

EMISSION SPECTROSCOPY

INTRODUCTION:

The *emission spectrum* is the set of light frequencies emitted by substances after they have been excited with various forms of energy, most commonly heat or electrical. Since the frequency of light emitted under these conditions depends on the energies of the excited and ground states of electrons in the atoms, the spectrum serves as a very sensitive “fingerprint” of the atoms present. For example, by studying emission spectra of the stars, we can determine their chemical composition. Also, emission spectra are used to identify poisons in food, pesticides in the environment, and numerous substances in forensic samples.

Although emission spectroscopy has many practical uses, it is equally interesting because it provided the first quantitative information about the energy levels in atoms, and allowed chemists to calculate values for the allowable energies of electrons in atoms.

The **Bohr** equation (named after Danish physicist, Niels Bohr):

$$\text{(Equation 1)} \quad \nu \text{ (s}^{-1}\text{)} = 3.289 \times 10^{15} \text{ (s}^{-1}\text{)} \left[\frac{1}{n_f^2} - \frac{1}{n_i^2} \right]$$

can be used to calculate the frequency of light emitted (ν) when an electron falls from an upper level (n_i) to a lower level (n_f). The constant, $3.289 \times 10^{15} \text{ s}^{-1}$, is known as the Rydberg Constant. For the visible lines of the hydrogen spectrum, n_f is always 2, and the equation can be rearranged to the form $y = mx + b$ (the equation of a straight line, where m is the slope and b is the y-intercept):

$$\text{(equation 2)} \quad \nu \text{ (s}^{-1}\text{)} = -3.289 \times 10^{15} \left(\frac{1}{n_i^2} \right) + \frac{3.289 \times 10^{15}}{4}$$

A plot of ν vs. $\frac{1}{n_i^2}$ should give a slope equal to the Rydberg Constant (3.289×10^{15}), and an intercept equal to the Rydberg Constant divided by 4, if the electronic transitions all terminate on the second level.

In today's experiment we will observe emission spectra of electrically excited gases and, if your instructor chooses, thermally excited salts. A spectroscope will be calibrated by observing the helium spectrum. The calibrated spectroscope will be used to determine the wavelengths of the visible light spectrum (called the Balmer Series) in the hydrogen spectrum, and these wavelengths will be used to determine an experimental value for the Rydberg Constant. In addition an unknown salt or gas may be identified by its spectrum.

PROCEDURE:

A) Calibration of the spectrometer with the known He spectrum.

1) Observe the He spectrum, and note where the lines fall on the scale of the spectroscope. Record the scale readings and colors for the observed lines opposite their known wavelengths. Depending on your particular instrument, you should expect to see at least the 3 most intense lines and perhaps 4 or 5. Complete Table 1 on your data sheet.

2) Create a calibration curve by plotting “scale reading” vs. “wavelength”. This curve may not be a straight line, but it should be a smooth curve.

B) Hydrogen Spectrum

1) Observe the hydrogen spectrum and record the scale readings for the visible lines in Table 2 on your data sheet.

2) Use your calibration curve from A) to determine the wavelengths from the scale readings. Calculate the frequencies from the wavelengths, using the appropriate formula. Add these values to Table 2 in the appropriate column.

3) Assuming that the lowest observed frequency corresponds to an n_i value of 3 and that each succeeding frequency corresponds to n_i of 4, 5 etc., plot frequency vs. $\frac{1}{n_i^2}$. Determine the slope and multiply by -1. Compare this value to the expected value for the Rydberg Constant. Determine your % experimental error. Remember that % experimental error is:

$$\frac{\text{Observed value} - \text{Reference value}}{\text{Reference value}} \times 100$$

Identity of Unknowns:

1) Observe the spectrum of an “unknown” gas emission tube and record the scale readings of the emission lines in Table 3 of your Data sheet. Use your calibration curve from A) to convert the scale readings to wavelengths and use the attached charts to identify the “unknown”.

2) Observe the spectra of some salts in the following manner. Replace the emission tube with a Bunsen burner placed near the spectroscope slit. Dip a nichrome wire into some HCl and hold it in the flame until the impurities have been removed. Dip the wire into HCl again, then into a sample of “unknown” salt. Hold the wire in the Bunsen burner flame and observe the emission spectrum and record the scale readings of the emission lines in Table 4 on your Data sheet. Use your calibration curve from A) to convert the scale readings to wavelengths and use the attached charts to identify the “unknown”.

Ne		Ar		O		Hg		Xe	
λ	Intensity	λ	Intensity	λ	Intensity	λ	Intensity	λ	Intensity
470.4	1500	360.6	1000	395	300	366.3	24	418	500
471.5	1000	364.9	800	407	300	404.7	180	433	500
540.0	2000	394.7	1000	408	800	407.8	12	446	500
585.2	2000	394.8	2000	419	500	435.8	400	450	500
603.0	1000	415.8	1500	441	300	577.0	24	462	1000
607.4	1000	416.4	1000	459	300	579.1	28	467	2000
616.3	1000	426.6	1200	465	300			473	600
621.7	1000	434.5	1000	533	500			484	1000
626.6	1000	470.2	1200	616	1000			492	500
633.4	1000	518.7	1800	646	500			508	1000
640.2	2000	549.5	1000	777	1000			529	899
650.6	1000	565.0	1500	795	1000			542	1000
667.8	500	750.4	700					597	800
								687	700
								699	700

Ba		Ca		Cd		Cu		K	
λ	Intensity	λ	Intensity	λ	Intensity	λ	Intensity	λ	Intensity
455.4	6500	318	400	346.6	250	325	1000	404.4	32
493.4	2000	393	600	361.1	360	327	1000	766.5	1800
553.5	650	397	500	467.8	80	329	150	769.9	900
614.1	2000			480.0	140	331	250		
649.6	1200			508.6	280	353	250		
				643.8	26	406	200		
						465	200		
						515	200		
						522	250		
						578	150		
						627	100		
						740	100		

Li		Na		Sr	
λ	Intensity	λ	Intensity	λ	Intensity
460.2	13	568.3	7	408	4600
497.1	8	569.9	14	422	3200
610.4	320	589.0	2000	461	6500
670.8	3600	589.1	1000	472	320
616.1	6	616.1	6	481	480
				526	480
				548	700
				550	300
				640	900
				650	550
				688	480

EMISSION SPECTROSCOPY
Data Sheet

Name _____ Section _____ Date _____

TABLE 1

<u>Wavelength of He Line</u>	<u>Relative Intensity</u>	<u>Line Color</u>	<u>Scale Reading</u>
438.8	300	_____	_____
447.6	100	_____	_____
492.2	600	_____	_____
587.5	1000	yellow_____	_____
667.8	600	_____	_____
706.6	200	_____	_____

TABLE 2

<u>Line Color</u>	<u>Scale Reading</u>	<u>Wavelength (nm)</u>	<u>Frequency(sec⁻¹)</u>	<u>n_i</u>	<u>1 / n_i²</u>
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

TABLE 3

Unknown Gas # _____

<u>Line Color</u>	<u>Scale Reading</u>	<u>Wavelength (nm)</u>
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TABLE 4**Unknown Salt #** _____**Line Color****Scale Reading****Wavelength(nm)****CALCULATIONS:****Part B:**

1) Determination of Rydberg constant from your experimental data

2) % error on Rydberg constant

_____ (s⁻¹)

_____ %

Part C:

1) Unknown Gas identity _____

2) Unknown salt identity _____

EMISSION SPECTROSCOPY**Prestudy**

Name _____ Section _____ Date _____

1) a) Calculate the frequency of light emitted when an electron moves from $n = 5$ to $n = 2$, in the hydrogen atom.

b) Convert the above frequency to wavelength, in nm.

c) Calculate the energy of the above light.

d) What color would the above light have? _____

2) A student performs this experiment and obtains a value of $3.02 \times 10^{15} \text{ s}^{-1}$ for the Rydberg Constant. Calculate the student's % error.