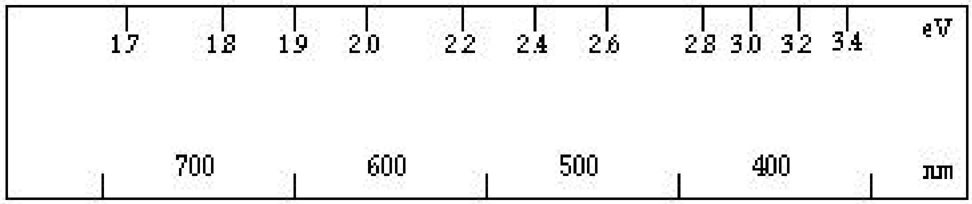
Energy, Frequency, Wavelength and the Electromagnetic Spectrum

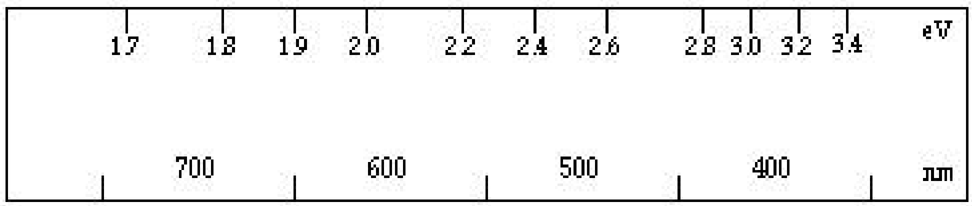
The light from a heated element is made of several different colors all mixed together. A spectroscope separates these colors. Some spectroscopes use a prism to separate the colors and some use a diffraction grating. A diffraction grating is a piece of glass or plastic with thousands of lines marked on it. Because the light goes into the spectroscope through narrow lines, it is bent into its constituent wavelengths. The set of lines produced by a heated element is called its spectrum. In this activity, you will use a spectroscope to view some different spectra and to investigate the nature of light.

- Using colored pencils, fill in the spectra observed for any three different substances.

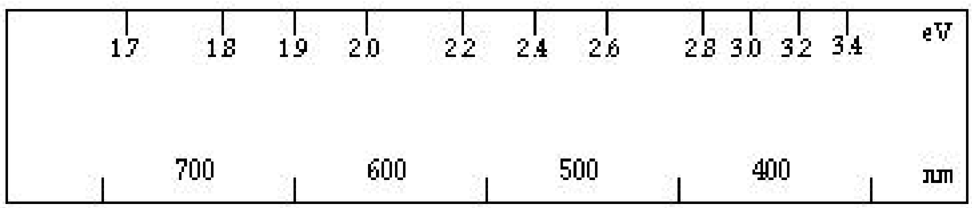
Spectrum source ______________________________________



Spectrum source ______________________________________

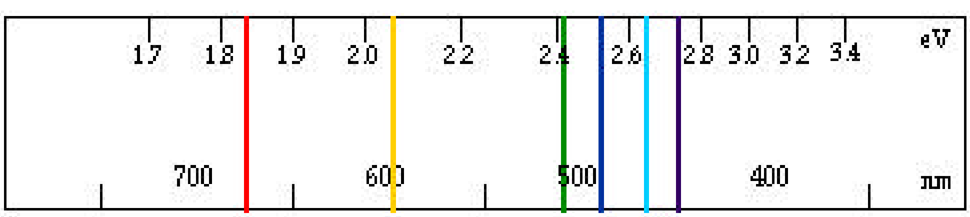


Spectrum source ______________________________________



Each spectral line represents a photon of electromagnetic energy emitted as electrons fall from excited states back to their ground states. Most of what we know about electrons comes from the study of light.

We are able to see these photons as spectral lines because their energy falls in the part of the electromagnetic spectrum that we know as visible light. The spectroscope contains two scales for measurement. The top scale indicates the energy of the photon in electron volts (eV), while the bottom scale indicates the wavelength of the photon in nanometers (1 nm = 1×10^{-9}m). To continue our investigation of light, we will use the emission spectrum for helium, which is shown below.



Construct a data table similar to the one below.

Frequency (Hz)	Energy (J)	Energy (eV)	Wavelength (nm)

- Use helium's spectrum to complete the data table with energy (eV) and wavelength (nm) for the six spectra lines shown.

- Using the conversion factor (one J = 6.2×10^{18} eV), fill in the energy (J) column in the data table.

We also know that the frequency of light is equal to the ratio of the speed of light to the wavelength.

$$v = \frac{c}{\lambda}$$

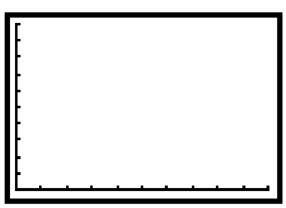
Where:
v = frequency in Hertz (Hz) = (1 / sec)
c = speed of light (3.0×10^{17} nm / sec)
λ = wavelength

- Use the above equation to complete the Frequency (Hz) column in your data table for spectral lines of helium.

- Construct scatter plots for the following and sketch the graphs:

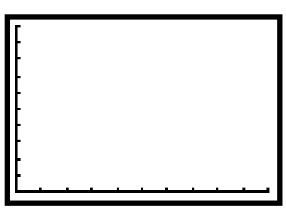
DIRECTIONS FOR TI-82/83

[Y=] Clear all equations
Set up the [STAT] EDIT table with the following data:
L1=frequency (Hz)
L2=energy (J)
L3=wavelength (nm)



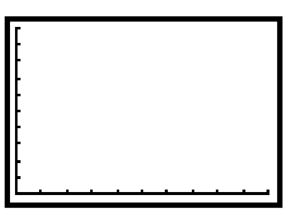
frequency (Hz) vs. wavelength (nm)

[2nd] [Y=]
Plots Off
Plot1
ON
[scatter] Xlist=L3 Ylist=L1
[ZOOM]
ZoomStat



energy (J) vs. wavelength (nm)

[2nd] [Y=]
Plots Off
Plot1
ON
[scatter] Xlist=L3 Ylist=L2
[ZOOM]
ZoomStat



energy (J) vs. frequency (Hz)

[2nd] [Y=]
Plots Off
Plot1
ON
[scatter] Xlist=L1 Ylist=L2
[ZOOM]
ZoomStat

Use your graphs to complete the following statements:

Q1. As the frequency increases, the wavelength _______________.
Q2. As the energy increases, the wavelength _________________.
Q3. As the frequency increases, the energy ___________________.

In 1905, a German physicist named Max Planck discovered the same relationship for energy and frequencies as you have plotted in graph number three.

Calculate the line of best fits for the graph of energy (j) vs. frequency (Hz). Record the regression equation in your lab notebook and add the regression line to your graph.

Linear Regression Equation

y= __________________________

Directions for the TI-82/83

• TI-82 / 83

STAT CALC LinReg(ax+b) ENTER L1 , L2 ENTER

Q4. What is the value of b for your data?

Q5. Is it correct to assume that (0,0) is a valid origin for this set of data, or should the equation have a some y-intercept value other than zero? (Be sure to consider what you are graphing) Explain.

Q6. Write a word equation for this graph by substituting into the slope-intercept equation (y=mx+b) the variable names for x and y, and b=zero.

Q7. Substitute the units for energy and frequency into the word equation and solve for the slope of the line. What are the units for the slope?

The slope of the line for this graph relates the energy of an electromagnetic wave to its frequency. This value is called **Planck's constant,** which is symbolized as "h", just as the speed of light has the symbol "c". Planck's constant, like pi or the speed of light, never changes. It is a physical constant. The excepted value for Planck’s constant is 6.63×10^{-34} J • sec.

Q8. Use the following equation to calculate the percentage error in your calculations of Planck’s constant.

$$\text{Percent Error} = \frac{|\text{ accepted value - experimental value }|}{\text{accepted value}} \times 100 \text{ percent}$$

Q9. Use the following symbols to write an equation that makes energy equal to frequency.

h for plank's constant
E for Energy
v for Frequency

Q10. Using what you have learned in this exercise, compile a list of new equations, graphs, conversion factors and physical constants into your notes.

Findings

F1) Explain why the emission spectrum of a substance is like a fingerprint.

F2) The numbers at the bottom of the spectroscope scale give a wavelength reading for the light emitted in nanometers (1×10^{-9} meters). Record the approximate range of wavelengths for the colors of the visible spectrum.

Color	Red	Orange	Yellow	Green	Blue	Indigo	Violet
λ Range (nm)							

Label the following relationships as directly proportional or indirectly proportional.

F3) Wavelength and frequency of electromagnetic radiation.

F4) Energy and frequency of electromagnetic radiation.

F5) Energy and wavelength of electromagnetic radiation.

F6) Energy and distance of energy level to the nucleus.