)		
boron (B)		
calcium (Ca)		
copper (Cu)		
lithium (Li)		
potassium (K)		
sodium (Na)		
strontium (sr)		

9. Dip the **nichrome wire directly into your unknown** and based upon the results in **Table II**, identify the metal present. Place your results in **Table III**.

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Beware! There are traces of sodium almost everywhere, so don't be fooled by a slight sodium flame.

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10. Check your results with your TA.

Table III :

Unknown number	Predicted metal	WHY ?

TA checking answer : Try # 1 ______________

Try # 2 ______________

Experiment II: Determining the Color of the Wavelengths

1. Place the cuvette with the white plastic (in the bottom) in the spectrophotometer and set the wavelength at **560 nm**.

2. Look down into the cuvette to observe the **white plastic** and the reflected light (ie.light of 560 nm).

Rotate the cuvette to maximize the reflected light and leave the cuvette in this position.

Everybody in the group should look down into the cuvette to see the reflected colors!!.

3. Write down the color observed in Table IV.

4. **Without touching the cuvette**, set the spectrophotometer to the other wavelengths listed in **Table IV** and determine their color.

5. **After all the wavelengths have been recorded**, remove the cuvette containing the white plastic. If nobody in your group detects a color, mark that square with a large X.

Table IV :

Wavelength	Color	Wavelength	Color	Wavelength	Color
400 nm		520 nm		640 nm	
440 nm		560 nm		680 nm	
480 nm		600 nm		720 nm	

Experiment III : Collecting a Transmission Spectrum of a Colored Solution

Background :

The spectrophotometer detects how much light passes through the sample to the detector. We measure the extent to which light of a specific wavelength can pass through a sample in percentage. We call this the percent transmittance and define it as follows:

$$\text{Percent transmittance (\%T)} = \frac{\text{transmittance of sample}}{\text{transmittance of blank}} * 100$$

Percent transmittance is measure of what fraction of the incident light passes through the sample. To accomplish this we first measure the transmittance of a blank.
We will use water as our blank. Water is clear and colorless so we will say that it is perfectly transmitting of visible light. Therefore to calibrate our spectrophotometer, we must set it so water is perfectly transmitting. We do this by filling a cuvette with water, placing it in the spectrophotometer, and setting the read-out to 100 percent...fully transmitting.

<u>Procedure for Experiment III:</u>

1. There should be **two clean cuvettes** in a beaker by your spectrophotometer.

2. Fill one with **deionized water** (this is the BLANK) and put in the spectrophotometer to calibrate the spectrophotometer with the wavelength selector set at **400 nm**.
   a. **Set the % T to 100 %.** See the instructor or TA for help with this.

Save the cuvette filled with water because you'll need to calibrate the spectrophotometer at every wavelength you measure (this is because the intensity of the light source and the sensitivity of the detector vary with wavelength).

3. Fill the **second cuvette** with the **colored solution** at your desk (**<u>RED OR BLUE</u>**).

4. Place the cuvette with the colored solution in the spectrophotometer and measure it's percent transmittance (% T).

5. Record the data in Table V.

6. <u>Change the wavelength to 440 nm. Blank the spectrophotometer with water. Measure the % T of the colored solution and record the data.</u>

7. **Continue this process for the rest of the wavelengths and record your data in Table V.**

8. Obtain the data (<u>from another group</u>) for the solution (red or blue) that you did not measure.

Table V : REMINDER: MEASURE **<u>EITHER</u>** THE RED OR BLUE DYE.
Obtain the data for the other solution from your neighbor.
You will predict the %T of the green solution in a later step

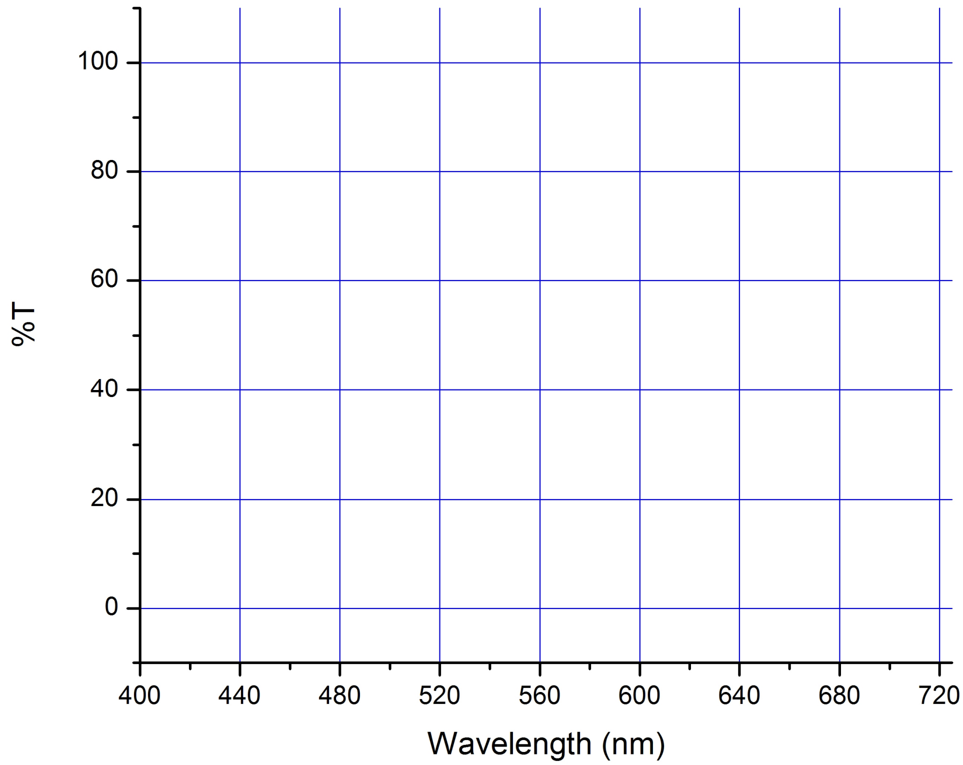
<u>Circle the solution (either red solution or blue solution) that your group measured.</u>

Red Solution		**Blue Solution**		**Predicted Green Solution**	
Wavelength	**% T**	**Wavelength**	**% T**	**Wavelength**	**% T**
400 nm		400 nm		400 nm	
440 nm		440 nm		440 nm	
480 nm		480 nm		480 nm	
520 nm		520 nm		520 nm	
560 nm		560 nm		560 nm	
600 nm		600 nm		600 nm	
640 nm		640 nm		640 nm	
680 nm		680 nm		680 nm	
720 nm		720 nm		720 nm	

9. For the red and blue solutions, **prepare a plot of wavelength (on the x axis) vs. % T (on the y axis)** using your data in Table V.

a. Place both of these spectra on Graph I. This type of graph is called a **spectrum.**

<u>Graph I: Graph of wavelength vs % T for the colored solutions</u>



10. In the small table below, write the **<u>colors</u>** associated with each wavelength (the data from **Table IV**).

	400	440	480	520	560	600	640	680	720
Color									

Colors are from Table IV.

11. Based on your results with the red and blue solutions - which colors (and wavelengths) are absorbed and which are transmitted - **make a prediction of what you think the spectrum will look like for a green solution.**

a. Predict **"low" , "medium" or "high" transmittance** at each of the wavelengths listed.

b. **Put your prediction in Table V** (previous page)

SEE NEXT PAGE!!!

12. **Table VI :** Answer the following questions using **Graph I**.

Question	Red Solution	Blue Solution
Which **colors** of the visible spectrum have the highest transmittance ?		
What **wavelengths** are associated with these colors ?		
Which **colors** of the visible spectrum have the lowest transmittance ?		
What **wavelengths** are associated with these colors ?		
Was the red solution very effective at absorbing red light ?		
Was the blue solution very effective at transmitting blue light ?		

THE END ☺